



Challenges and Approaches of Electric Vehicles Powertrain Mount System Optimization for NVH, Buzz Squeak Rattle and Durability

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Abstract

In electric vehicles, the powertrain mounting system design has challenges different from conventional internal combustion engine (ICE) powertrains. Due to the absence of source noise, the customer predominantly experiences the buzz, squeak and rattle (BSR) noise. The 6 degrees of freedom (DOF) modal frequency target is less stringent than a three-cylinder or four-cylinder ICE powertrain. The durability loads in EV also differ due to less powertrain

weight. In this paper, a study has been carried out about balancing all three main performance parameters of modal decoupling, BSR and durability through powertrain mount design optimization. The article shows that a carryover ICE powertrain mount has typical issues in Electric Vehicle (EV). A case study has discussed in detail how to manage those issues. Finally, it is concluded that a particular focus is required during an early stage of mount design to address these challenges for an EV.

Keywords

EV, BSR, NVH, Durability

Introduction

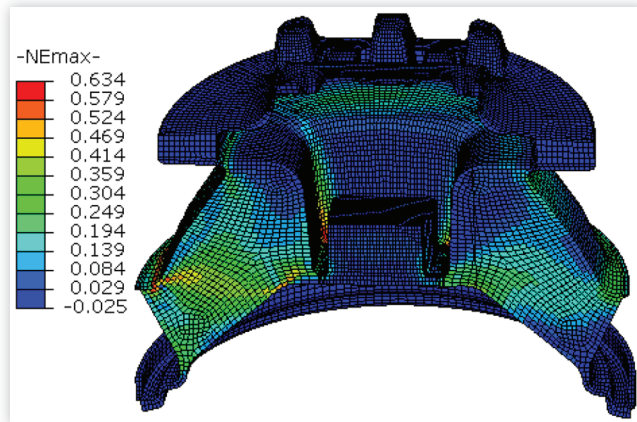
Powertrain mounting system optimization for ICE has been studied, refined and applied for many years with numerous applications. Whether in ICE or EV, the engine mounting system has similar input, control, and noise factors as mentioned in [Figure 1](#) to achieve expected NVH, BSR and durability targets. The input signal for EV's is different than ICE as EV powertrain has a quieter engine presence compared to ICE's. The main differences are the absence of idle load case, engine start/stop load cases, higher excitation frequencies, lighter mass moment of inertias in EV compared to an ICE. The high torque and fast change in torque during acceleration and deceleration require a stiff and progressive load-deflection curve in the non-linear zone of engine mounting. Also, the 6 degrees of freedom (DOF) modal frequency targets in ICE are quite relaxed in EV. As a result, the 6 DOF modes are comparatively easier to place in the EV modal map. The BSR noise issue is more prominent in EVs than ICE because of the difference in powertrain masking effect. Failure in addressing BSR issues is often the biggest challenge faced by car manufacturers during the EV development stage. Even perfectly optimized powertrain mounts for EV's fail to deliver the best NVH due to BSR noise. The next challenge is to meet durability targets. In EV's, the powertrain is lighter than the similar ICE class, so the durability load cases are also different.

However, as the torque rise is quick in EV, which leads to a higher engine roll in EV than an ICE engine. In this paper, a 6 DOF optimization for the mounting system is carried out. BSR issues are discussed. After that, the mount progression curve correction is done to balance BSR and NVH aspects through stopper gap optimization. Finally, the RLDA based durability load cases are checked on revised progression curves to estimate the corresponding rubber strain. The simulated durability cycles are calculated from the Wohler curve of the rubber compound. The ratio of estimated cycles (N1) and the total target cycles (N) is called relative damage. The total damage is calculated for each block cycles for final life estimation. Focus is given to balancing the engine mounting progression curve through optimization. So, a 6 DOF study is not enough for overall NVH, BSR and durability target balancing. Proper attention is required to choose all performance aspects and system-level noise factor to achieve the overall target as per customer expectation.

