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Impact of Powertrain Dimensional Variation on Buzz, Squeak and Rattle Noise for Cradle Type Electric Vehicle

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Abstract

There are two types of EV (electric vehicle) currently in use, namely modified EV and dedicated EV. Generally, we use a modified EV in cost-sensitive markets where we can commonize platform between internal combustion engine (ICE) and EV vehicles. For modified EV, we use the cradle to support the powertrain components, which connects to the engine mount, which in turn attaches to extended members and subframe. The fabricated cradle has many welding components that cause dimensional variation at the rear-mount attachment point on gearbox, which creates a reduction in the dynamic envelops significantly. The decrease in clearance often results in BSR noise, which we have simulated in the rig as well as on rope track. On a rough road, this noise is predominant. This buzz, squeak and rattle (BSR) noise also results in Tip in/ Tip out noise, which is quite uncomfortable for the customer during sudden acceleration and deceleration. This paper explains in detail about the contribution of dimensional variation of the cradle and various powertrain components on the rear mount attachment point and the way to mitigate the issue. Finally, it shows that an optimized mounting system, the dimensional variation of the cradle in modified EV can result in various noise, vibration and harshness (NVH) issues if not duly addressed during packaging and dynamic envelope study.

Keyword

NVH, EV, Cradle, BSR, NVH, Dimensional Variation

Introduction

The primary function of engine mount in an electric vehicle is to support powertrain and isolate the source vibration from the powertrain. We always focus on various NVH aspects like seat rail vibration, steering rail vibration, Tip in/Tip out, judder and in-cab noise, high-frequency resonance. Here the general approach is to design optimum engine mount location and optimum stiffness for best system-level and vehicle level modal alignment and durability. As, we all know, electric vehicles are susceptible to BSR noise. Now, what will happen even after best engine mounting system design fails to eliminate BSR noise that arises due to dimensional variation of various powertrain and cradle components? The best design effort will go for a toss if we do not consider the dimensional variation due to production tolerances and do not validate the system for best limits.

The BSR vibration for engine mount is discussed for ICE in reference [1] where the engine mount's internal design and soft to soft contact to address BSR noise, are discussed. The stopper design technique in engine mount is discussed in reference [2] whereby modification of stopper shape to reduce the contact surface is explained in detail with a case study. Automotive BSR noise classification and source identification studied by the neural method is discussed by [3]. The BSR noise generation mechanism due to contact is studied by [4] with the basic principle of generation. The vibration test method for BSR noise generation in spot-welded structures is discussed in [5]. This study is specific to BSR noise generation in the EV engine mounting system due to powertrain dimensional variation. The internal mount design or stopper design often fails to address the BSR issue due to dimensional variation of cradle type modified electric vehicle. There is no research work found in this specific area, especially for cradle type EV's, which is very commonly used by the original equipment manufacturer (OEM) for cost and time advantage. This paper focuses on the study of BSR issue due to dimensional variation and the way to address it. A case study has been presented for verification of dimensional variation analysis (DVA) concept.

example, BIW variations of +/-1.2 in the Z direction for long members or tolerances within cradle assembly can't be controlled further.

We can see here that by controlling the above major contributors, dimensional variation was reduced to from 4.5 mm (Table 2) to 3 mm (Table 4) in Z, but there are other variations as there are multiple contributors with their best tolerances.

For 02 -Subframe side variations in Z and X direction.

On subframe side variations, the contributing parameters are mainly subframe matching on BIW in 'Z' and subframe location tolerances in X and Y respectively. Here also, there are the best possible tolerances and can't be further controlled. So no further reduction is possible as per manufacturing tolerances.

As per DVA contribution analysis (Table 6 and 7), for the contributor a) diameter 12+/-0.2 holes on bracket assembly RH side Motor mount to M10-0.22 bolts on the motor, contribution analysis suggested reducing the holes diameter from 12+/-0.2 to 10.5+/-0.2 for M10 bolt.

For the contributor, b) B mount holes with diameter18 + 0.5 with M12 bolt was controlled in diameter 15 +0.5.

