Abstracts of papers related to NVH published in 2015

Al-Aawar, N. & Arkadan, A.-R.A., 2015. Optimal Control Strategy for Hybrid Electric Vehicle Powertrain. *IEEE Journal of Emerging and Selected Topics in Power Electronics*, 3(2), pp.362–370. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929161978&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: An optimal control strategy is developed for the powertrain of hybrid electric vehicles (HEVs) to minimize the fuel consumption while maintaining good performance and drivability. A novel robust identifier using the generalized notion of power approach is developed and used to accurately predict the performance characteristics of the powertrain. The uniqueness of this model is its ability to represent both internal combustion engine (ICE) unit and electrical motor generator (EMG) unit of the powertrain system in one state space system of equations. Thus, it allows proper characterization of the interaction of both units considering the irreversibility of the entropy generation by the ICE unit, load small disturbances, and magnetic material nonlinearity as well as space and time harmonics of the EMG unit. The optimal control strategy is developed in two stages. The first uses a mathematical search algorithm based on the calculus of variation to minimize fuel consumption and develop needed torque to achieve a good performance. The second stage employs a fuzzy logic algorithm to ensure good drivability (comfort). The superiority of the optimization algorithm is demonstrated by applying it to a prototype HEV with split power configuration and by comparing simulation results with readily available benchmark data.

Baumgart, R. et al., 2015. *Comparison and Evaluation of a New Innovative Drive Concept for the Air Conditioning Compressor of Electric Vehicles*, SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923197063&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The development of energy efficient air conditioning systems for electric vehicles is an ever increasing challenge, because the cooling as well as the heating of the passenger compartment reduces the cruising range dramatically. Electric cars are usually equipped with a scroll compressor and a separate electric motor with appropriate power electronics. However, this solution is critical in terms of the installation space, the weight and also the costs. Therefore, an innovative and energy efficient drivetrain structure for electric vehicles was developed, which integrates the motor of the A/C-compressor directly into the drivetrain. Thus it is possible to switch off the compressor motor and to use the main motor for the drive of the compressor at certain driving situations. As a result, the operating point of the main motor can be shifted to a better efficiency. Moreover, in urban traffic the compressor motor can be used to drive the vehicle if the efficiency of the compressor motor is higher than the efficiency of the main motor. Thereby the efficiency and the cruising range of the vehicle can be increased. This contribution presents a new powertrain concept which realizes the above mentioned mechanical coupling of the main motor and the

compressor motor. This new concept is compared with a standard electric car which is equipped with a separate scroll compressor. Both systems are evaluated by means of the achievable cruising range for different driving cycles and environmental conditions.

Ter Beek, M. & Soffker, D., 2015. Observer-based identification of nonlinear clutch friction under operating conditions. In *2009 European Control Conference, ECC 2009*. Institute of Electrical and Electronics Engineers Inc., pp. 5051–5056. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928202680&partnerID=tZOtx3y1.

Abstract: This article presents a detailled description of the industrial application of a Proportional-Integral-(PI-)observer for identification of the dry friction in a torsion damper utilized in a vehicle clutch. The identification of the friction characteristics are performed on the basis of powertrain oscillation measurements that are recorded during vehicle operation. The available measurement instrumentation is limited to angular velocity sensors, providing measurements from the engine flywheel, the transmission inputshaft and the front wheels. The clutch friction torque is calculated from the measured angular motion of the transmission and the torque balance about the transmission inertia. These torques are not measured directly, but are estimated by an observer containing a model of the powertrain. The plant model and the observer are described in detail in this contribution. Furthermore, a method is explained which is used to extract the dry friction component from the identified effective torque, which acts on the transmission input shaft. The restrictions for the presented task are limited test time, a limited measurement setup and the lack of opportunity to dismount the test specimens for measurements on test rigs. Under these boundary conditions, the concept of PI-observer in conjunction with the mathematical treatment of the observed system states and external inputs has produced identification results of adequate accuracy.

Chen, J. et al., 2015. Multi-objective optimization of powertrain mount system concurrently considering energy decoupling and vehicle vibration. *Zhongguo Jixie Gongcheng/China Mechanical Engineering*, 26(8), pp.1129–1135. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929335470&partnerID=tZOtx3y1.

Abstract: Simplified vehicle vibration TPA model was established based on the actual transfer path test datum. On the basis of that, multi-objective optimization model of powertrain mount system was established based on GPSO algorithm with considering energy decoupling and vehicle vibration, mounting stiffness parameters were taken as design variables. Taking a truck for example, a multi-objective optimization solution was conducted. The test and optimization results show that the optimization method can get better energy decoupling and lower vehicle vibration, while achieving the optimal matching of energy decoupling and cars and low vibration.

Czapnik, B. et al., 2015. Conceptual design of battery electric vehicle powertrains. *International Journal of Vehicle Design*, 67(2), p.137. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84925864103&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Alternative vehicle powertrain systems are currently the most promising solutions to meet the energetic and ecological challenges in the individual mobility. To accomplish the keen competition, considering the decreasing lead time and costs for a vehicle design and the aim to develop the optimal powertrain design, methods that ensure a quick evaluation of various configurations of a powertrain system are required. Although utilising powertrain simulation models is a common approach in powertrain design, there is a need for quick generalised analytical models. In this paper, an analytical model is developed using the example of a battery electric vehicle (BEV) with the aim of a quick exploration of powertrain design solutions. Moreover, a comparison between the analytical method and a numerical simulative method with respect to their accuracies and complexities is shown. Finally, a Pareto frontier analysis of energy consumption, driving performance, range and cost for BEVs is accomplished.

Dimitrova, Z. & Maréchal, F., 2015. Energy integration on multi-periods and multi-usages for hybrid electric and thermal powertrains. *Energy*, 83, pp.539–550. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84926416167&partnerID=tZOtx3y1 [Accessed May 11, 2015].

Abstract: The improvement of the efficiency of vehicle energy systems promotes an active search to find innovative solutions during the design process. This requires more accurate modeling of complex systems, which offers new ways to improve the design efficiency of energy systems. The vehicle is a highly dynamic system. The size and the efficiency of the convertors are dependent on the dynamic driving profile. In order to increase the energy efficiency, using energy integration techniques, an adapted methodology is required to choose the best points for the integrated system design. The idea is to clusterize the dynamic profile on typical multi-periods of the vehicle use. The energy system design is then optimized for these typical multi-periods. In this article a new methodology is applied on hybrid electric vehicles, in order to define the energy integrated powertrain configuration of the vehicle. The energy recovery potential of a single stage Organic Rankine Cycle for a thermal engine in combination with a hybrid electric powertrain is assessed for different drive cycles profiles and comfort situations. After the energy integration, a multi-objective optimization is applied to define the optimal design of a hybrid electric vehicle with a waste heat recovery system.

Eckert, J.J. et al., 2015. *Multibody Mechatronic Systems* M. Ceccarelli & E. E. Hernández Martinez, eds., Cham: Springer International Publishing. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928233982&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The vehicle longitudinal dynamics is responsible for calculating the vehicle power consumption to attend a specific route, estimating, by the equations, the forces acting on the system such as aerodynamic drag, rolling resistance, climbing resistance and the driver behavior. The gear shifting strategies influence significantly in the

vehicle acceleration performance and fuel consumption because it changes the powertrain inertia and the engine speed. The literature presents gear shifting strategies based on the engine power and torque. A fuel economy strategy is more difficult to determine, because it depends on a large number of factors like the engine efficiency, vehicle speed, transition ratio and required acceleration. This paper presents a study based on the US06 standard velocity profile, in which the high speeds and acceleration stretches create a situation where the vehicle performance is limited by the engine available power and by the tire-ground traction limit. Because of the many factors involved in the vehicle behavior, it was developed an algorithm to optimize the gear shifting process to choose the more adequate strategy to each stretch. The analysis were performed by co-simulation between the multibody dynamics software Adams™ and Matlab/Simulink™, where is defined the vehicle power demand.

Fang, Y., Zhang, T., Chen, F.F., et al., 2015. Effects of multiple excitations on vibration characteristics of an electric powertrain. *Zhendong yu Chongji/Journal of Vibration and Shock*, 34(8). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929631040&partnerID=tZOtx3y1.

Abstract: Considering the internal dynamic excitations of gears and the electromagnetic excitations of an electric motor, a dynamic finite element model for transmission system and structure system of an electric powertrain was established, and the dynamic responses of the powertrain were calculated with the numerical simulation method. The effects of tangential electromagnetic force and gear mesh impact force on the vibration characteristics of the electric powertrain were analyzed. A test bench was used to detect the vibration acceleration of the powertrain in a semi-anechoic chamber. Comparison showed that the simulated results agree well with the test data.

Fang, Y., Zhang, T., Yu, P., et al., 2015. Experimental study on vibration and noise of electric powertrain. *Zhendong Ceshi Yu Zhenduan/Journal of Vibration, Measurement and Diagnosis*, 35(2), pp.218–224. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929624552&partnerID=tZOtx3y1.

Abstract: The vibration and noise sources between a pure electric vehicle and an internal combustion engine vehicle are very different due to their different powertrains. In this paper, the vibration and noise characteristics of an electric powertrain are tested in a semi-anechoic chamber. Spectral and order analyses are used to identify the electric powertrain's main vibration and noise sources. The contribution of each excitation to vibrations and noises in different conditions is analyzed, and the sound quality of the electric powertrain is analyzed based on psychoacoustic parameters. This research provides experimental support for the noise, vibration and harshness (NVH) optimization of the electric powertrain and demonstrates the need for further research on electric vehicle sound quality.

Guo, R. et al., 2015. A novel visual transfer path analysis method with coupled vibration source based on inverse substructuring technique. *Tongji Daxue*

Xuebao/Journal of Tongji University, 43(4), pp.584–591. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929736986&partnerID=tZOtx3y1.

Abstract: Due to the limitations of the existing transfer path analysis (TPA) methods, a novel TPA method with coupled vibration source is proposed based on the frequency response function (FRF)-based substructuring technique and the detailed process of the method is also proposed. The new method is applied to a simplified finite element model simulating the powertrain and the body of a vehicle. The dynamic characteristics of the substructures and the joints can be identified in coupled condition by the inverse substructuring approach. And then the FRFs of the coupled system can be obtained through the FRFs of the substructures by substructuring approach. Furthermore, the vibration transfer path contribution analysis is carried out and the dominant paths and substructure FRFs are found. The novel method is proved to be feasible and convenient to be applied in the engineering.

Heinicke, M. & Wagenhaus, G., 2015. Sustainability in the car-based mobility: the case of the electric vehicle Editha. *International Journal of Energy Sector Management*, 9(1), pp.105–119. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928479509&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Purpose – Considering the well-known finiteness of resources and particularly in the light of previous concepts to ensure car-based mobility, this paper aims to outline to what extent the cost structure for sustainable mobility is still acceptable in the foreseeable future for the majority of people. The production and use of energy for mobility is a decisive factor for the future development of entire regions. This can be directly derived from the dramatically evolving energy cost in the recent years rooted in an increasing scarcity of known resources.
Design/methodology/approach – On the basis of available new technology components, researchers from the University of Magdeburg (Germany) have converted a conventional car into an electric vehicle. Hereby, energy efficiency and sustainability were in the direct focus of the product redesign. Furthermore, a LCC analysis complements the qualitative analysis. Findings – Thus, a driving concept for electric mobility in the urban environment was drawn up which meets the criterion of suitability for everyday use due to an e-conversion. Moreover, the outstanding efficiency of the designed powertrain is demonstrated. Research limitations/implications – Using the research electric vehicle Editha, the researchers point out which technical options can be inferred from available components for the creation of mobility in the urban environment. However, the source of energy is crucial to assess if the claim for sustainability is fulfilled. Social implications – The paper illustrates that a monetary advantage of electric vehicles, such as the prototype Editha, arises after seven years due to disproportional purchase costs.
Originality/value – In this context, the proposed driving concept of the prototype represents a transitional solution from vehicles with central engine to hub wheel electric engines. In addition, Editha is the first roadworthy and suitable for daily use research vehicle using an individual electric motor for each rear wheel without manual gearbox.

Hoshi, T., 2015. Technique for Predicting Powertrain Self-Excited Vibration at Vehicle Start-Up. *SAE International Journal of Engines*, 8(4), pp.2015–01–1674. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928729663&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: A clutch FEM model was created to quantitatively understand the operation and dynamic friction characteristics of the facing materials. And a simulation model for dynamic behavior analysis of the torque transmission characteristics from a transmission that incorporates drivetrain damping characteristics to the vehicle body was constructed. The data of the actual vehicle was also measured when vibration occurs and loss torque is generated by friction in the drivetrain, and damping characteristics were determined from the measurement values. In order to confirm the usefulness of this method, the construction of a clutch that suppresses self-excited vibration was examined by simulation and the reduction of vibration in an actual vehicle was confirmed.

Lechowicz, A. & Augustynowicz, A., 2015. *Mechatronics - Ideas for Industrial Application* J. Awrejcewicz et al., eds., Cham: Springer International Publishing. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84921367766&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This paper presents the results of mathematical modeling and simulation involving vehicle properties designed with a simple parallel hybrid powertrain and a planetary gear for the use in buggy hybrid vehicle. This system consists of a planetary set and combines two power sources: combustion engine (ICE) and electric motor (EM). The powertrain consists of a simple planetary set and two additional gears with constant speed ratios. A wide range of transmission ratios is obtained due to various speed of electric motor which is directly connected to the sun gear in the planetary set. The model of the whole vehicle has been developed in MATLAB/Simulink environment. It describes the vehicle, internal combustion engine, electric motor and a planetary set.

Li, L. & Singh, R., 2015. Analysis of start-up transient for a powertrain system with a nonlinear clutch damper. *Mechanical Systems and Signal Processing*, 62-63, pp.460–479. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928612979&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The transient vibration phenomenon in a vehicle powertrain system during the start-up (or shut-down) process is studied with a focus on the nonlinear characteristics of a multi-staged clutch damper. First, a four-degree-of-freedom torsional model with multiple discontinuous nonlinearities under flywheel motion input is developed, and the powertrain transient event is validated with a vehicle start-up experiment. Second, the role of the nonlinear torsional path on the transient event is investigated in the time and time-frequency domains; interactions between the clutch damper and the transmission transients are estimated by using two metrics. Third, the harmonic balance method is applied to examine the nonlinear characteristics of clutch damper during a slowly varying non-stationary process in a simplified and validated single-degree-of-freedom powertrain system model. Finally,

analytical formulas are successfully developed and verified to approximate the nonlinear amplification level for a rapidly varying process.

Liang, X. et al., 2015. A Study on the Torsional Vibration of Fuel Cell Vehicle Sensor Powertrain. *Sensor Letters*, 13(2), pp.180–184. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84924011982&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The study on the vibration of Fuel Cell Vehicle (FCV) with its own characteristics is still at the initial stage. Firstly, this paper expounds the changes of propulsion system of FCV with respect to automobile with internal-combustion engine, and vehicle structure changes and related system changes it induces from a system engineering point of view. An analysis of inherent property of sensor powertrain system and a torsional vibration resolution combined with the excitation suffered during the accelerated motion are proposed based on the torsional vibration model of a FCV sensor powertrain system.

Ma, X. et al., 2015. *Proceedings of SAE-China Congress 2014: Selected Papers*, Berlin, Heidelberg: Springer Berlin Heidelberg. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84927616366&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: To analyze torsional vibration of the powertrain system for series hybrid vehicle, which consisted of dynamic vibration absorber (DVA), V12 diesel engine, speed increaser, and a generator, a lumped parameter model of torsional vibration and its vibration equation is established. Based on this model, the inherent vibration characteristic is calculated by using Matlab. And forced vibration analysis including order and resonance amplitude analysis is carried out considering no-load and full-load conditions. The results indicate that the working speed chosen is appropriate.

Mashadi, B. et al., 2015. Control of a twin clutch transmission for smooth gearshifts. *Mathematical and Computer Modelling of Dynamical Systems*, 21(4), pp.389–409. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84930764331&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The flow of torque in a twin clutch transmission is investigated and the different phases of torque transfer between the two clutches are studied. In order to prevent torque backlash and intense wear in dry clutch plates, a proper clamp force regulation is used. A full vehicle simulation that includes vehicle and powertrain components is set up. A Fuzzy logic control system is found suitable for clamp force and engine throttle controls. For upshift and downshift cases, the design of controllers for the gearshift process is carried out by defining proper membership functions and Fuzzy rules using Matlab/Simulink™ software. The effectiveness of the control system is investigated by simulating two upshift and downshift cases. Results indicate that the control system is successful in regulating the clutch clamp forces and the engine throttle in such a way that a smooth torque flow in the transmission is achieved in all cases.

Newman, K., Kargul, J. & Barba, D., 2015. Development and Testing of an Automatic Transmission Shift Schedule Algorithm for Vehicle Simulation. *SAE International Journal of Engines*, 8(3), pp.2015–01–1142. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928720033&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The Advanced Light-Duty Powertrain and Hybrid Analysis (ALPHA) tool was created by EPA to estimate greenhouse gas (GHG) emissions from light-duty (LD) vehicles [1]. ALPHA is a physics-based, forward-looking, full vehicle computer simulation capable of analyzing various vehicle types combined with different powertrain technologies. The software tool is a MATLAB/Simulink based desktop application. In order to model the behavior of current and future vehicles, an algorithm was developed to dynamically generate transmission shift logic from a set of user-defined parameters, a cost function (e.g., engine fuel consumption) and vehicle performance during simulation. This paper presents ALPHA's shift logic algorithm and compares its predicted shift points to actual shift points from a mid-size light-duty vehicle and to the shift points predicted using a static table-based shift logic as calibrated to the same vehicle during benchmark testing. An explanation of, and a process for tuning, the user defined parameters is presented and example applications of the algorithm in transmission and engine sensitivity studies are described.

Panneerselvan, I. et al., 2015. *High Fidelity Modeling and HIL Porting of a Hybrid Electric Car Development*, SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923205753&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: A hybrid electric powertrain being a complex system requires analysis of all its subsystems to optimally utilize, size components for performance evaluation and control strategy development. An integrated high fidelity model of these can lower development costs, time and achieve the targeted performance while allowing for early redefinition of the system. A high fidelity model of a sedan car featuring chassis with longitudinal and lateral dynamics, suspension with joints, tires calculating longitudinal & lateral forces during vehicle motion, Engine model with combustion & dynamics of reciprocating and rotating components, Electric motors, Battery system, and gearbox with synchronizers and friction components was developed. Powertrain components were interconnected using 3D rotational flanges. Weight distribution was accomplished by appropriately locating various powertrain components using 3D supporting mounts, which help to study the mount forces as well. The environment definition covers aspects like type of terrain, gradient, ambient pressure, temperature & humidity and path velocities for a drive cycle. A driver model commands steering, accelerating and braking to follow the defined path. Model scalability could be accomplished in various levels like the engine model could be scaled from Crank Angle based to simple mean value. Thus, emphasizing on particular aspect of simulation like Fuel Economy or emission trials, powertrain dynamics study, etc. Model portability into third party systems provides flexibility in performing HIL simulations. This Dymola model is being used in the HIL testing of control strategies using RT-labs Opal-RT hardware. A major hurdle of computational overrun in real-

time was overcome by splitting the plant model and accommodating in 3 different cores of the RT hardware.

Pisaturo, M., Cirrincione, M. & Senatore, A., 2015. Multiple Constrained MPC Design for Automotive Dry Clutch Engagement. *IEEE/ASME Transactions on Mechatronics*, 20(1), pp.469–480. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923211139&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In this paper, a multiple model predictive controller (MPC) is proposed for the management of passenger car start up through dry clutch in automated manual transmission. Based on a high-order dynamic model of powertrain system, the feedback controllers are designed by using the crankshaft angular speed and the clutch disk angular speed as measured variables. Moreover, the MPC is developed to comply with constrains both on the input and on the output. The aim of the controller is to ensure a comfortable lockup and to avoid the stall of the engine as well as to reduce the engagement time. Numerical results show the good performance of the MPC with constrains in overcoming critical operating conditions. Comparisons with similar state-of-the-art works are also shown.

Popov, A.P. & Nerubenko, G., 2015. Noise Reduction in Novel Transmission with 3D Point Contact Gear System. *SAE International Journal of Engines*, 8(4), pp.2015–01–1669. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928730886&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Increasing challenges on reducing fuel consumption has opened the new directions in Powertrain technologies. The example of such technology implemented in geared transmission is the usage of novel type of gears with 3D point system of mesh engaging which was invented, patented and developed by Alexei P. Popov. The paper identifies the milestones of R&D that were undertaken to create the new type of geared transmission. Using the Winkler hypothesis Alexei P. Popov has developed and designed new type of point contact which made possible to lower a contact stresses in comparison to the values of a contact stresses for teeth having linear contacting interaction. The new shapes of tooth were invented and the methodological tools were developed for engineers providing the formulas for design and forming geometry of tooth with high stress capacity. The patented profiles would be applied for a design of all kinds of transmissions successfully replacing the conventional vehicle gear transmissions. The results of theoretical analysis combined with experiments on prototypes illustrate the proof of developed mathematical modeling. The synthesis of new type of gearing is presented. The test results for transmission of extra heavy vehicle and for transmission of light truck are discussed. The 25% - 40% reduction of sizes and weights, and reduced noise levels up to 22 dBA are the advantages of transmissions based on invented gears having 3D point system of engaging.

Robinette, D. et al., 2015. Performance Characterization of Automatic Transmission Upshifts with Reduced Shift Times. *SAE International Journal of Engines*, 8(3),

pp.2015–01–1086. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928723511&partnerID=tZOtx3y1 [Accessed June 8, 2015].

Abstract: As the number of fixed gear ratios in automatic transmissions continues to increase in the pursuit of powertrain system efficiency, particular consideration must continue to be focused on optimizing the design for shifting performance. This investigation focuses on the effect of shift time on the performance attributes of shift quality, durability, on schedule fuel consumption and enablers to further reduce shift time. A review of fundamental design features that enable reduced shift times in both planetary and dual clutch transmissions is presented along with key operating features of both the transmission and engine/prime mover. A lumped parameter metric is proposed to assess and compare the upshift controllability of new transmission architectures and powerflows using simple analysis. The durability of fast shift times during performance maneuvers are quantified through calculation of shifting clutch energy and power from analysis and form measurements on a powertrain dynamometer. In addition to perceived powertrain performance, powertrain dynamometer measurements running the FTP test schedules fuel consumption trends with respect to inertia phase shift time and can provide upwards of 1.25% by optimization of shift times depending on powertrain details. The paper concludes with vehicle measurements comparing part and wide-open throttle shift times for 6 and 8 speed planetary automatics transmissions.

Sivertsson, M. & Eriksson, L., 2014. Design and Evaluation of Energy Management using Map-Based ECMS for the PHEV Benchmark. *Oil & Gas Science and Technology – Revue d'IFP Energies nouvelles*, 70(1), pp.195–211. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84924325042&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Plug-in Hybrid Electric Vehicles (PHEV) provide a promising way of achieving the benefits of the electric vehicle without being limited by the electric range, but they increase the importance ofthe supervisory control to fully utilize the potential ofthe powertrain. The winning contribution in the PHEV Benchmark organized by IFP Energies nouvelles is described and evaluated. The control is an adaptive strategy based on a map-based Equivalent Consumption Minimization Strategy (ECMS) approach, developed and implemented in the simulator provided for the PHEV Benchmark. The implemented control strives to be as blended as possible, whilst still ensuring that all electric energy is used in the driving mission. The controller is adaptive to reduce the importance ofcorrect initial values, but since the initial values affect the consumption, a method is developed to estimate the optimal initial value for the controller based on driving cycle information. This works well for most driving cycles with promising consumption results. The controller performs well in the benchmark; however, the driving cycles used show potential for improvement. A robustness built into the controller affects the consumption more than necessary, and in the case ofaltitude variations the control does not make use ofall the energy available. The control is therefore extended to also make use oftopography information that could be provided by a GPS which shows a potential further decrease in fuel consumption.

Sun, G. et al., 2015. Numerical modeling and active noise control of impact road noise inside a vehicle compartment. *Noise Control Engineering Journal*, 63(1), pp.72–85. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923914847&partnerID=tZOtx3y1.

Abstract: Even though active noise control (ANC) technique has been widely investigated and proven its efficiency for low-frequency vehicle interior noise control, current applications are mainly for the steady noise process such as powertrain noise and uniform road noise. When impulsive road disturbances due to road bumps or potholes are present, they may hinder the performance of the ANC system. One of the reasons is that the prevalent ANC algorithm, namely the filtered-x least mean square (FxLMS) algorithm, has been developed assuming that the signals follow the normal distribution. The impact road noise due to a sudden impact may exhibit a non-Gaussian characteristic. Hence, the FxLMS algorithm may not be appropriate for controlling this type of impulsive noise. In this study, a robust ANC system configured with a modified FxLMS (MFxLMS) algorithm by incorporating thresholds on reference and error signal paths is proposed for impact road noise control. To aid in the control system design, the spectral-based substructuring technique is implemented to develop a coupled vehicle system model to simulate the impulsive interior acoustic response due to road unevenness. The vehicle passenger compartment is simplified as a 3-dimensional flexible-panel backed cavity model, which is coupled with the tire-wheel system modeled as a flexible ring element and rigid wheel through the suspension system represented by a spring-damper model. The tire-road interaction is modeled as a set of flexible elements with certain stiffness over a half-cosine wave road bump. Numerical simulation results show that the proposed ANC system can effectively deal with the interior impact road noise without instability issue that may occur in the existing FxLMS algorithm. In fact, results show that approximately 8 dB reductions are achieved at the driver's ear position.

Sun, Z. et al., 2015. NVH Development of Aluminum Axles. *SAE International Journal of Passenger Cars - Mechanical Systems*, 8(2), pp.2015–01–2188. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84938568854&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This paper discusses approaches to properly design aluminum axles for optimized NVH characteristics. By effectively using well established and validated FEA and other CAE tools, key factors that are particularly associated with aluminum axles are analyzed and discussed. These key factors include carrier geometry optimization, bearing optimization, gear design and development, and driveline system dynamics design and integration. Examples are provided to illustrate the level of contribution from each main factor as well as their design space and limitations. Results show that an aluminum axle can be properly engineered to achieve robust NVH performances in terms of operating temperature and axle loads.

Tong, D. & Hao, Z., 2015. The energy decoupling and robust design of mounting system based on six sigma method. *Qiche Gongcheng/Automotive Engineering*, 37(2), pp.194–199. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84927745524&partnerID=tZOtx3y1.

Abstract: In order to improve the vibration isolation performance of powertrain mounting system, a deterministic optimization on mounting parameters (the stiffness, position and angle of mounting) is conducted by using adaptive simulated annealing algorithm with maximizing the energy decoupling rates of mounting system as objective, the natural frequencies of system vibration as constraints. Considering the variation of mount stiffness due to manufacturing error, and for enhancing the reliability and robustness of design, Monte Carlo simulation (MCS) technique is used to analyze the reliability of new design scheme, and design for six sigma (DFSS) technique is adopted to perform further optimization on mounting system. The results show that compared with deterministic optimization, with optimization by using MCS and DFSS techniques, the nominal energy decoupling rates and natural frequencies of powertrain mounting system have not much change, but the reliability and robustness of system are greatly improved.

Tribioli, L., Cozzolino, R. & Barbieri, M., 2015. Optimal control of a repowered vehicle: Plug-in fuel cell against plug-in hybrid electric powertrain. In *AIP Conference Proceedings*. American Institute of Physics Inc., p. 570014. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928101816&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This paper describes two different powertrain configurations for the repowering of a conventional vehicle, equipped with an internal combustion engine (ICE). A model of a mid-sized ICE-vehicle is realized and then modified to model both a parallel plug-in hybrid electric powertrain and a proton electrolyte membrane (PEM) fuel cell (FC) hybrid powertrain. The vehicle behavior under the application of an optimal control algorithm for the energy management is analyzed for the different scenarios and results are compared.

Walker, P.D. & Zhang, N., 2013. Numerical investigations into shift transients of a dual clutch transmission equipped powertrains with multiple nonlinearities. *Journal of Vibration and Control*, 21(8), pp.1473–1486. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928978544&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The purpose of this paper is to numerically investigate the influence of nonlinearities applied to vehicle powertrains equipped with a dual clutch transmission, including gear backlash, dual mass flywheel hysteresis, and torque pulses from the engine. To achieve this goal, a multi-body dynamic model of such a powertrain is constructed for transient vibration studies. Incorporated into this model is a combination of two nonlinear contact backlash models: for gear pairs a line-of-action force contact model is used to represent backlash in the mesh, and, for engaged synchronizer dog gears, a torsional nonlinear contact model is applied. This powertrain model is then used to study the response to shift transients under different conditions, including with and without engine torque harmonics, the variation of mesh damping and tooth clearance, and the impact of torsional vibration absorbers.

Simulation results demonstrate that engine torque harmonics, mesh clearance, and external damping sources have a significant impact on duration of excitation, while the impact of mesh damping is less significant.

Wang, C. et al., 2015. Structure optimization and its validation for compound power-split e-CVT. *Zhongguo Gonglu Xuebao/China Journal of Highway and Transport*, 28(3), pp.117–126. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928227209&partnerID=tZOtx3y1.

Abstract: In order to enhance the operating efficiency of conventional automatic transmission, based on the ravigneaux gear set, a novel compound power-split device with compact structure was designed, and the dynamic and kinematic equations of the compound power-split device were derived. By integrating and matching two motors with the compound power-split device, a new electronic-continuously variable transmission was constructed. An equivalent lever diagram was used to simplify the structure, and then an advanced structure with two brake clutches was presented based on the analysis of the electrical power-split characteristics and efficiency of the transmission. The mathematic equations of hybrid powertrain which was equipped with this optimized transmission were established, and the operating modes and the control strategies were analyzed by utilizing the equivalent lever diagrams. The power and economic performance of the proposed compound power-split transmission were validated by the off-line simulation and compared with previous design. The results show that the modified transmission can give additional engine direct driving mode and 3 electric driving modes, and the power and economic performance are both raised by 8.6% and 5.6% respectively.

Wang, D. & Jiang, R., 2015. Optimization Matching of Powertrain System for Self-Dumping Truck Based on Grey Relational Analysis. *SAE International Journal of Materials and Manufacturing*, 8(2), pp.2015–01–0501. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928780936&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In this paper, the performance simulation model of a domestic self-dumping truck was established using AVL-Cruise software. Then its accuracy was checked by the power performance and fuel economy tests which were conducted on the proving ground. The power performance of the self-dumping truck was evaluated through standing start acceleration time from 0 to 70km/h, overtaking acceleration time from 60 to 70km/h, maximum speed and maximum gradeability, while the composite fuel consumption per hundred kilometers was taken as an evaluation index of fuel economy. A L<inf>9</inf> orthogonal array was applied to investigate the effect of three matching factors including engine, transmission and final drive, which were considered at three levels, on the power performance and fuel economy of the self-dumping truck. Furthermore, the grey relational grade was proposed to assess the multiple performance responses according to the grey relational analysis. In this process, the principal component analysis was employed to determine the corresponding weights of the five indicators. Then the optimal combination of the engine, transmission and final drive was determined according to the Taguchi

methodology. Finally, a confirmation test was conducted to verify the optimal matching factors obtained by the proposed approach. The results indicated that the fuel economy of the improved self-dumping truck has been improved prominently, whilst its power performance completely satisfies the engineering design requirement. Hence, the optimization method based on the Taguchi method and grey relational analysis is an effective approach for the optimization matching of the powertrain system.

Wang, X. et al., 2015. Application Study on the Dynamic Programming Algorithm for Energy Management of Plug-in Hybrid Electric Vehicles. *Energies*, 8(4), pp.3225–3244. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928666201&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: To explore the problems associated with applying dynamic programming (DP) in the energy management strategies of plug-in hybrid electric vehicles (PHEVs), a plug-in hybrid bus powertrain is introduced and its dynamic control model is constructed. The numerical issues, including the discretization resolution of the relevant variables and the boundary issue of their feasible regions, were considered when implementing DP to solve the optimal control problem of PHEVs. The tradeoff between the optimization accuracy when using the DP algorithm and the computational burden was systematically investigated. As a result of overcoming the numerical issues, the DP-based approach has the potential to improve the fuel-savings potential of PHEVs. The results from comparing the DP-based strategy and the traditional control strategy indicate that there is an approximately 20% improvement in fuel economy.

Wang, Y. & Deng, Z., 2014. Control of a hybrid excitation machine with open-winding structure for hybrid electric vehicles. In *2014 17th International Conference on Electrical Machines and Systems (ICEMS)*. IEEE, pp. 2910–2916. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84922825320&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Vector-controlled permanent magnet machine with open-winding structure can realize voltage regulation over a wide speed range and improve the generator power factor as well as the system integration degree when used in Hybrid Electric Vehicles (HEV). However, it is difficult for the above system to control the energy distribution between the battery and the engine. Hence, in order to realize the energy distribution control in multi-energy powertrain of HEV, a hybrid excitation generator system with open-winding structure is investigated in this paper and a double closed-loop control of battery current and generator excitation current is employed. Simulation results demonstrate the feasibility and effectiveness of the energy distribution control scheme.

Yang, C. et al., 2015. Robust coordinated control for hybrid electric bus with single-shaft parallel hybrid powertrain. *IET Control Theory & Applications*, 9(2), pp.270–282. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84921730299&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The efficient coupling driving control is a key technique that affects both the fuel economy and drivability of the hybrid electric bus (HEB). However, the uncertainties resulting from the complex driving condition and the powertrain would affect the control performance. To solve this problem, this study proposes a novel control approach, which is elaborately integrated with multi-controllers under the consideration of properties of the city-bus-route and the hybrid powertrain configuration. First, a torque split strategy with the automated mechanical transmission (AMT) gear-shifting strategy is employed to adapt the driving intention quantified by fuzzy logic. Then the coordinated control mechanism is constructed through utilising the electric machine (EM) to compensate the response deviation of engine torque, meanwhile a robust controller is designed to withstand parameter perturbation and external disturbance existing in EM. Simulation results show that the operating points of the engine and EM are adjusted into the high-efficiency areas with the assistance of AMT gear-shifting, and the EM torque tracking performance especially when parameter perturbation and external disturbance appear. Moreover, the strategy adaptively distributed the driving torque in the predefined working modes for different driver's intentions. Thus, the efficient coupling driving of HEB might be implemented by the proposed method.

Ye, M., Li, X. & Cheng, Y., 2015. Rapid control prototyping of electric vehicle equipped with electric-mechanical continuously variable transmission. *Zhongguo Gonglu Xuebao/China Journal of Highway and Transport*, 28(1), pp.112–119. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84924336780&partnerID=tZOtx3y1.

Abstract: In order to check the functions and performance of electric-mechanical continuously variable transmission (EMCVT), the control system frame of electric vehicle (EV) equipped with EMCVT was designed on an electric car platform. Control strategies of vehicle and transmission ratio of EMCVT were investigated. Based on the control strategies the control software of EMCVT equipped EV was framed. Control models were built by using MATLAB/Simulink/Stateflow and, input and output moduli were developed with Motohawk. The control software was compiled and downloaded to the electric control unit with automatic codes generation. In this way, the rapid control prototyping was developed. Finally the prototype electric vehicle was assembled with control system, EMCVT, motor system and battery system. The results show that the transmission ratio of EMCVT equipped EV can be adjusted quickly, precisely and continuously. As a result operation points of powertrain are optimized and good running performance is achieved.

Yu, P. et al., 2015. Powertrain torsional vibration of a central-driven pure EV. *Zhendong yu Chongji/Journal of Vibration and Shock*, 34(10), pp.121–127. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84930517595&partnerID=tZOtx3y1.

Abstract: Aiming at driveline torsional, vibration of an EV, an electromechanical coupling simulation method considering dynamic characteristics of EV's control motor and driveline clearance/flexibility was proposed. Firstly, the driveline lumped mass vibration model was established considering the influence of electromagnetic

stiffness, its modal characteristics were studied and verified with tests. Then, the driveline lumped-distributed mass model was constructed considering backlash and flexibility of half shaft, the dynamic response simulation and test verification were conducted. Finally, the control motor model and the driveline electromechanical coupling model were built and simulated. The driveline torsion vibration response was obtained under the influence of torque ripple. Results showed that the proposed driveline electromechanical coupling simulation method can provide abundant dynamical phenomena, and its helpful to further reveal the driveline torsional vibration characteristics of an EV.

Zhu, B. et al., 2014. Gear shift schedule design for multi-speed pure electric vehicles. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 229(1), pp.70–82. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84919667237&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: As pure electric vehicles are considered to be a major growth trend in the automotive industry, research into and development of efficient electric powertrain systems and related control technologies have become popular research topics. The growing importance and use of multi-speed transmissions in these vehicles make shift schedule design and research a crucial aspect of the powertrain systems design of pure electric vehicles. This paper provides a gear shift schedule calculation method for pure electric vehicles, which includes a dynamic shift schedule and an economic shift schedule calculation method, demonstrating how to optimize the shift points and to produce the upshift and downshift lines based on the motor efficiency map. Through the establishment of a pure electric vehicle model, simulation results show that a properly designed shift schedule can improve the working region of the motor and can refine the dynamic performance and the economic performance of the vehicle. Finally, rig testing results are demonstrated to be comparable with simulations and indicate the correctness of the method.

Zhu, X. et al., 2015. Robust control of integrated motor-transmission powertrain system over controller area network for automotive applications. *Mechanical Systems and Signal Processing*, 58-59, pp.15–28. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923069548&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Integrated motor-transmission (IMT) powertrain system with directly coupled motor and gearbox is a good choice for electric commercial vehicles (e.g., pure electric buses) due to its potential in motor size reduction and energy efficiency improvement. However, the controller design for powertrain oscillation damping becomes challenging due to the elimination of damping components. On the other hand, as controller area network (CAN) is commonly adopted in modern vehicle system, the network-induced time-varying delays that caused by bandwidth limitation will further lead to powertrain vibration or even destabilize the powertrain control system. Therefore, in this paper, a robust energy-to-peak controller is proposed for the IMT powertrain system to address the oscillation damping problem and also attenuate the external disturbance. The control law adopted here is based on a multivariable PI

control, which ensures the applicability and performance of the proposed controller in engineering practice. With the linearized delay uncertainties characterized by polytopic inclusions, a delay-free closed-loop augmented system is established for the IMT powertrain system under discrete-time framework. The proposed controller design problem is then converted to a static output feedback (SOF) controller design problem where the feedback control gains are obtained by solving a set of linear matrix inequalities (LMIs). The effectiveness as well as robustness of the proposed controller is demonstrated by comparing its performance against that of a conventional PI controller.

Abstracts of papers related to NVH published in 2014

Achyut, C., Manoj, R. & Ramkumar, R., 2014. Effects of trim and trim modeling on in-cab noise. In *21st International Congress on Sound and Vibration 2014, ICSV 2014*. International Institute of Acoustics and Vibrations, pp. 1911–1917. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84922667596&partnerID=tZOtx3y1.

Abstract: The passenger cabin noise of vehicle is generally consists of structure borne & air borne noise based on transfer path & frequency range. Structure borne noise is produced by vibration of vehicle panels induced by powertrain excitation or road input. Air borne noise is radiated noise from outside of vehicle cabin into the cabin through sealing leakages. In Finite Element (FE) modeling of full vehicle, various soft trims (headliner, seats, carpet etc.) are represented by lump masses which represent the dynamic behaviour of the trim, with the reason being that trim induced stiffness change to body structure is generally negligible but the acoustic properties of such soft trim component are not considered. This simplification has proven to be effective & sufficient for low frequency (0-150 Hz) analysis. However as the frequency goes into the mid-frequency range (200-500Hz), the elastic behaviour of the trim may impose some effect on acoustic response; some trims may have noticeable sound absorptive performance which is not negligible. To develop a methodology for modeling the soft trim, a sample FE model is created with ANSA software. The FE model is validated with the experimental results from reference paper. The developed methodology is applied on the actual vehicle's FE model. A method to predict the interior noise of vehicle cabin which includes various trims (headliner, seats, carpet etc.) with the help of finite element methods is developed successfully. A method to model various soft trims is developed successfully with help of ANSA, NASTRAN software.

Akiyama, T. et al., 2014. Shaft Torque Vibration Control of Drive-Train Bench. *IEEJ Transactions on Electronics, Information and Systems*, 134(7), pp.909–916. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904968509&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Drive-train bench is utilized to test power-train components of a vehicle such that transmission, torque-converter, etc. In order to simulate the torque vibration of engine, it is necessary to control the amplitude and the static value of the shaft torque of drive-train bench. In this paper, we propose a shaft torque vibration control method composed of three controllers. In the low frequency band, we propose a static shaft torque controller of I-PD with 1st order low-pass filter which is robustly stable even in the case of stiffness variation of the power-train component. In the high frequency band, we design a resonance suppression controller by mu-synthesis method. Its controller does not change the characteristics of low-frequency. We combine the static shaft torque controller, the resonance suppression controller and an automatic tuner of vibration amplitude reference. © 2014 The Institute of Electrical Engineers of Japan.