The powertrain mounting system in EV is quite similar in layout as compared to ICE. Depending on packaging space, load transfer and type of electric vehicle, the powertrain mounting system can be classified as shown in [Table 1](#) for EV. Mainly two types of EV, namely modified and dedicated with the transverse or longitudinal powertrain. Mounting systems

TABLE 3 Durability load on right side mount

Mount	X dir. (N)	Y Dir. (N)	Z Dir (N)	Total damage
Right side mount	-3200 to +1000	-320 to +250	-4230N to +3025	
Calculated Total Damage	0.26	0.15	0.40	0.81

FIGURE 15 CAE with strain rate

and the strain levels are plotted as shown in [Figure 15](#). The value of 0.634 indicates the strain level as 63.4% in the color plot.

The corresponding strain values are picked from loading on rubber and fed back from the Wohler curve for the estimated no of the cycle. The estimated and required no of cycles are called damage for that particular block. Generally, the cumulative damage should be <1 to have a durable design. The calculated cumulative damage was 0.81 for right side mount, which is <1 and satisfies the damage criteria.

This study shows how to design a stopper gap for the BSR noise issue and the corresponding strain rate to achieve the durability cycle. Here every step, a proper balancing of design parameters to meet the performance target is required. Otherwise, some of the other parameters will become not OK in terms of meeting overall performance requirements.

Results and Discussion

The study of attribute balancing is done for the powertrain mounting system. A powertrain mount suitable for ICE for BSR noise becomes worse due to the absence of a powertrain masking effect. Mount load-deflection characteristics, BSR issues resolution through progression curve adjustment is made. The simulated load is evaluated for overall damage.

A similar type of load measurement/analysis was done for all three mounts in all three directions. Block cycles were created based on force-deflection characteristics, and then CAE is done based on Wohler's curve, as mentioned in [Figure 9](#). Total damage for durability was estimated. In this particular study, the BSR issue was observed from the right side mount. Hence, load-deflection characteristics adjustment done only

in right side mount and overall modal alignment, durability and BSR impact shown in the case study.

Accordingly, the stopper gap was designed to address BSR and durability together. As the primary linear stiffness was not changed, there was no change in dynamic stiffness at 15Hz, which corresponds to no change in modal separation targets in 6 DOF. The transient characteristics were designed through the stopper gap and non-linear progression.

Overall, balancing all three primary targets has been discussed in this paper in detail for the electric vehicle powertrain mounting system.

Conclusions

The requirement matrix during a vehicle-level system development has been discussed. The forward and backward interaction among various performance nodes plays a critical role while optimizing the system to meet overall performance.

Conflicts of various performance targets can be resolved by finding a solution space rather than optimizing individual system-level targets like optimizing kinetic energy coupling. Solution spaces are regions in the design space where all requirements are considered satisfactory.

Here firstly, a 6 DOF optimization is done through optimization for modal alignment and decoupling of modes. Then the stopper gaps are designed to take care of the BSR noise issue. While doing that, durability loads are calculated and checked to ensure that the rubber strain rate met the cumulative damage. Finally, this paper presents the approach to have a proper balance among NVH, BSR and durability while meeting attribute targets.

The significant aspects of BSR, durability and NVH are covered in this paper. However, more complex system-level interaction during engine mount development in EV is the future scope of the study. There is various potential risk associated with the application of traditional ICE powertrain mount design process in EV. The shift of focus is also needed to include the impact of driveshaft integration, engine roll movement during sudden braking in EV, which can also cause various types of noises in EV.

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Definitions/Abbreviations

Mount 1,2,3 - Right, Left and Rear Mount

BSR - Buzz, Squeak and Rattle

CoG - Centre of Gravity

DOF - Degree of Freedom

EPDM - ethylene propylene diene monomer

EV - Electric Vehicle

ICE - Internal Combustion Engine

KE - Kinetic Energy

MRE - Main rubber element

NVH - Noise Vibration and Harshness

NR - Natural rubber

NBR - Nitrile-butadiene rubber

OEM - Original Equipment Manufacturer

RLDA - Road load data acquisition

RPN - Risk priority number