Through the DVA analysis with various iterations, the dimensional correction for major contributor a and b was done on the actual component to minimize the total dimensional variation on the vehicle. The final results are mentioned in Table 4 and 5, respectively.

Green colour dimensional variation indicates Major improvement; Yellow colour dimensional variation indicates Moderate improvement; Grey colour indicates Minor improvement.

The remaining contribution was due to multiple non-controllable dimensional tolerances. Through various DVA iterations, around 33% dimensional variation has been reduced in Z, and 23% variation has been reduced in X (statistical +/-3σ) which are feasible and manufacturable. The actual test result of BSR noise post modification of identified dimension was done on the vehicle. It was found to be satisfying for all vehicles as the final gap with dimensional variation improved to 3 mm minimum which led to avoidance of metal to metal contact. The BSR noise issue was resolved.

Various powertrain components contribution and their contribution are studied in DVA. Table 6 and Table 7 show that the maximum contribution of parts, if appropriately controlled, can have a significant effect on overall dimensional variation at rear mount zone. Hence, based on analysis, these two dimensions are identified and introduced in production through a feasibility study.

Conclusions

This paper explained the BSR noise due to dimensional variation. BSR noise source was identified first. Then, on vehicle rear mount, the gap with subframe was measured for ten vehicles which were plotted for BSR noise. Then, DVA analysis was done to identify the contribution of various parts dimension from powertrain components (Path 01) and also from Subframe towards rear mount side (Path 02). The cumulative effect was studied.

The maximum contribution element was identified through Pareto, and we also checked manufacturing feasibility for modification. Design action was taken to reduce those identified major contributors to minimize the 3σ variation in Z and X-direction, respectively.

Finally, with a modified dimension, parts were fitted and noise issue was eliminated on the vehicle. Around 33% dimensional variation was reduced in Z, and 23% variation was reduced in X through this study which ultimately helped to eliminate BSR issue.

Even a good engine mounting system design will fail to address the BSR discomfort if DVA of various associated components is not considered before the design stage. This paper shows that the dimensional variation effect on system level NVH for a modified cradle type EV to be addressed adequately in advance for a robust engine mount system performance.

References

1. Hazra, S., and Gupta, I., "Engine Mount Design Technique to Address Vehicle Level Buzz, Squeak and Rattle," in *2017 IEEE Transportation Electrification Conference (ITEC-India)*, doi:10.1109/ITEC-Indiameter2017.8333721.
2. Hazra, S., and Deshmukh, S., "Engine Mount Stopper Design Techniques to Balance Vehicle Level Buzz, Squeak, Rattle and Durability," SAE Technical Paper 2020-01-0401, 2020, https://doi.org/10.4271/2020-01-0401.
3. Bu, S.-J., Moon, S.-M., and Cho, S.-B., "BSR (Buzz, Squeak, Rattle) Noise Classification Based on Convolutional Neural Network with Short-Time Fourier Transform Noise-Map," *The Journal of the Acoustical Society of Korea* 37(4):256-261, 2018, doi:10.7776/ASK.2018.37.4.256.
4. Ahn, S., and Ih, K.D., "Basic Principle of BSR (Buzz, Squeak, Rattle) Noise according to the Generation Mechanism," *The Journal of the Acoustical Society of Korea* 37(5):309-316, 2018, doi:10.7776/ASK.2018.37.5.309.
5. Kwak, Y., Lee, J., and Park, J., "Experimental Study to Investigate the Structural Integrity of Welded Vehicle Structure for BSR (Buzz, Squeak, Rattle) Noise by Vibration Measurement," *The Journal of the Acoustical Society of Korea* 38(3):334-339, 2019, doi:10.7776/ASK.2019.38.3.334.
6. Zhu, D., Pritchard, E.G.D., and Silverberg, L.M., "A New System Development Framework Driven by a Model-Based Testing Approach Bridged by Information Flow," *IEEE Systems Journal* 12(3):2917-2924, 2018, doi:10.1109/JSYST.2016.2631142.