Aktir, Y. et al., 2014. Modal Analysis of Automotive Clutch Using Finite Element Method. In *Volume 2: Dynamics, Vibration and Control; Energy; Fluids Engineering; Micro and Nano Manufacturing*. ASME, p. V002T07A010. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916917742&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Clutch system is an important element in the vehicle powertrain. It transmits the rotation from the crankshaft to the gearbox input shaft and filters axial and torsional vibrations providing from engine or induced by friction. This paper discusses axial dynamic behavior of automotive clutch for manual transmission. For this study, a tridimensional finite element model of clutch system is developed to simulate a clutch shaker test. First, an impact hammer test is performed to identify vibration properties of each clutch component. A prestressed modal analysis is then carried out to determine mode shapes and its associated natural frequencies of the clutch assembly. Shaker and simulation results are eventually compared to validate the clutch model. This latter offers for the design phase, a tool to avoid natural vibrations or to vibrate at specified frequencies.

Alexa, O. et al., 2014. Simulating the Torque and Angular Speed Distribution within a Heavy Vehicle's Planetary Gearbox. *Applied Mechanics and Materials*, 659, pp.127–132. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84920658508&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Simulating the real-time working of a system a complex challenge that had been developed lately within almost all fields of activity, of course including mechanical engineering as well. If one wants to reveal the torque and angular speed distribution onto the elements of a planetary gearbox, issuing a virtual model was previously needed. This model should replicate both the physical structure and the real working behavior. The modeled and simulated gearbox is a planetary type one. The power flows along the gearbox throughout three simple planetary mechanisms (sun gear and crown type) by successively locking different components with the aid of some multi-plate clutches (acting as locking clutches or brakes). The simulation of the friction element's engagement is achieved by introducing a physical signal that replaces the pressure of the hydraulic command system. We mention that the pressure evolution has been previously experimentally determined, in order to model the force that acts on the actuator's piston that, at its turn, presses the plates. The paper reveals the working cycles of the friction elements as well as the working modes of the planetary sets. It also reveals the time histories of the power flowing throughout the gearbox. The friction elements are modeled considering their three working stages: fully disengaged, partially engaged and fully engaged. The planetary sets are modeled starting from Willis equation for the speed distribution. For the torque distribution we used the energy conservation law as well as the torque balance law. Should be also mentioned that the virtual simulating model took into account the effects of the twisting vibrations, spinning inertia of the mechanical components and shafts' elasticity.

Arib, M.R.M.N. et al., 2014. Using transmissibility and vibration power flow methods to evaluate the effectiveness of elastomeric mounts for vibration and noise

control. In *21st International Congress on Sound and Vibration 2014, ICSV 2014*. International Institute of Acoustics and Vibrations, pp. 538–545. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84922595976&partnerID=tZOtx3y1.

Abstract: This paper presents the results of an experimental evaluation of elastomeric mounts used to isolate vibration from a block (representing a powertrain) to a structure test rig (representing a vehicle structure). Four types of elastomeric mounts were considered, where three of them are from green material natural rubber (SMR CV60, ENR50 and DPNR) and one from petroleum based synthetic rubber (EPDM). Measurement of the dynamic stiffness and loss factor of these elastomers were initially performed. Dynamic stiffness and loss factor were measured in the axial direction for a range of frequency between 5 Hz and 150 Hz at with a dynamic amplitude of 0.2 mm (p-p). Shaker excitation using random vibration signal in the frequency range of 10 Hz to 150 Hz at constant force magnitude was applied to the block in order to quantity the effectiveness of the elastomeric mounts. Measured vibration amplitudes in the axial direction on both sides of each mount were used to calculate the transmissibility and vibration power flow. Sound radiation from a plate attached to the structure test rig was also measured to evaluate the elastomeric mounts contribution to structure-borne noise. The results from transmissibility showed that vibration was high on EPDM, particularly in the ranges 25 to 35 Hz, 60 to 80 Hz and 100 to 120 Hz. ENR50 ability to reduce or damped the amplitude at resonance was found to be the best as compared to the other elastomers. The total vibration power flow was observed to be highest on ENR50 followed by EPDM. The high transmissibility on EPDM was due to its high dynamic stiffness and low loss factor. The larger total vibration power flow on ENR50 was attributed to its high dynamic stiffness and high loss factor.

Asl, H.A., Azad, N.L. & McPhee, J., 2014. Math-based torque converter modelling to evaluate damping characteristics and reverse flow mode operation. *International Journal of Vehicle Systems Modelling and Testing*, 9(1), p.36. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893982231&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This paper presents math-based torque converter modelling and simulation in both forward flow mode and reverse flow mode operations. Since a torque converter plays an important role in transferring power from an engine shaft to the transmission shaft and vice versa and affects the fuel consumption and vehicle longitudinal dynamics, simulating the dynamic behaviour of this component in different operating modes is of great importance. Our torque converter model is validated with the experimental results of the Honda CRV during the forward flow mode operation. The main focus of this research is on reverse flow mode simulation, and the application of the proposed math-based torque converter model to evaluate damping characteristics of a torque converter due to undesired disturbances generated either from engine pulsations or from road bumps and potholes. The simulation results show that a torque converter efficiently damps high frequency disturbances introduced from the engine shaft to the transmission side and vice versa.

Barillon, F., Polac, L. & Thevenard, C., 2014. A method to estimate automotive powertrain inertia properties using operational vibrations. In *Proceedings of ISMA 2014 - International Conference on Noise and Vibration Engineering and USD 2014 - International Conference on Uncertainty in Structural Dynamics*. KU Leuven, pp. 2395–2408. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84913607962&partnerID=tZOtx3y1.

Abstract: Today, fuel consumption and weight reduction issues in automotive industry lead to downsizing with the development of 3-cylinder engines. These powertrains present high level of idle vibrations due to the excitation of engine rigid body modes. Inertia properties thus need to be well known to be reintroduced into numerical simulation prognosis. Pendulum method and modal method are well-known methods to estimate the inertia tensor of a solid, but reveals quite difficult and time consuming to be applied in situ on a complete vehicle. This paper proposes an original method to estimate the inertia properties (c.o.g. position, mass and inertia tensor) of a powertrain using operational vibrations. Both numerical and test results are presented showing the efficiency of the method.

Bennur, M., Guan, J. & Mandal, D., 2014. Advancement in Vehicle Development Using the Auto Transfer Path Analysis. *SAE International Journal of Passenger Cars - Mechanical Systems*, 7(1), pp.113–124. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903440239&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper presents the most recent advancement in the vehicle development process using the one-step or auto Transfer Path Analysis (TPA) in conjunction with the superelement, component mode synthesis, and automated multi-level substructuring techniques. The goal is to identify the possible ways of energy transfer from the various sources of excitation through numerous interfaces to given target locations. The full vehicle model, consists of superelements, has been validated with the detailed system model for all loadcases. The forces/loads can be from rotating components, powertrain, transfer case, chain drives, pumps, prop-shaft, differential, tire-wheel unbalance, road input, etc., and the receiver can be at driver/passenger ears, steering column/wheel, seats, etc. The traditional TPA involves two solver runs, and can be fairly complex to setup in order to ensure that the results from the two runs are consistent with subcases properly labeled as input to the TPA utility. However, auto TPA allows necessary data needed for the TPA analysis to be requested in a single frequency response analysis run. The TPA breaks down the total response to partial contributions from interface points under operation loads. Partial contributions to total response are then computed by multiplying transfer function with the force transmitted through each interface location. By comparing the results of two-step TPA with auto TPA, the effectiveness and efficiency of the auto TPA have been demonstrated for three load cases: a) powertrain excitation for cruising acceleration to engine torque (A/T) and noise to engine torque (P/T), b) propshaft imbalance, and c) rough road excitation, which is based on the power spectral density (PSD) function. © 2014 SAE International.

Van Berkel, K. et al., 2014. Fast and Smooth Clutch Engagement Control for a Mechanical Hybrid Powertrain. *IEEE Transactions on Control Systems Technology*, 22(4), pp.1241–1254. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903311183&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Automatically controlled clutches are widely used in advanced automotive powertrains to transmit a demanded torque while synchronizing the rotational speeds of the shafts. The two objectives of the clutch engagement controller are a fast clutch engagement to reduce the frictional losses and thermal load, and a smooth clutch engagement to accurately track the demanded torque without a noticeable torque dip. Meanwhile, the controller is subjected to standard constraints such as model uncertainty and limited sensor information. This paper presents a new controller design that explicitly separates the control laws for each objective by introducing three clutch engagement phases. The time instants to switch between the subsequent phases are chosen such that the desired slip acceleration is achieved at the time of clutch engagement. The latter can be interpreted as a single calibration parameter that determines the tradeoff between fast and smooth clutch engagement. The controller is elaborated for a mechanical hybrid powertrain that uses a flywheel as a secondary power source and a continuously variable transmission. Simulations and experiments on a test rig show that the control objectives are realized with a robust and relatively simple controller. © 2013 IEEE.

Borman, S. et al., 2014. The Development of a Flexible Hybrid Vehicle Control Unit. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899540134&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: MAHLE Powertrain have developed a plug-in hybrid demonstrator vehicle. To support this one-off prototype, a flexible control unit has been developed, which is easily re-configurable and adaptable to any vehicle architecture. The unit operates using software developed in-house to achieve a fully configurable vehicle control unit (VCU), intended to provide a rapid and cost effective platform for the development of demonstrator and small validation prototype vehicle fleets. The executable code is auto-generated from graphical Simulink / TargetLink models, which greatly reduces development time and risk of errors. The graphical source code also provides comprehensive documentation for users of the system. This paper describes the resulting vehicle control unit and gives details of the application of the unit within the plug-in hybrid demonstrator vehicle. The reconfiguration of the unit from a series hybrid application to a parallel application will also be used to illustrate the speed and ease with which the architecture of the controller can be adapted. Copyright © 2014 SAE International.

Cao, F.P., 2014. Optimization of Automotive Powertrain Based on Genetic Algorithm. *Applied Mechanics and Materials*, 556-562, pp.2426–2430. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84902096175&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In order to improve the performance of the cars, an optimization algorithm of transmission parameters that take into account automotive dynamic and fuel economy based on genetic algorithm was presented in the paper. Firstly, the origin underway accelerate time was chose as the dynamic target function, and the 100 kilometers fuel consumption of 15-cycle driving was used to evaluate fuel economy, and the two objectives functions were putted into a comprehensive objective function. Then, the constraints were established using the requirement of automobile power performance and transmission design, and the genetic algorithm was adopted to do the optimization. At last, a simulation experiment was design to confirm the validity and effectiveness of the proposed method. © (2014) Trans Tech Publications, Switzerland.

Castelli-Dezza, F. et al., 2014. Design and realization of a quadricycle for urban mobility. In *2014 Ninth International Conference on Ecological Vehicles and Renewable Energies (EVER)*. IEEE, pp. 1–8. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904479980&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: The need to decrease pollution in urban zones has pushed toward severe regulations in term of low-emission limits. The effect of this "environmental awareness" is an increased interest in Light Electric Vehicles (LEV). The construction of a LEV is presented in this paper. This vehicle has been designed specifically to be powered by electric motors, the suspension system and the general layout have been developed accordingly. The main features of GreenFun, (this is the name of the prototype), are an extensive use of composite and lightweight materials, a special suspension system layout, a 4WD powertrain realized by means of 4 electric motor hubs and the use, for the first time in a production vehicle, of 4 measuring wheels that are able to measure the forces acting between the pneumatic tires and the road. These information are used as input for the vehicle control systems in order to enhance performance and safety. © 2014 IEEE.

Chen, K. & Lü, P., 2014. Simulation method for vibration isolation performance of vehicle powertrain mounting system. *Zhongguo Jixie Gongcheng/China Mechanical Engineering*, 25(20), pp.2830–2834. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84908572897&partnerID=tZOtx3y1.

Abstract: The properties of vehicle's noise vibration harshness(NVH) was affected by the vibration isolation of powertrain mount system. Using the mechanism of vibration isolation to conclude the vibration transmitting rate expression which was defined by RMS; based on the mechanism of double layer vibration isolation, a 6-DOF model of a powertrain mounting system and a 12-DOF full vehicle model including the car frame were built respectively, the inherent characteristics and frequency response of the two models were compared by the simulation analysis; and under the idling conditions, acceleration response of the powertrain mounting system was studied; the vibration transmitting rate curve of the mounting points was obtained eventually. The results show that the full vehicle model can response the vibration characteristics of a

powertrain mounting model and get the vehicle's vibration isolation transmitting rate at the same time.

Chen, Q., Shu, H. & Wang, K., 2014. Study on powertrain system for CNG-electric hybrid city bus. *Journal of Mechanical Science and Technology*, 28(10), pp.4283–4289. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84919690430&partnerID=tZOtx3y1 [Accessed March 24, 2015].

Abstract: In order to obtain better economy and power performances of compressed natural gas (CNG) and electric hybrid city bus, the powertrain system is designed and studied in this paper. Based on manufacturing technology, operation cost and dynamic property, economy is regarded as the main optimization goal for CNG-electric hybrid city bus, which determines the structure of powertrain system of CNG-electric hybrid city bus. Vehicle control strategy is established by working conditions. Some key component parameters are matched and designed. Work model of motor/generator is established, and torque characteristic curve of motor/generator is obtained. Full vehicle model of CNG-electric hybrid city bus is established by ADVISOR software. Comparison with tradition natural gas city bus, the maximum gradability rises by 69.8%, the maximum gradability of 20 km/h is 25.4%, the maximum speed rises by 8.6%, and the acceleration performance of 0∼50 km/h rises by 21.9%. The fuel consumption reduces by 23.3% in the BC-CTC cycle working condition, and the fuel consumption reduces by 25.1% in the ECE+EUDC cycle working condition. So, the performances of power and economy have been obviously improved, compared with traditional CNG city bus, which indicates that this method can be used to study the powertrain system of CNG-electric hybrid city bus.

Chen, X. et al., 2014. Hanger Location Design and Vibration Isolation of an Exhaust System. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899512342&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: In the present study, the research of the exhaust system is performed in three steps. In the first step, the average driving degree of freedom displacement (ADDOFD) is calculated by the free modal analysis of the exhaust system. It is easy to find the reasonable location of the hanger according to the value of the ADDOFD, since it represents the relative size of some DOF's response displacement at excitation state. The second of which is to analyse the vibration isolation performance of the exhaust system based on the first step. The dynamic analysis of the exhaust system together with the powertrain is studied, by which way the unit sinusoidal excitation is applied at the powertrain's mass centre, so that the response force at the hanger can be obtained. Finally, the relationship between the constrained model of the exhaust system and the stiffness of the hanger is investigated, which is significant in engineering.

Chindamo, D., Gadola, M. & Romano, M., 2014. Simulation tool for optimization and performance prediction of a generic hybrid electric series powertrain. *International Journal of Automotive Technology*, 15(1), pp.135–144. Available

at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84897721706&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Hybrid and electric vehicles are taking an increasingly important slice of the market, gaining much interest from major car manufacturers which have decided to invest in this sector, taking as example the pioneers like Toyota. The key factor to hybrid and electric vehicle success is a good overall mileage achieved from the battery back or powertrain. The purpose of this work is to provide a support to design, testing, and development of such vehicles through the implementation of a mathematical model in order to simulate the operation and predict the performance of a generic ground vehicle equipped with either a purely electric or a hybrid-electric type powertrain. The model should enable the user to estimate the impact of various control strategies on mileage range, efficiency, energy consumption, etc. The model should also allow for a significant time to market reduction with all the related benefits in terms of cost etc. A validation is also provided, based on the application of this tool on a so-called micro-car (0.5t GVW class). Thanks to a joint research project with the manufacturer it has been possible to compare model results with real-world data directly obtained during road testing with the help of a data acquisition system. © 2014 The Korean Society of Automotive Engineers and Springer-Verlag Berlin Heidelberg.

Cipollone, R. et al., 2014. Model based Design and Optimization of a Fuel Cell Electric Vehicle. *Energy Procedia*, 45, pp.71–80. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893652983&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Alternative vehicle powertrains (hybrid, hydrogen, electric) are a right answer to the emissions problem in very congested urban areas. The most effective alternative choice is surely represented by fuel cell vehicles. The design and optimization of this kind of powertrain can take a great benefit from mathematical models which include auxiliary management and control strategies of the energy fluxes: the use of a virtual platform limits the expensive and time-consuming experimental activity. The Authors present a lumped parameter mathematical model of a hybrid vehicle fed by a fuel cell pack. The propulsion system (fuel cell and battery) is accurately designed according to energy balancing. The mechanical power is given by an electric machine, whose behavior as alternator allows the energy recovery during braking. This aspect is treated with particular care (inside the overall vehicle and powertrain modeling). Vehicle's stability and safety has been also verified before recovering energy, re-modulating the braking action. © 2013 The Authors.

Cordiner, S. et al., 2014. Torque Setpoint Tracking for Parallel Hybrid Electric Vehicles Using Dynamic Input Allocation. *IEEE Transactions on Control Systems Technology*, 22(5), pp.2007–2015. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84905221051&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper addresses the coordinated control of the internal combustion engine and the electric motor in a parallel hybrid electric vehicle, when both of them

are running. In deciding how much torque each motor contributes, both long term energy oriented and short term drivability goals must be considered. The first contribution in this paper consists of proposing an architecture in which three main functional blocks are present, namely a steady-state performance generator, providing an energy oriented torque contribution, a transient performance generator providing a drivability oriented torque contribution, and a dynamic input allocator blending the outputs of the other two blocks in such a way as to satisfy both the short and the long term goals. The second contribution consists in showing how the input allocator must be designed. The other two blocks can be designed following any of several recipes already described in the literature. Experimental validation of the proposed approach confirms the relevance of accounting for the different motor dynamics in the allocator design.

Coronado, P.D.U. & Garza, H.A., 2014. Analysis of energy efficiency and driving range of electric vehicles equipped with a bimotor architecture propulsion system. *International Journal of Electric and Hybrid Vehicles*, 6(2), p.152. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84910595644&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: Electric vehicles (EVs) offer the potential for energy-efficient transportation. To increase consumer acceptance, improved driving range and fault-tolerant traction represent two important challenges. This paper proposes a powertrain architecture that can provide fault-tolerant traction and increase the driving range for EV. In the proposed system, the traction power of two motors is combined through a planetary gear train (PGT). The propulsion system can operate with only one motor or with any combination of speeds in the two motors. The performance of the proposed powertrain architecture is analysed through simulations. Two different configurations are compared with conventional electric powertrain designs. The simulations account for different types of driving cycles and electric motor efficiency maps. Results indicate that the proposed powertrain architecture produces improvements in overall efficiency and driving range.

Crain, T. et al., 2014. Powertrain Integration and Controls Development Process for a Parallel Through the Road Plug-in Hybrid Electric Vehicle. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899511348&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The University of Washington Advanced Vehicle Works team has spent the last two years designing and integrating a Parallel Through The Road (PTTR) PHEV drive system into a stock Chevy Malibu as part of the EcoCAR 2 Advanced Vehicle Technology Competition. This paper presents the integration efforts performed throughout year 2 in an effort to produce a 65% “buyoff ready” prototype vehicle. EcoCAR2 challenges 16 universities across North America to reduce the environmental impact of a 2013 Chevrolet Malibu without compromising consumer acceptability. The architecture chosen by the team to address these goals is a PTTR PHEV which provides all-electric operation to displace petroleum usage, four wheel drive mode to improve utility performance for consumers, and an efficient charge-

sustaining mode using 20% biodiesel (B20). The PTTR architecture is the lowest cost architecture to provide all of these benefits, and it does so without compromising the safety or performance of the platform. Copyright © 2014 SAE International.

Deuszkiewicz, P. et al., 2014. Modeling of Powertrain System Dynamic Behavior with Torsional Vibration Damper. *Advanced Materials Research*, 1036, pp.586–591. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84920719827&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The paper presents the results of experimental and model research of powertrain system built with torsional vibration damper. The behaviour of powertrain system with and without vibration damper was shown in the conditions of acceleration and deceleration with different increases of rotational speed. Next, authors describe the process of building a mathematical model of such a system and its identification on the basis of experimental results. When examining the results obtained with empirical and model research, it has been shown that in the structural and parametric identification of model of such system, the main factor affecting the right development of the structure should be dynamic criterion, since the only use of static criteria leads to big errors. On the basis of such model we can make some structural solutions to the system to minimize torsional vibrations.

Dextreit, C. & Kolmanovsky, I. V., 2014. Game Theory Controller for Hybrid Electric Vehicles. *IEEE Transactions on Control Systems Technology*, 22(2), pp.652–663. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84896815918&partnerID=tZOtx3y1 [Accessed March 30, 2015].

Abstract: This paper describes the development and experimental implementation of an energy management controller for hybrid electric vehicles (HEVs) based on the application of game theory (GT). This controller is constructed as a feedback Stackelberg equilibrium in the noncooperative game between the driver and the powertrain with the cost penalizing fuel consumption, NOx emissions, battery state of charge deviation, and vehicle operating conditions deviation. This control policy is drive-cycle and time independent. A description of the controller implementation with ancillary strategy elements is given. Experimental results from tests in a parallel HEV prototype vehicle are presented and compared with the existing baseline controller in terms of fuel consumption and NOx emissions. The HEV powertrain configuration is advanced and includes a high-speed diesel engine, two electric motors, and automated converterless transmission. Over the New European Driving Cycle (NEDC), the GT controller, with minimal calibration effort, demonstrates better performance than the existing baseline controller that is calibrated from the deterministic dynamic programing solution over NEDC. We also demonstrate that the GT controller substantially outperforms the baseline controller over other real-world-focused driving cycles while providing good drivability. © 1993-2012 IEEE.

Dimitrova, Z. & Maréchal, F., 2014. Environomic design of vehicle integrated energy system - Application on a hybrid electric vehicle energy system. *Chemical Engineering Transactions*, 39(Special Issue), pp.475–480. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84908083507&partnerID=tZOtx3y1.

Abstract: With the increasing trend of mobility of the human population, vehicles have to face the problem of primary energy resources scarcity. The vehicles need higher efficiency and better adaptation to the alternative energy sources. The need to improve the efficiency of the vehicle energy system motivates to search for innovative solutions during the design process. The main design criteria for modern sustainable development of vehicle powertrain are the high energy efficiency of the conversion system, the competitive cost and the lowest possible environmental impacts. These objectives are most of the time antagonistic. To cope with this challenge the automotive engineers need a structured optimization methodology. A multi-objective optimization methodology is being applied as search for the best powertrain design solutions. This kind of approach named "multi-objectives optimization" is based on genetic algorithms, which are based on the process of natural selection. An innovative decision- making methodology, using this optimization technic is currently under development at PSA Peugeot Citroën. The idea is to obtain simultaneously a population of possible design solutions corresponding to the most efficient energy system definition for a vehicle. These solutions are optimal from a technical, economic and environmental point of view. In this article the methodology is applied on a hybrid electric vehicle study in order to define the powertrain configuration of the vehicle, estimate the cost of the powertrain equipment and show the environmental impact of the technical choices on the lifecycle perspective of the vehicle. For that a physical model of a hybrid electric vehicle is made. This model is coupled with a cost model for the vehicle and life cycle assessment (LCA) technics are used for the environmental assessment. After multi-objective optimization, the outcoming solutions from the Pareto frontiers curve are analysed.

Ding, H. et al., 2014. Automobile power-train-coupling vibration analysis on vehicle system. In *INTERNOISE 2014 - 43rd International Congress on Noise Control Engineering: Improving the World Through Noise Control*. Australian Acoustical Society. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923549411&partnerID=tZOtx3y1.

Abstract: Engine is one of the main vibration sources, and it has a big impact on the vibration characteristics of the car. Reasonable design of suspension system can obviously reduce the vibration of automobile powertrain and the body. Aiming at the vehicle vibration induced by automobile engine, the powertrain mounting system is put into the environment of vehicle to study its coupling vibration characteristics. A multi-body dynamic model including powertrain, vehicle, body and suspension system is established to carry out the simulation calculation, then analyze the vibration transmissibility and the coupling vibration between powertrain and vehicle. The research shows that there is difference in vibration characteristics between vehicle model and six-degree-of-freedom model of mounting system. After optimizing the parameters of mounting system, the vibration transmissibility has significantly reduced, thus the vibration reduction effect has been effectively improved.

Dost, P., Schael, M. & Sourkounis, C., 2014. Comparison of Control Methods for Asynchronous Motors within Electric Vehicles. In *2014 IEEE Vehicle Power and Propulsion Conference (VPPC)*. IEEE, pp. 1–6. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84934325240&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper compares two control methods for electric vehicle propulsion by means of asynchronous motors. The basic underlying powertrain configuration and the control structure is presented. Two control methods, a symmetrical sinusoidal modulation and a rotational space vector hysteresis control are introduced and compared. Simulations are shown for both controllers using a single asynchronous motor. The rotational space vector hysteresis controller allows a reduction of power losses by a reduction of switching processes. Furthermore it gives the opportunity to avoid filter effort by reducing single high amplitude harmonic influence.

Duan, J., Li, M. & Lim, T.C., 2014. A computational-efficient active sound tuning system for steady-state and transient vehicle powertrain response. *International Journal of Vehicle Noise and Vibration*, 10(1/2), p.77. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84900625066&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Conventional vehicle active noise control (ANC) methods aimed mainly at attenuating the cabin interior noise usually do not account for sound quality effects. In this paper, an active sound tuning (AST) system is proposed to reshape the vehicle powertrain response based on the predetermined vehicle interior sound quality criteria. Since it is important to develop a computational-efficient algorithm in real-world application, the time-frequency domain filtered-x least mean square (TF-FXLMS) algorithm is utilised in the AST system. The proposed TF-FXLMS algorithm significantly reduces the computational complexity compared to the conventional time-domain FXLMS algorithm by calculating the gradient estimate in frequency domain. The proposed AST system applied to powertrain response is validated by tuning individual engine order response, which is targeted for either enhancement or attenuation, under both steady-state and transient operating conditions. © 2014 Inderscience Enterprises Ltd.

Edelberg, K. & Hedrick, J.K., 2014. A High Level approach to mean value modeling of an automotive engine during cold-start. In *2014 American Control Conference*. IEEE, pp. 3165–3170. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84905675442&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Wide-spread use of the model-based design process in automotive powertrain system development is increasing the need for accurate dynamic models. Model-based design inherently requires these models to be rapidly producible and easily verifiable. The High Level Modeling (HLM) approach and corresponding High Level Modeling Tool (HLMT) have been developed in response to these necessities. In this work, the HLM methodology is applied to a cold-start engine system. An existing physical/empirical model is reformulated in a conserved quantities

framework to satisfy the requirements of HLM. The modified model is then implemented and simulated in HLMT. Simulation results are validated against real engine data. Comparison of results demonstrates the new model successfully predicts cold-start engine dynamics despite the replacement of many empirically derived equations. © 2014 American Automatic Control Council.

Eisele, G. et al., 2014. 15 Years of Transfer Path Analysis VINS in the Vehicle NVH Development - Selected Results. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84938488224&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: Transfer path analysis is a powerful tool to support the vehicle NVH development. On the one hand it is a fast method to gain an overview of the complex interplay in the vehicle noise generation process. On the other hand it can be used to identify critical noise paths and vehicle components responsible for specific noise phenomena. FEV has developed several tools, which are adapted to the considered noise phenomena: Powertrain induced interior noise and vibration is analyzed by VINS (Vehicle Interior Noise Simulation), which allows the deduction of improvement measures fast enough for application in the accelerated vehicle development process. Further on vehicle/powertrain combinations not realized in hardware can be evaluated by virtual installation of the powertrain in the vehicle, which is especially interesting in the context of engine downsizing from four to three or six to four cylinders. Road induced interior noise is investigated by “Chassis-VINS” or “Fast-VINS”, depending on the required level of detailing and project timing. With the upcoming change of pass-by noise legislation VENS (Vehicle Exterior Noise Simulation) supports the target oriented component development to fulfill the legal limits. The application of these methods on more than one hundred vehicles - from microcar to heavy duty truck - in the last decade allows for rating vehicle noise shares relative to the state of the art. Selected examples of different vehicles show possible distributions of several airborne and structure borne noise paths.

Emadi, A., 2014. Hybrid electric locomotive powertrains. In *2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific)*. IEEE, pp. 1–6. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916215049&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: With the increasing awareness of fuel consumption and combustion engine exhaust emissions, more electrified locomotives emerge as promising solutions to fulfill the new requirements of being “Green”. This paper aims at reviewing the present situation and development of hybrid electric locomotive powertrains. The present diesel-electric locomotive powertrains, motor-assist locomotive powertrains as well as their alternators and traction motors are reviewed. Various other locomotive hybrid powertrains are also presented with the future trends discussed.

Fang, D.G. et al., 2014. Application Research of Virtual Prototype Technology in the Variable Stiffness Suspension Matching of Light Bus. *Applied Mechanics and Materials*, 538, pp.118–121. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84901723624&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: In order to meet the ride comfort requirements of the light bus under no load and full-load condition,its rear suspension employs two-level variable stiffness leaf spring. For reasonably matching the two values of the variable stiffness and the damping force curve of the damper, one kind of virtual prototype technology was used. The virtual spring model of two-level variable stiffness was created in Adams-Chassis and the center-curve of the leaves was based at the free-state of the leaf spring. Then the front suspension, the rear suspension, the steering system, the powertrain & drineline system, the braking system, the wheels and bus body were respectively builded in Adams_Car, and they consituted the virtual assembly model of the light bus. So we could use the virtual model to conveniently test the performance of the ride comfort and handling stability under the no load and full-load state. Based on the ISO test standards, the virtual objective evaluation indexes were all calculated. According to these indexes, the two-level variable stiffness and the damping force curve were optimized. At last, the optimization results were verified by testing the optimized light bus. Experimental results shows that virtual optimization technology could play an important role in solving engineering problems. © (2014) Trans Tech Publications, Switzerland.

Fang, Y. et al., 2014a. Joint simulation of radiated noise of electric powertrain based on finite element modeling and boundary element method. *Nongye Gongcheng Xuebao/Transactions of the Chinese Society of Agricultural Engineering*, 30(21), pp.40–46. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84918819964&partnerID=tZOtx3y1.

Abstract: Evaluation of the NVH (noise, vibration and harshness) performance of automotive powertrain has been an integral part of the vehicle development process. Although electric vehicles are generally considerably quieter than their counterparts powered by internal combustion engines, some problems about NVH still exist, which are becoming more challenging in terms of the future of vehicle. Firstly, the sound only from dominant engine but not from tire, wind or auxiliaries disappears, which consequently becomes increasingly audible due to the removal of the masking sound of broadband engine. Moreover, the interior noise is characterized by high-frequency noise components which can be subjectively perceived as annoying and unpleasant. Thirdly, as the electric vehicle develops toward the direction of high speed and large torque, electric vehicle vibration and noise problems highlight gradually. The subject of this paper is the numerical and experimental evaluation of the acoustic behavior of an electric powertrain, which is helpful for the electric vehicle in the design stage. For this purpose, a co-simulation method based on finite element modeling (FEM) and boundary element method (BEM) for the acoustic radiation analysis of an electric powertrain under multi-excitations is presented. The vibration and noise characteristics of electric vehicle are quite different from that of internal combustion engine due to different exciting forces. The calculation of the internal excitations of motor-reducer integrated drive system is the foundation of dynamic analysis. The internal dynamic excitations of a certain electric powertrain in rated revolution are calculated by theoretical analysis and numerical simulation method on the basis of

gear dynamics and electromagnetism, including the electromagnetic radial force, electromagnetic tangential force and external circuit in the motor, and the time-varying gear meshing stiffness, meshing error and meshing impact in the gear system. The amplitude of the electromagnetic forces is concentrated on the current harmonic frequencies, while the gear meshing force is on the meshing frequencies. On this basis, a structural dynamic model is established based on FEM to carry out the vibration modal analysis and calculate the vibration responses. The analysis shows that the electric motor can be influenced by the reducer, which makes the NVH characteristics of the electric motor are totally different from that without reducer. Then, an…

Fang, Y. et al., 2014b. Research and analysis of the internal excitations of electric powertrain. *Zhendong Ceshi Yu Zhenduan/Journal of Vibration, Measurement and Diagnosis*, 34(3), pp.496–502. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904472594&partnerID=tZOtx3y1.

Abstract: The vibration and noise characteristics of electric vehicles are quite different from those of internal combustion engines. The calculations of the internal excitations of the motor-reducer integrated drive system are the foundation of dynamic analysis. In this paper, the internal dynamic excitations of a certain electric powertrain in rated revolution are calculated by a theoretical analysis and numerical simulation method on the basis of gear dynamics and electromagnetism, including the electromagnetic radial force, torque ripple and external circuit in the motor, and the gear time varying meshing stiffness, meshing error and meshing impact in the gear system. This research lays the foundation for dynamic analysis of the electric powertrain.

Fang, Y. & Zhang, T., 2014. Modeling and Analysis of Electric Powertrain NVH Under Multi-source Dynamic Excitation. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84938498332&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Because of the vehicle market competitive and of the raise of customers' demanding, NVH performance became an important job, especially for new energy vehicles. As the electric vehicle moving into the direction of high speed and large torque, electric vehicle vibration and noise problems highlighted gradually. In recent years, CAE has played an increasing role in the design, development and optimization of powertrain NVH at component and system levels. The subject of this paper was the numerical and experimental evaluation of the electromagnetic and vibro-acoustic behavior of an electric powertrain. For this purpose, a coupled and fully flexible dynamics model of the electric powertrain was developed. Then electromagnetic forces including both radial and tangential force and gear mesh excitations including time-varying meshing stiffness, meshing error and meshing impact were computed, which were used to perform forced response analysis on the full FE mesh of the powertrain housing. An experimental bench was used to test the vibration acceleration and radiation noise of the electric powertrain in semi-anechoic room. By the numerical and experimental analysis, the effect of multiple excitations on NVH

performance of Electric powertrain was studied. Considering the importance of subjective perception of product quality, objective evaluation of sound quality based on psychoacoustics parameters was studied to analyze the subjective perception of the powertrain sound quality. Thus, a template for end to end solution to predict NVH performance from an electric powertrain was established.

Feng, R.H. et al., 2014. A fast and effective calculation method for engine radiated noise. *Zhendong yu Chongji/Journal of Vibration and Shock*, 33(18), pp.198–203. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84907941138&partnerID=tZOtx3y1.

Abstract: In order to solve the engine radiated noise problems accurately and efficiently, a Matlab program was developed here based on the surface vibration velocity method to calculate the radiated sound power. Several numerical examples including simple plate, engine head cover and engine powertrain were used to compare the accuracy and efficiency of the boundary element method, the fast multipole boundary element method and the Matlab program software. Results showed that for engine head cover and engine powertrain radiated sound power analysis problems, the comsumed time for the calculation with the Matlab program developed here is 1/123 or 1/108 of that with the fast multi-pole boundary element method, and 1/25 or 1/141 of that with the boundary element method, under the condition keeping a high calculation accuracy.

Fischer, J. et al., 2014. Measurement and analysis of the interior noise and the transfer path of acoustic phenomena into the driver cabin of a battery electric vehicle. In *INTERNOISE 2014 - 43rd International Congress on Noise Control Engineering: Improving the World Through Noise Control*. Australian Acoustical Society. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923568275&partnerID=tZOtx3y1.

Abstract: Driving comfort is an important factor for buying decisions. This is especially apparent in battery electric vehicles (BEV) where the acoustic quality is an elementary distinguishing feature, since the masking of an internal combustion engine (ICE) is no longer present. Despite the importance of the acoustic quality, there is a general lack of knowledge of how to measure and interpret the high frequency noise generated by an electric powertrain with respect to the NVH behavior influencing the passengers. In this contribution, the measurement results of the interior noise of a battery electric vehicle are analyzed. Specific methods for determining the torsional vibration of the powertrain as reference value are also presented. Furthermore, a method for measuring and interpreting the transfer path of acoustic phenomena from the drivetrain of a battery electric vehicle into the passenger cabin is presented. The measurements are performed in the context of the IPEK-X-in-the-Loop Framework on a roller test bench in a semi-anechoic chamber.

Fischer, T. & Mueller, S., 2014. New Concepts for Drag Torque Control in the Power Electronic Control Unit. In *SAE Technical Papers*. SAE International. Available

at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899568026&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: The domains of powertrain and brake systems are continuously merging due to the integration of electric drives and their ability to generate high acceleration and recuperative torque. However, high recuperative torque might lead to a locking motor and consequently cause a stability issue in electric and hybrid vehicles. This paper focuses on the special case of recuperation by coasting; i.e., the torque request is set after releasing the accelerator pedal. In this case the mechanical brake is not used. For off-highway vehicles this new feature in the inverter will suppress the slipping and locking up of the tires, without the need of additional external sensors. Slipping of the tires, e.g. when the tires lose grip, can occur due to excessive torque from the motor. In this case the motor torque exceeds the minimum feasible deceleration torque, given by road friction. We have developed a new non-linear control approach, which limits the requested torque directly inside the inverter (power electronic control unit). The control unit will monitor the torque and speed of the motor and validate their plausibility. When detecting an invalid decrease of the speed, the recuperation torque is reduced in order to control slipping. By this, the torque will stay as close as possible to the slip limit and recuperation performance is maximized. In this paper the authors cover and show that it is feasible to control slipping of tires in hybrid passenger cars and off-highway vehicles only by taking into account detailed physical models of the electric motor, the vehicle and the road contact with-out any means of additional external sensors. Copyright © 2014 SAE International.

Fu, H., Feng, C. & Xue, S., 2014. Vibration suppression control of an integrated powertrain of electric and hybrid vehicles using LQR controller and reduced-order observer. In *2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific)*. IEEE, pp. 1–6. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916212061&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This paper presents a vibration suppression control method for a motor-gearbox directly coupled integrated powertrain of electric and hybrid vehicles. The integrated powertrain is modeled as a two-mass system. Based on the analysis of the system dynamics, the oscillation of torsional angle and relative speed difference needs to be controlled to improve driving performance. To this end, an optimal LQR controller with a reduced-order observer is proposed to suppress the vibration caused by the oscillation of torsional angle in the system. A computer simulation model is developed to verify the effectiveness of the proposed control scheme. The simulation results illustrate that the estimated states are close to the reference states. It is also shown that the oscillation of the system is significantly suppressed. And both torsional angle and relative speed difference are well controlled under different gear ratios, which is beneficial for enhancing shift quality. Therefore, the proposed vibration control scheme is suitable for the integrated powertrain of electric and hybrid vehicles.

Guo, Y. et al., 2014. Vibration and acoustic characterization of a gearbox system with spur gears, shafts, bearings, and a compliant housing. In *Proceedings of ISMA*

2014 - International Conference on Noise and Vibration Engineering and USD 2014 - International Conference on Uncertainty in Structural Dynamics. KU Leuven, pp. 1033–1042. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84913587037&partnerID=tZOtx3y1.

Abstract: The gear tooth mesh is a primary source of audible noise in powertrain systems. This work considers the connection between gears, shafts, bearings, and a housing structure within the model of a complete drivetrain system to understand how gear vibration propagates through structures and radiates to the surrounding environment. A vibro-acoustic model of an actual gearbox, with all the aforementioned components, is developed. The procedure uses combined finite element, lumped-parameter, and acoustic boundary element models. Experimental vibration and noise measurements of the actual system confirm the predictions of this modeling process. This tool is used to quantify the differences in vibration when rolling bearings and journal bearings are used. The radiated noise of a gear-shaft-bearing-housing system using standard rolling element bearings is compared to an identical system with modified journal (wave) bearings.

Gwak, D.Y. et al., 2014. Application of subharmonics for active sound design of electric vehicles. *The Journal of the Acoustical Society of America*, 136(6), p.EL391. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84910028331&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The powertrain of electric vehicles generates an unfamiliar acoustical environment for customers. This paper seeks optimal interior sound for electric vehicles based on psychoacoustic knowledge and musical harmonic theory. The concept of inserting a virtual sound, which consists of the subharmonics of an existing high-frequency component, is suggested to improve sound quality. Subjective evaluation results indicate that the impression of interior sound can be enhanced in this manner. Increased appeal is achieved through two designed stimuli, which proves the effectiveness of the method proposed.

Hall, W.J., 2014. The Operation of HT-PEM Fuel Cells Coupled to Lithium Ion Batteries in a Fleet of Light Passenger Vehicles. *Fuel Cells*, 14(6), pp.945–953. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84918527409&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: High temperature polymer electrolyte membrane (HT-PEM) fuel cells offer some advantages over their low temperature equivalent, but there have been relatively few reports into their use in vehicles. This paper describes the power train design and operation of a fleet of Microcab H2EV vehicles. The power train consisted of a HT-PEM fuel cell coupled via a DC/DC convertor to a lithium iron phosphate traction battery, which was then connected to two Lynch motors. The integration and operation of all the major power train components is described. Also described here is the vehicle control unit that uses digital and analog communications to provide overall management of the vehicle. Details are given of all the safety systems designed into the vehicle. Some data describing the performance of the H2EV power-train during

typical drive cycles is presented, which shows that the system was functional. It is concluded that HT-PEM fuel cell light vehicles are viable, but the heating and cooling time of the fuel cell needs to be significantly reduced.

Hallez, R. & Vansant, K., 2014. A case study for predicting wind noise inside a car compartment using a multi-disciplinary CFD and Acoustic approach. In *Proceedings of ISMA 2014 - International Conference on Noise and Vibration Engineering and USD 2014 - International Conference on Uncertainty in Structural Dynamics*. KU Leuven, pp. 301–316. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84913594501&partnerID=tZOtx3y1.

Abstract: Environmentally conscious OEMs are making cars ever more efficient by using lightweight steel and composite materials. The weight reduction exercise highlights the benefits of powertrain energy resource optimization, but being lighter can also present a challenge for in-vehicle acoustic performance. The body panels, such as windows, floor, roof and doors, should be designed and mounted in such a way that yields sufficiently high transmission loss for exterior noise sources. Wind noise is such an external noise source which forms an important contributor to the total in-vehicle noise at higher vehicle speeds, especially if the vehicle is electrically powered. This paper examines the acoustic performance of a car model when subjected to hydrodynamic wind loads typical of high speed operation. The sound transmission through a glass window loaded by turbulent flow, caused by the wind interaction with the A-Pillar, were measured and simulated on a simplified car model in collaboration with Hyundai. For the simulation study, the turbulent field is first captured by a transient CFD analysis. The noise sources are captured using compressible CFD. These pressure results on the window are applied as loading on a vibro-acoustic model to predict cabin Sound Pressure Level up to high frequencies (4 kHz) using LMS Virtual. Lab Acoustics. As the pressure loads are caused by the turbulent flow phenomena they are to some extent random in nature. Depending on the stochastic characteristics of the pressure loading, different approaches to pre-process and to apply the load data are presented. Each approach is evaluated on its accuracy and performance and based on this recommendations are provided. Finally the effects of flow speed and yaw angle on the interior noise are investigated demonstrating the potential for mature industrial applications.

Han, P. et al., 2014. Research on the Shift Schedule of Dual Clutch Transmission for Pure Electric Vehicle. *Applied Mechanics and Materials*, 496-500, pp.1318–1321. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893967505&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The shift schedule is one of the core contents of main control logic of pure electric vehicle drive control system. With the right shift schedule, the vehicle can obtain good power performance and fuel economy. A shift schedule of dual clutch transmission(DCT) for pure electric vehicle based on powertrain coordination control is presented in this paper. Based on conventional vehicle shift schedule, the DCT shift schedule of pure electric vehicle drive system with powertrain coordination control is analyzed in detail. In order to verify the effectiveness of the shift schedule, some

simulations are carried out. The results show the shift schedule of dual clutch transmission for pure electric vehicle based on powertrain coordination control can improve the vehicle power performance. © (2014) Trans Tech Publications, Switzerland.

Hong, L., Dhupia, J.S. & Sheng, S., 2014. An explanation of frequency features enabling detection of faults in equally spaced planetary gearbox. *Mechanism and Machine Theory*, 73, pp.169–183. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84889677304&partnerID=tZOtx3y1 [Accessed July 15, 2015].

Abstract: Equally-spaced planetary gearboxes are important power-train components for varied engineering systems. Their failures can result in significant capital losses and pose safety concerns. The vibration measurements perceived by a sensor mounted on the gearbox housing can provide valuable diagnostic information while providing no interference to the normal gearbox operation. However, such vibration based monitoring techniques are difficult to implement in planetary gearboxes due to the complex nature of measured vibration spectra that is a result of planets revolving with respect to the stationary sensors mounted on the gearbox housing. Previous research carrying out simulation and experiments using such measurements have reported distinct sideband patterns in the resulting vibration spectra, which differ significantly from the spectra of a normal fixed-axis/parallel gear pair system. In this paper, a Fourier series analysis is used to explain these distinct sideband patterns that contain rich diagnostic information. The results obtained are useful to understand the cause of the observed vibration behavior in both healthy and faulty planetary gearboxes, and identify the locations of these additional frequency components introduced by the damaged gear in an otherwise complex measured vibration spectrum. Thus, the formulation presented in this paper can assist in developing robust feature extraction algorithms for early detection of planetary gearbox failures. The theoretical derivations presented in this paper are validated by both dynamic simulations, and experiments on a dynamometer test bed using a 750 kW gearbox damaged during its operation while installed in a wind turbine. The predicted fault frequencies for observed faults in the annulus and sun gears of the gearbox are vividly presented in the experimentally measured frequency spectrum. © 2013 Elsevier Ltd.

Hula, A. et al., 2014. Analysis of Technology Adoption Rates in New Vehicles. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899538427&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper examines the pace at which manufacturers have added certain powertrain technology into new vehicles from model year 1975 to the present. Based on data from the EPA's Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends database [1], the analysis will focus on several key technologies that have either reached a high level of penetration in light duty vehicles, or whose use in the new vehicle fleet has been growing in recent years. The findings indicate that individual manufacturers have, at times, implemented new technology across major portions of their new vehicle offerings in only a few model

years. This is an important clarification to prior EPA analysis that indicated much longer adoption times for the industry as a whole. This new analysis suggests a technology penetration paradigm where individual manufacturers have a much shorter technology penetration cycle than the overall industry, due to “sequencing” by individual manufacturers. Copyright © 2014 SAE International.

Ivens, T. et al., 2013. Model-based eco-driving and integrated powertrain control for (hybrid) electric vehicles. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–9. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911440042&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The Netherlands Organisation for Applied Scientific Research (TNO) is engaged in research, development and testing of a range of technologies relating to hybrid and electric vehicle energy management and performance. The impact of driver behaviour on vehicle energy consumption is a significant factor, and one which can often be reduced with eco-driving, typically 5-10% or higher in some cases. Eco-driving can be extended not only to take into account information sources, improved user acceptance, and integration with powertrain control. In this paper, TNO illustrates the possible applications of model-based control for (hybrid) electric vehicles and shows preliminary results of the developed system.

Jackson, T., 2014. Trends towards increasing use of mechatronics in aftertreatment. In *Emissions 2014, Papers and Presentations*. Global Automotive Management Council, pp. 88–97. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84910020616&partnerID=tZOtx3y1.

Abstract: Aftertreatment mechatronics will play an increasingly important and expanded role in emissions and powertrain strategy New aftertreatment technology such as electronic valves promises significant performance and fuel efficiency opportunities Innovative aftertreatment mechatronics products enable simplified engine emissions and efficiency strategies Early involvement necessary for optimization Active mechatronic strategies can solve thermal management, acoustic, and efficiency challenges, especially in regulatory transitions.

Jadhav, S.M., 2014. Powertrain NVH Analysis Including Clutch and Gear Dynamics. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899530770&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: Objective of this research is to reduce gear rattle and whine noise. Study includes measurement of noise, vibration on transmission for source identification in order to eliminate rattle, whine through optimization of gear design and clutch damper performance. In order to optimize, we measured transmission torsional vibration and analyzed for proper selection of clutch dampers to reduce engine vibration transfer function to transmission. Through Noise & Vibration FFT, order and color map analysis we identified noise sources and further scope for specific gears design

improvement. Hence test methodology adopted for development of gears and clutch damper successfully eliminated noise. Copyright © 2014 SAE International.

James, B.M. & Hofmann, A., 2014. Simulating and Reducing Noise Excited in an EV Powertrain by a Switched Reluctance Machine. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84938517251&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The noise performance of fully electric vehicles is essential to ensure that they gain market acceptance. This can be a challenge for several reasons. Firstly, there is no masking from the internal combustion engine. Next, there is pressure to move to cost-efficient motor designs such as Switched Reluctance Motors, which have worse vibro-acoustic behaviour than their Permanent Magnet counterparts. Finally, power-dense, higher speed motors run closer fundamental frequency to the structural resonances of the system [1]. Experience has shown that this challenge is frequently not met. Reputable suppliers have designed and developed their "quiet" subsystems to state of the art levels, only to discover that the assembled E-powertrain is unacceptably noisy. The paper describes the process and arising results for the noise simulation of the complete powertrain. The dynamic properties are efficiently modelled as a complete system and subjected to motor excitation (torque ripple, electro-magnetic forces and rotor imbalance). Innovation in this project comes from the speed of the modelling and analysis, so that analysis and data interpretation comes early enough in a project to be effective in reducing the noise problems. This contrasts with the approach of simulating problems that have already occurred in testing. Actions to reduce the motor noise are explained and identified. System dynamic response identifies the operating points in which different excitation mechanisms are most problematic and steps are taken to reduce the dynamic response. Also, problematic conditions can be identified where innovative motor control algorithms are necessary.

Kagnici, F., 2014. Engine Mount Vibration Sensitivity to Stiffness and Mass Properties of Major Components. In *Volume 1: Applied Mechanics; Automotive Systems; Biomedical Biotechnology Engineering; Computational Mechanics; Design; Digital Manufacturing; Education; Marine and Aerospace Applications*. ASME, p. V001T02A002. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916624992&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: In order to have an optimized NVH design concept, the design engineers must exchange during the development a lot of attributes that together defines the new engine NVH performance. Moreover, each engine NVH system performance is dependent of many variables. In this respect, 6-Sigma methodology (DMAIC and DCOV) is an excellent tool to support engineers to evaluate systems variables and achieve the required performance. Engine mount brackets' vibrations have high priority for the NVH performance of the powertrain. Effects of major components on the engine mount vibrations come up as a major topic whenever an error state takes place and improvement is required. This study aims to identify the effect of engine block, ladderframe, head and transmission stiffness and mass properties on 2EO

acceleration levels of the 4 cylinder engine power train. Dynamic analysis will be performed under the kinematic engine loadings. There are 2 steps for identifying the objective. The first step is to eliminate the factors which has not significant main and cross effect on engine mount vibrations. Full factorial DOE runs with two levels are performed for this purpose. Hyperstudy tool is used for the DOE design, simulation automation and post processing. After defining the effective factors, 256 Latin Hypercube DOE runs are performed to obtain response surfaces and meta - model. DOE runs are done in Hyperstudy, results are exported to enCORE and transfer functions are calculated by Kriging method. According to the results, a proposed course of action for engine mounts' accelerations DOE study is prepared and a methodology for this course is executed.

Karras, N., Kuthada, T. & Wiedemann, J., 2014. An Approach for Water Jacket Flow Simulations. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899519567&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The increasing importance of electric mobility results into the need for optimizing all power train components to further reduce the energy consumption of the vehicle. The aim of this study is to predict the thermal behavior and the pressure losses in water jackets of electric machines by use of CFD. The heat loss of electric machines in passenger cars is sufficient to let its components reach critical temperatures. For this reason, the optimization of heat dissipation plays an important role. The goal of efficient heat dissipation is a high heat transfer coefficient. At the same time, the pressure loss should be low in order to reduce the required power of the pump. Flow simulations can help to evaluate different water jacket concepts in an early stage of development. In this work, the validation of flow simulations in water jackets is based on measurements of a simplified geometry with constant boundary conditions. Afterwards, a coupled flow simulation of Exa PowerFLOW® and Exa PowerTHERM® is set up with the boundary conditions adopted from the measurements. A comparison of the results shows good correlation for the investigated flow rates, inlet coolant temperatures and wall temperatures. The deviation of the pressure losses between measurement and simulation are close to the measurement accuracy. With these results it is possible to develop and optimize water jackets based on a digital development process. Additionally, this enables to obtain the characteristic map for heat transfer coefficients and pressure losses of digital prototypes for cooling system simulations in the early development phase. Copyright © 2014 SAE International.

Kennings, P. et al., 2014. Developing powertrain mounting systems in the virtual engineering world using a full vehicle nvh simulator. In *INTERNOISE 2014 - 43rd International Congress on Noise Control Engineering: Improving the World Through Noise Control*. Australian Acoustical Society. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923570644&partnerID=tZOtx3y1.

Abstract: At Bentley Motors, the development approach for powertrain mounts has ramped up in recent years, from Hardware based test comparisons in the early years

through to our CAE based development with “Physical Simulation”. This latest technique, known as the Full Vehicle NVH Simulator (FVS), allows the engineering team to physically evaluate a laboratory based vehicle with high correlation to the vehicle on road -thiscreates a realistic and useable link between objective data and subjective feel.The tool is powerful in that it allows the team to achieve the required attribute balance betweenride comfortandpowertrain NVH. Advances made towards Bentley’s carbon footprint, like variable displacement engines (selectively reducing the number of active cylinders during operation), adds to the challenges of this attribute balance. This change results in lower firing orders at which mount isolation is required, making spectral tuning of the mount stiffness more challenging owing to the lower frequencynature of this operating range. The physical simulation technique which has been used for powertrain mounts development within Bentley has become a business advantage owing tothe reduced number of prototypes required for testing and, therefore, reduced product development costs with accurate predictions ahead of design freeze.

Kim, N., Lohse-Busch, H. & Rousseau, A., 2014. Development of a model of the dual clutch transmission in autonomie and validation with dynamometer test data. *International Journal of Automotive Technology*, 15(2), pp.263–271. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84897743543&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Owing to ever more stringent regulations and customers’ expectations, auto manufacturers have been considering numerous technology options to improve vehicle fuel economy. One of these is transmission technology, which has been shown to be one of the most cost-effective technologies. Over the past few years, transmissions have significantly evolved and have impacted both performance and fuel efficiency. As one of the advanced tranmissions, the dual clutch transmission (DCT) is the first automatic transmission to provide better efficiency than manual transmissions. DCTs provide reduced shift shocks and better driver comfort in addition to higher top speeds and torques. In this paper, a model and shifting controller for the DCT are developed in the vehicle systems context using Autonomie, a model-based vehicle simulation tool. Finally, the Autonomie DCT model and control strategy are validated using vehicle test data from Argonne's Advanced Powertrain Research Facility. © 2014 The Korean Society of Automotive Engineers and Springer-Verlag Berlin Heidelberg.

Kuduva Shanthulal, V.K. et al., 2014. Single Cylinder Diesel Engine Mount Configuration for Reduced Vibration in a Three-Wheeled Vehicle. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84938613724&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: The diesel power train (engine and transmission) is the most significant mass contributor in a three- wheeled vehicle. High idling vibrations from the engine get transmitted to the structure and the body panels through the engine mounts. Isolation of these vibrations by proper design of rubber mounts is the most effective engineering approach to improve ride quality of vehicle. In the present study, a

mathematical model of the powertrain and mount system is developed; with the engine and transmission being assumed to behave as a rigid body (6 degrees-of-freedom) and the compliance comes from the mounts. As a first step, the modes and natural frequencies are obtained. Following this the response to unbalanced inertial forces for an excitation frequency range of 20-60 Hz (1200-3600 rpm) has been obtained. The model is validated by comparing its results with results of previous published research work. Also, motoring experiments are conducted on a baseline configuration to obtain the vibration response at mounts and mode shapes through ODS (Operational Deflection Shape) for validating the math model. A detailed parametric study is conducted and a new combination of mount system design variables were arrived as proposed solution which in comparison with baseline configuration showed that the vibration response reduces by 40% at idling and 60% in the engine operating range. Experiments conducted on the improved design show similar improvement. Thus, using this validated analytical math model, a closer-to-optimal design can be obtained with minimal dependency on iterative experimental methods which are costlier and time consuming.

Leblanc, B. & Koch, A., 2014. Results exploration and decision making with NVH-CAE applications. In *Proceedings of ISMA 2014 - International Conference on Noise and Vibration Engineering and USD 2014 - International Conference on Uncertainty in Structural Dynamics*. KU Leuven, pp. 3993–4008. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84913528688&partnerID=tZOtx3y1.

Abstract: NVH-CAE engineers commonly deal with huge amount of results data. This has to be managed efficiently so that effort can be better invested into the root cause analysis of noise and vibration issues. With two automotive applications, it will be shown how to achieve this goal. In the first example a tool for “what if” analysis based on existing simulation results for full vehicle NVH will be demonstrated and the benefits highlighted. This is achieved using transfer path analysis; where a response is stripped down to the contribution of each attachment point for a given type of vehicle loading. This enables the user to study how the vibration coming from the chassis and powertrain sources, is transferred through the vehicle body (the receiver) resulting in radiated noise into the driver’s cabin. In the second example it will be shown how two numerical approaches can validate each other in the area of brake noise where the complex tribology nature of the contact is dominating the vibration issues and makes the problem non-linear. Transient simulation results and instability analysis outcomes are compared and post-processed in order to identify sensitive components providing engineers useful information on system behavior.

Lee, C.C. et al., 2014. Conceptual Powertrain Components Matching for a Hybrid Electric Vehicle with a Single Clutch-Coupled Traction Motor. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899521624&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Electrification of powertrain system for motored vehicles is one of the most important strategies being taken by many automakers to meet the stringent CO2

reduction required by laws in many countries, the marketplace-driven ownership cost reduction request, and the social and political energy sustainability needs. A hybrid electric vehicle (HEV) concept, having an electrified powertrain system comprising an internal combustion engine (ICE), a transmission with multiple discrete gear ratios, and a single electric motor with a coupling clutch is being implemented at FAW R&D to meet the strict Chinese Corporate Average Fuel Economy (CAFÉ) target. To specify the components of the parallel hybrid electric powertrain, a design of experiment (DOE) is conducted to calculate the sensitivities of the fuel efficiency to the specifications of key components, such as types of the ICE and number of gear ratios of the transmission, in different drive cycles. A prototype build based on the powertrain design concept is planned for dynamometer testing to confirm the fuel economy potential for a follow-up development program of the HEV. Copyright © 2014 SAE International.

Li, J. et al., 2014. Coordinated Control of Downshift Powertrain of Combined Clutch Transmissions for Electric Vehicles. *Energy Procedia*, 61, pp.1917–1920. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84922383817&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In order to improve the shift quality of electric vehicles equipped with combined clutch transmission, a dynamic model of shifting process is established. The shift jerk and friction work are chosen as a comprehensive control target. Linear quadratic optimal control to optimize the shifting process of planetary transmission is used, in which motor is involved. The simulation results show by the coordinated control of the motor torque and oil pressure the shift jerk and friction work are decreased by 32% and by 48% respectively, compared with combined clutch control only.

Li, Q. et al., 2014. Study on the Influences of the Structural Parameters of Hydraulic Engine Mounts on their Vibration Isolation Characteristics. *Key Engineering Materials*, 620, pp.200–205. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84906265452&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Hydraulic engine mounts (HEMs) are important vibration isolation parts in vehicle powertrain mounting systems. The structural parameters of HEMs are the main factors which determine their vibration isolation characteristics. It is of great significance to discover the influences of the structure parameters on their vibration isolation characteristics in the design and study of HEMs. HEMs with different rubber materials, lengths and cross-sectional areas of the inertia tracks are designed and manufactured, and their frequency response characteristics are investigated by experimental and analytical methods. The influences of these structural parameters on the vibration isolation characteristics of HEMs are educed. The analytical methods and conclusions are instructive for the design and tuning of the vibration isolation characteristics of HEMs. © (2014) Trans Tech Publications, Switzerland.

Li, S., Cui, N., et al., 2014. Controller-free ratio-variable gearbox for hybrid powertrain: Implementation and testing. In *2014 IEEE International Conference*

on Robotics and Biomimetics (ROBIO 2014). IEEE, pp. 2333–2337. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929587159&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: To provide a high starting torque and to work under a high rpm range are the design requirements for the integrated startgenerators (ISG) used for intelligent vehicles with hybrid powertrains. However, meeting with both of these two requirements usually involves with sophisticated motor and controller design and high manufacturing cost. Hence, a transmission with variable reduction ratio is desired to be configured between the ISG and the engine. In an earlier paper, a Controller-Free Ratio-Variable gearbox design concept has been introduced, which can auto change gear ratios in a purely mechanical way and avoid from using any controller or actuators. This paper represents the work on implementation, testing and evaluation of the gearbox. The performance of the gearbox proof to be functional though the test result.

Li, S., Wei, J., et al., 2014. Controller-free ratio-variable gearbox for parallel hybrid powertrain. In *2014 4th IEEE International Conference on Information Science and Technology*. IEEE, pp. 792–796. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84910593431&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: A transmission from the engine crank to the main transmission with variable reduction ratio is desirable for the hybrid electric vehicles, especially for micro/mild hybrid vehicles with auto start-stop function, for the sake of reducing the design requirements for integrated starter-generator and thus reducing the cost. This paper presents a solution to the issue by introducing a Controller-Free Ratio-Variable gearbox. Unlike other solutions, the proposed gearbox avoids from using actuators to change gear ratios but realize the function in a purely mechanical and fully automatic way. This feature reduces system complexity and improves system stability, as electronic-based info sensing and actuating are not as robust in the engine compartment. Also, the feature allows to change gear ratio faster and thus better protecting integrated starter-generator from over speeding. In this paper, the principle of the gearbox is explained and its performance under different conditions is studied.

Li, X.M., 2014. Powertrain system modeling and performance simulation about parallel-series hybrid electric vehicle. *Chang'an Daxue Xuebao (Ziran Kexue Ban)/Journal of Chang'an University (Natural Science Edition)*, 34(5), pp.161–168. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84909978157&partnerID=tZOtx3y1.

Abstract: In order to better evaluate the various performance of the electric vehicle, based on the design of traditional vehicle driving system and transmission line and its power optimisation, the motor component was selected and matched after the design, optimization and match of the driving system according to the vehicle structure, and then the drive system and control strategy of the hybrid electric vehicle were modeled and simulated in Matlab/Simulink environment. The performance of the power and emission was simulated and researched under the CYC_UDDS and CYC_1015 cycle

conditions. The results show that the premise of dynamic performance, oil saving rate can reach to 24% and 30% respectively, and the emission performance has been greatly improved in the original models. It provides some references for the study on the simulation of electric vehicle in our country.

Li, Z.Q., Chen, S.X. & Wei, Q.F., 2014. Study on calculating method of vibration decoupling for automotive powertrain mounting system. *Jisuan Lixue Xuebao/Chinese Journal of Computational Mechanics*, 31(2), pp.187–191. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84900510263&partnerID=tZOtx3y1.

Abstract: At present, the main task of designing a mounting system of automotive engine powertrain is to select appropriate stiffness, position and angle of mounting components so that free-vibration modal frequency of the mounting system can avert from the exciting-force frequency at the idle speed of the engine and the natural frequency of vibration of the vehicle body and that the decoupling degree of each mode shape is increased as far as possible, so as to improve the vibration-isolation effect of the mounting system. The design of a mounting system based on strict decoupling at predetermined frequencies is to make the modal frequencies of the designed mounting system completely equal to the frequencies predetermined in accordance with the frequency planning of automotive design, and to enable strict decoupling of each mode shape of each mode, i. e. , the decoupling degree of vibration energy in every direction equals to 1. Based on a free-vibration equation for a mounting system, this paper presented an equation system for designing a mounting system with strict decoupling at predetermined frequencies, provided a solving method for this equation system by using the method of constructing function, so as to provide an optimal design method more efficient and simpler than the current modal optimization method of mounting system. Relevant examples validated the correctness of equations and solving method of the strict-decoupling design at predetermined frequencies.

Liang, X. et al., 2014. A Study on the Parameter Matching and Optimization of FCV Powertrain. *Applied Mechanics and Materials*, 602-605, pp.2848–2854. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84906506246&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This article take powertrain system design of fuel cell electric vehicle (FCV) as researching object, focus on parameter matching and optimization of powertrain system for FCV, and makes parameter matching and optimization of powertrain system for a fuel cell vehicle. © (2014) Trans Tech Publications, Switzerland.

Lindenthaler, D. & Neumayer, M., 2014. Improved load modelling for switching power supplies in electrified vehicles. In *2014 IEEE 23rd International Symposium on Industrial Electronics (ISIE)*. IEEE, pp. 824–829. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84907345216&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: The trend for hybrid powertrain concepts has led to a widespread application of electric drives and electronic inverters in electrified vehicles. The operating principle of switched mode power supplies causes different motor excitations with respect to the excitation signals under stationary conditions. I.e. the motor is driven by fast transient switching signals instead of single harmonic signals, respectively. The simulation based prediction of occurring side effects like resonances becomes a matter about the accuracy of the load model. In this paper we present improved load modelling for electric motors in electrified vehicles to cover occurring side effects due to switching power supply excitation.

Liu, H. et al., 2013. Natural and Forced Vibration of Hybrid Electric Vehicle Powertrain. *Applied Mechanics and Materials*, 448-453, pp.3141–3146. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84887563567&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In this paper, the natural vibration characteristics of a hybrid vehicle powertrain are simulated. The nonlinear dynamic model is proposed by using the lumped parameter method, and the dynamic response characteristics of the powertrain with a wide range change of engine speed and torque are studied. The conclusions provide the basis for the system design and control strategies constituting of hybrid vehicle powertrain.

Liu, H. et al., 2014. Simulation on the dynamic characteristics of in-wheel-motor powertrain system in distributed drive electric vehicle. *Qiche Gongcheng/Automotive Engineering*, 36(5). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84902468597&partnerID=tZOtx3y1.

Abstract: A simulation model for the in-wheel-motor drive system of distributed drive electric vehicle is built with Matlab/Simulink software, and a simulation is conducted to analyze the dynamic characteristics during start, acceleration and regenerative braking. The results show that the sudden change in output torque of in-wheel motor drive system will cause chattering in speed and acceleration and affect the dynamic characteristics of vehicle. Aiming at the factor most affected by output torque chattering, a state feedback control method is adopted to solve the vibration problem of system, improve the dynamic characteristics and enhance the reliability, durability and ride comfort of vehicle.

Liu, Z. et al., 2014. Analysis on hanger location and hanger isolator of an exhaust system with powertrain. In *2014 International Conference on Mechatronics, Electronic, Industrial and Control Engineering, MEIC 2014*. Atlantis Press, pp. 1344–1347. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928009405&partnerID=tZOtx3y1.

Abstract: To improving the NVH (Noise, Vibration and Harshness) performance of vehicles, the NVH performance of exhaust system must be considered. As hanger is the main vibration transfer path and hanger isolator is the crucial vibration isolation components, it is necessary to study hanger location and stiffness of vibration

isolation. About the study of exhaust system is executed in four steps. Firstly, according the free modal analysis of the exhaust system, the ADDOFD (Average Driving Degree of Freedom Displacement) is acquired, and the suitable location of hanger is confirmed soon. Secondly, studied the powertrain influences to the vibration performance of exhaust system, the constrained modal frequencies must avoid the engine idle resonant frequency. Thirdly, the dynamic analysis of the exhaust system is researched based on the second step, in which way 100000N·mm sinusoidal excitation is applied at the powertrain's barycenter in the crankshaft rotation direction, and then the response reaction force (less than 5N) of the hanger are gained. Finally, the relationship between the bending and torsional modes of exhaust system and the stiffness of the hanger isolator are inquired. It is of great engineering significance.

Lu, B., He, H.W. & Guo, H.Q., 2014. Powertrain mount system optimization design for hybrid vehicle. *Journal of Beijing Institute of Technology (English Edition)*, 23, pp.72–77. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84921019822&partnerID=tZOtx3y1.

Abstract: The powertrain mount system of hybrid vehicle (HV) was a typical energy coupling system, which has follow features: multi-constraints, multi-objective and high nonlinear, it is difficult to solve the coupling optimization problem of the mount system by using the traditional optimization method. The outside point penalty function method was adopted to construct a reasonable objective function, which transformed multi-constraints, multi-objective problem into unconstraint single objective problem. A combination optimization algorithm was adopted to solve the 6-order rigid-body modal energy decoupling problem of the mount system. The optimization results show that the combination optimization method can effectively solve the problem of the mount energy coupling.

Lu, M., 2013. An Improved Design Method for Automotive Powertrain Rubber Mounts. *Advanced Materials Research*, 853, pp.520–525. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891916682&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The objective of the powertrain mount design is to find the geometry which meets the desired stiffness and damping requirements. For the conventional rubber mount, which is composed of a rubber element bonded into a metal bracket, its stiffness can be predicted using FEA but the damping is evaluated by physical testing. This paper introduces a design method at which the damping coefficient of the rubber mount is to be predicted theoretically based on the assumption that the phase angle for a rubber compound is constant. Absence of physical test in this proposed new design process, the development time from concept to production is reduced.

Lu, M.H. & Jen, M.U., 2014. Target setting and source contribution for sound quality of a Motorcycle. In *INTERNOISE 2014 - 43rd International Congress on Noise Control Engineering: Improving the World Through Noise Control*. Australian Acoustical Society. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84923583735&partnerID=tZOtx3y1.

Abstract: Sound quality is an essential competitive attribute for motorcycles' marketing. In this study, the sound perception of a motorcycle, powered by a 400 cc single-cylinder engine, didn't achieve its "sporty" statement and the associated sound quality refinement engineering was initiated. The first phase of refinement included benchmark, noise source contribution and target setting. This paper focuses on the methods in setting sound target through source contribution and sound synthesization. Noise data were measured in a hemi-anechoic chamber with a rolling road facility. Loudness, sharpness and order spectra were used to provide objective quantification metrics. From the results of subjective and objective evaluation, it was concluded that the motorcycle studied should increase its sound pressure level, loudness and sharpness; it also should magnify the lower integer-order components of the perceived sound and suppress the single-cylinder engine characteristic half-order components. The noise source contribution results validated the exhaust and intake systems should be improved first to fulfill a favorable sound quality. Combining the objective, subjective and source contribution results, this study successfully synthesized a promising and feasible vehicle level sound target. It was then cascaded to get the synthesized intake and exhaust noise targets for next CAE design modification.

Mammetti, M. & Roche Arroyos, M., 2014. The Study of Torque Control Characteristics for the Optimization of the NVH of an Electric Vehicle. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899510963&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Over recent years IDIADA has developed several prototype electric vehicles as well as testing a number of electric powertrain configurations. Generally the electric motor output shaft delivers the torque to the transmission under a considerable level of high-frequency load variation and with noticeable torque irregularities that must be smoothed out in order to fulfill general NVH targets. This paper deals with the development phase of a prototype vehicle in which a specific testing activity was carried out to improve the overall NVH behavior of the powertrain. For this purpose, the mechanism of energy transference from the current to the motor and from the motor to the downstream driveline components was deeply characterized. The activity was aimed at smoothing the abrupt change in torque delivery and limiting the transfer of torque irregularities from the motor to the transmission. The torque control software calibration and the driveline elements were developed in order to reduce the noise and vibration critical frequency ranges. New methodologies and testing approaches focused on electric powertrain allowed an accurate analysis in frequency and time domain for the detection of the causes of the NVH issues and helped to properly optimize the torque delivery. The study finally enabled the definition of the powertrain specifications with particular attention to the electric motor torque control and the transmission elements for the entire vehicle speed range.

Meier, C., Lieske, D. & Bikker, S., 2014. NVH-Development of Electric Powertrains - CAE-Methods and NVH-Criteria. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84938501842&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: Electric cars are getting popular more and more and the expectations of the customers are very challenging. Concerning comfort, the situation is clear: customers want an electric car to be quiet and without any annoying noise from the powertrain. To develop an electric powertrain with a minimum noise level and minimized whining it is necessary to have an accurate CAE-simulation and precise criteria to assess whining noise. Based on the experience with electric powertrains in research cars the CAE-modelling was improved and a new "whining intensity factor" was acquired for the development of Daimler's electric cars. The results are a very low noise level and a minimized whining noise, nearly not noticeable giving a comfortable sound to the customers of the smart electric drive and the B-Class Electric Drive.

Mosquera-Sánchez, J.A. et al., 2014. A multi objective sound quality optimization of electric motor noise in hybrid vehicles. In *Proceedings of ISMA 2014 - International Conference on Noise and Vibration Engineering and USD 2014 - International Conference on Uncertainty in Structural Dynamics*. KU Leuven, pp. 1371–1385. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84913528785&partnerID=tZOtx3y1.

Abstract: The use of hybrid and electric powertrains in passenger vehicles bring unusual narrowband auditory stimuli into the passengers compartment. When attempting to shape and control those effects, in either a passive or active approach, it is possible that one aspect of the soundscape is addressed at the expense of evidencing other unwanted noise components. Therefore, a proper handling of the different disturbance components is needed, which would take into account the intricate interrelation between those components and its cross effects on the various sound quality metrics relevant to this application. This paper discusses the performance and outcomes of two multi-objective evolutionary algorithms in dealing with the vector optimization of four sound quality metrics, namely Loudness, Roughness, Sharpness and Tonality, when applied to an electric motor driven powertrain, as perceived in the passengers compartment of a hybrid vehicle. Some criteria concerning the identification and optimization of the responsible narrowband components for the aforementioned psychoacoustic perceptions are given, together with a discussion about the parameters of the two evolutionary algorithms which guarantee convergence and diversity of solutions over the Pareto set of trade-offs, in a single solver run. An active sound quality control is implemented through computer simulations for tackling a synthesized stationary powertrain-induced noise, hence demonstrating the viability of accomplishing the desired sound quality targets devised during the vector optimization stage.

Nerubenko, G., 2014. New concept of vibration mitigation in hybrid vehicle powertrain. In *21st International Congress on Sound and Vibration 2014, ICSV 2014*. International Institute of Acoustics and Vibrations, pp. 1412–1419.

Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84922662412&partnerID=tZOtx3y1.

Abstract: The hybrid electrical vehicle has a combined source of power consisting of fuelled internal combustion engine and electric motors connected to the batteries. The rotations of engine crankshaft/motors shafts are transferred through transmission gearing arrangement and differential to vehicle wheels. The torsional resonance vibrations have always been a main problem for hybrid automobile powertrain. The effective reduction of torsional vibrations in powertrain could be achieved by implementing of the new design approach based on optimal insertion in powertrain structure the devices based on George Nerubenko US Patent 7,464,800 having the control system with instantaneous frequencies tuner and variable damping device adjusted for all operational frequencies in running engine, motors, transmission and differential. The study of dynamical performance of proposed device is presented. The patented scheme would be applied for a design of Flywheel and Torsional Vibration Damper. The same scheme is used for design of which are properly installed and used in engine, clutches, transmission gearing and differential box. A description and structural details of universal device with the control system are shown. The model for implementation of proposed device in hybrid vehicle powertrain is introduced. Test results received from experiments and mathematical simulations illustrate the effectiveness of new concept approach.

Ord, D. et al., 2014. Powertrain Design to Meet Performance and Energy Consumption Goals for EcoCAR 3. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899535487&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The Hybrid Electric Vehicle Team (HEVT) of Virginia Tech is excited about the opportunity to apply for participation in the next Advanced Vehicle Technology Competition. EcoCAR 3 is a new four year competition sponsored by the Department of Energy and General Motors with the intention of promoting sustainable energy in the automotive sector. The goal of the competition is to guide students from universities in North America to create new and innovative technologies to reduce the environmental impact of modern day transportation. EcoCAR 3, like its predecessors, will give students hands-on experience in designing and implementing advanced technologies in a setting similar to that of current production vehicles. The primary goals of the competition are to improve upon a conventional internal combustion engine production vehicle by designing and constructing a powertrain that accomplishes the following: Reduce Energy ConsumptionReduce Well-to-Wheel (WTW) GHG EmissionsReduce Criteria Tailpipe EmissionsMaintain Consumer Acceptability in the area of Performance, Utility, and SafetyMeet Energy and Environmental Goals, while considering Cost and Innovation This paper presents results from several modeling problems and conceptual vehicle designs. First, the power and energy at the wheels to meet acceleration and gradeability performance requirements are documented. Next, to compare several different fuel sources including E10, E85, and B20 fuels for a given base conventional vehicle, drive cycle fuel energy consumption is documented and used to find WTW GHG impact. The conventional vehicle modeling is validated by

comparing to measured fuel consumption and acceleration performance data from a conventional vehicle. To compare a battery electric vehicle (BEV) to the conventional vehicle, drive cycle electric grid energy consumption and GHG results from sizing a motor and battery to meet performance and range requirements are found. Very significant vehicle light-weighting (300 kg) would be required to accommodate a battery system large enough to meet the range goal of 320 km (200 mi). From here, the advantages of powertrain electrification are examined by constructing a Series Hybrid Electric Vehicle model. The model is used to size engine/generator and battery components in the powertrain. Additionally, different hybrid vehicle energy management strategies are explored to evaluate overall charge balance operation. Waste heat conversion to meet electric accessory …

Pallas, M.A., Chatagnon, R. & Lelong, J., 2014. Noise emission assessment of a hybrid electric mid-size truck. *Applied Acoustics*, 76, pp.280–290. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84884850751&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In the attempt to improve urban environmental conditions, city or national incentives encourage the use of cleaner vehicles, including hybrid electric vehicles. This paper explores the actual noise impact of this alternative drivetrain technology on the noise emission of a mid-size delivery truck powered by a parallel hybrid powertrain, compared with an equivalent internal combustion engine truck on the basis of pass-by noise measurements. It investigates jointly the overall emission, the main noise sources and the vertical directivity of the vehicle. The essential benefit results from the existence of a full-electric mode below 50 km/h, with a significant noise reduction which may exceed 8 dB(A) at low constant speed. Even if smaller, this noise advantage is still valuable when the vehicle is accelerating or braking. Due to weaker noise emitted upwards, the benefit should be even greater for residents living on upper building floors. The rolling noise associated with the drive wheel/road contact is the main noise source in all driving situations in electric mode, and beyond 50 km/h in the configurations with engine.

Pan, G.Y., Yang, X. & Yan, Y., 2013. Optimization of Vehicle Powertrain Mounting System and its Performance. *Applied Mechanics and Materials*, 441, pp.580–583. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891099951&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In order to solve the vibration problem of diesel engine powertrain assembly at its idle state, a six degree-of-freedom dynamics model of the powertrain mounting system is established and a optimization based on Adams/View is applied to simulation and analysis on the powertrain mounting system with energy decoupling method. The results show that the optimized repositioning mounts installation position can effectively improve decoupling rate in main vibration directions of mounting system. Based on this, the vibration transmissibility and acceleration response before and after optimization are simulated. The results show that the optimized engine mounting system makes a great improvement of vibration isolation performance.

Park, G. et al., 2014. Integrated modeling and analysis of dynamics for electric vehicle powertrains. *Expert Systems with Applications*, 41(5), pp.2595–2607. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84890123348&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Powertrain of an electric vehicle (EV) is a compound system with an electrical sub-system, such as batteries, inverters, and electrical motors, as well as a mechanical sub-system, including transmissions, differential, and wheels. Since the electrical systems directly affect the vehicle driving performance and dynamics of an EV, integrated modeling considering both the mechanical and electrical systems is essential to assess ultimate kinetic and dynamic characteristics of an EV in terms of input electrical quantities. In this paper, an entire analytic model for the powertrain of EVs is developed to describe EV dynamics with respect to electrical signals, in consideration of both mechanical and electrical systems. Theoretical models based on mathematical expressions, combining the mechanical power system and the electrical power systems, are derived for predicting the final vehicle driving performance as a function of electrical quantities. In addition, a Matlab model of an EV is developed to verify the derived mathematical analysis model. Based on the theoretical model of the powertrain, a variety of relationships between electrical quantities and vehicle dynamics, such as velocity, acceleration, and forces of the EVs, are finally investigated and analyzed.

Parmar, V. et al., 2014. Multi-Physics Simulation Model for Noise and Vibration Effects in Hybrid Vehicle Powertrain. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84937484834&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Over the past 30 years, simulation of the N&V (Noise and Vibration) behaviour of automotive drivelines became an integral part of the powertrain development process. With current and future HEVs (Hybrid-Electrical Vehicles), additional phenomena and effects have entered the scene and need to be taken into account during layout/design as well as optimization phase. Beside effects directly associated with the e-components (namely electric whistle and whine), torque changes caused by activation/deactivation of the e-machine give rise to vibration issues (e.g. driveline shuffle or clonk) as well. This is in particular true for transient operation conditions like boosting and recuperation. Moreover, aspects of starting the Internal Combustion Engine (ICE) using the built-in e-machine in conjunction with the dynamic behaviour of torsional decoupling devices become increasingly important. In order to cope with above-mentioned effects a multi-physics simulation approach is required. The following paper proposes a simulation approach that incorporates the domains of the ICE thermodynamics, the mechanical driveline system, the electric components, the vehicle, as well as the fundamental control functions. A special emphasis is put onto non-stationary transient operation, which requires a full coupling between the involved domains. Moreover, the aspect of a combined 1D/3D mechanical modeling is outlined, with the background of scaling model fidelity for components of particular interest and importance (e.g. Dual Mass Flywheel, Centrifugal Pendulum Vibration Absorber, and Gear Stages). A combination of the AVL's Simulation Tools BOOST RT, CRUISE and EXCITE is utilized for this

purpose. The paper outlines the modeling procedure for the different domains, their interaction and coupling and finally shows how different N&V effects can be simulated and evaluated in a comprehensive way.

Pasdar, A.H., Azadi, S. & Kazemi, R., 2014. High-precision, real-world modeling of a semi-automatic powertrain. *SIMULATION*, 90(9), pp.1041–1058. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84927667799&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In a mechatronical approach, the design of a highly detailed, physically based model of a semi-automatic powertrain suitable for supervision has been explicated. In each part of the powertrain system, ultimately developed dynamical models have been exploited to make sure the whole model is up-to-date and is close to a real system. Advanced dynamical equations of an engine, a clutch, a gearbox and a driveline as well as a tire and a vehicle dynamic model for analyzing longitudinal performance have been considered. A well-suited automated manual transmission (AMT) along with a mean value transient spark-ignition (SI) engine model has been inserted to complete the solution. In order to simulate a real vehicle, the nonlinearities of the powertrain system mainly generated in the engine and clutch have drawn attention. Transient behavior of the system is a key parameter for design; hence, both steady-state and transient modeling such as of the gear shift procedure were considered. All parts of the model have been verified against experimental data. Finally, an overall simulation of the powertrain and vehicle in an in-city Economic Commission for Europe (ECE) cycle and a complete involved simulation of a gear shift process using Simulink have been performed to examine the level of the modeled dynamics. Lastly, it will be clear that use of nonlinear and real-world models can enhance the modeling and make it comparable to a real system.

Pei, D.J., Qin, D.C. & Pan, S.C., 2014. Powertrain Simulation Research of Coaxial Series-Parallel Hybrid Electric Bus. *Advanced Materials Research*, 945-949, pp.1333–1338. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903384769&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In order to know the vehicle performance of coaxial series-parallel hybrid electric bus, on the basis of the analysis of the powertrain's structure and operation mode, the control strategy is made, the simulation system is introduced by the secondary development of Advisor, the simulation result is analyzed and used. Through the analysis of vehicle dynamic performance, fuel economy, SOC value change of super capacitance, and the torque relations of main components, it is known that coaxial series-parallel hybrid electric bus can satisfy the requirements of the city bus' working condition, and the operation relations between the power components can be mastered, which provides the technical support for the coaxial series-parallel hybrid electric vehicle development. © (2014) Trans Tech Publications, Switzerland.

Perfetto, A. et al., 2014. Ethanol optimized powertrain for medium duty trucks. In *ASME 2014 Internal Combustion Engine Division Fall Technical Conference, ICEF 2014*. Web Portal ASME (American Society of Mechanical Engineers).

Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84919363708&partnerID=tZOtx3y1.

Abstract: This paper includes a detailed description of an optimized E85 concept engine developed for medium duty applications (Class 4-6 trucks) targeting ultra-low carbon emissions while maintaining power and delivering competitive cost of ownership. The engine is a light weight, downsized and boosted in-line 4 cylinder with air handling, fuel, and combustion systems designed specifically for E85 capability, producing high brake mean effective pressure (BMEP) at high thermal efficiency. It is integrated with a 12V start/stop system including a smart alternator for improved energy management. The present work demonstrates that even with the relative difference in the cost per heating value of fuel, using E85 can be upwards of 20% lower in cost while running middle to high loads. Combining high BMEP capability and a highly downsized engine displacement can ensure operation at high specific load where engine thermal efficiency is very good even in pickup-and-delivery type drive cycles. The performance characteristics of this engine were mapped using stoichiometric combustion and a three way catalyst for emissions control. The ability to perform at or close to Maximum Brake Torque (MBT) spark timing throughout the torque curve has been facilitated by an optimized combustion system design along with direct injection. The high engine thermal efficiency and knock tolerance of this combustion system eliminates the need for fuel enrichment anywhere in the engine map.

Qin, D., Wang, Y. & Hu, M., 2014. Powertrain parameter design for the electric vehicle considering driving cycle. *Chongqing Daxue Xuebao/Journal of Chongqing University*, 37(1), pp.7–14. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84896506116&partnerID=tZOtx3y1.

Abstract: In allusion to the defects of traditional theory matching method, the authors propose a new power matching method which combines theoretic calculation and cycle working condition together for powertrain of pure electric automobiles. Based on dynamic constraint, the peak power of motor is determined. In order to make the motor work in high efficiency area, the power needed by vehicles in ten cycles is analyzed and the motor rated power is determined. Regular effect pattern of battery parameters on dynamic property and driving range of entire vehicle is analyzed. With defining a conception of acceleration time influence factor and continue driving range influence factor, motor parameters are amended. The transmission ratio is optimized with taking the power of the entire vehicle as constraint and the maximum driving range in constant speed condition as object, and the driving range is greatly improved. The output power of battery in different SOCs is simulated, and it's found that when the SOC closes to lower limit, the output power of battery is able to satisfy the demand of the vehicle.

Raghvendra, G., Shende, D. & Pathak, U., 2014. Augmenting Light Weighting Horizon in Automotive. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84906748790&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: Better ride and comfort, enhanced safety, reliability and durability, lower running cost as well as cost of ownership continue to be challenges for automotive OEMs. Higher fuel efficiency is considered as USP not only for lower running cost but also is hygiene factor from sustainability point of view. This has necessitated the need for Augmenting Light weighting horizon in automotive OEMs. Augmenting this leads to invention of innovative materials and processes for emerging cost competitive market. This paper focuses on technology efforts towards augmenting light weighting Horizon in Automotive. Light weighting concepts being explored by OEMs with the help of automotive component manufacturers from Powertrain - Engines & Transmission, Chassis and Suspension are discussed. The Innovative concepts and case studies covered include Hollow Crankshaft and Camshafts, PM gears, composite / bimetallic brake drum, steering knuckle & leaf spring, hollow Anti Roll Bar (ARB) & Front Axle Beams (FAB), high strength polymers for fuel tank etc.

Rao, M.V., Frank, J. & Raghavendran, P., 2014a. Analysis of Drive Line Vibration and Boom Noise in an All Wheel Drive Utility Vehicle. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899512793&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: The customer demand for all wheel drive (AWD) vehicles is increasing over the period of time which also requires NVH performance on par with front wheel drive vehicles. AWD vehicles are equipped with power transfer unit, propeller shaft and independent rear differential assembly to achieve their functional requirement. The additional drive train components in AWD vehicles may amplify torsional fluctuations in the drive line. Hence achieving the NVH performance of AWD vehicles on par with FWD vehicles without any major change in the existing design is a major challenge. In this work, an AWD vehicle with severe body vibration and booming noise is studied. The operational measurements are taken throughout the drive train on all sub-systems from engine to the rear part of the body in the problematic operating condition. An operational deflection shape analysis is conducted to visualize the vibration behavior of the drive train. The result of analysis shows that the dynamic torsional fluctuations of the drive shaft and rear drive module (RDM) vibration are the major contributors for the high levels of vibration and noise. Powertrain torsional vibration measurements are also carried out with and without the part of the drive train that belongs to AWD. The reduction in vibration to certain extent is achieved by optimizing the stiffness of RDM mounts. The complete vibration and boom is eliminated by installing a tuned mass damper on RDM. The reduction of 4 dB (A) in interior noise and 5 dB in seat vibration are achieved with the effect of modifications.

Rao, M.V., Frank, J. & Raghavendran, P., 2014b. Measurement Technique for Quantifying Structure Borne and Air Borne Noise Levels in Utility Vehicle. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899540145&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Accurate quantification of structure borne noise is a challenging task for NVH engineers. The structural excitation sources of vibration and noise such as powertrain and suspension are connected to the passenger compartment by means of elastomer mounts and spring elements. The indirect force estimation methods such as complex dynamic stiffness method and matrix inversion method are being used to overcome the limitations of direct measurement. In many practical applications, the data pertaining to load dependent dynamic stiffness of the connections especially related to mounts is not available throughout the frequency range of interest which limits the application of complex dynamic stiffness method. The matrix inversion method mainly suffers from the drawback that it needs operational data not contaminated by the effect of other forces which are not considered for calculation. In this paper, a new method is proposed in which the structure borne noise associated with powertrain is quantified easily and reliably. The powertrain is disconnected at its mounting locations from the vehicle without changing its position and orientation. The test is conducted in idling, stationary run up and 2nd gear run up conditions on plain road surface. The difference in the noise levels of tests conducted with and without mounts is the structure borne contribution from the powertrain. The technique is also helped in reducing the time taken for matrix inversion method without the need for complete removal of source. The new method also helps in finding the dynamic stiffness of the powertrain mounts over the wide frequency band of interest.

Rejab, M.N.A., Rahman, R.A., et al., 2013. Measurement of Noise inside the Compartment and Vibration on both Sides of Elastomeric Powertrain Mounts of Passenger Car. *Applied Mechanics and Materials*, 471, pp.59–63. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891526155&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This paper presents an evaluation on elastomeric mount used to isolate vibration from powertrain to chassis or structure vehicle. The assessments started with measurement of noise inside compartment, and exhaust noise. This is followed by the measurement of vibration on both sides of elastomeric mounts. The noise in the compartment and exhaust noise is measured according to BS 6086: 1981 and BS ISO 5130: 2007. The noise in the compartment and vibration is tested in three conditions. Firstly, engine is run-up with load (driving at second gear); secondly, without load; and thirdly, without load but hanging. A microphone is fixed at the ear of the mannequin. The “fast” response and “A” weighting sound level meter were used for measurement noise in the compartment and exhaust noise. The vibration is measured in terms of acceleration on both sides of each elastomeric powertrain mounts. Two accelerometer transducers are fixed on both sides of powertrain elastomeric mounts. One side was identified as a source of vibration and the other as receiver of vibrations. The results showed that the pattern of overall vibration level on source and receiver increased from 1050 RPM (idling) to 4000 RPM on all test conditions. Vibration transmitted to chassis or receiver structure was analyzed using transmissibility concept. By evaluating test condition of engine run-up without load, informed that the front and rear mounts showed a high level transmissibility contributing to structure-borne noise.

Rejab, M.N.A., Rahman, R.A., et al., 2013. Measurement of Vibration Power Flow through Elastomeric Powertrain Mounts in Passenger Car. *Applied Mechanics and Materials*, 471, pp.30–34. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891507809&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The effectiveness of vibration isolator or mount can be done by quantifying the vibration energy flow through the isolators. This can provide information on the quantification of the vibration energy flow from the powertrain to the structure or chassis. Vibration energy flow through mount is identified as vibration power flow that is one of vibration transmission paths. This paper presents vibration power flow through four elastomeric mount. The vibration (source and receiver of accelerations) was measured by running engine at constant speed and without load conditions in varying speeds starting from 1050 RPM to 4000 RPM. The vibration was measured only in zdirection (vertical direction). The noise inside compartment was measured at the condition of engine run-up without load condition and was measured starting from 1050 RPM to 4000 RPM engine speed. The results from vibration power flow analysis showed that the main vibration energy transmission was high from front mount and rear mount, around engine speed 3200 RPM, and booming noise occurred around 3200 RPM due to structure-borne noise. © (2014) Trans Tech Publications, Switzerland.

Rosbi, S. et al., 2014. Evaluation of dynamic absorber to suppress subharmonic nonlinear vibration in car powertrain. In *MOVIC 2014 - 12th International Conference on Motion and Vibration Control*. Japan Society of Mechanical Engineers. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84925372674&partnerID=tZOtx3y1.

Abstract: This paper analyzes a suppression method for nonlinear vibration called subharmonic vibration of order 1/2 in car powertrains by using a dynamic absorber. In car powertrains, the torsional forced vibration caused by engine combustion leads to reduced ride quality. Thus, in the torque converter of an automatic transmission car, a piecewise-linear spring called a damper is used to reduce the transmission of the forced vibration into the vehicle frame. However, subharmonic vibration occurs in the actual vehicle when the spring restoring characteristics are around the switching point. The fundamental vibration frequency of the subharmonic vibration is half of the engine forced vibration frequency. Although the design of the dynamic absorber used to suppress the forced vibration has been established for linear systems, the optimum design for suppressing subharmonic vibration of order 1/2 has not yet been investigated. In this study, the powertrain is modeled using a multi-degree-of-freedom system for the actual vehicle, including the engine, torque converter, transmission gears, and wheels. An equation of motion is developed by also considering the restoring force of the piecewise-linear spring. The numerical result shows that subharmonic vibration occurs when the engine excitation frequency is almost twice the second mode of the natural frequency, and the result shows good agreement with the experimental data. Then, the dynamic absorber is introduced to suppress the occurrence of subharmonic vibration. In this paper, the optimum design of the dynamic absorber used to suppress the subharmonic vibration is discussed. The

numerical results show that with the appropriate natural frequency and damping ratio, the optimally designed dynamic absorber is capable of suppressing the occurrence of subharmonic vibration.

Rossi, C., Pontara, D. & Casadei, D., 2014. e-CVT Power Split Transmission for Off-Road Hybrid-Electric Vehicles. In *2014 IEEE Vehicle Power and Propulsion Conference (VPPC)*. IEEE, pp. 1–6. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84934300429&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Traction system based on electric driven Continuously Variable Transmission (e-CVT) is widely used in full hybrid powertrains for passenger cars. This paper deals with a new solution for the layout of the e-CVT, which is based on coaxial and concentric arrangement of the electric machines. The hybrid electric transmission based on the e-CVT is proposed for the application on agricultural tractors.

Roy, H.K., McGordon, A. & Jennings, P.A., 2013. Real-world investigation of a methodology for powertrain component sizing of hybrid electric vehicles. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–9. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911416386&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Hybrid electric vehicles (HEVs) have emerged as near term sustainable technologies to reduce fossil-fuel dependency. The variation in fuel economy (FE) due to the variation in driving patterns exists in hybrid electric vehicles (HEVs). Powertrain component size optimisation based on a methodology considering a range of driving patterns including different traffic conditions and driving styles simultaneously has previously demonstrated the potential to reduce variation in FE over standard legislative driving patterns. Though standard legislative driving patterns are useful for comparative study, there are evidences that legislative driving patterns are often considerably different from real-world driving. Therefore to ensure wide applicability, the methodology needed to be validated for real-world driving pattern. This paper applied the methodology for ten real world driving patterns over a predefined route consisting of urban and highway driving to investigate the applicability of the methodology in real world. The study was carried out using a series-parallel Toyota Prius HEV. A rule based supervisory control strategy was considered as the energy management. A genetic algorithm was considered as the optimisation method. The methodology demonstrated the potential to reduce variation in FE by up to 33% in real world driving.

Ruan, J., Zhang, N. & Walker, P., 2014. Comparing of the effects of CVT and DCT on the EVs including braking energy recovery. In *8th Australasian Congress on Applied Mechanics, ACAM 2014, as Part of Engineers Australia Convention 2014*. Engineers Australia, pp. 942–950. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84934312487&partnerID=tZOtx3y1.

Abstract: We seem going through a tough time. The remaining fossil fuel is limited and the price is higher and higher. Tens of millions brand new vehicles go into markets every year. This causes serious environment problem, especially in some developing countries. Electric vehicles (EVs), as the most promising environment friendly transportation, attract significant attention of OEMs and researchers when the using of traditional fossil fuel based vehicles are restricted by many metropolis to alleviate air pollution and reduce the reliance on imported crude oil. However the consumer acceptance of EVs is still restricted by the limited range in comparison to its counterpart-internal combustion engine vehicles. More and more people attempt to integrate various transmission systems to EVs to extend the mileage and improve the performance of electric vehicle. Continuously Variable Transmission and Dual Clutch Transmission are two popular options currently. Their characteristics are considered more suitable than other transmission systems to the powertrain of EVs. In this paper, two models have been designed to simulate the city cycle performance for EVs equipped with CVT and 2-Speed DCT respectively. A comprehensive comparison has been made to discuss the advantages and disadvantages of two different multispeed transmission system applied on the EV, which includes both propelling and regenerative braking circumstance considering the structure complexity, cost and efficiency.

Sakhaei, B. & Durali, M., 2014. Vibration Transfer Path Analysis and Path Ranking for NVH Optimization of a Vehicle Interior. *Shock and Vibration*, 2014, pp.1–5. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904117884&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: By new advancements in vehicle manufacturing, evaluation of vehicle quality assurance has got a more critical issue. Today noise and vibration generated inside and outside the vehicles are more important factors for customers than before. So far several researchers have focused on interior noise transfer path analysis and the results have been published in related papers but each method has its own limitations. In present work, the vibration transfer path analysis and vibration path ranking of a car interior have been performed. As interior vibration is a source of structural borne noise problem, thus, the results of this research can be used to present the structural borne noise state in a vehicle. The proposed method in this paper does not need to disassemble the powertrain from the chassis. The procedure shows a good ability of vibration path ranking in a vehicle and is an effective tool to diagnose the vibration problem inside the vehicle. The simulated vibration spectrums in different speeds of the engine have a good compliance with the tested results; however, some incompatibilities exist and have been discussed in detail. The simulated results show the strength of the method in engine mount optimization. © 2014 B. Sakhaei and M. Durali.

Schael, M. & Sourkounis, C., 2014. Doubly-fed induction motors for electric vehicle propulsion. In *2014 Ninth International Conference on Ecological Vehicles and Renewable Energies (EVER)*. IEEE, pp. 1–7. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904497075&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper presents a concept for the usage of two distributed doubly-fed induction machines in an electric vehicle. The underlying motion model is shown and the general necessity for the usage of an electric differential for the powertrain is explained and simulation results are presented. Using this concept, the mechanical differential gear can be effectively replaced and synchronisation problems as existing with other electric differential solutions can be reduced.

Shah, A. et al., 2014. NVH Integration of Twin Charger Direct Injected Gasoline Engine. *SAE International Journal of Passenger Cars - Mechanical Systems*, 7(3), pp.1221–1228. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84924426109&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The increased focus and demands on the reduction of fuel consumption and CO2 requires the automotive industry to develop and introduce new and more energy efficient powertrain concepts. The extensive utilisation of downsizing concepts, such as boosting, leads to significant challenges in noise, vibration and harshness (NVH) integration. This is in conflict with the market expectation on the vehicle's acoustic refinement, which plays an increasingly important role in terms of product perception, especially in the premium or luxury segment. The introduction of the twin charger boosting system, i.e. combining super and turbo charging devices, enables downsizing/speeding in order to achieve improved fuel economy as well as short time-to-torque, while maintaining high driving dynamics. This concept requires also extensive consideration to NVH integration. The NVH challenges when integrating a roots type supercharger are very extensive. The high frequency source characteristics of the supercharger result in complex wave propagation inside the intake duct system since exciting pulsation orders are well above duct cut-on frequencies. The source strength in relation to audible interior tonal noise threshold is also very high. In addition the background masking levels in terms of mainly combustion related powertrain and road noise are low with the consequence that the orders (tonal noise components) can be prominent and annoying even with a high degree of acoustic source treatment (remedies). The scope of this paper is to describe quantification of the charging system noise radiation and propagation including subsystem target cascading synthesis.

SHANGGUAN, W., 2014. Methods for Measuring and Predicting Fatigue Life of Rubber Mounts of Vehicle Powertrain. *Journal of Mechanical Engineering*, 50(12), p.126. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84900019213&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: A fatigue experiment is carried out for a rubber dumbbell cylindrical specimen and a rubber mount of vehicle powertrain. The dumbbell cylindrical specimen and the mount for vehicle powertrain are made of filled natural rubbers with the same formula. The calculation method for three damage parameters to estimate fatigue of rubbers is described and discussed. The damage parameters include strain energy density, maximum principal Green-Lagrange strain and effective stress. Based on the measured fatigue life data of dumbbell cylindrical specimen, three models using different damage parameters to predict rubber fatigue life is presented. The

fatigue life of the mount predicted by the three models is estimated and is compared with the experimental fatigue life. The fatigue life calculated using the modes with strain energy density or maximum principal Green-Lagrange strain as the damage parameter is in a poor agreement with the experimental fatigue life within a factor of four. The model using effective stress as damage parameter can predict the fatigue life within a factor of two, which is the best prediction among the three models. It's concluded that the proposed model for fatigue life prediction with the effective stress can be used to estimate the fatigue life for a rubber mount of vehicle powertrain. © 2014 Journal of Mechanical Engineering.

Shanmugam, M., Kharatmal, R. & Satpute, S., 2014. Rapid Design and Development of Noise Radiating Engine Components. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899517967&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: This paper describes the rapid design and development of thin walled powertrain components which act as external cover for engine subsystem assemblies. Computer Aided Engineering plays a major role in reducing the overall product development lead time. An approach by using "Simulation Driven Design and Development" helps the developers to bring the necessary confidence about the components' required functionality during the design stage itself. During the design stage, typical inputs available for the development of these components are the broad dimensions obtained from the packaging considerations. The designer is required to develop the concepts targeting least noise radiation from component surfaces due to various excitations. Based on cost considerations, the designer can even opt for plastic materials instead of steel. The current paper considers two major noise radiation members namely valve cover and timing gear cover for rapid product development. A conventional modal analysis followed by harmonic response studies provides the basis for the iterations towards designing these members. The modal analysis, harmonic response studies and noise radiation efficiency calculations are performed by using a commercial FEA program. It is observed that the suggested Simulation Driven Design and Development approach has reduced the development time from 2 months to 3 weeks for the design finalization. Copyright © 2014 SAE International.

Shehovtsov, V. et al., 2014. Influence of elements dynamic cohesiveness in power shafting on torsional vibrations spreading and dynamic equality of reducible model. *Mechanics*, 20(2), pp.190–196. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84902249388&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper presents investigation of torsional vibrations spreading in powertrain shafting. Influence of dynamic cohesiveness of system elements vibration on this spreading was researched. Cases of vibrations energy transfer without energy losses was described.

Shi, X.F. & Zou, Y., 2014. Model development and analysis on hybrid powertrain system based on Modelica. *Journal of Beijing Institute of Technology (English Edition)*, 23, pp.213–219. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84921029031&partnerID=tZOtx3y1.

Abstract: The dynamic system model of Toyota Prius was developed based on Modelica on the open platform OpenModelica, and the rule-based control strategy was proposed to complete its dynamic computing and system analysis. Then the system was simulated in specific conditions. Simulation results show that the developed model can effectively reveal the dynamic characteristics of parallel-series hybrid drive system for hybrid vehicles, and can be used to do the optimization research of energy management strategies and powertrain. Additionally, there are a lot of advantages for the development of multi-domain model using Modelica.

Shin, J.W. et al., 2014. Design of 2-speed transmission for electric commercial vehicle. *International Journal of Automotive Technology*, 15(1), pp.145–150. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84897729993&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: As environmental and economic interests increase, the need for eco-friendly vehicle such as an electric vehicle (EV) has increased rapidly. Various research of enhancing EV powertrain efficiency and relibility have been studied. In this study, 2-speed shift gears mechanism is designed by using simpson type planetary gear train. This transmission has two planetary gear unit. Gear position is determinded by which ring gear is fixed. Internal components of the transmission are designed for satisfying the required specification of EV. We analyze gear strength, gear mesh efficiency, and transmission efficiency. By manufacturing the transmission prototype and performing some experiments, we verify the application suitability of this transmission.

Sivertsson, M. & Eriksson, L., 2014. Design and Evaluation of Energy Management using Map-Based ECMS for the PHEV Benchmark. *Oil & Gas Science and Technology – Revue d'IFP Energies nouvelles*, 70(1), pp.195–211. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84924325042&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Plug-in Hybrid Electric Vehicles (PHEV) provide a promising way of achieving the benefits of the electric vehicle without being limited by the electric range, but they increase the importance ofthe supervisory control to fully utilize the potential ofthe powertrain. The winning contribution in the PHEV Benchmark organized by IFP Energies nouvelles is described and evaluated. The control is an adaptive strategy based on a map-based Equivalent Consumption Minimization Strategy (ECMS) approach, developed and implemented in the simulator provided for the PHEV Benchmark. The implemented control strives to be as blended as possible, whilst still ensuring that all electric energy is used in the driving mission. The controller is adaptive to reduce the importance ofcorrect initial values, but since the initial values affect the consumption, a method is developed to estimate the optimal initial value for the controller based on driving cycle information. This works well for most driving cycles with promising consumption results. The controller performs well in the benchmark; however, the driving cycles used show potential for improvement.

A robustness built into the controller affects the consumption more than necessary, and in the case ofaltitude variations the control does not make use ofall the energy available. The control is therefore extended to also make use oftopography information that could be provided by a GPS which shows a potential further decrease in fuel consumption.

Spanoudakis, P. et al., 2014. Evaluation of a 2-speed transmission on electric vehicle's energy consumption. In *2014 IEEE International Electric Vehicle Conference (IEVC)*. IEEE, pp. 1–6. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84934300903&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In order to explore the impact of transmission use on the energy/fuel consumption of zero emission vehicles, a 2-speed gearbox was developed and tested. The gearbox is installed on a hydrogen fuel cell powered urban vehicle, the ER14, a prototype designed by the TUC Eco Racing team at the Technical University of Crete. In this work the ER14 is used as a testbed vehicle so as to measure and evaluate fuel consumption with and without gear changing. Actual road tests were conducted and experimental results are presented, showing reduction of electric vehicle energy consumption with the use of the gearbox.

Stoermer, C. & Tibba, G., 2014. Powertrain Co-Simulation using AUTOSAR and the Functional Mockup Interface standard. In *Proceedings of the The 51st Annual Design Automation Conference on Design Automation Conference - DAC '14*. New York, New York, USA: ACM Press, pp. 1–1. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903147670&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: Model-based Systems Engineering plays a key role in the au- tomotive industry by reducing the development costs while designing more complex controllers. Thanks to the contin- uous improvement of models accuracy and their computa- tional performance, introducing system simulation in form of "in-the-loop" simulations in early stages of the development is possible. However, this is often limited by the eorts required to integrate and co-simulate heterogeneous mod- els originating from dierent domains (e.g. electronic, me- chanic, hybrid, etc). This work presents a standard-based integration, simulation and analysis solution leveraging the AUTomotive Open System ARchitecture (AUTOSAR) and the Functional Mockup Interface (FMI) [1] standard, and enabling a seamless transition from Model- to Software-in- the-loop simulations. Moreover, we demonstrate an accurate powertrain co-simulation based on the above-mentioned so- lution. Copyright 2014 ACM.

Sun, G. et al., 2014. Active control of vehicle powertrain noise using inverse model LMS algorithm. In *INTERNOISE 2014 - 43rd International Congress on Noise Control Engineering: Improving the World Through Noise Control*. Australian Acoustical Society. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923625218&partnerID=tZOtx3y1.

Abstract: Current active noise control (ANC) technology cannot yield a balanced performance over broad frequency range when applied to powertrain noise control. It is because most of these ANC systems are configured with the traditional filtered-x least mean squares (FXLMS) algorithm with an inherent limitation in the frequency-dependent convergence behavior. In particular, the phase delay of the secondary path in the FXLMS algorithm will significantly affect the convergence speed and thus lead to a relatively poor tracking ability for the transient event. In this study, a novel inverse model least mean square (IMLMS) algorithm is proposed for active powertrain noise control system with an enhanced convergence speed in order to better track the variation of noise signatures due to unavoidable change in the engine speed. The IMLMS algorithm is realized by utilizing the inverse model of the secondary path to minimize the effect of its dynamics on algorithm's convergence to gain a significant improvement in the convergence speed and tracking ability. Numerical simulation using measured powertrain noise responses is also performed to demonstrate the effectiveness of the proposed algorithm. Results show obvious improvement in the convergence speed and appreciable noise reductions over a broad engine rotational speed range.

Tang, X. et al., 2014. Study on the torsional vibration of a hybrid electric vehicle powertrain with compound planetary power-split electronic continuous variable transmission. *Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science*, 228(17), pp.3107–3115. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84918532149&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: A torsional vibration dynamic model is established with the commercial software ADAMS to predict the torsional vibration characteristics of a compound planetary power-split hybrid electric vehicle. By calculating and simulating the built model in ADAMS, the natural frequencies and corresponding modes are obtained. The results agree well with previous work, which derives the conclusions by solution of the system dynamics equations of hybrid driveline. Moreover, the main factors that influence the torsional vibration of the powertrain under the excitation of engine and electric motors are analyzed by the forced vibration analysis. The calculated results show that the low frequencies occur mainly in the torsional vibration of wheels and vehicle, while the high orders are related to the torsional vibration of differential, sun gears and planets. The results also show that the amplitude of torsional vibration of driveline is the lowest when the damping and stiffness of torsional damper are 15-Nms/rad and 618-Nm/rad respectively, the halfshaft stiffness is 2760-Nm/rad and the rotational inertial of engine is 0.42-kgm2. The research can be used to support the further development of the power-split hybrid electric vehicle.

Tang, X.F. & Liu, Y., 2014. Research on evaluation method of powertrain sound power level. *Neiranji Gongcheng/Chinese Internal Combustion Engine Engineering*, 35(4), pp.51–54. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84906823353&partnerID=tZOtx3y1.

Abstract: The regression equation and normalization method were used to study the sound power level. Analyzed data of sound power level of five powertrains in WOT sweep condition, the corresponding regression equation, normalization equation and standard deviation were obtained. Results show that power sound level of powertrain in WOT sweep condition can be fitted by a linear regression equation Lw=mlgn+b, then various fitted curves can be normalized. The method may be used to assess and compare sound power level of powertrains, its accuracy satisfactory the grade 2 accuracy uncertainty requirements of sound power lev

Taratorkin, I. et al., 2014. Dynamic Loading Reduction of Multiplate Clutches Lined Plates of the Vehicle Powertrain. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84909942599&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: The paper presents the findings of the investigation of initiation conditions for parametric resonances in the nonlinear system "Engine unit - Torque Converter - Planetary Transmission Elements (Drum and Lined Plate)". The mentioned oscillations and resonances form dynamic loading of powertrain lined plates. In terms of the research results the paper validates the ways of tuning parametric oscillations. These ways provide for the increasing of durability of multiplate clutches plates of vehicle powertrain. The evaluation of dynamic stability was performed on the basis of the analysis of Mathieu equation and Ince-Strutt diagram. The restriction of modulation depth parameter is proposed by filtering of high-frequency disturbances which are generated in the nonlinear system by different oscillation sources (power unit - internal combustion engine (ICE) or electric motor (EM), hydrodynamic processes in the hydraulic transformer - torque converter or hydraulic coupling, oil supply pump). The efficiency evaluation of the influence of the developed actions on lined plate's durability was performed.

Tarsitano, D. et al., 2014. Energy Management Algorithms Comparison for an Electric Bus with an Hybrid Energy Storage System by Means of Dynamic Programming. In *2014 IEEE 80th Vehicular Technology Conference (VTC2014-Fall)*. IEEE, pp. 1–5. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84919429970&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Low emission vehicles are an attractive research field for the automotive industry. A feasible solution for urban buses is a full electrical powertrain powered both by a supercapacitor, rechargeable at each bus stop while passengers are getting on and off, and, in the worst operating conditions such as traffic jams or long runs, by a conventional battery. The result is a hybrid energy system where an energy management function is required in order to divide the power request between the two onboard energy storage systems. Different energy management functions have been previously developed and validated using numerical simulation. This paper presents a comparison of various algorithms developed with an optimal algorithm defined using Dynamic Programming.

Ustun, O. et al., 2014. Design and manufacture of electric powertrain and its cooling system for ITU EV project. In *2014 International Conference on Electrical Machines (ICEM)*. IEEE, pp. 730–735. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916197611&partnerID=tZOtx3y1 [Accessed June 16, 2015].

Abstract: In recent years all expositions of cars show that every car manufacturing company is developing at least one electric vehicle. Recently, ITU ALEK (Istanbul Technical University Alternative Energy Club) members and its supervisor created an electric vehicle project called ITU EV (electric vehicle). This project is about developing a drive system for a conventional internal combustion engine (ICE) vehicle. The project which started in 2011, has four different main research areas. These are electric powertrain which includes water cooling design, battery part, controlling part, mechanical construction and outer design part. In this study, electric powertrain design, cooling calculations and design, and production parts of the project will be investigated. For electric drivetrain a special design of 70 kW BLDC (brushless dc) motor is produced and laboratory tests are made. The rated voltage is chosen as 355 V.

Walker, P.D. & Zhang, N., 2014. Active damping of transient vibration in dual clutch transmission equipped powertrains: A comparison of conventional and hybrid electric vehicles. *Mechanism and Machine Theory*, 77, pp.1–12. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84896759938&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The purpose of this paper is to investigate the active damping of automotive powertrains for the suppression of gear shift related transient vibrations. Conventionally, powertrain vibration is usually suppressed passively through the application of torsional dampers in dual clutch transmissions (DCT) and torque converters in planetary automatic transmissions (AT). This paper presents an approach for active suppression of transient responses utilising only the current sensors available in the powertrain. An active control strategy for manipulating engine or electric machine output torque post gear change via a proportional-integral-derivative (PID) controller is developed and implemented. Whilst conventional internal combustion engine (ICE) powertrains require manipulation of the engine throttle, for HEV powertrains the electric machine (EM) output torque is controlled to rapidly suppress powertrain transients. Simulations for both conventional internal combustion engine and parallel hybrid vehicles are performed to evaluate the proposed strategy. Results show that while both the conventional and hybrid powertrains are both capable of successfully suppressing undesirable transients, the EM is more successful in achieving vibration suppression. © 2014 Elsevier Ltd.

Wang, C. et al., 2014. Development of a Compact Compound Power-Split Hybrid Transmission Based on Altered Ravigneaux Gear Set. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899508272&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: Several types of power-split hybrid transmissions are outlined and the strengths and weaknesses of typical compound power-split prototype designs are summarized in this paper. Based on an modified Ravigneaux gear set, a novel compound power-split hybrid transmission with compact mechanical structure is presented, its dynamic and kinematic characteristics in equations and operating modes are described, and then equivalent lever diagrams are used to investigate the proposed compound power-split device. Control strategies in different operating modes are discussed with the simplified combined lever diagram, and a global optimization method is implemented to find the optimum operation point for the hybrid powertrain. To evaluate the fuel economy of a hybrid car equipped with this hybrid transmission, a forward powertrain simulation model is developed and real vehicle performance tests are conducted in the chassis dynamometer. Simulations and test results show that the proposed hybrid transmission can improve the efficiency of the powertrain and demonstrate lower fuel consumptions than the corresponding conventional vehicle. We conclude that the most effective strategy for reducing the cost of vehicle powertrain manufacturing, decreasing the difficulty of control and improving vehicle fuel efficiency during city driving is to employ the new compound power-split hybrid transmission.

Wang, H. et al., 2014. A study on the effect of non-proportional damping and gyroscopic moment on powertrain mounting system. *Qiche Gongcheng/Automotive Engineering*, 36(1), pp.101–106. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84894538410&partnerID=tZOtx3y1.

Abstract: Based on energy decoupling theory, an optimization on the powertrain mounting system of a bus is conducted with genetic algorithm, and the rule of the effects of non-proportional damping and gyroscopic effect on vibration decoupling is studied for optimized mounting system. The results show that non-proportional damping has significant influence on the vibration characteristics of system, which mainly aggravate the coupling between translational and rotational vibrations. Its effect is getting more sever with the rise in the degree of non-proportional damping. The effects of gyro moment are mainly on the pitch and yaw responses of powertain and the intensification of vibration coupling between them in low frequency range.

Wang, J. et al., 2014. Dynamic coordinated control method of gear shifting without clutch operation for hybrid electric vehicle. *Jiaotong Yunshu Gongcheng Xuebao/Journal of Traffic and Transportation Engineering*, 14(5), pp.51–58. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911491714&partnerID=tZOtx3y1.

Abstract: In order to decrease gear shifting impact, shorten gear shifting time and improve vehicle accelerating performance, a dynamic coordinated control method of gear shifting without clutch operation for hybrid electric vehicle was proposed based on dual-motor hybrid electric powertrain. The driven motor of automatic transmission input shaft was controlled to fast realize rotate speed synchronization in gear shifting process without clutch operation so as to shorten gear shifting time. The driven motor of automatic transmission output shaft was controlled to prevent clutch from over

wearing because of frequent separation and combination, and the continuous torque output of driving system was achieved by using motor torque on the output shaft of transmission to reduce the impact degree in gear shifting. Test result shows that vehicle driving force keeps stable in gear shifting because of the dynamic coordinated control method. Compared with the traditional gear shifting method, clutch impact degree reduces by about 60%, and vehicle accelerating performances improve by 5.53% and 5.94% under 0-50 and 0-60 km·h-1 accelerating conditions, respectively.

Wang, R.G., Zhang, M.J. & Shi, C.L., 2014a. A New Powertrain System for Electric Hybrid Vehicles. *Applied Mechanics and Materials*, 577, pp.408–411. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904973371&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: A new powertrain system was developed for electric vehicle driving application with adoption of one electric motor and one set of planetary gear set. With the control of fork, the sleeve of synchronizer can mesh two different parts on the left and right side; the system can provide pure electric driving, hybrid driving and regenerative braking operation modes to meet vehicle practical conditions. It can reduce both power train structure size and cost with fewer parts. © (2014) Trans Tech Publications, Switzerland.

Wang, R.G., Zhang, M.J. & Shi, C.L., 2014b. New Powertrain Development for Electric Hybrid Vehicles. *Applied Mechanics and Materials*, 654, pp.217–220. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84920683537&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: A new type of powertrain system was developed for electric hybrid vehicles. It is mainly composed of engine, first electric motor, first shaft, synchronizer mechanism, second electric motor, planetary gear set and second shaft. The adoption of one planetary gear set and synchronizer mechanism make it can be operated in four different operation modes with high energy efficiency and lower cost, its four operation modes are pure electric driving, hybrid driving, independent engine driving and regenerative braking. These four operation modes can fit the vehicle practical conditions according to order from the control system.

Wang, Y. & Deng, Z., 2014. Control of a hybrid excitation machine with open-winding structure for hybrid electric vehicles. In *2014 17th International Conference on Electrical Machines and Systems (ICEMS)*. IEEE, pp. 2910–2916. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84922825320&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Vector-controlled permanent magnet machine with open-winding structure can realize voltage regulation over a wide speed range and improve the generator power factor as well as the system integration degree when used in Hybrid Electric Vehicles (HEV). However, it is difficult for the above system to control the energy distribution between the battery and the engine. Hence, in order to realize the energy distribution control in multi-energy powertrain of HEV, a hybrid excitation generator system with open-winding structure is investigated in this paper and a double closed-

loop control of battery current and generator excitation current is employed. Simulation results demonstrate the feasibility and effectiveness of the energy distribution control scheme.

Wang, Y. & Sun, D., 2014. Powertrain Matching and Optimization of Dual-Motor Hybrid Driving System for Electric Vehicle Based on Quantum Genetic Intelligent Algorithm. *Discrete Dynamics in Nature and Society*, 2014, pp.1–11. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84912143470&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In order to increase the driving range and improve the overall performance of all-electric vehicles, a new dual-motor hybrid driving system with two power sources was proposed. This system achieved torque-speed coupling between the two power sources and greatly improved the high performance working range of the motors; at the same time, continuously variable transmission (CVT) was achieved to efficiently increase the driving range. The power system parameters were determined using the "global optimization method"; thus, the vehicle's dynamics and economy were used as the optimization indexes. Based on preliminary matches, quantum genetic algorithm was introduced to optimize the matching in the dual-motor hybrid power system. Backward simulation was performed on the combined simulation platform of Matlab/Simulink and AVL-Cruise to optimize, simulate, and verify the system parameters of the transmission system. Results showed that quantum genetic algorithms exhibited good global optimization capability and convergence in dealing with multiobjective and multiparameter optimization. The dual-motor hybrid-driving system for electric cars satisfied the dynamic performance and economy requirements of design, efficiently increasing the driving range of the car, having high performance, and reducing energy consumption of 15.6% compared with the conventional electric vehicle with single-speed reducers.

Wang, Z. & Zhang, X., 2014. Modeling and simulation on vehicle transmission efficiency. *Qiche Gongcheng/Automotive Engineering*, 36(10), pp.1285–1288. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84910054963&partnerID=tZOtx3y1.

Abstract: According to the situation that actual transmission efficiency varies with the speed and load of engine, and the properties and temperature of oil and fluid etc, a mathematical model for transmission efficiency is presented with comprehensive consideration of above mentioned factors. Compared with the traditional calculation using constant value of parameters, the results with the model proposed are more accurate, providing a technical basis for the prediction of transmission power loss and the selection of vehicle powertrain.

Wu, G., Zhang, X. & Dong, Z., 2014. Optimal Control for Ensured Drivability of Paralell HEVs/PHEVs during Mode Transition. In *SAE Technical Papers*. SAE International. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84899556627&partnerID=tZOtx3y1 [Accessed April 25, 2015].

Abstract: Plug-in hybrid electric vehicles (PHEVs) with post-transmission parallel configuration attracted considerable attention due to their capacity to operate in either electric vehicle (EV) mode or hybrid electric vehicle (HEV) mode. Meanwhile, the added flexibility and multiple operation modes add additional challenges to vehicle control with acceptable drivability, particularly during the mode transition from the EV and HEV, since proper control is needed for the internal combustion engine (ICE), motor and coupling device to achieve smooth and fast transition, under various vehicle operation constraints such as mode-transition duration, vehicle acceleration fluctuation and friction loss of the dry clutch. In addition, the engagement of dry clutch features torque discontinuity due to slip-stick phenomenon and the dynamic behavior of the ICE further increases the nonlinearity of the powertrain system. This research introduces a method for identifying the theoretically optimal drivability during mode transition and feasible control schemes to effectively coordinate different powertrain components and achieve desirable drivability without violating vehicle operation constraints. Firstly, a post-transmission parallel PHEV is modeled using MATLAB Simulink and US DOE-ANL's AUTONOMIE, and partially verified using a research prototype PHEV-EcoCAR, developed on the GM Chevrolet Malibu platform at University of Victoria. Secondly, the problem of optimal control for drivability is formulated, considering the vehicle operation constraints. Dynamic Programming (DP) is applied to the Simulink powertrain model to identify the optimal control solutions. Simulation results for the studied vehicle are presented and analyzed to illustrate the new approach and its advantages.

Yan, M.G. et al., 2014. Torsional vibration response and parameter influence analysis for the entire drive line of a hybrid electric bus. *Gongcheng Lixue/Engineering Mechanics*, 31(SUPPL.), pp.223–227. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904384369&partnerID=tZOtx3y1.

Abstract: A dynamic simulation model was established using AMESim for investigating the torsional vibration in the drive line of a series-parallel hybrid electric city transit bus. The torsional vibration analysis was conducted to understand the influence of main factors. Based on typical city bus operating characteristics, operating procedures were constructed, in which the hybrid powertrain experienced vehicle launching, low-speed running, engine start, high-speed running and regenerating braking. Simulations were performed to understand the influence of key component design parameters or a dynamic duty cycle. Simulation results show that the torsional vibration responses are closely related to spring stiffness and damping coefficient of the input damper and clutch damper, as well as the degree of speed synchronization upon clutch engagement. The results also reveal that the torsional vibration of a drive line is effectively reduced by reducing the ISG motor torque for starting the engine, and by limiting the acceleration of the hybrid powertrain when a rapid acceleration or a deceleration happens.

Yan, X.J., Jiang, W.K. & Cao, C., 2014. Vibration isolation optimization of a vehicle powertrain mounting system based on simulated annealing and genetic algorithm. *Zhendong yu Chongji/Journal of Vibration and Shock*, 33(23),

pp.155–159. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84920510492&partnerID=tZOtx3y1.

Abstract: Aiming at vibration isolation effect of one vehicle powertrain mounting system was insufficient, its natural frequencies and the decouple rate of the system were taken as integrated optimal objectives, and the simulated annealing and genetic algorithm (SAGA) were used to optimize the mounting stiffness parameters. The optimized results showed that its natural frequency deployment is more reasonable and the decouple rate in the major vibration direction increases. The vehicle vibration isolation test results showed that the vibration isolation effects of the optimized mounting system meet design requirements.

Yang, C. et al., 2014. Electromechanical coupling driving control for single-shaft parallel hybrid powertrain. *Science China Technological Sciences*, 57(3), pp.541–549. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84896542887&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The single-shaft parallel hybrid powertrain with the automatic mechanical transmission (AMT) is an efficient hybrid driving system in the hybrid electric bus (HEB), while the electromechanical coupling driving control becomes a complicated question to find a transient optimal control method to distribute the power between the engine and the electric machine (EM). This paper proposes an innovative control method to deal with the complicated transient coupling driving process of the electromechanical coupling driving system, considering the accelerating condition and the cruising condition mostly in the city driving cycle of HEB. The EM might be operated at driving mode or generating mode to assist the diesel engine to work in its high-efficiency area. Therefore, the adaptive torque tracking controller has been brought forward to ensure that the EM implements the demand torque as well as compensate the torque fluctuation of diesel engine. The d-q axis mathematical model and back stepping method are employed to deduce the adaptive controller and its adaptive laws. Simulation results demonstrate that the proposed control scheme can make the output torque of two power sources respond rapidly to the demand torque from the powertrain in the given driving condition. The proposed method could be adopted in the real control of HEB to improve the efficiency of the hybrid driving system. © 2014 Science China Press and Springer-Verlag Berlin Heidelberg.

Yang, J. & Zhu, G.G., 2014. Predictive Boundary Management Control of a Hybrid Powertrain. In *Volume 2: Dynamic Modeling and Diagnostics in Biomedical Systems; Dynamics and Control of Wind Energy Systems; Vehicle Energy Management Optimization; Energy Storage, Optimization; Transportation and Grid Applications; Estimation and Identification Method*. ASME, p. V002T20A002. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929252278&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Hybrid Electric Vehicle (HEV) is capable of improving fuel economy with reduced emissions over traditional vehicles powered by the internal combustion engine alone. However the HEV durability is significantly limited by the battery useful life; and the battery life could be significantly reduced if it was operated over

its allowed charging or discharging limits, which could occur especially at extremely low battery temperatures, leading to permanent battery damage and reduced battery life. In order to extend the battery life, this paper proposed a battery boundary management control strategy based upon the predicted desired torque to proactively make the engine power available to reduce future battery over-discharging. The proposed control strategy was validated in simulations and its performance was compared with the baseline control strategy under US06, and other four typical city and highway driving cycles. The simulation results show that the proposed control strategy is very effective when the battery temperature is under zero Celsius degree, and the over-discharged power is reduced more than 65% under aggressive US06 and ARB02 driving cycles, 45% under highway and city FTP and city NYCC driving cycles, and 30% under highway IM240 driving cycle, respectively.

Yang, Y., Chu, Z.G. & Xiong, M., 2014. Transfer path analysis of booming noise in a car cabin based on impedance matrix method. *Zhendong yu Chongji/Journal of Vibration and Shock*, 33(18). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84907939398&partnerID=tZOtx3y1.

Abstract: In order to recognize sources of interior booming noise in a car cabin at the engine speeds of 2 900 r/min and 3 750 r/min, the transfer path analysis based on the impedance matrix method was conducted and the condition number was restricted by setting a threshold to reduce ill-condition error. Results showed that the transfer paths corresponding to the x direction of the powertrain's right mount, the z direction of the powertrain's right mount and the z direction of the powertrain's rear mount are the main contribution paths to the booming noise at 2 900 r/min, the cause of big contribution for the former two is that they have a large exciting force, and that for the latter is that it has a high path sensitivity; the transfer paths corresponding to the x direction of the powertrain's right mount and the z direction of the powertrain's rear mount are the main contribution paths to the booming noise at 3 750 r/min, the cause of big contribution for the former is that it has a large exciting force, and that for the latter is that is has a high path sensitivity. These results provided a guidance for noise control and improvement of car's sound quality.

Yang, Y.P., Shih, Y.C. & Chen, J.M., 2014. Real-time driving strategy for a pure electric vehicle with multiple traction motors by particle swarm optimization. In *7th IET International Conference on Power Electronics, Machines and Drives (PEMD 2014)*. Institution of Engineering and Technology, pp. 3.2.06–3.2.06. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84901845694&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper introduces a real-time torque-distribution driving strategy for a pure electric vehicle. This vehicle is driven by a powertrain of three traction motors: an indirectly-driven traction motor for front wheels and two in-wheel motors installed inside both rear wheels. Their torque distribution is determined by particle swarm optimization theory for minimizing energy consumption according to the torque-speed-efficiency maps of all the traction motors. Simulation results by hardware-in-the-loop show that the driving efficiency of the proposed real-time torque-distribution

driving strategy by particle swarm optimization is close to the results from the global optimization method by dynamic programming.

Yin, Q., Wu, Z. & Rui, X., 2014. Parameter design and optimization of electric vehicle. In *2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific)*. IEEE, pp. 1–7. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916240186&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Improving the efficiency of powertrain system is a critical issue for electric vehicle's technologies. Suitable parameters of this system are beneficial to enhancing the fuel economy and extending the mileage since battery on electric vehicle has a limit of capacity. In this paper, we establish models of vehicle system and components in MATLAB/Simulink to study parameter design for electric vehicle. We apply genetic algorithm in optimizing parameters of the prototype. Control strategy is also discussed to obtain the optimal performance of electric vehicle. We use simulations to test our proposed design. The electric vehicle can meet the requirement of power and fuel economy characteristic. Improvement is obtained through optimizing the parameters of transmission. These results show an agreement between the theory and our design.

Yoon, J.-Y. & Singh, R., 2014. Examination of super-harmonics in a multi-degree of freedom nonlinear vibration isolation system: Refined models and comparison with measurements. *Mechanical Systems and Signal Processing*, 48(1-2), pp.368–387. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84901695181&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: A multi-degree of freedom vibration isolation experiment consisting of a powertrain, three powertrain mounts including a dynamic load sensing hydraulic mount, a sub-frame, and 4 bushings is examined in both time and frequency domains. Since the hydraulic mount exhibits nonlinear phenomena, super-harmonics are observed in motion, pressure and interfacial force measurements when the system is sinusoidally excited. Refined indirect force estimation methods are proposed with a focus on the super-harmonics. This includes the development of a quasi-linear fluid system model with embedded spectrally varying and amplitude-sensitive parameters. The reverse path spectral method is employed using the measured relative motion and upper chamber pressure in the nonlinear hydraulic mount. The relevant transfer functions (with effective parameters for both rubber and hydraulic paths) are used to estimate the interfacial forces. Up to six harmonics of the fundamental excitation frequency are examined, and the contribution of each path is clarified. The proposed quasi-linear fluid system model including super-harmonics extends prior work on indirect force estimation methods and successfully predicts the interfacial forces in the multi-degree of freedom vibration isolation system. The quasi-linear fluid system model, however, seems to be inadequate in estimating the sub-harmonic responses. © 2014 Elsevier Ltd.

Yu, X. et al., 2014. Structural transfer path analysis of automobile tire/road noise. In *INTERNOISE 2014 - 43rd International Congress on Noise Control*

Engineering: Improving the World Through Noise Control. Australian Acoustical Society. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84923551591&partnerID=tZOtx3y1.

Abstract: With refinement of powertrain, tire/road induced noise has become an important parameter within vehicle development. It is necessary to reveal the transfer characteristics of tire/road noise for suppressing it. This paper presents an experimental analysis of the structural-borne contribution of noise and vibration for a vehicle driving on a coarse road, using a simplified transfer path analysis method (TPA). The simplified TPA method is used to identify the major noise transfer paths of tire/road noise based on subjective evaluation and objective measurement, which is fast and cost-saving compared with conventional TPA method. The vehicle tire/road noise is analyzed by the simplified TPA method, which shows the rear suspensions are the major contribution components. A TPA model for the rear suspension noise and vibration is built up and the transfer path testing is carried out. The comparison of measured and recalculated interior sound pressure level shows a good correlation. The results show Z- direction of the torsion beam axle and Z- direction of the left shock absorber are significant contribution paths to the interior noise. To improve the tire/ road noise and not to sacrifice the side effects such as handling and durability, the torsion beam axle structure is modified.

Zhang, D. et al., 2014. Robust optimization of powertrain mounting system based on Taguchi method. *Qiche Gongcheng/Automotive Engineering*, 36(4). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84901314064&partnerID=tZOtx3y1.

Abstract: In order to improve the vibration isolation performance and the optimization robustness of power-train mounting system, a 6 DOF dynamics model for the mounting system is built first and a preliminary optimization on its stiffness parameters is conducted by using genetic algorithm with maximizing decoupling rate of 6 DOFs as objective and the stiffnesses in three directions of each mount as design variables. Then among the outcomes of preliminary optimization, the one with high decoupling rate and reasonable stiffness distribution is selected as object with signal to noise ratio as evaluation indicator, one or more robust optimizations are carried out by applying Taguchi method and a more desired optimized solution is obtained. Finally, a robustness analysis is performed with Monte Carlo technique. The results show that the scheme can effectively improve the decoupling rate of 6 DOFs and enhance the robustness of mounting system, while ensuring the reasonable distribution of stiffness.

Zhang, G., 2014. *Practical Applications of Intelligent Systems* Z. Wen & T. Li, eds., Berlin, Heidelberg: Springer Berlin Heidelberg. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84921888050&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Powertrain Matching has a greater impact on dynamics, fuel economy, and emissions performance. In order to improve the Hybrid Vehicle efficiency and drive

quality, and reduce the pollutions, taking electronic continuously variable transmission (ECVT) as the research object, we comprehensively analyzed the Vehicle Matching Theory, Integrated Control and Intelligent Calibration, and developed a road map for the current and future ECVT technologies: taking the engine power loss rate, fuel utilization, and purification rate of pollutants as the optimization objectives; matching the ECVT, Engine, Motor and Battery with Vehicle's best working status; and establishing the ECVT Matching and Intelligent Calibration and Control Strategy.

Zhang, X. et al., 2014. Automated modeling and mode screening for exhaustive search of Double-Planetary-Gear power split hybrid powertrains. In *ASME 2014 Dynamic Systems and Control Conference, DSCC 2014*. American Society of Mechanical Engineers. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84929340512&partnerID=tZOtx3y1.

Abstract: Double Planetary Gear (PG) power-split hybrid powertrains have been used in production vehicles from Toyota and General Motors. Some of the designs use clutches to achieve multiple operating modes to improve powertrain operation flexibility and efficiency at the expense of higher complexity. In this paper, an automatic modeling and screening process is developed, which enables exhaustively search through all designs with different configurations, clutch locations and operating modes. A case study was conducted based on the configuration used in the model year 2010 Prius and Camry hybrids. It was found that by adding clutches, fuel economy can be improved significantly for plug-in hybrid (charge depletion) operations.

Zhang, Z. et al., 2014. Investigation and development of a new brushless DC generator system for extended-range electric vehicle application. In *2014 IEEE Energy Conversion Congress and Exposition (ECCE)*. IEEE, pp. 3155–3162. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84934293318&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The on-board generators of hybrid electric vehicle are overviewed. Based on the doubly salient electro-magnetic machine (DSEM), a new brushless DC (BLDC) generator system for the extended-range electric vehicle (E-REV) application is proposed. The principle of the DSEM, the configuration of the generator system, and the E-REV powertrain are introduced. The operation principle and the power matching relationship among the generator system, battery and the drive system are investigated, and the control strategy is presented as well. A 45kW doubly salient BLDC generator and the associated generator system controller for the E-REV application are designed and developed. The experimental results indicate that the doubly salient BLDC generator system exhibits simple and reliable configuration, convenient controllability and high operation performance with constant current/power output capability. The new BLDC generator system is a promising option for the increasing E-REV application.

Zhong, Z. et al., 2014. Automotive powertrain co-simulation with Modelica and Simulink. In *2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific)*. IEEE, pp. 1–5. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916232652&partnerID=tZOtx3y1 [Accessed July 9, 2015].

Abstract: We highlight an automotive powertrain co-simulation solution for developing SiL (Software in loop) simulation environment. This solution provides a co-simulation interface for importing control algorithm from Simulink to Modelica environment using RTW toolbox. Detailed illustration is given on how to realize this co-simulation interface. To verify the co-simulation solution, a SiL environment is constructed for an AMT control software, and a virtual vehicle acceleration experiment is launched in a Modelica simulation environment. This experiment gives reasonable results and validates the co-simulation solution.

Zhou, J., Shen, X. & Liu, D., 2014. Modeling and simulation for electric vehicle powertrain controls. In *2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific)*. IEEE, pp. 1–4. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84916198541&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: This paper reviewed the main stream of commercial software for electric vehicle simulation and briefly discussed the advantage of physical modeling tool. A dynamic simulation model of electric vehicle (EV) was developed using Matlab/Simulink and SimPowerSystem/SimDriveline toolbox. The EV model has a configurable structure that is suitable to simulation with multiple fidelity levels. This advantage will combine simulation models associated with deployment and test for different controllers to a single platform. It has multiple running rates and different solvers for subsystems in order to speed up simulation. The electrical system model is capable to simulate power electronics behavior both on average and switching level. An automated mechanical transmission (AMT) model and its controller were developed for heavy duty application, such as a city bus. It can simulate drive train discontinuous behavior (e.g. clutch engage/disengage) and longitudinal vibration.

Zhu, B. et al., 2014. Gear shift schedule design for multi-speed pure electric vehicles. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 229(1), pp.70–82. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84919667237&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: As pure electric vehicles are considered to be a major growth trend in the automotive industry, research into and development of efficient electric powertrain systems and related control technologies have become popular research topics. The growing importance and use of multi-speed transmissions in these vehicles make shift schedule design and research a crucial aspect of the powertrain systems design of pure electric vehicles. This paper provides a gear shift schedule calculation method for pure electric vehicles, which includes a dynamic shift schedule and an economic shift schedule calculation method, demonstrating how to optimize the shift points and to

produce the upshift and downshift lines based on the motor efficiency map. Through the establishment of a pure electric vehicle model, simulation results show that a properly designed shift schedule can improve the working region of the motor and can refine the dynamic performance and the economic performance of the vehicle. Finally, rig testing results are demonstrated to be comparable with simulations and indicate the correctness of the method.

Abstracts of papers related to NVH published in 2013

Adam, B., 2013. *Proceedings of the FISITA 2012 World Automotive Congress*, Berlin, Heidelberg: Springer Berlin Heidelberg. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903624700&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Research and/or Engineering Questions/Objective The paper describes a simulation tool for determination of vehicle energy consumption under dynamic conditions, suitable for early stages of design. It describes vehicle dynamics in longitudinal direction and the appropriate efficiencies of engine, transmission and accumulation components (if used). The simulation tool is targeted to the optimization of vehicle powertrains with respect to reducing the vehicle fuel consumption, CO2 production and increasing the overall efficiency of the vehicle. It is also used to evaluate the possible benefits of new powertrain concepts. The objective of this paper is to demonstrate the possibilities of the developed tool on a comparison study of several powertrain layouts. Methodology The simulation tool is based on ordinary differential equations and a dynamic expandable library of vehicle component features. Various powertrain components are represented by a dynamically expandable library of component modules. Each module represents a particular component of a powertrain such as gearbox, engine, wheels, vehicle body etc. Modules may be modified to more complex models at any time or even replaced by different modules to represent different powertrain layouts. Mechanical part of the powertrain is modelled with multi body simulation approach. Particular powertrain elements are represented either by mass elements or stiffness/ damping elements. Electric part of vehicle powertrain such as electric engines and battery models are based on simple circuit models and/or look-up table based models. All required input data may be obtained by targeted simulations using multi-dimensional methods or by experiments. Results The result of this study is a comparison of various less or more common powertrain layouts. Its aim is not to present accurate results that correspond to each powertrain type, but more to point out the advantages and disadvantages of particular powertrain types. The simulation tool itself should also be considered as a result, because it provides a powerful tool for powertrain evaluation, topology layout optimization and may be adapted for various simulation tasks. Limitations of this study This simulation tool is designed to provide quick initial estimates with minimal input data or to serve as a part of X in the loop (XiL) tests, where X stands usually for hardware, software, man, etc. Therefore a lot of simplifications must have been applied. However, the dynamic…

Albers, A. et al., 2013. Method for measuring and interpreting the surface velocities induced by torsional vibration in the drivetrain of a battery electric vehicle. In *42nd International Congress and Exposition on Noise Control Engineering 2013, INTER-NOISE 2013: Noise Control for Quality of Life*. OAL-Osterreichischer Arbeitsring fur Larmbekampfung, pp. 498–507. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904460063&partnerID=tZOtx3y1.

Abstract: The driving comfort is a factor of growing importance for buying decisions. For battery electric vehicles (BEV) the acoustic quality will as well be an elementary distinguishing feature, since the masking of an internal combustion engine is no longer present. Opposing the importance of the acoustic quality is the lack of knowledge of how to measure and interpret the high frequency noise generated by an electric powertrain with respect to the influence on the passengers. In this contribution a method for measuring and interpreting the transfer path of acoustic phenomena for an electric powertrain with a permanent magnet synchronous machine (PMSM) and a two stage transmission is presented. Thereby the excitation of the PMSM housing and the excitation of the gearbox by the PMSM are analyzed. The surface velocities are measured by the use of PSV 400 3D Scanning Vibrometer in a special setup. The measurements are performed in the context of the IPEK-X-in- The-Loop Framework on a powertrain test bench in an anechoic chamber. These measurements will be validated using the same setup on the IPEK acoustic roller test bench.

Alessandro, P., 2013. Detailed Powertrain Dynamics Modelling in Dymola - Modelica. In K. Taketoshi, ed. *IFAC Proceedings Volumes (IFAC-PapersOnline)*. pp. 434–439. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84885912705&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Two Modelica libraries for engine and powertrain modeling are presented called the Powertrain Dynamics library and the Engines library. Together, these libraries enable the modeling and simulation of powertrain systems including their fluid dynamic, pollutant emission, mechanical and thermal performance in one simulation environment (Dymola). The libraries are defined using the object orientated modelling language Modelica. The libraries are used to study the response of the vehicle and powertrain during dynamic driving events such as vehicle launch, tip-in and tip-out driveability and powertrain nvh. The benefits of using a dynamic torque converter model compared to a steady state model for these applications are presented.

Anon, 2013. SAE 2013 Noise and Vibration Conference and Exhibition, NVC 2013. *SAE Technical Papers*, 4. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881202596&partnerID=tZOtx3y1.

Bassett, M., Hall, J. & Warth, M., 2013. Development of a dedicated range extender unit and demonstration vehicle. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–11. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911455629&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: Current focus on the reduction of tailpipe CO2 emissions of road vehicles is increasing the interest in hybrid and electric vehicle technologies. Pure electric vehicles, however, require bulky, heavy and expensive battery packs to enable an acceptable driveable range to be achieved. Extended-range electric vehicles (EREVs) partly overcome the limitations of current battery technologies by having a “range

extender" unit, which consists of an on-board fuel converter that converts a liquid fuel, such as gasoline, into electrical energy whilst the vehicle is driving. This enables the traction battery storage capacity to be reduced, though still maintaining an acceptable vehicle driving range. Over the past 3 years, MAHLE Powertrain has designed and developed an engine specifically for the use as a range extender. Key attributes for the engine have been identified and the appropriate engine technology selected. The resulting design highlights are presented and the development and optimisation of the engine to meet its performance targets is described, along with the resulting performance achieved. A current production compact-class car was used as a donor vehicle for conversion into an EREV demonstrator to enable verification of the operation range extender unit. The resulting vehicle is intended to reflect likely, near to market, steps to further the wider adoption of electric vehicles in the compact-class passenger car segment. This paper presents details of the EREV demonstrator developed and the Range Extender system integration. Recent activities have focussed on refining the range extender operating strategy to minimise the fuel consumption and NVH performance of the vehicle, as well. The resulting operating strategy for the engine is described and results showing the measured fuel efficiency of the vehicle are presented.

Beigmoradi, S. & Jahani, K., 2013. Optimum acoustical design of muffler using numerical simulation. In *42nd International Congress and Exposition on Noise Control Engineering 2013, INTER-NOISE 2013: Noise Control for Quality of Life*. OAL-Osterreichischer Arbeitsring fur Larmbekampfung, pp. 306–313. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904470551&partnerID=tZOtx3y1.

Abstract: The level and character of noise emitted by exhaust system has significant effect on the overall acoustic performance of vehicle powertrain and sound quality which is received by occupants. In addition to meeting aforementioned objective, the exhaust system must meet exterior noise regulation which is ordered by governments. In this study, acoustic performance of the vehicle exhaust system is investigated. Numerical simulation is applied for this aim that is the fastest and the most economical method in early design stages of vehicle development process. Thickness optimum design is performed in order to improve acoustic performance of exhaust system. Robust parameter design, based on Taguchi method, is utilized to find proper values for muffler thickness components. It is concluded that robust parameter design method significantly reduces time and cost of calculations for estimating optimum thickness of exhaust system parts.

Binder, S.W. et al., 2013. New Launch Devices for Automatic Transmissions. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881203592&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Hydrodynamic launch elements, from the Foettinger principle of the torque converter to the first series production HCC wet clutch, are becoming more relied on in the transmission world for their high power density, launch comfort, and vibrational isolation capability. In order to attain the ambitious fuel economy

objectives of the future, engine vibrations have to be successfully isolated from the driveline at low engine speed ranges without the use of the hydrodynamic circuit. This is now all the more challenging as new combustion engines are producing higher torsional vibrations as a result of fewer cylinders, higher combustion pressures, cylinder deactivation, and lower critical speeds. This paper will describe the next generation of powertrain vibrational isolation, dampening via powersplit. Additionally, a next generation wet launch element, the Hydrodynamically Cooled Clutch will be discussed. A brief description of the current state of the art dampening technologies will be reviewed, highlighting the limitations of these solutions which pave the way for the new generations. The challenge with front wheel drive or hybrid layouts is to reduce the dimensions of the hydrodynamic and clutch systems, while sustaining high thermal capacity in order to improve vibrational isolation, and ensure protection against judder in a challenging packaging environment. Copyright © 2013 SAE International.

Bogema, D. et al., 2013. High-Frequency Time Domain Source Path Contribution: From Engine Test Bench Data to Cabin Interior Sounds. *SAE International Journal of Passenger Cars - Mechanical Systems*, 6(2), pp.1293–1299. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878797962&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This work presents an application of airborne source path contribution analysis with emphasis on prediction of wideband sounds inside a cabin from measurements made around a stand-alone engine. The heart of the method is a time domain source path receiver technique wherein the engine surface is modeled as a number of source points. Nearfield microphone measurements and transfer functions are used to quantify the source strengths at these points. This acoustic engine model is then used in combination with source-to-receiver transfer functions to calculate sound levels at other positions, such as at the driver's ear position. When combining all the data, the in-cabin engine sound can be synthesized even before the engine is physically installed into the vehicle. The method has been validated using a powertrain structure artificially excited by several shakers playing band-limited noise so as to produce a complicated vibration pattern on the surface. First the excited structure is studied alone; next a vehicle cabin was lowered onto the structure without touching. As a result we can compare the combination of using only in-vehicle operating/transfer data or using powertrain only operating data and in-vehicle transfer data for synthesizing interior sounds. Very good agreement between the two procedures was obtained and comparable to the actual sound measured inside the cabin during operation. In addition to verifying the above procedure, the same near-field microphone setup, whether powertrain alone or with cab on top, can be used to assess the radiated sound power from the vibrating structure. The procedure is outlined and the obtained sound power spectra are validated against a standardized hemisphere sound power measurement showing very good agreement in general. 2013 SAE International.

Burdzik, R. & Konieczny, Ł., 2013. Application of Vibroacoustic Methods for Monitoring and Control of Comfort and Safety of Passenger Cars. *Solid State Phenomena*, 210, pp.20–25. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84887582255&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The paper presents the possibilities of application of vibroacoustic methods for monitoring and control of comfort and safety of passenger cars. It is described the WSA program for vibration signals processing. The paper presents some results of prototype experimental research and conception of the monitoring and control of comfort and safety system. The results of the WSA modules can be the input signal for the damping properties control system integrated with mechatronics system of vibration absorbing elements of suspension or engine and powertrain system mounting and springing elements. © (2014) Trans Tech Publications, Switzerland.

Cauet, S., Coirault, P. & Njeh, M., 2013. Diesel engine torque ripple reduction through LPV control in hybrid electric vehicle powertrain: Experimental results. *Control Engineering Practice*, 21(12), pp.1830–1840. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84888025441&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This paper presents a case of persistent harmonic active control for an HEV (Hybrid Electric Vehicle) powertrain. The active control is adapted for a hybrid powertrain consisting of a one-cylinder diesel engine, coupled with a PMSM (Permanent Magnet Synchronous Machine). The PMSM assures the propulsion of the vehicle, as in conventional mild-hybrid electrical vehicles. In addition, it provides speed ripple reductions of the diesel engine. Due to the HEV speed variation, the active control must match this variation. The speed is introduced as a parameter in order to devise an LPV (linear parameter varying) control strategy. The suitability of LPV control for engine torque ripple reduction is demonstrated through a torque control implementation of the PMSM. The control strategy uses the internal model principle of multi-sinusoidal persistent disturbances. The controller is designed to involve several steps, including LMI-based (Linear Matrix Inequalities) optimization. The results show that, for the first and second orders of the ripple, speed oscillations can be reduced when the speed varies. An industrial test bed is used to validate the effectiveness of the approach and the power consumption of the strategy is analyzed. © 2013 Elsevier Ltd.

Chen, F.F., Yu, P. & Zhang, T., 2013. Modal Analysis for the Powertrain of Electric Vehicle by Finite Element Method. *Applied Mechanics and Materials*, 437, pp.140–145. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84886789455&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The finite element model of an electric automotive powertrain is the basis of the research on its vibration and noise. In this paper, the vibration properties of dynamically-loaded housing are first obtained based on finite element calculation, which is testified by the modal test. It provides the reference for the establishing of electric automotive powertrain. © (2013) Trans Tech Publications, Switzerland.

Chen, J.-S. & Hwang, H.-Y., 2013. Engine automatic start-stop dynamic analysis and vibration reduction for a two-mode hybrid vehicle. *Proceedings of the Institution*

of Mechanical Engineers, Part D: Journal of Automobile Engineering, 227(9), pp.1303–1312. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84884164874&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Hybrid electric vehicles are an effective solution for reducing pollution and improving the fuel economy. Their control strategy often makes the vehicle control unit shut down and restart the internal-combustion engine for better fuel consumption. Starting and stopping the engine can cause driveline vibration, which is easily passed to the driver through the vehicle structure, causing ride discomfort. This research simulates the neutral start and stop of a two-mode hybrid system and correlates this with hardware tests. It investigates a pulse cancellation algorithm to cancel undesired vibration and to smooth ripples in the engine speed during automatic start-stop transitions. Electric motors provide torque to cancel unwanted torque impulses from uneven automatic starts or stops. This study also investigates the damper-bypass clutch. The results show that using pulse cancellation and the damper-bypass clutch can significantly reduce the reaction torque acting on the engine block and vibration of the seat track during automatic start-stop transitions. © 2013 IMechE.

Chen, S., Jian, K. & Li, R., 2013. Model identification of vehicle powertrain mounting system. *Metalurgia International*, 18(SPEC.4), pp.289–297. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84874266145&partnerID=tZOtx3y1.

Abstract: accurately acquiring the inertia properties and the unbalanced forces of the powertrain is one of the important requisites for active vibration isolation of a vehicle powertrain mounting system. Based on the damping controllability of the magneto-rheological damper and the relativity between the unbalanced forces and rotate speed of the engine, a new method for identifying inertia parameters and unbalanced forces of the engine was proposed by measuring engine mount accelerations and support reactions on different damper coefficients. Compared with traditional methods, this method has the merits of targeted, repeated test without motor lifting, all parameters identified simultaneously. The effectiveness of this method was verified by a simulation modeling and the testing of a four-cylinder four-stroke powertrain. Results show that the recognition accuracy of inertia parameters meets the engineering needs and the unbalance force identification results are more realistic compared to a simplified formula.

Chen, S.X. et al., 2013. The optimization of engine mounting system based on an equivalent model. *Gongcheng Lixue/Engineering Mechanics*, 30(11), pp.221–226. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891917208&partnerID=tZOtx3y1.

Abstract: An equivalent analysis model for an engine mounting system is built with the ANSYS software. The engine powertrain is idealized to an equivalent composite body composed of one inertial body and one elastic body. Every mounting component is simplified as one spring along its three principal elastic axes and the powertrain mass, and rotational inertia and exciting-force loading locatiosn are accurately embodied. The modal analysis, optimization of energy decoupling degree and

resonant frequency of an equivalent model were carried out in ANSYS. Results show that the equivalent modeling method is valid and feasible. For an engine mounting system, this model provides a new simplified modeling method for the modal analysis and optimization of dynamic response and vibration isolation rate in ANSYS.

Chen, Y.-H. et al., 2013. The New Powertrain Virtual Analysis Process in Engine Design and Development. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881214949&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Due to new federal regulations and higher environmental awareness, the market demands for high fuel economy and low exhaust emission engines are increasing. At the same time customer demands for engine performance, NVH and reliability are also increasing. It is a challenge for engineers to design an engine to meet all requirements with less development time. Currently, the new engine development time has been trimmed in order to introduce more products to the market. Utilizing CAE technology and processes in an engine development cycle can enable engineers to satisfy all requirements in a timely and cost-effectively way. This paper describes a new Powertrain Virtual Analysis Process which has been successfully implemented into Chrysler PTCP (Powertrain Creation Process) and effectively utilized to shorten and improve the product development process. This new virtual analysis process guides the product development from concept through the production validation phases. Based on the new process, CAE engineers collaborate with product development, quality, dyno/vehicle test and design CoE (Center of Excellence) teams to establish the concept study plans and quality documents (boundary diagram, functional model, DFMEA and DVP&R) of components and systems; complete and execute the CAE plans according to DVP&Rs; optimize the mechanical and reliability test plans depending on CAE contribution; assess the product design risk based on CAE results and existing test data at each design phase before physical tests start; utilize CAE tools to provide solutions when failures are found during tests; and close loop of virtual analysis process by summarizing lessons learned from product development. This paper summarizes CAE technologies used in this new virtual analysis process during a new Chrysler I4 engine design and development. These technologies include NVH, 1D engine performance, CFD gas/coolant flow, conjugate heat transfer, crankcase breathing, lubrication, and structure durability. The new virtual analysis process helped meet challenging engine program targets that required 88% new engine parts (excluding carry over fasteners/sealants) in only 22 months from program approval to start of production. Copyright © 2013 SAE International.

Chuan, L., Minghui, L. & Ziliang, Z., 2013. Characteristics of transmission for electric motor. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–4. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911383680&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: As the development of electric vehicle, the power of motor takes more and more important position in the total powertrain. Because the characteristic of motor is

totally different from combustion engine, so their requirements to transmission are different too. The development of electric vehicle is limited by traditional transmission which is suitable only for combustion engine. The requirement of vehicle, the different of characteristic between engine and motor, and the characteristic of demanded power of daily driving cycle are analysed in this paper. Compared with engine, the requirements of motor to transmission are less gears, more torque tolerance capacity in input shaft and more efficiency.

Dai, F. et al., 2013. *Proceedings of the FISITA 2012 World Automotive Congress*, Berlin, Heidelberg: Springer Berlin Heidelberg. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84869476905&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The noise and vibration performance of powertrain is main contributor for vehicle NVH (Noise, Vibration and Harshness) issue. To achieve better NVH performance, it is critical to conduct NVH optimization during the powertrain initial design stage. This paper presents an investigation of optimize vehicle powertrain NVH performance via modification of excitation-radiation system of powertrain. To minimize excitation force of the gearbox with special focus on gear pair dynamic characteristics via the gear profile modification, and to reduce transmission housing noise radiation via enhance its stiffness, are the main objective of optimization. The excitation forces are analyzed by Multi Body Dynamics (MBD) method, considering different excitation mechanisms of the powertrain. The vibro-acoustic behavior of powertrain is obtained by FEM/BEM coupled analysis. The acoustic transfer vector (ATV) calculation is used to predict the powertrain sound power level (SPL) and panel contributions. Based on the acquired NVH data of the powertrain, the optimization which couples the transmission gear profile modification for attenuating gear system excitation and the structure stiffness modification for reducing transmission housing noise radiation is proposed. Experiment validation is conducted in order to evaluate the modified results. The evaluation shows that the optimization can effectively reduce powertrain noise and vibration.

Du, C.Y. & Yu, F.F., 2013. Analysis of Engine Camshaft Bearing Loosening Fault Based-on Model Simulation and Vibration Signal. *Advanced Materials Research*, 694-697, pp.896–900. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878728674&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Virtual technology is used for simulation analysis of engine camshaft bearing-loosening fault. Firstly, dynamic model of engine powertrain and its valve-train is established, and then the model parameters could be set to simulate the camshaft bearing loosening fault, so the vibration acceleration signals on engine cylinder head can be obtained by simulation calculation. Then by analyzing and comparing with the vibration signals in the normal state, camshaft bearing-loosening fault features are extracted. The analytical result based-on model simulation and vibration signal is used to guide the actual engine fault diagnosis.

Duan, J. et al., 2013. Virtual Secondary Path Algorithm for Multichannel Active Control of Vehicle Powertrain Noise. *Journal of Vibration and Acoustics*, 135(5), p.051014. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881300305&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: An enhanced multiple-input multiple-output (MIMO) filtered-x least mean square (FXLMS) algorithm using improved virtual secondary path is proposed as the basis for an active noise control (ANC) system for treating vehicle powertrain noise. This new algorithm is developed to overcome the limitation caused by the frequency-dependent property of the standard FXLMS algorithm and to reduce the variation of convergence speed inherent in multiple-channel cases, in order to improve the overall performance of the control system. In this study, the convergence property of the proposed algorithm is analyzed in the frequency domain in order to yield a better understanding of the physical meaning of the virtual secondary path. In practice, because of the arrangement and sensitivities of the actuators (speakers), transducers (microphones), and physical environment, the magnitude response of the main secondary paths can be very different from each other. This difference will cause difficulty in the overall convergence of the algorithm, which will result in minimal attenuation at some of the channels. The proposed channel equalized (CE) virtual secondary path algorithm is designed to tackle this difficulty by equalizing the mean magnitude level of the main secondary paths and by adjusting other secondary paths correspondingly to keep the coupling effects among the control channels unchanged. The performance of the proposed algorithm is validated by analyzing a twoinput two-output active powertrain noise control system. Copyright © 2013 by ASME.

Dupont, J.-B., Bouvet, P. & Wojtowicki, J.-L., 2013. Simulation of the Airborne and Structure-Borne Noise of Electric Powertrain: Validation of the Simulation Methodology. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881216937&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The noise radiated by an electrical motor is very different from the one generated by an internal combustion engine. It is characterized by the emergence of high frequency pure tones that can be annoying and badly perceived by future drivers, even if the overall noise level is lower than that of a combustion engine. Even if the excitation due to electromagnetic phenomena of electric motors is well known, the link to the dynamic excitation generating vibrations and noise is not done. The purpose of this work is to propose a multi-physical approach to simulate the dynamic forces and noise radiated by electric motors. The principle is first to calculate the excitation due to electromagnetic phenomena (Maxwell forces) using an electromagnetic finite element solver. This excitation is then projected onto the structure mesh of the stator in order to calculate the dynamic response. Finally, the radiated sound power is calculated with the aid of a standard acoustic finite element method. The calculation methodology assumes a weak coupling between the different physical levels. Other low frequency phenomena such as balancing may be added to the signal in order to enhance the simulation accuracy. This 3-step procedure is applied to an electric motor of an automotive drivetrain. The calculation is performed

for a run-up, resulting in deflection shapes and in a radiated power spectrogram. The acoustic pressure due to the electrical machine is also calculated and the noise can be reviewed for different motor speeds. One typical application could be the evaluation of the structure borne and airborne noise generated in the cabin and the aural assessment of future powertrains. Copyright © 2013 SAE International.

Erdelyi, H.E. et al., 2013. Powertrain Mounting System Layout for Decoupling Rigid-Body Modes in the Vehicle Concept Design Stage. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881207397&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This paper presents a method and corresponding software implementation for powertrain (PWT) mounting system layout design for decoupling rigid-body modes in the torque roll axis system. The novelty in the proposed method is that it requires a minimal set of inputs for determining mount topology, orientation and stiffness properties for decoupling powertrain modes, and as such it can be used at early design stages, unlike the conventional approaches based on analysis and optimization techniques. Consequently, PWT mounts can be positioned and oriented close to their optimal configuration, allowing to develop more realistic full vehicle models for conceptual (or early stage) designs and to run a more accurate dynamic analysis concerning secondary ride and vibrations. The proposed methodology is illustrated on a powertrain mounting system design example case. First an analysis is performed on a given PWT with an initial mount configuration then the proposed method is used to design an improved mounting system layout. Copyright © 2013 SAE International.

Feng, R. et al., 2013. Efficient and Accurate Evaluation and Improvement of Engine Radiated Noise. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881214303&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: In engine radiated noise analysis, the conventional boundary element method (BEM) is unsuitable for conducting large-scale acoustic simulations because of low calculation efficiency. The Fast Multipole boundary element method (FMBEM), although greatly improved calculation efficiency for large-scale acoustic simulations, has the problem of low efficiency at the low frequency region and low accuracy at the high frequency region. Those methods cannot meet the requirements of design engineers to get the results in a couple of days. In order to solve the powertrain radiated noise problems accurately and efficiently, some simplified methods and scripts were developed in big-three auto makers and suppliers, such as DIRA. Those scripts are very fast and can meet the timing requirement, but generally, without clear physical meaning. A simplified method and a Matlab program was developed in this paper based on surface vibration velocity to calculate the radiated sound power, which can be compared with other conventional methods and commercial software packages. The complete analysis procedure applied for powertrain radiated noise analysis is elaborated and presented in this paper. Several numerical examples including engine block and engine powertrain system were used to compare accuracy and efficiency among BEM, FMBEM, and the surface vibration

velocity method. Results show that for the engine block and engine powertrain analysis problems, the Matlab program developed in this paper could reduce the calculation time to 1/133 or 1/104 comparing to FMBEM, and 1/68 or 1/124 comparing to BEM, while keeping the high calculation accuracy. Copyright © 2013 SAE International.

Findeisen, B. et al., 2013. NVH Optimization of Driveline with Mathematical Optimization Methods. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881204495&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The Noise, Vibration and Harshness (NVH) behaviour of the powertrain, the driveline and the mounting is playing a very important role in the vehicle development process. The method described in this paper presents the coupling of Multi Body Simulation (MBS) with mathematical optimization tools exemplary for a powertrain mounting at a passenger car vehicle. It is shown, how this approach is integrated in the IAV-development process for validation and for optimization, i.e. finding the best solution for reaching the NVH targets. In early stage of development process, torsional vibration models are used to simulate e.g. the decoupling between engine and transmission. To simulate further physical effects, the models must be more and more detailed with a lot of additional parameter. One challenge for valid models is the parameter identification. The process to do this successfully with mathematical methods will be described. After validation of the basic model the optimization procedure will start. To reach the defined NVH targets, e.g. mounting acceleration or sound pressure in the passenger compartment, a sensitivity analysis is done. Based on this the influence of several parameters to the targets is investigated. Results are many best possible parameter solutions w.r.t. other restriction, e.g. manufacturing and costs, the optimum of parameter values is detected. Copyright © 2013 SAE International and Copyright © 2013 SIAT, India.

Freeman, T., Thom, B. & Smith, S., 2013. Noise and Vibration Development for Adapting a Conventional Vehicle Platform for an Electric Powertrain. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881196173&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: With the current focus of the automotive industry on improving fuel consumption, it is becoming increasingly more common to adapt current/existing vehicle platforms for integration with electric powertrains. This integration can have an impact on many areas of the vehicle development process, including noise and vibration performance. Alongside the understood benefits to fuel economy, electric powertrains can present many unique noise and vibration related development challenges which require specific attention, particularly for cases in which a conventional gasoline engine vehicle platform is used as a surrogate for the electric powertrain. In this paper, several of the potential noise and vibration development activities will be highlighted, including discussions on powertrain vibration, accessory noise and vibration, and acoustic package material development to deliver a refined noise and vibration experience to the customer. Copyright © 2013 SAE International.

Genuit, K., 2013. What will be the influence of e-mobility on soundscape? In *Proceedings of Meetings on Acoustics*. pp. 040053–040053. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878973057&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The increasing electrification of the powertrain after 125 years of continuous development of the internal combustion engine will not only lead to a sound pressure level reduction of vehicle exterior noises but to a complete change of sound quality. With this expected development road traffic noise affected persons hope for quiet cities and a better quality of life. The creation and successful preservation of quiet zones in cities and to avoid harmful effects of noise exposure are special focuses in European noise policy. However, different surveys have shown the increased risk of accidents for pedestrians and cyclists with respect to collisions with quiet vehicles, which caused a lively discussion about acoustical warning systems for the prevention of crashes. But it is obvious, that major conflicts between quietness and safety arise. Consequently, to address this issue, on the one hand sustainable concepts must be developed for the successful avoidance of accidents and on the other hand the general traffic noise must be minimized. The sound of electric vehicles will influence in a significant way our soundscape at places and cities in the future. This is a special challenge for psychoacoustics to provide helpful contribution besides the A-weighted sound pressure level. © 2013 Acoustical Society of America.

Geoffriault, M. et al., 2013a. Active reduction of vibrations in synchronous motors. In *IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society*. IEEE, pp. 3293–3298. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893626167&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Electric vehicles rise new issues, among them high frequency noise, that are coming from electric powertrain. This noise is caused by interaction between magnetic radial forces and mechanical stator structure. Current harmonics may excite stator natural frequencies, thus leading to vibrations responsible for acoustic noise. In this paper, we propose a new method based on control to reduce current harmonics. They are modeled as the consequence of a sinusoidal disturbance at a given frequency. This is estimated by an observer and this estimation is used to cancel harmonic components contained in stator currents. © 2013 IEEE.

Geoffriault, M. et al., 2013b. Active reduction of vibrations in synchronous motors by use of an estimator. In *2013 IEEE International Conference on Control Applications (CCA)*. IEEE, pp. 808–813. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84902269988&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Electric vehicles rise new issues, among them high frequency noise, that are coming from electric powertrain. This noise is caused by interaction between magnetic radial forces and mechanical stator structure. Current harmonics may excite stator natural frequencies, thus leading to vibrations responsible for acoustic noise. In this paper, we propose a new method based on control to reduce current harmonics.

They are modeled as the consequence of a sinusoidal disturbance at a given frequency. This is estimated by an observer and this estimation is used to cancel harmonic components contained in stator currents. © 2013 IEEE.

Girstmair, J., Schaffner, T. & Karas, Ł., 2013. NVH optimization of engine subsystems for the early development phase. In *42nd International Congress and Exposition on Noise Control Engineering 2013, INTER-NOISE 2013: Noise Control for Quality of Life*. OAL-Osterreichischer Arbeitsring fur Larmbekampfung, pp. 474–482. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904501867&partnerID=tZOtx3y1.

Abstract: In the last decennium automotive industry has been facing continuously growing expectations with regard to the noise quality of passenger cars. Since engine noise considerably contributes to the overall driving sensation as well as to the pass by noise, the acoustic optimization of the powertrain plays a major role in the development process. The current state of the art approach for NVH optimization of internal combustion engines is based on simulations and measurements on the entire engine assembly. Due to the fact that a complete engine model or hardware is needed, the biggest disadvantage of this approach is that the results are only available in a rather late stage of the development process. An efficient design process allowing for early stage conceptual choices and subsequent acoustical optimization is consequently not possible. In this paper it is shown that numerical optimization of the NVH performance of IC engines not necessarily requires a full engine model. It is instead suggested that improvements can also be obtained by early stage optimization of separate sub-systems, provided representative excitation and boundary conditions are applied. Several examples assessing the effect of subsystem optimization on the full system performance are given.

Hafidi, A. El, Loredo, A. & Martin, B., 2013. Characterization of the dynamic interaction between chassis and powertrain of a vehicle using the coupling matrix. *Journal of Vibroengineering*, 15(3), pp.1341–1353. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84884569065&partnerID=tZOtx3y1.

Abstract: This study is concerned with the vibration transmission between two subsystems of a vehicle: the chassis which is considered as an elastic structure and the powertrain which is considered as a rigid body. The study is carried out based on a new coupling matrix constructed from equations of dynamic behavior of each subsystems. This matrix depends only on the impedance matrices of the two subsystems and the mechanical characteristics of the linking mounts. Under some assumptions, a simplified expression to obtain the overall behaviour of the entire system is proposed. Despite its sensitivity to the degree of coupling between the subsystems, this method can be applied to the case of sub-structures with weak coupling. The results obtained from a simple example and from a more complex industrial structure representing a city bus are presented. © VIBROENGINEERING.

Hoang, N. et al., 2013. Development of a torsional dynamic absorber using a magnetorheological elastomer for vibration reduction of a powertrain test rig. *Journal of Intelligent Material Systems and Structures*, 24(16), pp.2036–2044. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84885463875&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This article presents the development of a torsional adaptive tunable vibration absorber using a magnetorheological elastomer for vibration reduction of a powertrain test rig. The magnetorheological elastomer used to develop the adaptive tunable vibration absorber consists of silicone polymer, silicone oil and magnetic particles with the weight percentages of 60%, 20% and 20%, respectively. Experimental testing is conducted to obtain the magnetorheological elastomer's properties, such as Young's modulus and the damping ratio, and effective formulas are derived to facilitate the design of the adaptive tunable vibration absorber. With the derived formulas, a magnetorheological elastomer-based adaptive tunable vibration absorber is designed and manufactured, and experimental testing is also conducted to validate the design. The results of experiments show that the magnetorheological elastomer-based adaptive tunable vibration absorber can work in a frequency range from 10.75 to 16.5 Hz (53% relative change). Both the designed and experimental results of the adaptive tunable vibration absorber's frequencies are in good agreement. A powertrain model is used to validate the magnetorheological elastomer-based adaptive tunable vibration absorber's effectiveness, and the numerical simulations show that the powertrain frequencies are shifted away from the resonant frequency; thus, the powertrain's steady-state vibration can be significantly reduced. This magnetorheological elastomer-based adaptive tunable vibration absorber will be a promising new device for vibration reduction of vehicle powertrains. © The Author(s) 2013.

Hu, J., Zhao, L., et al., 2013. The characteristics analysis and decoupling study on the active mount system of powertrain. *Qiche Gongcheng/Automotive Engineering*, 35(6). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84884522952&partnerID=tZOtx3y1.

Abstract: The characteristics analysis and decoupling study on the active mount system of powertrain are conducted in this paper. Firstly, the approximate linear model and analytic model for the active mount system of powertrain are set up and verified. Then with the complete response decoupling in torque roll axis direction at idle speed and the rational allocation of natural frequencies as objectives, and using Pareto genetic algorithm, a decoupling optimization on the parameters of the passive part of active mount and the position and stiffness of each mount is performed. Finally the results of optimization are verified by simulation, indicating the effectiveness of decoupling scheme adopted.

Hu, J., Chen, W. & Huang, H., 2013. Decoupling analysis for a powertrain mounting system with a combination of hydraulic mounts. *Chinese Journal of Mechanical Engineering*, 26(4), pp.737–745. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881389058&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The existing torque roll axis (TRA) decoupling theories for a powertrain mounting system assume that the stiffness and viscous damping properties are constant. However, real-life mounts exhibit considerable spectrally varying stiffness and damping characteristics, and the influence of the spectrally-varying properties of the hydraulic mounts on the powertrain system cannot be ignored. To overcome the deficiency, an analytical quasi-linear model of the hydraulic mount and the coupled properties of the powertrain and hydraulic mounts system are formulated. The influence of the hydraulic mounts on the TRA decoupling of a powertrain system is analytically examined in terms of eigensolutions, frequency, and impulse responses, and then a new analytical axiom is proposed based on the TRA decoupling indices. With the experimental setup of a fixed decoupler hydraulic mount in the context of non-resonant dynamic stiffness testing procedure, the quasi-linear model of the hydraulic mount is verified by comparing the predictions with the measurement. And the quasi-linear formulation of the coupled system is also verified by comparing the frequency responses with the numerical results obtained by the direct inversion method. Finally, the mounting system with a combination of hydraulic mounts is redesigned in terms of the stiffness, damping and mount locations by satisfying the new axiom. The frequency and time domain results of the redesigned system demonstrate that the torque roll axis of the redesigned powertrain mounting system is indeed decoupled in the presence of hydraulic mounts (given oscillating torque or impulsive torque excitation). The proposed research provides an important basis and method for the research on a powertrain system with spectrally-varying mount properties, especially for the TRA decoupling. © Chinese Mechanical Engineering Society and Springer-Verlag Berlin Heidelberg 2013.

Hwang, H.-Y., 2013. Minimizing Seat Track Vibration That is Caused by the Automatic Start/Stop of an Engine in a Power-Split Hybrid Electric Vehicle. *Journal of Vibration and Acoustics*, 135(6), p.061007. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84889040652&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The use of hybrid electric vehicles is an effective means of reducing pollution and improving fuel economy. Certain vehicle control strategies commonly automatically shut down or restart the internal combustion engines of hybrid vehicles to improve their fuel consumption. Such an engine autostart/stop is not engaged or controlled by the driver. Drivers often do not expect or prepare for noticeable vibrations, noise, or an unsmooth transition when the engine is autostarted/stopped. Unsmooth engine autostart/stop transitions can cause driveline vibrations, making the ride uncomfortable and the customer dissatisfied with the vehicle. This research simulates the dynamic behaviors associated with the neutral starting and stopping of a power-split hybrid vehicle. The seat track vibration results of analysis and hardware tests of the baseline control strategy are correlated. Several antivibration control strategies are studied. The results reveal that pulse cancellation and the use of a damper bypass clutch can effectively reduce the fluctuation of the engine block reaction torque and the vibration of the seat track by more than 70% during the autostarting and stopping of the engine. The initial crank angle can have an effect on the seat track vibration as well. Copyright © 2013 by ASME.

Ivens, T. et al., 2013. Model-based eco-driving and integrated powertrain control for (hybrid) electric vehicles. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–9. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911440042&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The Netherlands Organisation for Applied Scientific Research (TNO) is engaged in research, development and testing of a range of technologies relating to hybrid and electric vehicle energy management and performance. The impact of driver behaviour on vehicle energy consumption is a significant factor, and one which can often be reduced with eco-driving, typically 5-10% or higher in some cases. Eco-driving can be extended not only to take into account information sources, improved user acceptance, and integration with powertrain control. In this paper, TNO illustrates the possible applications of model-based control for (hybrid) electric vehicles and shows preliminary results of the developed system.

Jin, Y., Zhang, J. & Guan, X., 2013. Theoretical calculation and experimental analysis of the rigid body modes of powertrain mounting system. *WSEAS Transactions on Applied and Theoretical Mechanics*, 8(3), pp.193–201. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84885237531&partnerID=tZOtx3y1.

Abstract: The performance of dynamic property of the mount is influenced by multiple factors and strongly depends on the working conditions. This means that the modal parameters of powertrain mounting system would make changes under different operating conditions. A novel approach to simulate the actual working condition is proposed in the testing of dynamic stiffness. Then the mechanical model of powertrain mounting system based on dynamic stiffness is established in this paper. In order to examine the rationality and accuracy of the computational model based on dynamic stiffness; experimental modal analysis is performed by multiple means and methods in this paper. Through the contrast analysis, advantages and disadvantages of these methods are illustrated and it is shown that using the method of Operational Modal Analysis could obtain more accurate and more reliable results. Based on the experimental and evaluation results, it is shown that there is smaller relative error and higher fitting degree between the calculation results based on dynamic stiffness and the results obtained from operational modal analysis. Moreover, the proposed method also enjoys satisfactory consistency with the actual working condition.

Keshavarz, A. et al., 2013. Refinement of Powertrain Transmitted Vibration by Optimizing the Geometrical Parameters of Vehicle Body Structure. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881216271&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The main purpose of this research is to reduce the transmitted engine vibration to the subframe structure via improving the mobility of engine mountings. In fact, the main focus is on the geometry optimization of the subframe part,

implementing the design of experiments method, to increase the dynamic stiffness of the part to reduce the vibration transfer function in the mountings location. In order to perform the optimization process, the front end model of the reference vehicle including the suspension, steering system, engine and deriveline system is generated in FE software. According to the prevalent guidelines, the mobility of engine mountings should be greater than target value which is usually obtained through benchmarking. To do so, some structural parameters that are apt to influence on the mobility function, e.g the section of subframe, thickness of subframe and vehicle body are selected as design variables for doing the design of experiments analysis. On the basis of that, the dominant design variables are introduced to the RSM method to reach the optimum case.

Kou, Y.S. & Weslati, F., 2013. Development of a Hybrid Powertrain Active Damping Control System via Sliding Mode Control Scheme. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881198658&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This paper presents the design of a hybrid powertrain damping control algorithm using the sliding mode control (SMC) scheme. Motor control-based active damping control strategy is used to ensure smooth drive line operation and provide the driver with seamless driving experience. In the case of active damping control, motor and engine speeds are measured to monitor the driveline state, and corrective motor torques are generated to dampen out drive line vibrations. Drive lines are prone to internal vibration (engine, clutches and motors) as well as external disturbances caused by road inputs. As such, fast-response actuator-based damping control systems are desirable in a hybrid powertrain application, where a torque converter is generally not used. The most significant aspect of an active damping control algorithm is the error calculation, based on proper states information, and torque determination based on the adaptive control gain applied to the nonlinear system. For the proposed control approach, reference states are computed for different transmission modes and the tracking errors are calculated using actual measured states. The damping control torque is determined using the proposed SMC, which is developed after an analysis of the drive line model, and uses the motors as actuators to minimize the effects of internal and external disturbances. This control algorithm is developed for a power-split hybrid powertrain system and the response of the powertrain under the damping control is evaluated using vehicle-level testing, and results are discussed. Copyright © 2013 SAE International.

Li, Z. & Sandhu, J., 2013. Transmission Torque Converter Arc Spring Damper Dynamic Characteristics for Driveline Torsional Vibration Evaluation. *SAE International Journal of Passenger Cars - Mechanical Systems*, 6(1), pp.477–482. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878798972&partnerID=tZOtx3y1.

Abstract: Torsional vibration dampers are used in automatic and manual transmissions to provide passenger comfort and reduce damage to transmission & driveline components from engine torsionals. This paper will introduce a systematic method to model a torque converter (TC) arc spring damper system using Simdrive

software. Arc spring design parameters, dynamometer (dyno) setup, and complete powertrain/driveline system modeling and simulation are presented. Through arc spring dynamometer setup subsystem modeling, the static and dynamic stiffness and hysteresis under different engine loads and engine speeds can be obtained. The arc spring subsystem model can be embedded into a complete powertrain/driveline model from engine to wheels. Such a model can be used to perform the torsional analysis and get the torsional response at any location within the powertrain/driveline system. The new methodology enables evaluation of the TC damper design changes to meet the requirements. Simulation results reported provide examples of the presented virtual analysis method's capability. © 2013 SAE International.

Liu, H. et al., 2013. Natural and Forced Vibration of Hybrid Electric Vehicle Powertrain. *Applied Mechanics and Materials*, 448-453, pp.3141–3146. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84887563567&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In this paper, the natural vibration characteristics of a hybrid vehicle powertrain are simulated. The nonlinear dynamic model is proposed by using the lumped parameter method, and the dynamic response characteristics of the powertrain with a wide range change of engine speed and torque are studied. The conclusions provide the basis for the system design and control strategies constituting of hybrid vehicle powertrain. © (2014) Trans Tech Publications, Switzerland.

Lu, M., 2013. An Improved Design Method for Automotive Powertrain Rubber Mounts. *Advanced Materials Research*, 853, pp.520–525. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891916682&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The objective of the powertrain mount design is to find the geometry which meets the desired stiffness and damping requirements. For the conventional rubber mount, which is composed of a rubber element bonded into a metal bracket, its stiffness can be predicted using FEA but the damping is evaluated by physical testing. This paper introduces a design method at which the damping coefficient of the rubber mount is to be predicted theoretically based on the assumption that the phase angle for a rubber compound is constant. Absence of physical test in this proposed new design process, the development time from concept to production is reduced. © (2014) Trans Tech Publications, Switzerland.

Luan, W. & Wu, G., 2013. Launch simulation for AMT based on 6-DOF model of vehicle powertrain. *Nongye Jixie Xuebao/Transactions of the Chinese Society for Agricultural Machinery*, 44(4), pp.1–7. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84876446215&partnerID=tZOtx3y1.

Abstract: The launch for vehicle equipped automated mechanical transmission was studied. Based on the torsional vibration parameters of vehicle powertrain, such as inertia, stiffness and damp, 6-DOF model of vehicle powertrain was established. Considering the variable friction coefficient and cushion spring nonlinear

compression characteristic of clutch driven plate, it controlled the changing rate of throttle opening, engaging displacement and speed according to the opening of acceleration pedal to keep the constant speed of engine while launching. Through the method of simulation, the launching control method with constant engine speed was proved to be feasible. The clutch output torque and jerk value while launching considering torsional vibration factor of powertrain was obtained. The results of simulation were closer to the reality.

Luccarelli, M., Matt, D. & Spena, P.R., 2013. Impact of electromobility on automotive architectures. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–8. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911381359&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The introduction of alternative powertrain technologies has brought increased design freedom in spaces within a vehicle that were previously constrained by traditional ones. Such freedom will affect the overall architecture and appearance of future alternative cars. However, these vehicles require the design, development, and integration of new specific components that are not relevant in conventional combustion-driven cars. This paper is a short review of challenges and methodological approaches regarding the design for changeability in future alternative vehicle production and design, and in particular, of methods coping with interchangeability. Modularity is seen as an appealing design approach that supports vehicle manufacturers for a wider spectrum of different interchangeable technologies, involving both production processes and products. The concepts of modularity in production, modularity in design, modularity in use, and technical modularity are here presented.

Mammetti, M., Garcia, J. & Roche Arroyos, M., 2013. Wavelet Analysis for Frequency Disturbance Characterization in an Electric Vehicle. *SAE International Journal of Alternative Powertrains*, 2(3), pp.428–442. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84892176062&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Reduction of CO2 emission is a mandatory objective for every actor in the field of automotive transport, and electric vehicles (EV's) are increasingly becoming an effective option for both OEMs and customers. However, components development and vehicle integration for EV's present new challenges that must be faced and new issues which need to be solved. In particular electric motor control systems are developed to achieve the same comfort conditions as in conventional vehicles. IDIADA developed a prototype electric commercial vehicle in which both the motor and driveline were integrated. The electric motor output shaft delivers the torque to the transmission under a certain level of load variation and with torque irregularities that must be smoothed out in the transmission components. This paper studies the results of the testing of the prototype vehicle carried out to improve the overall NVH behavior of the powertrain. The test results revealed that abrupt change in frequency content must be limited in order to avoid torque irregularities from the motor to the transmission. The abrupt change in current from the inverter to the motor

was also studied by means of the wavelet analysis to reduce a given frequency range of load irregularities. This methodology permits a very accurate study in the frequency and time domain allowing the detection of the changes in time of the signals even for slight deviations and helps to properly specify the motor control characteristics. This study enabled the definition of the powertrain specifications and the electric motor control system for the entire vehicle speed range. Copyright © 2013 SAE International.

Meek, B., Van Der Auwear, H. & De Langhe, K., 2013. *Proceedings of the FISITA 2012 World Automotive Congress*, Berlin, Heidelberg: Springer Berlin Heidelberg. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84869484738&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: ERTRAC predictions currently show EV growing their market share to around 20 % of new vehicles sold by 2030, to meet these demands NVH engineers will be challenged to define and refine the sound, comfort and feel of tomorrow's automobile without hindering the drive for more efficient vehicles. Often though, improvements in efficiency such as those gained by weight reduction bring extra challenges to the NVH engineer as their concerns become secondary to performance and efficiency gains. This paper aims to show how NVH activities can positively aid efficiency gains for electric vehicles with examples of some recent simulation and test work carried out on electric vehicles. NVH Engineering takes on a new focus for Electric Vehicles with the removal of broadband internal combustion engine (ICE) noise, significant differences are found in the noise spectrum when comparing an Electric Vehicle (EV) with an ICE vehicle. EV noise is characterised by tonal harmonic noise related to the number of poles on the electric motor. Results from vehicle benchmarking tests together with analysis highlight the relative quietness in the low/mid frequency range (<1 kHz). An example of how this can offer opportunities for weight reduction is shown using NVH simulation tools to demonstrate that early application of NVH engineering can aid weight reduction while maintaining acceptable interior sound levels and quality. The choice of electric motor is often dictated by technical, financial and logistical limitations, increasingly in the automotive industry is researching alternative motor configurations that do not permanent magnets such as switched reluctance motors which do not contain magnetic materials which are expected to become increasingly expensive and scarce as demand grows. The drawback of SRM is increased noise and control complexity. A methodology using a combined 1D multi-physics approach and 3D finite element analysis approach is shown with initial results that can help optimize the mechanical design and controls of the SRM in parallel, maximising power without impairing the acoustic performance. Finally with a quieter powertrain a challenge facing vehicle manufacturers is how to alert vulnerable road users to the presence or movement of the electric vehicle, pedestrian warning systems are seen as the best solution but how can you optimize these systems, Fast Multipole BEM tools can help simulate the propagation so sound and the effect of the environment around it…

Miyasato, H.H., Simionatto, V.G.S. & Dias Júnior, M., 2013. Automotive Powertrain Vibrations Running on Wide Open Throttle Engine Conditions. In *Volume 4A: Dynamics, Vibration and Control*. ASME, p. V04AT04A087. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84903480069&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Powertrain vibrations is a great concern in the automotive industry, once they are related to many Noise, Vibration and Harshness (NVH) phenomena. These are very complex system once their dynamic behaviour, in many cases, involve the interaction between the combustion engine and the remaing components of the powertrain, such as the clutch, transmission, differential, etc. In this work a system approach is used. First, the torque generated by a four cylinder engine is obtained through the thermodynamic equations. Then, these torque curves for each cylinder are combined and used as the excitation of a simplified model of a front wheel drive powertrain. Finally, the influence of ignition angles on the combustion characteristics and on the order content of engine output torque is analyzed. Results show that significant changes may happen on the second and fourth order responses. Copyright © 2013 by ASME.

Mohamed, E.S., 2013. Design and performance analysis of the hybrid powertrain strategies for split hybrid vehicles with CVT. *International Journal of Electric and Hybrid Vehicles*, 5(3), p.195. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84888590989&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: A hybrid electric vehicle (HEV) is one of the most promising alternatives to a conventional engine-powered vehicle, which satisfies increasing customer's requirements. However, how much the hybrid vehicle is better than the conventional one depends heavily on its powertrain control strategy. The aim of the paper is to convert the internal combustion engine (ICE) to a split HEV with a continuously variable transmission (CVT), in which, the practical configuration of power train for a split hybrid electric is introduced. This is based on the analysis of the operation modes, which can operate the engine, generator and motor within its highly efficient range as much as possible and keep battery state of charge (SOC) at a reasonable level. A CVT is a transmission that can change steplessly through an infinite number of effective gear ratios. The performance of a CVT for an HEV was investigated, on the basis of theoretical simulation and practical road test in the chassis dynamometer. © 2013 Inderscience Enterprises Ltd.

Mohan, G., Assadian, F. & Longo, S., 2013. An Optimization Framework for Comparative Analysis of Multiple Vehicle Powertrains. *Energies*, 6(10), pp.5507–5537. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84886840203&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: With a myriad of alternative vehicle powertrain architectures emerging in the industry, such as electric vehicles and hybrid electric vehicles, it is beneficial that the most appropriate system is chosen for the desired vehicle class and duty cycle, and to minimize a given cost function. This paper investigates this issue, by proposing a novel framework that evaluates different types of powertrain architectures under a unified modular powertrain structure. This framework provides a systematic and objective approach to comparing different types of powertrain architectures

simultaneously, and will highlight the benefits that can be achieved from each architecture, thus making it possible to develop the reasoning for manufacturers to implement such systems, and potentially accelerate customer take-up of alternative powertrain technology. The results from this investigation have indicated that such analysis is indeed possible, by way of identifying the "cross-over point" between powertrain architectures, where one powertrain architecture transitions into a different architecture with increments in the required travel range. © 2013 by the authors; licensee MDPI, Basel, Switzerland.

Mohanty, A. & Fatima, S., 2013. An overview of automobile noise and vibration control. *Noise & Vibration Worldwide*, 44(6), pp.10–19. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84879808027&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: In this paper the current state-of-the-art techniques in automobile noise and vibration control are presented. Automobile designers and manufacturers have to pay attention to the global competition of their products, adherence to legislative regulations and passenger/driver comfort while designing an automobile and its components. Designers can take advantage of efficient numerical modeling techniques so that in before the prototype of the automobile is produced, the design can be tweaked and modified by using computer aided models to optimize the design with a target of achieving low noise and vibration levels in the prototype. Here, examples of some typical cases are provided where optimum levels of noise and vibration level are obtained in the design of automobile components using computer aided engineering techniques.

Molteni, G.-L., 2013. Advanced Reinforced Materials for Engine and Vehicle Efficiency. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881216940&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: New regulations are challenging the automotive industry to find technology solutions to meet new emissions and fuel economy standards. Engine downsizing and power boosting technologies, hybrid and electrical powertrain, overall vehicle downsize, lightweight structural materials and, fuel cells technology are demanding new materials to meet the new level of end-use performance, bring measurable benefits on light weight, and provide design solutions that will lead to lower total system cost. APF are one the enablers for lightweight materials hybridization and how a holistic consideration of materials, production processes and methods with regard to costs, time and quality is therefore necessary. These products can be used to help reduce weight in target applications, to improve performance and vehicle efficiency, thus contributing to help the industry to meet higher demand to lower CO2 emission thru better fuel economy. As the industry works on improving efficiency there is significant effort to reduce and minimize the amount of energy losses from the engine driveline and from the vehicle which includes another 5% of fuel efficiency drain from rolling resistance. Copyright © 2013 SAE International.

Morariu, M.C., Lupea, I. & Anderson, C., 2013. Troubleshooting Technics to Identify the Airborne and Structure-Borne Noise Content inside an Electric Vehicle. *Applied Mechanics and Materials*, 430, pp.297–302. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84886005494&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: An electric vehicle was subjected to on-road acoustic tests. A specific high frequency tone was perceived in a sound field dominated by wind and road noise. The car was instrumented with microphones which measured the noise inside the passenger compartment and with tachometers to record the motor's rotational velocity with respect to time. Waterfall diagrams were generated by tracking the spectrums of noise from fixed time samples against the rpm of the motor. The analysis of the diagrams revealed that high orders, like the 24th and 48th were responsible for the sound. These orders represent the acoustic response of the electromagnetic interaction between the stator and the rotor of the electric motor. To analyze the propagation of noise from the source (motor) to the target (driver), a transfer path analysis (TPA), respectively an airborne source quantification (ASQ) were proposed. The TPA focused on the structure borne noise generated by the forces transmitted into the body through the powertrain supports, and the ASQ, on the airborne noise radiated by the surface of the motor and gearbox casing. The conclusion was that the airborne noise is the main contributor to the total pressure level in the passenger compartment, but at lower speeds a strong structure borne noise content is present. © (2013) Trans Tech Publications, Switzerland.

Orzechowski, J. et al., 2013. Modeling and analysis of powertrain NVH with focus on growl noise. *SAE International Journal of Engines*, 6(2), pp.1340–1347. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878796553&partnerID=tZOtx3y1.

Abstract: Superior NVH performance is a key focus in the development of new powertrains. In recent years, computer simulations have gained an increasing role in the design, development, and optimization of powertrain NVH at component and system levels. This paper presents the results of a study carried out on a 4-cylinder in-line spark-ignition engine with focus on growl noise. Growl is a low frequency noise (300-700 Hz) which is primarily perceived at moderate engine speeds (2000-3000 rpm) and light to moderate throttle tip-ins. For this purpose, a coupled and fully flexible multi-body dynamics model of the powertrain was developed. Structural components were reduced using component mode synthesis and used to determine dynamics loads at various engine speeds and loading conditions. A comparative NVH assessment of various crankshaft designs, engine configurations, and in- cylinder gas pressures was carried out. The main results include the crankshaft front-end and rear-end vibrations, bearing caps accelerations spectrum, and structure surface velocity levels in octave and 3rd octave bands. The correlation with experimental data was used to validate the analytical model. The analysis shows that a stiffer crankshaft results in a reduction of forced excitation transmitted to the bottom-end structure. The bearing beam stiffener also reduces bearing cap accelerations significantly. Both structural enhancements result in dramatically reduced growl noise. Copyright © 2013 SAE International.

Pallas, M.A., Chatagnon, R. & Lelong, J., 2013. Noise emission and noise sources of a hybrid bus. In *42nd International Congress and Exposition on Noise Control Engineering 2013, INTER-NOISE 2013: Noise Control for Quality of Life*. OAL-Osterreichischer Arbeitsring fur Larmbekampfung, pp. 532–541. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84904467489&partnerID=tZOtx3y1.

Abstract: Awkward environmental conditions induced by dense traffic in urban areas lead many cities to expand sustainable public transportation services. In addition to contributing to the reduction of air pollution and energy consumption, the selection of hybrid buses against conventional buses may also impact on noise emission. The French research project ElLiSup has been developing a plug-in series hybrid bus, operating either in hybrid or electric mode. The noise emission of the vehicle has been assessed and compared with an equivalent Internal Combustion Engine (ICE) bus. Global and third-octave noise analysis has been performed, relying on the classical Controlled Pass-by (CPB) procedure, and on a microphone array beamforming technique for investigating the noise sources. Pass-bys at constant speed, with acceleration and braking have been considered. The hybrid bus provides significant noise reduction at constant low speed due to lower powertrain contribution, both in hybrid or electric mode. This advantage decreases with increasing speed, as rolling noise becomes prevailing. However, in some acceleration or even braking situations the increase of the motor's contribution in frequency ranges of high human ear sensitivity may put the hybrid bus at a disadvantage, even in electric mode.

Pan, G.Y., Yan, Y. & Yang, X., 2013. Optimization of Vehicle Powertrain Mounting System Based on Adams/View. *Applied Mechanics and Materials*, 328, pp.499–503. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84880152213&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: In order to solve the vibration problem of diesel engine powertrain assembly at its idle state, a six degree-of-freedom dynamics model of the powertrain mounting system is established and a optimization based on Adams/View is applied to simulation and analysis on the powertrain mounting system with energy decoupling method. The results show that the optimized repositioning mounts installation position can effectively improve decoupling rate in main vibration directions of mounting system, proving that the energy decoupling method has good effect on greatly improving the system's vibration isolation efficiency. © (2013) Trans Tech Publications, Switzerland.

Pan, G.Y., Yang, X. & Yan, Y., 2013. Optimization of Vehicle Powertrain Mounting System and its Performance. *Applied Mechanics and Materials*, 441, pp.580–583. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891099951&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: In order to solve the vibration problem of diesel engine powertrain assembly at its idle state, a six degree-of-freedom dynamics model of the powertrain mounting system is established and a optimization based on Adams/View is applied to simulation and analysis on the powertrain mounting system with energy decoupling

method. The results show that the optimized repositioning mounts installation position can effectively improve decoupling rate in main vibration directions of mounting system. Based on this, the vibration transmissibility and acceleration response before and after optimization are simulated. The results show that the optimized engine mounting system makes a great improvement of vibration isolation performance. © (2014) Trans Tech Publications, Switzerland.

Pant, A., Jain, C.P. & Panda, D.K., 2013. Numerical Modeling of Critical Path Contributions for NVH Prediction of Vehicle. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891589944&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: For any new vehicle development, NVH target setting is crucial activity. Structural modification are to be done in early design phase to improve cabin comfort by identifying the sensitive paths and taking appropriate countermeasures for reduction of noise or vibrations transmission to cabin. A benchmark vehicle is taken to define the target areas for next model development. Numerical computations with suitably modified virtual model are carried out to accelerate the development cycle. Transfer path analysis (TPA) is an established technique for estimation and ranking of individual low-frequency noise or vibration contributions via the different structural transmission paths from point coupled powertrain or wheel-suspensions to the vehicle body [1]. TPA technique can also be used to define the improvement targets for future vehicles. This paper presents the methodology of carrying out the “Target Setting” using TPA for numerical model development for new model prior actual prototyping which will result into achieving desired NVH level in cabin. The activity has been carried out on Cross-over 2WD platform which has been taken as a benchmark for next generation utility vehicle. Virtual model of subject vehicle is created and correlated with actual vehicle condition. For numerical input, noise transfer function is calculated on subject vehicle using Transfer Path Analysis technique [2] for decisive location inside cabin. Input force is also calculated for contribution analysis over a wide frequency range for different driving conditions. Using the operational data, the problem areas are identified and further improvement target are decided keeping the vehicle class in view. Structure-borne noise is the major source of noise inside the vehicle compartment; hence improvement of bush isolation is identified as major area of improvement. © 2013 SAE International.

Park, J., 2013. Development of engine clutch control for parallel hybrid vehicles. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–5. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911429254&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The parallel hybrid configuration in which a clutch is installed between an engine and a motor can shift its operation mode between pure electric and hybrid vehicle mode by engaging or disengaging the clutch. To enhance drivability of the system in shifting its operation mode, it is required to prepare appropriate measures to control the clutch in response to driving conditions. This paper introduces the hydraulic clutch control strategy which is composed of a synchronized engaging and a launch slip engaging maneuver. The strategy also covers the criteria to decide the

proper engaging method between above two candidates for current circumstance. This study also deals with the learning algorithm to compensate the variations of the clutch hardware and to realize consistent drivability across all units. The learning algorithm utilizes the traction motor and a pressure sensor to identify the all the variation terms of the clutch with the required level of accuracy.

Rejab, M.N.A., Rahman, R.A., et al., 2013. Measurement of Noise inside the Compartment and Vibration on both Sides of Elastomeric Powertrain Mounts of Passenger Car. *Applied Mechanics and Materials*, 471, pp.59–63. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891526155&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: This paper presents an evaluation on elastomeric mount used to isolate vibration from powertrain to chassis or structure vehicle. The assessments started with measurement of noise inside compartment, and exhaust noise. This is followed by the measurement of vibration on both sides of elastomeric mounts. The noise in the compartment and exhaust noise is measured according to BS 6086: 1981 and BS ISO 5130: 2007. The noise in the compartment and vibration is tested in three conditions. Firstly, engine is run-up with load (driving at second gear); secondly, without load; and thirdly, without load but hanging. A microphone is fixed at the ear of the mannequin. The “fast” response and “A” weighting sound level meter were used for measurement noise in the compartment and exhaust noise. The vibration is measured in terms of acceleration on both sides of each elastomeric powertrain mounts. Two accelerometer transducers are fixed on both sides of powertrain elastomeric mounts. One side was identified as a source of vibration and the other as receiver of vibrations. The results showed that the pattern of overall vibration level on source and receiver increased from 1050 RPM (idling) to 4000 RPM on all test conditions. Vibration transmitted to chassis or receiver structure was analyzed using transmissibility concept. By evaluating test condition of engine run-up without load, informed that the front and rear mounts showed a high level transmissibility contributing to structure-borne noise. © (2014) Trans Tech Publications, Switzerland.

Rejab, M.N.A., Rahman, R.A., et al., 2013. Measurement of Vibration Power Flow through Elastomeric Powertrain Mounts in Passenger Car. *Applied Mechanics and Materials*, 471, pp.30–34. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891507809&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The effectiveness of vibration isolator or mount can be done by quantifying the vibration energy flow through the isolators. This can provide information on the quantification of the vibration energy flow from the powertrain to the structure or chassis. Vibration energy flow through mount is identified as vibration power flow that is one of vibration transmission paths. This paper presents vibration power flow through four elastomeric mount. The vibration (source and receiver of accelerations) was measured by running engine at constant speed and without load conditions in varying speeds starting from 1050 RPM to 4000 RPM. The vibration was measured only in zdirection (vertical direction). The noise inside compartment was measured at the condition of engine run-up without load condition and was measured starting from

1050 RPM to 4000 RPM engine speed. The results from vibration power flow analysis showed that the main vibration energy transmission was high from front mount and rear mount, around engine speed 3200 RPM, and booming noise occurred around 3200 RPM due to structure-borne noise. © (2014) Trans Tech Publications, Switzerland.

Rodriguez, J.M., Meneses, R. & Orus, J., 2013. Active vibration control for electric vehicle compliant drivetrains. In *IECON 2013 - 39th Annual Conference of the IEEE Industrial Electronics Society*. IEEE, pp. 2590–2595. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893602265&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The present work describes a novel controller based on perturbation observers for reducing the oscillations and improving the stability in the powertrain of a full electric vehicle with in-board motors. Compared with more classical approaches, the proposed strategy permits to damp the resonance in the transmission line and to control the reaction torque on the road. To do that, the controller combines state feedback with a tyre reaction tracking loop. The former is intended to damp the resonance frequency of the drivetrain using pole placement, and the latter avoids low frequency oscillations and assures the proper reaction on the road. The inner state feedback loop is applied to the subsystem motor-gearbox-halfshaft-wheel, which can be perfectly characterized, and it is not affected by the nonlinear time-varying response of the tyre. This last magnitude is estimated with a perturbation observer without requiring complex nonlinear representations, and the obtained value is compared with the reference driver command. The outer tracking loop compensates for the tracking error. The proposed controller is compared with a more traditional algorithm based on a tachometric feedback, and it has proved a good performance in dry and snowy road conditions, properly working in presence of actuations of the traction control system in low adherence situations. © 2013 IEEE.

Roy, H.K., McGordon, A. & Jennings, P.A., 2013. Real-world investigation of a methodology for powertrain component sizing of hybrid electric vehicles. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–9. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911416386&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: Hybrid electric vehicles (HEVs) have emerged as near term sustainable technologies to reduce fossil-fuel dependency. The variation in fuel economy (FE) due to the variation in driving patterns exists in hybrid electric vehicles (HEVs). Powertrain component size optimisation based on a methodology considering a range of driving patterns including different traffic conditions and driving styles simultaneously has previously demonstrated the potential to reduce variation in FE over standard legislative driving patterns. Though standard legislative driving patterns are useful for comparative study, there are evidences that legislative driving patterns are often considerably different from real-world driving. Therefore to ensure wide applicability, the methodology needed to be validated for real-world driving pattern. This paper applied the methodology for ten real world driving patterns over a predefined route consisting of urban and highway driving to investigate the

applicability of the methodology in real world. The study was carried out using a series-parallel Toyota Prius HEV. A rule based supervisory control strategy was considered as the energy management. A genetic algorithm was considered as the optimisation method. The methodology demonstrated the potential to reduce variation in FE by up to 33% in real world driving.

Satué, R., 2013. Functional Vehicle Design for Urban Mobility. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881211403&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: When approaching new mobility solutions such as car-sharing, it soon becomes apparent that it may be necessary to develop specific vehicles for this application. In this paper, Applus IDIADA explains its experience in the development of the iShare, an electric vehicle conceived as a demonstrator of our complete vehicle development capabilities following the principle of development led by functionalities, with the consideration that it would be used in open car-sharing fleets running according to the MIT's (Massachusetts Institute of Technology) mobility-on-demand concept. This paper explains the process followed in order to reach the definition of the different parts, systems and components that are the result of the consideration of the Technical Functionalities, such as Active Safely, Passive Safely, Driveability, NVH, Fleet Management, Maintenance and Comfort, that in their turn result from the basic vehicle specifications defined from the analysis of the key functionalities of this vehicle that are suitability for the car-sharing business model and the mobility requirements of the potential customers. In particular, the paper includes details about the vehicle layout analysis and why a 4-wheel and 2-parallel seats configuration was chosen instead of 2- o 3-wheel or 2-tandem seats configuration, the powertrain, steering, suspension, braking, Passive Safety and energy efficiency concepts explored, the process allowing a customer to book and have access to a given vehicle without a physical key and finally the systems to allow the car-sharing operator to keep the cars in good conditions by replacing interior and exterior trims easily and inexpensively and recycling the materials to make new trims out of it. Copyright © 2013 SAE International and Copyright © 2013 TSAE.

Schruth, R. et al., 2013. Driving safety and comfort enhancements through efficient usage of e-powertrain functions. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–10. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911452973&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: The paper shows how different possibilities of electrified propulsion can bring more benefit into the vehicle regarding driving comfort, driving safety and driving pleasure without additional components. Complex control functionalities of electric motors in the propulsion system and their effects on the vehicle behavior are explained. It is shown, how advanced control functions can influence steering behavior, movements in the vehicle structure and the response behavior of component operation in a positive way. The shown robust technology with the cross-linked functions is versatile with different potentials for diverse drivetrain configurations. The paper demonstrates how to let the physical propulsion system untouched and

takes into account the interaction of all components of the entire vehicle. First tests, simulation and validation results are presented. This increases safety and comfort aspects but also more fun to drive and generate “the electric smile” on the customers face.

Shin, S.-H. & Hashimoto, T., 2013. Optimum order spectrum profiles for improvement of sound quality of car interior noise. *Noise Control Engineering Journal*, 61(6), pp.578–589. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893838576&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Sound quality (SQ)-based noise control is regarded as a useful tool for improving the competitiveness and popularity of a vehicle that is available on the market. Among the several sources affecting the SQ of vehicle noise, the features of the noise caused by a vehicle’s engine, powertrain, and intake and exhaust systems can be represented by order spectrum analysis. Especially, it is widely known that the first and second firing orders of an engine are key in determining the SQ of a car's interior noise. In this study, the relationship between the order spectrum of car interior noise and a passenger's perception of the noise was investigated; thereafter, optimum order spectrum profiles for improving the SQ were proposed for a range of engine types. To this end, car interior noise was recorded in passenger cars with different types of engines and their original order spectra were increased or decreased by applying adaptive digital filters. Subjective listening experiments based on the paired comparison method and semantic differential method were conducted with the original and modified interior noises to find an optimum order spectrum profile from the viewpoint of SQ and to investigate the effect of modification on a passenger's perception. As a result, it was confirmed that the half-order components as well as the firing orders should be regarded as important factors affecting the SQ of car interior noise. In addition, the SQ of car interior noise with the proposed optimum order spectrum profile was improved in terms of perceptual feelings: pleasant, harmonic, rough, etc. even though its tonal balance was slightly shifted to the high frequency side. © 2013 Institute of Noise Control Engineering.

Simionatto, V.G.S., Miyasato, H.H. & Dias Júnior, M., 2013a. Insights on Centrifugal Pendulum Vibration Absorber: Part One — Dynamic Modeling and Behaviour of Eigenvalues and Eigenvectors Along Rotating Speed. In *Volume 4A: Dynamics, Vibration and Control*. ASME, p. V04AT04A088. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903444633&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: An automotive powertrain is a system that is designed to transmit torque from the engine to the wheels of the vehicle, allowing it to move. The working principle of most of the vehicle engines is the internal combustion, which causes the torque generated by this engine to have important oscillatory components, which cause the powertrain to vibrate and generate noise, which is undesired. In order to control this vibration, among many engineering solutions is the centrifugal pendulum vibration absorber (CPVA), whose dynamic behaviour turns it is capable of reducing the amplitude of important order components of the power-train. It is usually installed

on the flywheel of the vehicle, although it is possible to install it in other parts, such as the clutch disk. Although the CPVA is an important type of passive vibration absorber, it was still not found in the literature a parametrized formulation which can be applied to any vibration absorber of this kind. For this reason, the aim of this work is to propose a formulation based on dimensionless parameters, which can be applied to any CPVA. With this formulation, the dynamic behaviour of a simple 2DOF torsional system with a CPVA, spinning at constant speed, is verified. It is important to mention that this work is the first part of a two part work. In the second part, this formulation is applied to a more complex system with a CPVA, and results are shown to be coherent with the analyses shown here. Copyright © 2013 by ASME.

Simionatto, V.G.S., Miyasato, H.H. & Dias Júnior, M., 2013b. Insights on Centrifugal Pendulum Vibration Absorber: Part Two — Behaviour of a FWD Powertrain With a CPVA on its Clutch's Flange. In *Volume 4A: Dynamics, Vibration and Control*. ASME, p. V04AT04A089. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903484303&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This work is the second and last part of a study whose aim is to present the vibrational aspects of a system with a centrifugal pendulum vibration absorber (i.e. CPVA). The aim of this work, specifically, is to develop a mathematical model of a front engine - front wheel drive powertrain to study gear rattle phenomenon, and to install on its clutch disk's flange a CPVA in order to understand what are the effects of this device on the dynamics of this system. Results from the linear analysis show that the eigenfrequen-cies of the system vary with the engine speed. They oscillate between the eigenvalues of the system without the CPVA and, for regions away from the tuning frequency of the pendulum, which is the second order of rotation of the engine, the behaviour of the system remains the same. However, near the tuning frequency of the pendulum, the behaviour of the system varies very much, and the amplitude of vibration of the gearbox's inner parts diminishes. Simulations of the powertrain without and with the nonlinear model of the studied device show that its presence reduces dramatically the vibrations inside the gearbox and its nonlinear character does not influence the effectiveness of this solution. Copyright © 2013 by ASME.

Sivakumar, A. et al., 2013. Elastomer Isolator Gear Design to Meet Noise, Vibration and Durability of Internal Combustion Engine. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84890328124&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Success of the vehicle in the market depends on comfort provided while usage, which also includes noise, vibration and harshness (NVH). In order to achieve comfort level, the NVH levels have to be as low as possible. Powertrain is the main source of NVH, in which internal combustion engine consists of crank shaft and balancer shaft. Crank shaft gear is connected and driven by crank shaft and balanced by integral eccentric mass coupled with gear. Balancer shaft is used for additional balancing of rotating masses. Pair of crank shaft and balancer shaft gears generates noise and vibration when unbalance in the system and backlash in the gears increase

while usage. The practice of interposing a vibration isolator on the surface of gear has been so far resorted for preventing transmission of vibration, therefore reduction in noise. In the work presented, balancer gear was made with sandwich design to reduce noise. Sandwich design comprises of Inner hub and outer ring with lug projections. Special purpose Elastomer is interposed in between inner hub and outer ring to meet NVH and design durability of two cylinder gasoline engine, used for passenger and light commercial vehicle. The recipe of this vibration isolator becomes an important factor in reducing the noise and vibration. The subject work led to successful evaluation of Isolator gear to meet functional targets and requirements. Copyright © 2013 SAE International.

Song, M. et al., 2013. Development of an electric oil pump control algorithm for an automatic-transmission-based hybrid electric vehicle considering the gear shift characteristics. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 228(1), pp.21–36. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893049248&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In this paper, an electric oil pump control algorithm for an automatic-transmission-based hybrid electric vehicle was proposed. Dynamic models of the hybrid electric vehicle powertrain and hydraulic control system, including a mechanical oil pump and an electric oil pump, were obtained, and a hybrid electric vehicle performance simulator was developed. Also, a flow consumption model of the hydraulic control system was constructed. To represent the characteristics of the hydraulic control system according to the change in the temperature of the automatic transmission fluid, a viscosity index concept was introduced. Based on the simulation and test results, a viscosity index-line pressure-electric oil pump power map was proposed to describe the power supply requirement according to the viscosity index and the required line pressure. Using the viscosity index-line pressure-electric oil pump power map, an electric oil pump control algorithm was suggested to control the electric oil pump by using multi-stage power for a given viscosity index. The mechanical oil pump speed at which the electric oil pump is turned off was obtained on the basis of the flow consumption model. The electric oil pump control algorithm was evaluated by experiments and simulations. The proposed electric oil pump control algorithm satisfied the target line pressure requirement according to the viscosity index. In addition, an electric oil pump control strategy during an automatic transmission gear shift was suggested for the situation in which the maximum line pressure required for the gear shift cannot be achieved by only the mechanical oil pump. The electric-oil-pump-assisted power was determined from the flow consumption model and the mechanical oil pump speed considering the gear shift. The simulation results confirmed that the electric oil pump control strategy satisfied the maximum line pressure during a gear shift. © IMechE 2013.

Sugyarto, E. & Takahashi, Y., 2013. Impact of Gear Bias Control on Vehicle NVH. In *Volume 5: 25th International Conference on Design Theory and Methodology; ASME 2013 Power Transmission and Gearing Conference*. ASME, p. V005T11A017. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84896976801&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: This paper is based on Honda product development and maturation related to noise and vibration. During the development, it was discovered that the vibration level of the vehicle did not meet the desired level. These studies are aimed to reduce the noise and vibration felt in vehicle by improving the powertrain as the main source of the vibration. During the investigation, it was discovered that manufacturing process change from tooth shaving to tooth honing could have significant impact on the final tooth profile that essentially impact the noise and vibration level of the vehicle. The studies focus on bias control to improve the vibration level. This paper will show complete relationship between actual gear profile, vibration level of unit as powertrain, and finally airborne noise level of the complete vehicle as the final product. The studies resulted in shifting bias control target for the gear tooth profile, which translates to improved noise and vibration level in vehicle.

Szatkowski, A., 2013. Passenger Vehicle Hybrid Hydraulic Powertrain Sound Quality Investigation. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881217009&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The sound quality of a prototype series hydraulic hybrid passenger vehicle powertrain was analyzed. Different sound quality metrics were evaluated to determine which one correlated best with the subjective assessment of sound quality, and a desired sound quality target was developed. Next, the effect of the design of the hydraulic powertrain components on sound quality was analyzed. Two extreme options were analyzed: stiff systems with a hard drive shaft or short fluid hoses, and soft systems with a soft drive shaft or long fluid hoses. Experimental results from these systems are presented in the paper. Finally, design recommendations were made to achieve the best sound quality of the hybrid hydraulic powertrain, and therefore maximum customer satisfaction.

Szumanowski, A., Liu, Z. & Krawczyk, P., 2013. Analyse of clutch-brake system control based on experimental tests and applied in hybrid power train. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–11. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911396882&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Clutch-brake system is important element in advanced Compact Hybrid Planetary Transmission Drive (CHPTD). The proper designed clutch/brake system equipped with planetary transmission and additional gears could save energy and improve performance of hybrid powertrain, especially during frequent vehicle starting and regenerative braking. This paper dedicate to design of clutch engaging control strategy in ICE starting procedure. The control of each element in CHPTD during ICE starting is described. Different clutch engaging control strategies are proposed and validated on laboratory stand for various conditions. Optimized control strategy for clutch engaging is selected by analysing the simulation and experimental test results.

Tanaka, K. et al., 2013. Design, manufacture, and environmental sustainability evaluations of advanced electric medium duty bus “WEB for Suntory.” In *2013*

World Electric Vehicle Symposium and Exhibition (EVS27). IEEE, pp. 1–9. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911386621&partnerID=tZOtx3y1 [Accessed August 28, 2015].

Abstract: This paper describes the design and manufacture of a highly practical electric medium duty bus called the WEB for Suntory (WEB: Waseda electric bus). The new electric medium duty bus has a 55-passenger capacity, which is significantly greater than the other vehicles in the WEB series. This project prioritized weight reduction and maximization of the passenger compartment space to develop a bus that meets the requirements for short distance transportation and very frequent charging. A new compact powertrain system incorporating the minimum number of lithium-ion batteries was developed. The intended purpose of the bus is to convey passengers on a plant tour along a steep and low-velocity route located at the foot of a mountainous region. The merits of an electric bus make it particularly suited to this usage scenario and route, which require environmentally sustainable transportation. The dynamic performance and environmental sustainability of the bus were evaluated based on long-term actual driving data. The results found that adopting this bus on this route greatly reduced energy consumption and CO2 emissions due to its efficient dynamic performance and energy regeneration system. The bus was charged from the solar power generation system installed at the plant, thereby further reducing CO2 emissions and running costs.

Tang, X. et al., 2013. Torsional vibration and acoustic noise analysis of a compound planetary power-split hybrid electric vehicle. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 228(1), pp.94–103. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84893110345&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Theoretical and experimental analyses of torsional vibrations and acoustic noise for a deep hybrid electric vehicle driveline including an electric, continuously variable transmission are carried out. The dynamic and mathematical models with 16 degrees of freedom in a matrix form are developed for the torsional vibration characteristics of the hybrid driveline. On the other hand, the noise sources of the hybrid electric vehicle powertrain excited in the pure electric mode and the hybrid drive mode are tested and measured using acoustic and speed sensors. The noise orders and the frequency domain responses are constructed using signal treatment and torsional vibration analysis. The theoretical predictions for the natural frequencies and the corresponding vibration modes of the hybrid driveline are presented. The noise test results are also given in accordance with the torsional vibration modes of the hybrid driveline in the pure electric mode and the hybrid drive mode. The noise sources due to the self-excited and frequency-multiplied vibrations are found, focusing on the compound planetary gear set in the power-split electric, continuously variable transmission. © IMechE 2013.

Toensmeier, P., 2013. Mass appeal: High-performance thermoplastics spark automakers' relentless drive to reduce weight and increase fuel economy. *Plastics Engineering*, 69(7), pp.6–14. Available at:

http://www.scopus.com/inward/record.url?eid=2-s2.0-84883305540&partnerID=tZOtx3y1.

Tonge, G. & Agrawal, S., 2013. Analysis of Open Plenum Structure for Reduction of Booming Noise. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881199125&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Low frequency structure borne booming noise is one of the important ride parameter and has become a key differentiator in the modern vehicle development. In most of the vehicles, windshield vibration is main concern for booming noise. One of the ways to get rid of this is to reduce the energy transferred from windshield to cavity by stiffening windshield mounting structure. The concept of open section plenum is evolved to meet pedestrian impact requirements which in turn affect noise, vibration and harshness (NVH) performance of vehicles. Open section plenum affects windshield structure to cause Boom and Powertrain noise concerns. This paper mainly focuses on improving the boom / powertrain noise performance by stiffening windshield mounting structure while still meeting the pedestrian impact requirements. An outcome of the study can be used as design guidelines for future vehicle development programs to meet NVH targets in an early stage of the program. Copyright © 2013 SAE International.

Tousignant, T. et al., 2013. NVH Target Cascading from Customer Interface to Vehicle Subsystems. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881203205&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The definition of vehicle and powertrain level targets is one of the first tasks toward establishing where a vehicle will reside with respect to the current or future state of industry. Though development of sound quality metrics is ongoing to better correlate objective data with subjective assessments, target setting at the vehicle level is relatively straightforward. However, realization of these targets depends on effective cascading to system and component levels. Often, component level targets are derived based on experience from earlier development programs, or based on selected characteristics observed during component level benchmarking. An approach is presented here to complement current strategies for component level target definition. This approach involves a systematic concept for definition of component NVH targets based on desired vehicle level performance and a consequent target break down. The target break down is performed using a TPA method in combination with knowledge about the typical behavior of excitations and transfer functions. Using this approach, target lines are derived for vehicle components such as powertrain, intake and exhaust systems. These targets are then cascaded down further to individual paths and split into targets for excitations and transfer functions (e.g., powertrain mount vibration and vibro-acoustic transfer paths of the vehicle body). This systematic target cascading process is helpful in developing a balance between NVH performance and other development goals. Copyright © 2013 SAE International.

Tsujiuchi, N. et al., 2013. *Topics in Nonlinear Dynamics, Volume 1* G. Kerschen, D. Adams, & A. Carrella, eds., New York, NY: Springer New York. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84880563566&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: In recent years, measures have been implemented to improve automotive environmental performance, such as increasing engine torque at low speeds and reducing idling speed. These measures tend to increase the engine's torque fluctuation, which adversely affects the noise and vibration (NV) phenomena of the powertrain. Demand continues to increase for NV measures in powertrains. Gear rattle, which is a general NV problem of powertrains, strongly influences the torsional stiffness and the hysteresis torque of the clutch damper, which is an absorption element of a powertrain, and the inertia of the transmission or the flywheel. In this paper, we built a mechanism analysis model of a powertrain that can predict gear rattle and examined the relevance of the first stage hysteresis torque of a clutch damper and the gear rattle behavior. © The Society for Experimental Mechanics Inc. 2013.

Walker, P.D. & Zhang, N., 2013. Influence of Engine Harmonics on Synchroniser Mechanism Dynamics. In *Volume 4A: Dynamics, Vibration and Control*. ASME, p. V04AT04A085. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84903440051&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Synchronizer mechanisms play an important role in the selection and engagement of gears in manual, automated manual and dual clutch transmissions (DCT). These mechanisms rely heavily on the balancing of torque loads in cone clutches, dog gears and from losses in the gearbox to ensure repeatable and reliable actuation, with excessive wear on friction and contact surfaces leading to degradation of actuation and potential mechanism failure. Dual clutch transmissions, in particular, provide a unique operating environment for synchronizers, most notably is its actuation with the engine still driving the wheels during normal driving conditions. Thus, the consideration of increased transmitted vibrations through the powertrain must be evaluated to study the impact of these vibrations on the synchronizer. To conduct this investigation this paper develops a detailed multi-body dynamic model of a typical automotive powertrain equipped with a dual clutch transmission. This includes engine models with torque harmonics that capture the instantaneous torque variations from piston firing in the engine. As the main consideration of this paper is the influence of engine harmonics, the semi-definite powertrain model is simplified to a fixed-free system and the response of the synchronizer mechanism to harmonic torque inputs is analyzed. Parametric analysis of the system is conducted to analyze the influence of variables - including gear ratio, torsional damper, system damping, and engine configuration - on the dynamic response of the mechanism. Results demonstrate the influence of each of these variables on synchronizer dynamics in the steady state, with stiffness of torsional damper having the strongest influence on forced vibration. Additionally, results vary significantly between single and dual lay-shaft transmissions. Copyright © 2013 by ASME.

Walker, P.D. & Zhang, N., 2013. Numerical investigations into shift transients of a dual clutch transmission equipped powertrains with multiple nonlinearities. *Journal of Vibration and Control*, 21(8), pp.1473–1486. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84928978544&partnerID=tZOtx3y1 [Accessed July 8, 2015].

Abstract: The purpose of this paper is to numerically investigate the influence of nonlinearities applied to vehicle powertrains equipped with a dual clutch transmission, including gear backlash, dual mass flywheel hysteresis, and torque pulses from the engine. To achieve this goal, a multi-body dynamic model of such a powertrain is constructed for transient vibration studies. Incorporated into this model is a combination of two nonlinear contact backlash models: for gear pairs a line-of-action force contact model is used to represent backlash in the mesh, and, for engaged synchronizer dog gears, a torsional nonlinear contact model is applied. This powertrain model is then used to study the response to shift transients under different conditions, including with and without engine torque harmonics, the variation of mesh damping and tooth clearance, and the impact of torsional vibration absorbers. Simulation results demonstrate that engine torque harmonics, mesh clearance, and external damping sources have a significant impact on duration of excitation, while the impact of mesh damping is less significant.

Wang, X., Yao, W. & Yang, Y., 2013. Modification of front wheel drive vehicle engine mounting system for reduction of drive-away shudder. In *20th International Congress on Sound and Vibration 2013, ICSV 2013*. International Institute of Acoustics and Vibrations, pp. 2869–2875. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84897098339&partnerID=tZOtx3y1.

Abstract: Vehicle take off shudder is sensitively felt by customers when the vehicle is driven at a low speed under drive away acceleration. The take-off shudder is complained of significantly by customers according to after sales statistics. Under an engine torque and half shaft angle, the drive-away shudder usually occurs during acceleration to a specific low speed, which makes the vehicle shakes severely. Aiming to provide a thorough investigation with possible design optimization of mounting system to reduce this lateral vibration, this paper focuses on a small car, the take-off shudder of which occurs at the speeds between 20Km/h and 30Km/h. A 12 Degree of Freedom (DOF) rigid body model will be established to simulate the engine and body system. The design of powertrain mounting system will be modified to achieve the reduction of the shudder level.

Wang, X.F. & Shi, J., 2013. The Powertrain in Vehicle Sound Power Test Method Research. *Applied Mechanics and Materials*, 380-384, pp.77–81. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84884870030&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: In this paper, an experimental study on the powertrain in vehicle sound power test was presented. The necessary parts retrofits and acoustic treatments for the powertrain sound power test in the vehicle were listed. The criteria and correction

method of the appropriate background noise level for the powertrain sound power level test in the vehicle were discussed. The powertrain sound power tests in the vehicle were achieved in the low noise chassis Dynamometer in the semi-anechoic chamber. Based on the test results, the acoustic component contributions for the powertrain sound power levels were given. © (2013) Trans Tech Publications, Switzerland.

Wellmann, T., Govindswamy, K. & Tomazic, D., 2013. Integration of engine start/stop systems with emphasis on NVH and launch behavior. *SAE International Journal of Engines*, 6(2), pp.1368–1378. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84878777594&partnerID=tZOtx3y1.

Abstract: Automatic engine start/stop systems are becoming more prevalent and increasing market share of these systems is predicted due to demands on improving fuel efficiency of vehicles. Integration of an engine start/stop system into a "conventional" drivetrain with internal combustion engine and 12V board system is a relatively cost effective measure to reduce fuel consumption. Comfort and NVH aspects will continue to play an important role for customer acceptance of these systems. Possible delay during vehicle launch due to the engine re-start is not only a safety relevant issue but a hesitating launch feel characteristic will result in reduced customer acceptance of these systems. The engine stop and restart behavior should be imperceptible to the driver from both a tactile and acoustic standpoint. The lack of masking effects of the engine during the engine stop phases can cause other "unwanted" noise to become noticeable or more prominent. Other comfort related criteria like a stable 12V board supply during the engine start phase or A/C usage during the engine stop phase need to be considered as well. This paper provides an overview of start/stop systems and starter concepts. The requirements for different transmission types and the associated start/stop challenges are described. The phases of an engine start are described in detail, and their influence on the vehicle vibration investigated. NVH related metrics for describing the engine start/stop and vehicle launch are introduced. Key design parameters of the powertrain and driveline on the start/stop NVH behavior are studied. In addition, the impact of engine start on the vehicle's launch behavior is analyzed. Comparisons of different start/stop systems are conducted and results from case studies on the influence to launch delay and "change-of-mind" engine restart are provided. Finally, the effect of missing masking noise during the engine stop phases is discussed. Copyright © 2013 SAE International.

Wong, P.K. et al., 2013. Design and Optimization on Active Engine Mounting Systems for Vibration Isolation. *Applied Mechanics and Materials*, 479-480, pp.202–209. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84891102882&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: In this paper, based on the previous research experiences in the lumped parameter modeling and study of active control mounts model, a test bench model of ACM in powertrain is described and the vibration model is implemented in MATLAB. In order to validate the implementation of the state equations in this work, a finite element analysis (FEA) method is used in ANSYS and compared with

analytical model for validate. After the validation, the control strategy is integrated into the analytical model by using the linear quadratic regulator (LQR) method, which is a well know design technique that provides practical feedback gains. Furthermore, this work examines the application of genetic algorithms (GA) in optimizing the weight matrices of LQR. Finally, this work will be useful in improved prediction and performance of vehicle NVH. © (2014) Trans Tech Publications, Switzerland.

Wu, F. et al., 2013. The multi-objective optimization of engine mount system concurrently considering energy decoupling rate and vibration isolation rate. *Qiche Gongcheng/Automotive Engineering*, 35(1). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84874472079&partnerID=tZOtx3y1.

Abstract: Energy decoupling rate and vibration isolation rate of engine mounts are the two important performance indicators in designing vehicle powertrain assembly. Through integrating Matlab and ADAMS by software iSIGHT, a math model concurrently considering both energy decoupling rate and vibration isolation rate is built, and a multi-objective optimization on the performance parameters of mounting system is conducted by using non-dominated sorting genetic algorithm. The results of real vehicle test verify the feasibility of the method proposed.

Wu, J. & Dong, Z.X., 2013. Two optimization models for robust design of a powertrain mounting system. *Zhendong yu Chongji/Journal of Vibration and Shock*, 32(20), pp.76–80. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84890198563&partnerID=tZOtx3y1.

Abstract: The mount stiffness of a powertrain mounting system (PMS) generally fluctuates around its nominal design value due to measurement inaccuracy, processing and installation errors, and material aging. To improve the robustness of the frequency allocation and decoupling layout of a PMS, an interval optimization model was presented. In this model, interval number was used to describe the uncertainty of the mount stiffness, interval reliability and interval probability indices were used to characterize the robustness of the decoupling layout and frequency allocation, respectively. Then, a six-sigma random robust optimization model for a PMS was constructed in this model, the fluctuation of the mount stiffness was assumed to obey a uniform distribution. The interval optimization and six-sigma random optimization approaches were used to maximize the decoupling ratios of a general car PMS under robustness requirements of frequency allocation and decoupling layout. Optimization results showed that both the interval optimization and the six-sigma random optimization can obtain satisfactory robust designs, and the optimization results of the two optimization models have a good consistency.

Yin, Q. et al., 2013. Optimization design of powertrain mounting system of electric drive truck. *Zhongguo Jixie Gongcheng/China Mechanical Engineering*, 24(20), pp.2826–2831. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84890840817&partnerID=tZOtx3y1.

Abstract: Based on the energy decoupling theory and the optimization theory, a 6 DOFs model was constructed concerning the characteristics of electric drive truck powertrain structure. The optimization of the mounting system was conducted by using genetic algorithms and simulated annealing algorithm for the purpose of maximizing decoupling rate of 6 DOFs mounting system. Before optimization, the main parameters affecting the results were analyzed by using Latin cube algorithm. Then the optimization solutions were considered as random variable with normal distribution feature, and a robustness analysis of the mounting system was made by using Monte Carlo method to observe the effects of the design value changes on the objective function. The results show that this optimization method can enhance the decoupling rate of powertrain mount effectively, and the results are reliable, which can meet the robustness requirements basically.

Zhao, H., Burke, A. & Zhu, L., 2013. Analysis of Class 8 hybrid-electric truck technologies using diesel, LNG, electricity, and hydrogen, as the fuel for various applications. In *2013 World Electric Vehicle Symposium and Exhibition (EVS27)*. IEEE, pp. 1–16. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84911458304&partnerID=tZOtx3y1 [Accessed August 27, 2015].

Abstract: Class 8 trucks using various powertrains and alternative fuel options have been analysed to determine their fuel economy, greenhouse gas emissions, and economic attractiveness at the present time (2013) and in the future. This was done by modelling the vehicles and simulating their operation on day, short haul, and long haul driving cycles. The economic attractive was determined by calculating the differential vehicle cost of each powertrain option and the corresponding breakeven alternative fuel price needed to recover the additional cost in a specified payback period with a fixed discount rate. The baseline vehicle was a diesel engine truck of the same weight and road load using $4/gallon diesel fuel. The use of some of the powertrains resulted in an energy saving and others resulted in higher energy consumption, but compared to the conventional Class 8 diesel trucks, conventional LNG-CI trucks, LNG-SI and LNG-CI hybrids, battery electric trucks, and fuel cell trucks can reduce CO2 emission by 24-39% over the day drive cycle and 12-29% over the short haul and the long haul drive cycles. The breakeven fuel price was calculated for all the powertrain/fuel options. The economic results indicate that at “today”s’ differential vehicle costs, none of the alternative powertrains/fuels are economically attractive except for the LNG-CI engine in the long-haul application (VMT=150,000 miles) for which the DGE cost is $2.98/DGE and the LNG cost is $1.70/LNG gallon. If the differential costs of the alternative powertrains are reduced by 1/2, their economics is improved markedly. In the case of LNG-CI engine, the breakeven fuel costs are $3.42/GDE, $1.96/LNG gallon for the long haul applications (VMT= 150,000 miles) with payback periods of 2-3 years. This makes LNG cost competitive at 2013 prices of diesel fuel and LNG. The fuel cell powered truck is also nearly cost competitive at VMT= 150,000 miles, but this requires a fuel cell cost of less than $25/kW. Hybridizing is not attractive except for the conventional diesel vehicle operating on the day cycle (some stop and go operation) for which the breakeven diesel price is about $2/gallon at 1/2 today's differential vehicle costs. The regulated

exhaust emissions from the LNG-CI engines will meet the same standards (EPA 2010) as the new diesel engines and use the same exhaust emission technology.

Zhong, Z.M. & Wei, Q., 2013. Modeling and Torsional Vibration Control Based on State Feedback for Electric Vehicle Powertrain. *Applied Mechanics and Materials*, 341-342, pp.411–417. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84883020937&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: Electric vehicles will longitudinally vibrate obviously under acceleration and regenerative braking conditions (because of torsional vibration of the electric vehicle powertrain). This paper includes models of motor rotor, gear reducer and differential assembly, half shafts, tire and body and nonlinear powertrain dynamic model in consideration of gear backlash and frictional characteristics between tire and ground. Real car tests confirm that it is correct under acceleration conditions. Then a two mass-spring damper linear model which is simplified from the nonlinear powertrain dynamic model is proposed to design torsional vibration control algorithm based on state feedback. The simulation results show that the algorithm can actively eliminate torsional vibration. © (2013) Trans Tech Publications, Switzerland.

Zhou, J., Yao, L. & Zhou, Z., 2013. Optimization of Vehicle Interior Noise Performance Based on Real Powertrain Excitation. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881210351&partnerID=tZOtx3y1 [Accessed August 31, 2015].

Abstract: The Vehicle NVH performance is the main factor influencing the vehicle ride comfort. With regard to the NVH performance, the interior booming noise problem in run-up condition caused by powertrain vibration is the most serious NVH problem. Lots of researches have been done upon the engine theory exciting force to do the simulation analysis and optimization of the interior vibration and noise performance. In this paper, the vibration excitation of the powertrain mount is measured by testing the mule car and the interior noise are simulated by using the full vehicle Finite Element Analysis (FEA) model. Then the panel contribution analysis (PCA) is implemented on the peak frequency of the results, and the greater influential panels to the interior noise are identified, then the structural modifications and the damping layout optimizations to reduce the interior structure-borne noise are proposed by the analysis. According to the optimization process, the vehicle interior noise performance is improved and meanwhile the effectiveness of this method is also verified. Copyright © 2013 SAE International.

Zhu, J.F. et al., 2013. Structural topology optimization based design of automotive transmission housing structure. *Jilin Daxue Xuebao (Gongxueban)/Journal of Jilin University (Engineering and Technology Edition)*, 43(3), pp.584–589. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84880980065&partnerID=tZOtx3y1.

Abstract: This paper introduces the variable density based topology optimization into the design of transmission housing structure. The optimization takes the constraints on

manufacturing condition into consideration. In order to increase the strength, stiffness and nature frequency of the transmission structure and control its weight, the static and dynamic topology optimizations of the transmission housing are carried out. According to the results of the topology optimization and the manufacturing constraints, a new rational transmission housing structure is designed. The stress analysis and modal analysis of the new design are carried out. The analysis results show that not only the stress level of the designed housing is lower than the material yield stress, but also the modal frequency avoids the powertrain system resonance.

Abstracts of papers related to NVH published in 2012

Andersson, N. & Abrahamsson, T., 2012. Driveline model calibration and validation in an automotive 4-cylinder Diesel application. In *Proceedings of the International Conference on Noise and Vibration Engineering ISMA 2012*. Katholieke Universiteit Leuven, pp. 3841–3855. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84906352896&partnerID=tZOtx3y1.

Abstract: We present a computational approach to driveline system simulations that aim to better capture how major system deformation modes vary and interact during operation. A prototype of a downsized front-wheeldrive powertrain was run in a physical rig-test and a nonlinear driveline torsional resonance response could be identified. A large-scale powertrain computational model that combines details of finite element component and multibody system design models was developed and used to simulate the rig-test response. The torsional response was calibrated using one subset of measured data and a complementing subset was used for validation. Simulation results show good qualitative agreement with measured responses. A minor parameter study shows how parameter settings of selected components influence the system normal modes.

Bayani Khaknejad, M. & Keshavarz, A., 2012. Refining Pickup Cabin NVH Quality via Optimising Exhaust Mountings Using DOE Method. In *SAE Technical Papers*. Available at: http://papers.sae.org/2012-01-2008/ [Accessed October 7, 2015].

Abstract: In this research the main focus is on reducing the transmitted engine vibration through exhaust line to the passenger cabin in a light commercial vehicle. The main approach is firstly to locate the mountings of the exhaust system based on the results of the modal analysis. Afterwards, the stiffness of the rubber hangers is optimised to minimize the measured vibration in the driver seat rail position. The optimisation approaches are executed considering the design of experiments method. To achieve this, the partial BIW model of the reference vehicle and the powertrain system is generated in FE software. The FE model of the exhaust system is validated by experimental results. In order to define the optimum stiffness for the exhaust rubber hangers, design of experiments method is used. The main candidate parameters for DOE analysis are exhaust rubber hangers in the front floor region in addition to the exhaust flexible joint stiffness. Dynamic parameters which have the most effects on reduction of vibration transfer function have been chosen based on the type of the joint and vibration transfer path. The selected parameters are involved in the optimisation loop to optimise the passenger cabin vibrations. Eventually, in order to evaluate the effect of the proposed modifications on the transmissibility function between the exhaust pipe line and body structure, results of the original and modified mountings are simulated and compared in the developed FE model of the body structure and powertrain system by measuring the seat rail vibration in the driver position.

Beloiu, D.M., 2012. Modeling and Analysis of Powertrain NVH. In *SAE Technical Papers*. Available at: http://papers.sae.org/2012-01-0888/ [Accessed October 7, 2015].

Abstract: Current modeling techniques of the powertrain noise, vibration and harshness (NVH) involve fully meshed structural components and rely, in general, on predefined excitation loads to evaluate linear transfer or structural attenuation functions. While effective for comparative assessment of various designs, these methods neglect the complex dynamic interactions between the powertrain structure and crankshaft, piston, valve train, timing drive, and accessory drive systems. This paper presents an overview of modeling methods of low and high frequency powertrain NVH with focus on dynamic interaction among structural components. A coupled and fully flexible multi-body dynamics model using AVL/Excite is presented. The model includes the cranktrain, crankcase, cylinder head, covers, oil pan, mounts, and transmission housing represented as finite element meshes. The main bearings are represented using elasto-hydrodynamic joints to account for the effect of oil film stiffness and damping as well as bearing clearance. The structural components are reduced using component mode synthesis and used to determine dynamic loads at various engine speeds and loading conditions. The main excitation sources relevant for both low and high frequency NVH and the influence of cylinder pressure, bottom end design, and crankshaft stiffness are discussed. An overview of piston related noise and modeling techniques to identify the causes and mechanisms leading to excessive impact noise in a floating piston pin design are presented.

Brandl, S., Graf, B. & Rust, A., 2012. NVH Challenges and Solutions for Vehicles with Low CO2 Emission. *SAE Int. J. Passeng. Cars - Mech. Syst.*, 5(3), pp.1084–1090. Available at: http://www.sae.org/technical/papers/2012-01-1532.

Abstract: Driven by worldwide climate change governments are introducing more stringent emission regulations with particular focus on fuel saving for CO 2 emission reduction. Downsizing and weight reduction are two of the main drivers to achieve these demanding regulations. Both aspects however might have a strong negative effect on the overall vehicle NVH behavior. Weight reduction directly influences NVH due to reduction of absorption and damping material and due to light-weight design affecting the dynamic responses of powertrain and vehicle structures. Engine downsizing however has multiple negative effects on NVH. Beside higher vibrations and speed irregularities due to lower cylinder numbers and displacements also reduction of sound quality is a critical topic that will be handled within this publication. The first part of this publication will focus on excitation of engines with different number of cylinders, an alternative mounting solution for 3 cylinder engines and an overview on the changes of sound quality for downsized engines. In the second part two solutions for vehicles with downsized engines will be presented. The first vehicle is equipped with a 4 cylinder engine and electrical cylinder. By applying appropriate NVH measures the same NVH behavior as for the original 4 cylinder without cylinder deactivation can be achieved. Second example is a vehicle powered by a turbo charged two cylinder engine. Using active noise generation the unconventional sound characteristic of that vehicle can be changed to that of a

standard 4 cylinder engine in order to increase sound quality and reduce real life fuel consumption by positive effects on driving behavior. © 2012 SAE International.

Chakrabarti, S. & Dapino, M.J., 2012a. Coupled axisymmetric finite element model of a hydraulically amplified magnetostrictive actuator for active powertrain mounts. *Finite Elements in Analysis and Design*, 60(3), pp.25–34. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0168874X12000972 [Accessed October 7, 2015].

Abstract: This article describes the recording of pedal vibration through the measuring of distance, force and acceleration of a clutch pedal. In addition to the measuring, testers evaluated the vibration. The results of this study illustrate the human perception of vibration on the foot. This method enables an objective evaluation for pedal vibration. © Oldenbourg Wissenschaftsverlag.

Chakrabarti, S. & Dapino, M.J., 2012b. Coupled axisymmetric finite element model of a hydraulically amplified magnetostrictive actuator for active powertrain mounts. *Finite Elements in Analysis and Design*, 60, pp.25–34. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0168874X12000972 [Accessed October 7, 2015].

Abstract: A coupled axisymmetric finite element model is formulated to describe the dynamic performance of a hydraulically amplified magnetostrictive actuator for active powertrain mounts. The formulation is based on the weak form representations of Maxwells equations for electromagnetics and Naviers equation for mechanical systems coupled using a nonlinear magnetomechanical constitutive law for terbium-dysprosium-iron (Terfenol-D). Fluid structure interaction is modeled by computing a bulk fluid pressure based on the volumetric deformation of the fluid chamber and coupling the fluid pressure to the structure through traction on the boundaries encompassing the fluid. Seal friction is quantified using the LuGre friction model. The resulting model equations are coded into the commercial finite element package COMSOL, which is used for meshing and global assembly of matrices. Results show that the model accurately describes the dynamic mechanical and electrical responses of the actuator. A parametric study performed using this model reveals that the actuators unloaded displacement can be improved by up to 140% by doubling the thickness of the fluid chamber components and reducing seal friction to a fourth of its original value. Other parameters such as permeability and conductivity of the permanent magnet and fluid bulk modulus have a minor effect on actuator performance.

Chang, J.-U. et al., 2012. Vibration Identification of Gasoline Direct Injection Engine Based on Partial Coherence Function. *Transactions of the Korean Society of Mechanical Engineers A*, 36(11), pp.1371–1379. Available at: http://koreascience.or.kr/journal/view.jsp?kj=DHGGCI&py=2012&vnc=v36n11&sp=1371 [Accessed October 7, 2015].

Abstract: This paper presents a method for estimating the contribution of vibration sources in gasoline direct injection engine parts with a multiple-input system. A

partial coherence function was used to identify the cause of the linear dependence indicated by an ordinary coherence function. To apply the partial coherence function to vibration source identification in the powertrain system of a gasoline direct injection engine, a virtual model of a two-input and single-output system is simulated. For the validation of this model, the vibration of the powertrain parts was measured by using triaxial accelerometers attached to the selected vibration sources-a high-pressure pump, fuel rail, injector, and pressure sensor. After calculating the partial coherence between each source based on the virtual model, the vibration contribution of the powertrain system is calculated. This virtual model based on the partial coherence function is implemented to determine the quantitative vibration contribution of each powertrain part. © 2012 The Korean Society of Mechanical Engineers.

Chen, D.M., Shangguan, W. Bin & Zhang, W., 2012. The design strategies and calculation methods for powertrain mounting system with multi-powertrain. *International Journal of Vehicle Design*, 60(1/2), p.3. Available at: http://www.inderscience.com/link.php?id=49155 [Accessed October 7, 2015].

Abstract: Multi-powertrain is defined as an engine plus different transmissions, or a transmission plus different engines in this paper. To reduce mount cost and production time, the mounts in a Powertrain Mounting System (PMS) with multi-powertrain should have the same stiffness or the same configurations. On the basis of this requirement, the design strategies and calculation methods for PMS with multi-powertrain are presented in this paper. In designing Multi-PMS (MPMS), an optimisation method to select mount stiffness in its Local Coordinate System (LCS) and locations based on the requirements for six rigid body modes and energy distributions of a PMS with multi-powertrain is developed. Then a procedure of designing Force vs. Displacement (F-D) relation for a mount to control the motion of each powertrain in multi-powertrain is proposed. Copyright © 2012 Inderscience Enterprises Ltd.

Chen, S. et al., 2012. An equivalent model for modal analysis of engine mounting system. In *Proceedings of the 2nd International Conference on Electronic and Mechanical Engineering and Information Technology, EMEIT 2012*. pp. 1128–1132. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84871302875&partnerID=tZOtx3y1.

Abstract: An equivalent analysis model for engine powertrain mounting system is built with the FEA software ANSYS, in which the engine powertrain is equivalent to a composite body of one inertial body and one elastic body, every mounting component is simplified as one spring along its three principal elastic axes and the powertrain mass and rotational inertia are accurately embodied. With this equivalent model, vibration modes and energy decoupling degrees can be calculated. The result of an example in ANSYS shows that this equivalent modeling method is validity and feasibility for engine powertrain mounting systems. © the authors.

Cloix, a et al., 2012. Characterisation of the booming noise variability in a vehicle. In *Proceedings of the International Cnference on Uncertainty in {S}tructural*

{Dynamics} {USD 2012}. Katholieke Universiteit Leuven, pp. 4523–4534. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84906337692&partnerID=tZOtx3y1.

Abstract: The powertrain is the main noise source inside a car cabin, especially at low frequencies. The “booming noise” felt by the car passengers is mainly due to the structure borne transfers from the engine to the car body, through the engine mounts. The noise variability observed within a population of identical vehicles can generate customers’ complaints and reduce the brand image. Due to the increasing focus on noise and vibration for future vehicles, there is a need from manufacturers to identify the variability sources. The current paper is based on the French research program MADIAV (“MAitrise de la DIspersion Acoustique de Véhicules”). The aim of this project is the control of the variability phenomena during the three vehicle development phases “design - optimisation - mass production”, in order to reduce the booming noise differences. This paper focuses on two measurement campaigns carried out on RENAULT cars, at the French production plant of Douai. The first one is performed on complete vehicles. The booming noise is recorded at passengers’ and driver's ears, during full-load run-up, and structure borne and vibro-acoustic transfers are also measured. It was possible to perform measurements on fifteen similar vehicles thanks to a fast and robust measurement protocol, developed and validated in terms of reproducibility on a dedicated vehicle. The second one is performed on thirteen identical car bodies in white, and focuses only on the vibratory behaviour, with a specific care of the roof, the floor, and the frame cross member. Both measurement processes are fully integrated to the car production flow. Through both measurements campaigns, the booming noise variability is characterised. Critical engine speeds and transfer paths are identified and analysed regarding variability levels. The effect of the car body trims are deduced from the comparison of both campaigns. Finally, the databases gathered are used in the research program, for the development and the validation of numerical methods simulating the variability phenomena (MSP method). These methods are presented in a companion paper [1].

Duan, X. et al., 2012. Nonlinear dynamic modeling and analysis of air damped rubber mount. *Zhendong Ceshi Yu Zhenduan/Journal of Vibration, Measurement and Diagnosis*, 32(1), pp.125–129. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84858973055&partnerID=tZOtx3y1.

Abstract: Air damped rubber mount (ADM) is a new kind of vibration isolator for automotive powertrains and other dynamic systems, and the dynamic characteristics and costs of ADM are between rubber mount and hydraulic mount. Nonlinear model with lumped mechanical and air elements for dynamic characteristic analysis of an ADM with a throttle orifice is proposed. A computer simulation for a typical ADM used in powertrain mounting system is performed, and the results are compared well with experimental data. The factors and laws that affected ADM dynamic characteristics, such as orifice diameter, orifice length, initial volume, excited amplitude and temperature are studied. And it is concluded that if the length of orifice

is unchanged, decreasing the diameter of orifice will provide better damping effect. The modeling method and simulation results presented in this paper will contribute to research and development of ADM.

Finger, K. et al., 2012. TPA and NVH Prognosis - Application to Mercedes Benz Car Development of New Hybrid Methods Coupling Digital Simulation with Prototype Testing Results. *SAE International Journal of Passenger Cars - Mechanical Systems*, 5(3), pp.1091–1100. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84863226492&partnerID=tZOtx3y1.

Abstract: Digital NVH development has become a common tool for any acoustic engineer. Vehicles in their early development stages are nowadays mainly described and validated as digital models. However there still remain needs for improvement in the domains of acoustic and vibration prediction, as instance: refining models, addressing intricate systems, and CAE resistant phenomena. In a background of increasing modularity and process transfers, hybrid methods coupling with testing results, have shown a great potential for improving the quality of NVH prognosis and development quality. Mercedes-Benz passenger car division has developed, tested and introduced a new engineering tool, based on the classical TPA applications coupled with hybrid simulation techniques. This toolbox is used to enhance the prognoses of acoustic interior noise and vibration comfort. The actual NVH development process for engines and vehicles is described with main quality gates and objectives, showing when established or new methods come into use. In order to reach an effective operational level of the toolbox, it was necessary to standardize and automate thoroughly the whole acquisition and processing chain. This meant defining a standard for data acquisition and structure, setting procedures for signal processing and analysis, and developing new measurement methods. The following examples are described: Automated measurement procedure for the reciprocal determination of transfer functions. Procedure for direct evaluation of input dynamical forces and airborne noise measurements acquired at engine test benches. In order to demonstrate the potential of mentioned methods, an application to the NVH development of an engine and the achieved end results are presented, illustrating the systematically project maturity evaluation, the virtual integration of engine and powertrain in some existing vehicle types, as well as the interactive virtual testing of different power train types, variants are other possibilities. © 2012 SAE International.

Guo, R., Zhang, L.-J., et al., 2012. Interior structure-borne noise reduction by controlling the automotive body panel vibration. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 226(7), pp.943–956. Available at: http://pid.sagepub.com/lookup/doi/10.1177/0954407011433119 [Accessed October 7, 2015].

Abstract: The adoption of a numerical method to perform vibration and acoustic analyses is attracting increasing attention because of its merits in saving costs and time. The analysis flow chart of structure-borne noise reduction by controlling the vehicle body panel vibration is proposed. A finite element analysis of a body in white

is performed according to this flow chart, using MSC. Nastran, and the experimental modal analysis of a body in white is also carried out. To verify the finite element model, a correlation analysis between the test and the finite element results is performed. After the acoustic boundary element model with seats has been constructed, the acoustic transfer vector is calculated using LMS software. A transfer path analysis is performed to estimate the powertrain and exhaust pipe operational forces at idle. Then the forces are input into the acoustic boundary element model to calculate the body panel velocity. By combining the acoustic transfer vector and the body panel velocity, the interior acoustic response can be obtained. The simulation results are verified by tests. To determine the main contribution panels for the interior sound pressure level, a panel acoustic contribution analysis is based on the boundary element method. Finally, constrained damping treatments are adopted to control the main panel vibration based on the results of the panel acoustic contribution analysis. The test results indicate that the sound pressure level of the interior noise at idle is reduced obviously before and after treatments, which has proved the correctness of the results from the panel acoustic contribution analysis. Therefore it is believed that the proposed analysis method is feasible for reducing interior structure-borne noise. © IMechE 2012.

Guo, R., Qiu, S., et al., 2012. Transfer path analysis and control of vehicle structure-borne noise induced by the powertrain. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 226(8), pp.1100–1109. Available at: http://pid.sagepub.com/lookup/doi/10.1177/0954407012438501 [Accessed October 7, 2015].

Abstract: Because of the higher requirements for vehicle comfort and people's increasing ecological consciousness, research on the interior noise in a vehicle has received wide concern, among which structure-borne noise is hard to diagnose and control. To solve the problem, the transfer path analysis method of powertrain structure-borne noise has been systematically analysed. By introduction of the powertrain source-path-receiver model, this method enables us to estimate and study the vibro-acoustic transfer functions and their operational forces. Since structure-borne noise is composed of multiple paths, the aim of this paper is to discuss different synthesis methods for this noise. On the basis of previous discussion, the transfer path analysis test of a certain vehicle is carried out, and the transfer function and operational data at idle and second-gear wide-open throttle are obtained. The test data are processed and an acoustic contribution analysis of the target is performed using LMS software. The results of analysis show that the right-hand side mount represents the main contribution path. Then the match principle of the bracket dynamic stiffness of the powertrain isolation system is proposed. On the basis of the transfer path analysis results and the above principle, the bracket on the body side of the right-hand side mount is improved by combination of the experimental transfer path analysis and the finite element method. The test results show that the A-weighted sound pressure level of the interior noise at idle and second-gear wide-open throttle are reduced by 2.9 dB(A) and 4 dB(A) respectively after improvement. Also there is no obvious booming noise at second-gear wide-open throttle. It is expected that this paper can

help automotive noise, vibration and harshness engineers to perform trouble shooting and sound design. © IMechE 2012.

Hu, J., Chen, W. & Ye, X., 2012. Decoupling study of a powertrain mounting system with effect of a compliant base. *Zhongguo Jixie Gongcheng/China Mechanical Engineering*, 23(23), pp.2879–2885. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84872223315&partnerID=tZOtx3y1.

Abstract: In order to achieve the TRA decoupling of a powertrain mounting system in the full vehicle model, a coupling model with a compliant base(flexible chassis, suspensions, wheels) and powertrain mounting system was established analytically. The accuracy of the model was verified by comparing the natural frequencies of the compliant base with the finite element method. The effects of compliant base on the coupled motions of a powertrain mounting system were analysed. A method of the TRA decoupling for the powertrain mounting system in the full vehicle model was proposed based on the modes' properties and decoupling index of the coupled system. The simulation and experimental results indicate that: the TRA of a powertrain mounting system in the full vehicle model is indeed decoupled and the vehicle comfort is improved when the proposed method is satisfied.

Hu, J.-F. & Singh, R., 2012. Improved torque roll axis decoupling axiom for a powertrain mounting system in the presence of a compliant base. *Journal of Sound and Vibration*, 331(7), pp.1498–1518. Available at: http://linkinghub.elsevier.com/retrieve/pii/S0022460X1100900X [Accessed October 7, 2015].

Abstract: The existing torque roll axis decoupling theories for powertrain mounting systems assume a rigid foundation, thus ignoring dynamic interactions between the powertrain and other sub-systems. To overcome this deficiency, a coupled mounting system problem is formulated based on the linear time-invariant system theory. The influence of a compliant base on torque roll axis decoupling is first analytically examined in terms of eigensolutions and frequency responses. Then, a new analytical axiom is proposed based on decoupling indices as well as given the properties of the coupling matrix. Five examples are chosen to examine frequency and time domain responses given the torque excitation along the crankshaft axis. To satisfy the new condition, the mounting system is redesigned in terms of the stiffness rates, mount locations, and orientation angles. The results show that the torque roll axis of the redesigned powertrain mounting system is indeed decoupled in the presence of a compliant base (given oscillating or impulsive torque excitation). Finally, eigensolutions are validated by using published data. © 2011 Elsevier Ltd. All rights reserved.

Hu, Q.G. et al., 2012. Isolation performance analysis and optimization of powertrain mounting system based on full vehicle model. *Dalian Haishi Daxue Xuebao/Journal of Dalian Maritime University*, 38(4), pp.73–77. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84872128295&partnerID=tZOtx3y1.

Abstract: According to the inadequacies of the existing powertrain mounting system ignoring the impacts of body mass, suspension stiffness damping, tire stiffness, and other factors, a nine-degree-of-freedom model of the powertrain mounting system based on complete vehicle is established, and theoretical analysis and simulation are made. On this basis, taking the minimization of acceleration responses as objective function, the powertrain mounting system is optimized to improve the NVH performance. Simulation results indicate that the engine mounting system established based on a full vehicle model is tally with the actual situation, the isolation performance of the suspension system is improved effectively, and the ride comfort is better for the optimized structural parameters.

Humbert, L., Pellerey, P. & Cristaudo, S., 2012. Electromagnetic and structural coupled simulation to investigate NVH behavior of an electrical automotive powertrain. In *SAE International Journal of Alternative Powertrains*. pp. 395–404. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84879969227&partnerID=tZOtx3y1.

Abstract: RENAULT aims to become the first full-line manufacturer putting to market zero-emission affordable electrical vehicles and is therefore developing 100 % electric powertrains. NVH problems related to electric machine design have nothing in common with those of gasoline or diesel engines: electric whistling is a high frequency harmonic phenomenon, easily detectable due to the low background noise of a non-thermal vehicle and mainly perceived as very unpleasant by the customer. Therefore we have developed a coupled numerical simulation between electromagnetic and structural models, making it possible to understand the influence of magnetic parts design on noise and vibration level. Impact of the spatial and time coherence between magnetic pressures and vibration modes of the motor will be explained. The novelty of our approach is to already take into account the whole powertrain structure radiation, including reducer and power supply boxes. Moreover we investigate the influence of the harmonic content of the supply current due to the regulation system, as well as the tangential forces effect on stator teeth. Copyright © 2012 SAE International.

Li, M., Duan, J. & Lim, T.C., 2012. Enhanced inverse model LMS algorithm for active control of harmonic response clusters. In *41st International Congress and Exposition on Noise Control Engineering 2012, INTER-NOISE 2012*. pp. 9812–9820. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84883591652&partnerID=tZOtx3y1.

Abstract: Harmonic responses can be seen widely in many applications, such as vehicle powertrain noise, gear vibration, and other rotating machineries. Hence, to develop an effective system for harmonic control is highly desirable. For single frequency control, it can be easily suppressed by most active control systems. However, when a cluster of harmonic responses that spreads over a wide frequency range or contains rapidly varying frequencies, the traditional filtered-x least mean square (FXLMS) algorithm may not be able to achieve significant enough reduction over a wide frequency range or track variations in frequency due to the large dynamic range of secondary path in that wide spectral range. In this study, an enhanced

algorithm, namely the inverse model least mean square algorithm (IMLMS), which utilizes the inverse model of the secondary path to minimize the effect of the secondary path dynamics on the algorithm convergence, is proposed to improve the convergence property and tracking ability of the active control system. Numerical simulation using synthesized signals was performed. Results show significant improvement on the convergence of the system and in turn achieving more reductions in the responses over a wide frequency range by the proposed scheme.

Liao, F. et al., 2012. Optimization of exhaust hangers location layout by vibration transfer function. *Tongji Daxue Xuebao/Journal of Tongji University*, 40(6), pp.926–931. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84864505432&partnerID=tZOtx3y1.

Abstract: An optimization method about layout of exhaust hangers location was presented by vibration transfer function(VTF). Mathematical model of the VTF from engine excitation to exhaust was established with finite element method by taking the layout of hangers location in a hybrid electric vehicle(HEV) as an example. Then summation of relative displacement response of points on the exhaust was calculated in range of vibration frequencies. Finally, an optimized layout was obtained on the basis of the minimum of the summation of relative displacement response. The results indicate that the hanger location is decided by engine excitation, modal participation factors and modal vectors of powertrain and exhaust together in the VTF method. It was proved that vibration accelerations of the exhaust and rail of seat in the optimization layout reduced by more than 17% in comparison with the initial one based on the test data of t he HEV. So the optimization method about layout of hangers location by the VTF can be resorted to hanger location design.

Liu, H. et al., 2012. The optimization study on the stiffness of coupling in vehicle powertrain based on iSIGHT platform. *Binggong Xuebao/Acta Armamentarii*, 33(2), pp.227–231. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84863274310&partnerID=tZOtx3y1.

Abstract: In order to decrease the response of torsional vibration, multi-object optimization model of vehicle powertrain is established, which represented system vibration and integrated forced torsional vibration analysis program by iSIGHT software. In this model, stiffness of the coupling is variable, objective function is to minimize additional vibration stresses of shafts, and the calculation is finished by Pointer optimizer. After optimize design, vibration amplitude of lumped masses and additional torsional vibration stresses of shafts are evidently reduced. It shows that the optimization model is effective and fast, and it can provide reference to the improving of stiffness of coupling.

Lu, S., Feng, H. & Zuo, Z., 2012. NVH Improvement of Vehicle Powertrain. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881204329&partnerID=tZOtx3y1 [Accessed September 3, 2015].

Abstract: This paper provides an investigation to improve vehicle powertrain NVH performance via modification of excitation and radiation system of powertrain. First of all, considering different excitation mechanisms of the powertrain, the excitation forces are analyzed. The FEM/BEM coupled analysis and the acoustic transfer vector (ATV) calculation as well as panel contribution analysis are applied to investigating the acoustic characteristics of the powertrain. Then a hybrid approach which couples the transmission gear profile modification for attenuating gear system excitation and the transmission housing modification for reducing transmission housing noise radiation is proposed to improve powertrain NVH performance. Experiment validation is conducted in order to assess the modified results. The assessment shows that this hybrid approach can effectively predict and reduce powertrain noise and vibration. Copyright © 2012 SAE International.

Naser Farooqui, M. & Wagle, C.S., 2011. Complete Powertrain Torsional Vibration Simulation and Correlation with Phisical Measurement. *Applied Mechanics and Materials*, 110-116, pp.2585–2589. Available at: http://www.scientific.net/AMM.110-116.2585 [Accessed October 7, 2015].

Abstract: Man, as a mechanical system, is extremely complex and its mechanical properties readily undergo change. There is a very little reliable information on the magnitude of forces required to produce mechanical damage to the human body. As in the case for many other dynamic systems, the human body has been found to exhibit resonance when exposed to vibration stimuli such as ground transportation vehicles. © (2012) Trans Tech Publications, Switzerland.

Novo, F.M.F. et al., 2012. Analysis of the Vibration Modes of an Automotive Propeller Shaft using FEM and Analytical Models. In *SAE Technical Papers*. Available at: http://papers.sae.org/2012-36-0224/ [Accessed October 7, 2015].

Abstract: Traditional propeller shafts using universal joints have been replaced by sophisticated and complex solutions that not only reduce weight, but also increase the performance of such systems in modern automotive vehicles. Due to its complexity that nowadays even may combine plastic and metallic components, traditional analytical models reach their limits to support engineers during their design phase. Particularly, in the case of their analysis under vibration, it becomes critical, as the life time of a propeller shaft and its components (bushes and joints) have to work far away from their natural frequency values. Analytical solutions seem not to be helpful anymore, when one need to reach a mostly precise value of a natural frequency of complex shafts. Although the FEM analysis nowadays is so far highly developed, they are still no responding to the increasingly demand for high accurate results in a short period of development time. This work focus on the development of a reliable method to simulate complex propeller shafts under vibration, including the components bush and joints and assessing its limits when compared to available analytical solutions. The paper presents a positive and efficient tool to the design phase of such powertrain products. Copyright © 2012 SAE International.

Plunt, J. & Easterling, W., 2012. How to Handle Low Weight Vehicle Concept Design and Conflicting NVH Targets. In *41st International Congress and*

Exposition on Noise Control Engineering 2012, INTER-NOISE 2012. pp. 830–838. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84883563551&partnerID=tZOtx3y1.

Abstract: Requirements for passenger car energy efficiency (fuel consumption) expressed by limits on CO2-emissions are expected to be lowered to 75g/km around 2020-2025 in EU. Energy efficiency depends on vehicle weight, aerodynamics, rolling resistance, powertrain efficiency etc. Vehicle weight is a major factor since it also allows downsizing of engines, less battery capacity etc. Serious weight reduction efforts in design of new cars the last 10- 15 years have been partly disappointing due to cost penalties. Powertrain efficiency has however been substantially improved. To realize substantial vehicle weight reductions, e.g. 30-40 %, radically changed vehicle concepts and materials have to be introduced. This paper discusses efficient NVH analysis methods with regard to low weight vehicle concept design. For premium (luxury) car segments the customer will value good comfort and the new vehicles should be similar or better with respect to NVH. This may be sharply in conflict with weight reduction ambitions unless NVH analysis and synthesis are seriously introduced very early in the design process. Simple communication of the first principles of good NVH design is necessary, yet based on sufficient objective analysis. Common CAE tools are not the best to use during rapidly changing alternative concept designs. New materials are introduced with uncertain dynamic properties. Simple modeling and testing can be more efficient for these first estimates of the NVH properties. Some examples from previous and ongoing industrial low weight research projects are included.

Qatu, M.S., 2012. Recent research on vehicle noise and vibration. *International Journal of Vehicle Noise and Vibration*, 8(4), p.289. Available at: http://www.inderscience.com/link.php?id=51536 [Accessed October 7, 2015].

Abstract: Vehicle noise, vibration and harshness (NVH) is usually among the top five attributes in terms of its priority in the design of automotive vehicles. Its priority in other types of vehicles (e.g., aerospace) is also important. Like other attributes of safety, performance, dynamics, fuel economy, NVH has to be considered closely in the design process. This manuscript presents a summary of recent research in the general area of NVH with an emphasis in the automotive field. It follows up on a previous review and classifies the phenomena by the main sources of NVH into powertrain, road and tyre, wind and other NVH. The last includes brake and chassis, squeak and rattle, electromechanical NVH, exterior (or drive-by) NVH and others. The paper provides a review of some of the recent literature in this field. Copyright © 2012 Inderscience Enterprises Ltd.

Sales, L.C.M. et al., 2012. Numerical and Experimental Vibration Behavior Evaluation of an Powertrain with Different Stiffness Levels. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881216716&partnerID=tZOtx3y1 [Accessed September 3, 2015].

Abstract: The vibrations related to powertrain stiffness contributes strongly to the vehicle acoustic comfort. The connection between the engine and transmission

influences the vibrational powertrain behavior. The subject of this work is the numerical and experimental behavior evaluation of an powertrain vibration behavior under influence of the connection between an internal combustion engine and the transmission. Were evaluated three powertrain configurations with different levels of stiffness. The results (based on natural frequencies modes) matched the experimental evaluations at vehicle. Copyright © 2012 SAE International.

Schulze-Fehrenbach, D., Rumpel, T. & Spengler, R., 2012. Low-speed Boom Noise - Escalating Relevance According to CO2- Targets and High Torque Engines. In *SAE Technical Papers*. Available at: http://papers.sae.org/2012-01-1547/ [Accessed October 7, 2015].

Abstract: The increasing shift of drive operation towards efficient engine operation points at very low engine speeds demands a concerted design and tuning of engine, drive-train, assembly attachment and body to avoid annoying low speed boom noise. An additional challenge in this area of conflict is the increasing torque of modern engines at low engine speeds. As an example for a standard passenger car, the modes of operation, which may lead to low speed boom noise, are described. Setting levers along the complete chain of effect are characterised - from cylinder pressure up to the radiating surfaces of the interior. To achieve challenging NVH-targets the application of nonlinear simulation systems is indispensable, in particular in the concept phase of a vehicle. The use of multi-body simulation is presented for a concentrated NVH-optimisation of powertrain and rear axle vibration behaviour to reduce low-speed boom noise. On entire vehicle level hybrid simulation models are useful. Measured or calculated body transfer functions in combination with multi-body simulation result in boom noise forecasts. Analysis conclusions enable the identification of effective setting levers and course of action, to achieve defined targets. Without testing support and measurement-based analysis an optimal tuning of all relevant components is impossible. With measurement techniques for mount load identification and running mode shape analysis parameters and physical quantities of the vehicle are measured for a subsequently verification with simulation results. The alliance of testing methods and CAE process during the hardware phase of the vehicle development process is described using the example of low speed boom noise. Copyright © 2012 SAE International.

Seo, D., 2012. A novel means to find where BSR noise is by using beamforming based on audio-fingerprint technology. In *41st International Congress and Exposition on Noise Control Engineering 2012, INTER-NOISE 2012*. pp. 1450–1460. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84883580020&partnerID=tZOtx3y1.

Abstract: The buzz, squeak and rattle (BSR) noises are three typical automotive interior noises. They are mostly due to the energy dissipation during excitation of a part (Buzz), a stick-slip by relative motion between material pairs (Squeak) and loose fitting of interior trim (Rattle). It is noteworthy that most of BSR noises are transient and the overall sound pressure levels are much smaller than main noise sources such as the engine, powertrain, etc. For these reasons, the locations of noise sources are difficult to identify. However, each BSR noise signal has a unique time-frequency

characteristic, depending on the mechanical part from which the noise is generated. Therefore, we could think that if we can use its time-frequency characteristics of the BSR noises, then it would be possible to specify the origin of a noise source. In this paper, we propose a novel method that combines an audio search algorithm and beamforming. For accurate classification of BSR noise sources, an acoustic fingerprinting and matching technique based on the music search algorithm is devised. The audio fingerprinting technique is then combined with the beamforming method, so that the directional information by using the beamformer can be jointly utilized with the source identification results. The matching rate is defined as a similarity measure. It enables beamformer to localize the target BSR source not using beamforming power. The test with the real BSR noise data shows that the proposed method can accurately identify the noise source even in the low SNR condition.

Shangguan, W., Chen, D., Ye, B. & Duan, X., 2012. A calculation method for the displacements of powertrain mounting system with torque strut. *Qiche Gongcheng/Automotive Engineering*, 34(9), pp.798–805. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84868346250&partnerID=tZOtx3y1.

Abstract: With consideration of the torsional stiffness of mounts, a calculation model of powertrain-torque strut system, including torque strut model is established for powertrain mounting system with torque strut. Then the displacements of powertrain and the displacements and forces of mounts in a real powertrain mounting system are calculated. The results show that in the working conditions of powertrain subjected to high torque or crash, the calculation using practical torque strut model (two-point model) can get more accurate results.

Shangguan, W., Chen, D., Ye, B. & Huang, X., 2012. The design of powertrain mounting systems in a vehicle model series. *Qiche Gongcheng/Automotive Engineering*, 34(1), pp.6–12. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84863012479&partnerID=tZOtx3y1.

Abstract: Taking natural properties optimization and displacement control of powertrain mounting systems in a vehicle model series as design requirements and its static stiffness and mounting position as optimization variables, a scheme of natural properties optimization for the powertrain mounting systems in a vehicle model series based on a common set of mounting structure is proposed. The design idea of displacement control for the powertrain mounting systems in a vehicle model series is discussed. With the powertrain mounting system having maximum mass in a vehicle model series as baseline, the force-displacement characteristic curve of each mount is designed and then the mount displacements of other powertrains are checked. Finally a calculation example is given and the results show that after optimization all mounts with common set of structure in each powertrain in a vehicle model series can have a good distribution of natural frequency and meet the displacement control requirements of each powertrain in different driving conditions.

Shangguan, W.-B. & Chen, D.-M., 2012. A method for calculating the displacements of a powertrain and mounts in a powertrain mounting system including torque struts under quasi-static loads. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 226(5), pp.634–647. Available at: http://pid.sagepub.com/lookup/doi/10.1177/0954407011424816 [Accessed October 7, 2015].

Abstract: A modelling and calculation method for obtaining the displacements of the powertrain's centre of gravity (CG) and mounts in a powertrain mounting system (PMS) including the torque struts under a static or quasi-static load is presented. A new mount model that is modelled as three-dimensional (3D) springs with both a translational stiffness along each axis of its local coordinate system (LCS) and a rotational stiffness around each axis of its LCS is presented. Also a torque strut is a generic construction and is regarded as a massless rigid body with a mount at each of its two ends.The equation and the solution method for estimating the displacements of the powertrain's CG and the mounts under a quasi-static load are developed when torque struts exist in a PMS. An example is given of the calculation and comparison of the displacements of the powertrain's CG and mounts in a generic PMS including a torque strut using both the method proposed in this paper and the conventional method published in the referenced papers. © Authors 2011.

Shin, C.W. et al., 2012. Analysis of abnormal vibration phenomena by a lock-up clutch operating in an automatic transmission systems. In *19th International Congress on Sound and Vibration 2012, ICSV 2012*. pp. 2882–2888. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84876227829&partnerID=tZOtx3y1.

Abstract: A lock-up clutch system has been widely adapted to the modern automatic transmission vehicles for reducing fuel consumption and improving efficiency of powertrain system. However, abnormal vibrations such as slip shudder and surge might be happened by a lock-up clutch operating at low engine speed. In this paper, we designed a simulation program which includes an engine, a torque converter, a lock-up clutch and a transmission, based on the dynamic equations of vehicle system. In order to investigate the effect of a lock-up clutch operation, fuel economy of a vehicle with a slip controlled lock-up system was compared to that with an only lock-up control in a low gear shift. This paper focused on an abnormal vibration by a lock-up clutch operating in the unstable regions of the engine performance curve. To analyze the abnormal vibrations in the powertrain, we carried out simulations for several driving conditions according to unstable regions of engine performance curve. The results of simulation depicted that the abnormal vibrations in the powertrain occur more severely in the unstable regions of engine as compared to stable regions.

Sontacchi, A. et al., 2012. Predicted Roughness Perception for Simulated Vehicle Interior Noise. *SAE International Journal of Engines*, 5(3), pp.2012–01–1561. Available at: http://papers.sae.org/2012-01-1561/ [Accessed October 7, 2015].

Abstract: In the past the exterior and interior noise level of vehicles has been largely reduced to follow stricter legislation and due to the demand of the customers. As a

consequence, the noise quality and no longer the noise level inside the vehicle plays a crucial role. For an economic development of new powertrains it is important to assess noise quality already in early development stages by the use of simulation. Recent progress in NVH simulation methods of powertrain and vehicle in time and frequency domain provides the basis to pre-calculated sound pressure signals at arbitrary positions in the car interior. Advanced simulation tools for elastic multi-body simulation and novel strategies to measure acoustical transfer paths are combined to achieve this goal. In order to evaluate the obtained sound impression a roughness prediction model has been developed. The proposed roughness model is a continuation of the model published by Hoeldrich and Pflueger [1]. Within the model simultaneous as well as temporal masking effects are considered. In addition, specific model parameters have been adjusted to predict subjective ratings of 18 experienced subjects, including mechanical engineers and audio engineers. The adapted roughness model has been developed by the usage of real sound stimuli measured in the car interior for different pre-defined engine types. Regression analysis shows that in most cases the subjectively perceived roughness can be predicted with good accuracy. Finally, the development model is tested with new stimuli not used in the development of the model; also for these new stimuli a good agreement of $R2 \geq 88\%$ could be achieved. After the discussion of the roughness prediction model, parameter variations for an automotive internal combustion engine (ICE) are discussed and compared with the aid of the new roughness model. From the results it is shown that the developed model is well suited to assess design changes and their consequences on the perceived roughness. Therefore, it can be used to develop roughness optimized solutions already in early design stages.

Sottek, R. & Philippen, B., 2012. Tire-Road Noise Analysis of On-Road Measurements under Dynamic Driving Conditions. *SAE Technical Papers*, 5(3). Available at: http://dx.doi.org/10.4271/2012-01-1550.

Abstract: The powertrain noise of cars has been reduced in the last decades. Therefore in many cases, rolling tires have increasingly become the dominant sources of vehicles' interior noise. For sound design or a reduction of tire-road noise it is important to know the individual noise shares of the tires and their transfer paths. Authentic tire-road noise can only be measured on a real road, not on a roller dynamometer. So far measurements have been performed during a coast-down on the road with the engine switched off, avoiding the influence of engine noise. Operational Transfer Path Analysis (OTPA) can be used to remove the uncorrelated wind noise, and to synthesize structure-borne and airborne tire-road noise based on input signals measured with microphones at the tires and a triaxial accelerometer at each wheel carrier. Simultaneously, the interior noise is recorded by an artificial head. Acceleration, deceleration or other driving maneuvers with the engine running can lead to different tire noises. In this case the conventional method cannot be applied because the engine sound is measured at the source (tires) and receiver locations (cabin). This would lead to incorrect OTPA transfer functions and the tire-road noise synthesis would contain unwanted engine sound shares. Thus, a Cross-Talk Cancellation (CTC) must be carried out between the tire and engine sources. In this paper a new approach is presented allowing for a tire-road noise analysis under

dynamic driving conditions. The applied CTC requires additional input signals at the engine. Copyright © 2012 SAE International.

Soundararajan, S., 2012. A Finite Element Methodology to Design and Validate the Performance of an Automotive Exhaust System. In *SAE Technical Papers*. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84881197941&partnerID=tZOtx3y1 [Accessed September 3, 2015].

Abstract: A modern exhaust system consists of various parts like manifold, flexible joint, catalytic converter, muffler and intermediate pipes. All these parts are integrated and serve the functional requirement of silencing the noise caused by high pressure exhaust gases leaving the engine and the level of emitting the toxic gases. The loads induced due to powertrain roll motion and the vibration characteristic from the ground and powertrain system is to be studied for the design of Exhaust system. The validation of exhaust system integrity is a challenging job. Thus the system, the design suggestions and iterations are studied using finite element approach to reduce product development time and cost. In this paper, an attempt is made to provide a design direction through finite element approach. However the scope of this paper is restricted only for the structural durability study of an exhaust system design. The transient vibration loads measured from structural durability tracks are used to perform the modal transient vibration study to an exhaust system design and the results are correlated between experimental tests and finite element simulations. The improvement in design is suggested targeting the performance expectation. Copyright © 2011 2012 SAE International.

Trepte, S. et al., 2012. Messtechnische Erfassung von Pedalvibrationen. *tm - Technisches Messen*, 79(2), pp.115–119. Available at: http://www.degruyter.com/doi/10.1524/teme.2012.0143 [Accessed October 7, 2015].

Abstract: This article describes the recording of pedal vibration through the measuring of distance, force and acceleration of a clutch pedal. In addition to the measuring, testers evaluated the vibration. The results of this study illustrate the human perception of vibration on the foot. This method enables an objective evaluation for pedal vibration. © Oldenbourg Wissenschaftsverlag.

Walker, P.D. & Zhang, N., 2012. Investigation of synchroniser engagement in dual clutch transmission equipped powertrains. *Journal of Sound and Vibration*, 331(6), pp.1398–1412. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84155172305&partnerID=tZOtx3y1 [Accessed October 7, 2015].

Abstract: Transient response of a dual clutch transmission (DCT) powertrain to synchroniser mechanism engagements is investigated using a lumped inertia model of the powertrain. Original research integrates lumped inertia powertrain models for the DCT with a detailed synchroniser mechanism model and two separate engine models, comprising of a mean torque model and a harmonic torque model, using torque derived from piston firing. Simulations are used to investigate the synchroniser

mechanism engagement process in a previously unscrutinised operating environment. Simulations are performed using both engine torque models, with the mean torque model demonstrates the highly nonlinear nature of synchroniser mechanism engagement, and the powertrain response to the engagement process. Through the introduction of harmonic engine torques, additional excitation is present in the mechanism during engagement, and increased vibration of the synchroniser sleeve results. The impact of vibrations is particularly important to the increased wear of indexing chamfer contact surfaces.

Wan, Y., Li, S. & Li, Y., 2012. Control method of reducing pass-by noise emitted by accelerating certain type of motor vehicles. *Zhendong Ceshi Yu Zhenduan/Journal of Vibration, Measurement and Diagnosis*, 32(5), pp.850–853. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84870432868&partnerID=tZOtx3y1.

Abstract: Pass-by noise outside car is an important indicator to evaluate vehicle noise. In order to reduce pass-by noise emitted by accelerating a certain type of motor vehicles in the trial-manufacture stage, this paper investigates the engine noise outside car, exhaust noise emitted by stationary automobile, and inlet and outlet wire speed of engine when the automobile entered the pass-by noise test area through the standard test method, it is found that the main reason of pass-by noise beyond the standard is the high inlet and outlet wire speed of engine, and a reasonable method of matching proper gearbox transmission ratio to reduce the vehicle acceleration noise is presented. The results show that the pass-by noise emitted by accelerating the car matched the new gearbox is reduced by 1.9dB (A) compared with the original value, and reach the national standard.

Wang, Y. & Lu, Z., 2012. Influence of elastic parameters on the natural vibrational characteristics of powertrain mounting system. *Qinghua Daxue Xuebao/Journal of Tsinghua University*, 52(1), pp.102–107. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84860324072&partnerID=tZOtx3y1.

Abstract: The influence of several elastic parameters on the natural vibrational characteristics of powertrain mounting system was analyzed using a dynamic model of the powertrain mounting system including the angular stiffness of the mounts and the flexible drive belt on the front of the engine. The natural vibrational characteristics of powertrain mounting system on several kinds of vehicles were analyzed with and without considering the angular stiffness of the mounts with parametric studies of the natural frequencies and mode shapes for various drive belt stiffnesses and orientation angles. The results show that natural vibrational characteristics of the powertrain mounting system are affected little by the angular stiffness of the mounts with the highest modal frequency (the mode shape is mainly rolling dominant) of the powertrain increasing notably with belt stiffness. Changes in the orientation angle have a notable influence on the 2nd to 6th natural vibration frequencies. Thus, the influence of the angular stiffness can be neglected, but the flexible drive belt strongly influences the system natural vibrational characteristics and should be included in powertrain mounting system models.

Wang, Y.H., Chen, Y.B. & Tsai, G.C., 2012. Frequency Analysis and Optimization Design of Car Powertrain Mounting System Based on ADAMS. *Applied Mechanics and Materials*, 215-216, pp.1131–1135. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84870508606&partnerID=tZOtx3y1 [Accessed September 3, 2015].

Abstract: This paper introduced the method that developed model and frequency analyses of powertrain mounting system based on ADAMS (Automatic Dynamic Analysis of Mechanical Systems). The six vibration frequencies and its corresponding modes were obtained and compared with experimental results. Mount stiffness of the four mounting parts were optimized to use Adams/Insight. The former low decoupling degrees and the new part stiffness were observed to improve the disadvantage and can reduce the vibration transfer. © (2012) Trans Tech Publications, Switzerland.

Wu, F., Liu, H. & Zeng, B., 2012. The Effects Research of Elastic Coupling on Torsional Vibration Test-Bed. *Applied Mechanics and Materials*, 229-231, pp.507–511. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84871374554&partnerID=tZOtx3y1 [Accessed September 3, 2015].

Abstract: The powertrain of vehicle is actually a multi-freedom torsional vibration system, its torsional vibration directly affect the vehicle' ride comfort and safety. In this paper, the effects of elastic couplings on the newly built torsional vibration test-bed were researched. Firstly, using the basic principle of equivalent conversion, established the torsional vibration equivalent model. Secondly, analyzed the free torsional vibration of the powertrain by the dynamics analysis software-ADAMS and obtained the torsional vibration characteristic of the powertrain with different elastic couplings. Finally, fitted out the curve of stiffness and natural frequency by the least squares method. © (2012) Trans Tech Publications, Switzerland.

Wu, J., 2012a. A robust optimization for the frequency and decoupling ratio of a powertrain mounting system based on interval analysis. *International Journal of Automotive Technology*, 13(3), pp.409–422. Available at: http://link.springer.com/10.1007/s12239-012-0038-z [Accessed October 7, 2015].

Abstract: This paper presents a robust optimization method to decrease the variations in the performance of the designed system caused by the unavoidable manufacturing, installation or measurement errors of the design variables. Generally, it is difficult and costly to determine statistical information with sufficient precision for uncertain design variables; in this study, interval numbers are used to describe the uncertain design variables, and only the bounds of these variables are required. An improved interval truncation method is presented for estimating the variation ranges of the system performances. The robustness estimations of the system performances are incorporated into the optimization formulation to obtain the nominal design variables, which could make the system performances relatively robust; therefore, the design robustness is estimated and improved in the optimization iteration process. The robust optimization method is applied to a general powertrain mounting system (PMS) to improve the design robustness of the PMS decoupling layout and frequency

allocation. The optimization results show that the robust optimization method could effectively increase the decoupling ratios in the interested vertical and pitch directions, and the frequency allocation is more robust than that obtained using the traditional deterministic optimization. © 2012 The Korean Society of Automotive Engineers and Springer-Verlag Berlin Heidelberg.

Wu, J., 2012b. Optimization method for powertrain mounting systems with uncertain parameters. *Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering*, 226(2), pp.147–157. Available at: http://pid.sagepub.com/lookup/doi/10.1177/0954407011416308 [Accessed October 7, 2015].

Abstract: This paper presents an interval optimization method to improve the design robustness of the decoupling layout and frequency allocation of powertrain mounting systems (PMSs). The effects of the uncertainties or variations of the powertrain inertia properties and design parameters on the optimization results are considered in the optimization process. Generally, it is difficult and costly to determine statistical information with sufficient precision for uncertain parameters, so here interval numbers are used to describe the uncertain parameters and only the bounds of them are required. Robustness indices of interval reliability and interval possibility degree are suggested for characterizing the robustness of PMS decoupling layout and frequency allocation respectively. The interval optimization problem is transformed to an equivalent deterministic one based on the robustness indices. The optimization results of a PMS show that the interval optimization method can significantly increase the robustness of the frequency allocation, especially in vertical and pitch directions. This will decrease the possibility of resonance between the powertrain and other parts, such as the wheel, car body, and frame. In contrast to the deterministic optimization method, although the decoupling ratios obtained by the proposed method decrease slightly, the interval optimization results can meet the decoupling layout requirement from the viewpoint of engineering. © 2011 BMW Group, Munich, Germany.

Wu, J. & Zhou, S.N., 2012. Robustness optimization method for frequency and decoupling ratio of powertrain mounting systems. *Zhendong yu Chongji/Journal of Vibration and Shock*, 31(4), pp.1–7. Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84863236030&partnerID=tZOtx3y1.

Abstract: Due to measurement inaccuracy, installation errors and aging, the mount stiffness of a powertrain mounting system (PMS) is usually not deterministic, thus the frequencies and decoupling ratios of a PMS are also somewhat uncertain. Interval numbers were used to describe the uncertainties of the mount stiffness as well as the frequencies and decoupling ratios of a PMS in consideration of being easy to obtain the variation ranges of the mount stiffness without knowing the probability distribution of the stiffness. An improved interval truncation method for obtaining the variation ranges of frequencies and decoupling ratios was presented and its computational accuracy was verified. To improve the design robustness of frequencies and decoupling ratios, an interval optimization method was presented. The presented optimization method was applied to a PMS for maximizing decoupling

ratios with frequency constraints. Optimization results show that the interval optimization can significantly increase the robustness of frequencies in roll and pitch directions. In contrast to the deterministic optimization, though the decoupling ratios in vertical and pitch directions decrease slightly, the interval optimization result can meet the decoupling layout requirement.

Xu, Z., Li, X. & Liu, H., 2012. Optimization of the powertrain mounting system of electric vehicle. *Qiche Gongcheng/Automotive Engineering*, 34(9). Available at: http://www.scopus.com/inward/record.url?eid=2-s2.0-84868371691&partnerID=tZOtx3y1.

Abstract: A 6 DOF rigid body dynamics model for the powertrain mounting system of a compact electric vehicle is created by using software CATIA and ADAMS. Then the natural characteristic and coupling characteristic of powertrain mounting system and the transient characteristics of electric vehicle in starting and braking conditions are analyzed. Taking account of the mounting position and angle of rubber mount elements, with the mount stiffness as design variables and the energy decoupling as objective, an optimization on mounts parameters is conducted with ADAMS/Insight. The results show that after optimization the extent of energy decoupling in mounting system is apparently enhanced and hence its vibration isolation performance significantly improves.

Zhang, P. & Song, X.L., 2012. Simulation Research of Vehicle Exhaust System Hanger Location. *Advanced Materials Research*, 482-484, pp.347–353. Available at: http://www.scientific.net/AMR.482-484.347 [Accessed October 7, 2015].

Abstract: To reduce the impact of exhaust system hanger layout on the vehicle vibration performance and research the method about the reasonable layout of the hanger, forst established the FE model of an automotive exhaust system and fixed up hanger locations by modal analysis and load distribution by statics analysis. Then according to the displacement and force response to the engine’s torque loaded on powertrain's mass centroid, adjusted hanger locations. At last, got the reasonable hanger location layout. The exhaust system hanger layout is used on a heavy truck and has the obvious effect. © (2012) Trans Tech Publications, Switzerland.

Zhang, Z.P. et al., 2012. Vibration Modal Analysis and Structural Optimal Design of Car Rear-View Mirror Based on ANSYS. *Advanced Materials Research*, 549, pp.848–851. Available at: http://www.scientific.net/AMR.549.848 [Accessed October 7, 2015].

Abstract: In order to improve the safety of the moving car,we have to make simulation and analysis of the dynamic characteristics of the car rear-view mirror. We should consider, in addition to the geometric dimensions, standards and demands, a reasonable choice of the mirror size and installing position, the dynamic characteristics of the car rear-view mirror in the design of the car rear-view mirror. In this paper, we use the finite element software ANSYS to simulate the vibration frequency and vibration modals of the car rear-view mirror under the condition of

excitation sources. Based on this and the strength analysis results of the rear-view mirror, we make a optimal design of the rear-view mirror structure. We get five-order vibration modals in working condition and analysis the size of displacement and deformation, and dynamic characteristics. The results show that because of the low modal frequency, the car rear-view mirror is easily inspired by the engine, powertrain system and road to vibrate. Besides, the deformation and the strain distribution of the rear-view mirror are not uniform. So we should control the low rank flexibility modal frequency within a certain threshold frequency when designing its structure. On the condition of little changes of its overall volume, the maximum equivalent stress of the rear-view mirror decreased by 30.5% through optimizing design.