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Influence of Powertrain Mount Stiffness Progressivity on Buzz, Squeak & Rattle Noise for Electric Vehicle

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Abstract

For a modified electric vehicle on the same internal combustion engine (ICE) platform, the primary consideration is to have no change in long member and pendulum type conventional engine mounting system to save development cost and timeline. Electric vehicle (EV) powertrain is comparatively lighter w.r.t the ICE. As a result, the engine mount's static preload setting point or powertrain centre of gravity under static powertrain load gets changed resulting in a change in stiffness for the same engine mount.

As the static stiffness changes, the dynamic stiffness and modal frequency also change. The 6 degrees of freedom (DOF) modal frequency has almost no impact on powertrain modes as EV powertrain modes, mainly, the motor frequency, is much higher than engine mount Eigen modes.

In this scenario, the gap management gets disturbed due to less static preload, and non-linearity gets affected. This paper will explain a case study on a modified EV, the change in modal map, its impact vis-a-vis ICE, and how this static stiffness progressivity issue is addressed to resolve buzz, squeak and rattle (BSR) noise.

Keywords

NVH, Engine mount, Non-linearity, BSR

Introduction

In ICE, the excitation to be isolated comes from two primary sources:

Firstly, torque fluctuations due to firing and inertia torques are most pronounced at low speeds and idle. Secondly, forces and couples due to the inertia of reciprocating components that increase with engine speed can be alleviated using balancer shaft(s).

The engine's good noise, vibration and harshness (NVH) performance is critical at idle (no masking noises). The powertrain is considered as a rigid body mass under static preloaded condition. A correct mounting system locates powertrain rigid bodies' natural frequencies at least $\sqrt{2}$ times below the lowest frequency of engine excitation at idle. The powertrain, on its mounts, always operates in the inertia-controlled region. The powertrain will vibrate much like the way it would vibrate if it were freely suspended.

As vibration is inertia controlled, the mount stiffness will have minimal effect on the motion amplitude (rigid-body natural frequencies must not encroach on the excitation frequency)

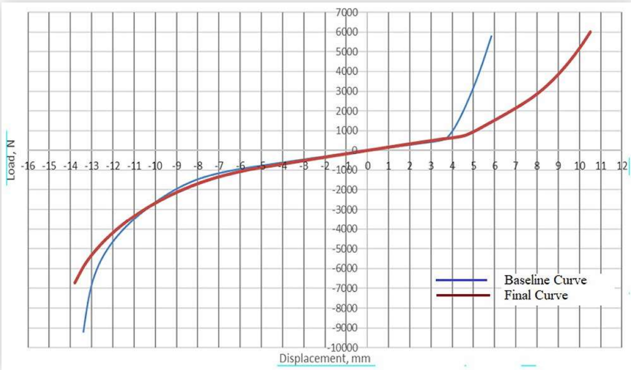
As it is not possible to control the powertrain's motion at idle with the mounting system, to ensure good NVH performance, it is necessary to provide more than 90% isolation.

Therefore, the engine mounts dynamic stiffness in large vibration motion direction should be minimized as far as possible.

The situation is different for EV as no excitation due to torque fluctuation and unbalance force exists in the frequency range where the mounting system operates. The primary excitation in EVs is from electromagnetic pulses and associated torque pulses from the motor. The noise radiated from the motor is usually far away from the modal frequencies, which is a function of dynamic stiffness and engine mounting system location. As a result, there is greater freedom on stiffness tuning of rubber mounts to achieve the required level of isolation efficiency.

The electric vehicle mounting system in EVs is different significantly from ICE due to powertrain source vibration forcing function, which is lower in EV based on motor design. As EVs are more silent due to the absence of engine presence, the customer expectations for NVH refinement are also high. EVs will unmask different types of noises which may

FIGURE 9 Tested Load (L) - deflection (d) curve of baseline and final-Right hand side mount in the Z direction



In the above highlighted green box, the free travel in -Z-direction was 3.97 mm. When an input amplitude was given as +/-5 mm, the right side mount's inner core was hitting the internal stopper. By eliminating internal stopper (Figure 10), the progressivity improved, and the BSR hitting noise eliminated.

The other direction progression curves are also checked, and it was observed that no changes in X&Y direction L-d curve due to change in stopper in the Z direction.

The subjective evaluation at the rope and objective evaluation at rig was done. It was observed that the BSR score with the final configuration was reduced to zero. The final score was the combination of both the evaluations. As a result of the mount progressivity adjustment in the Z direction, as shown in Figure 10. BSR score correlates the customer usage pattern on the actual field.

FIGURE 10 Baseline and final mount internal structure

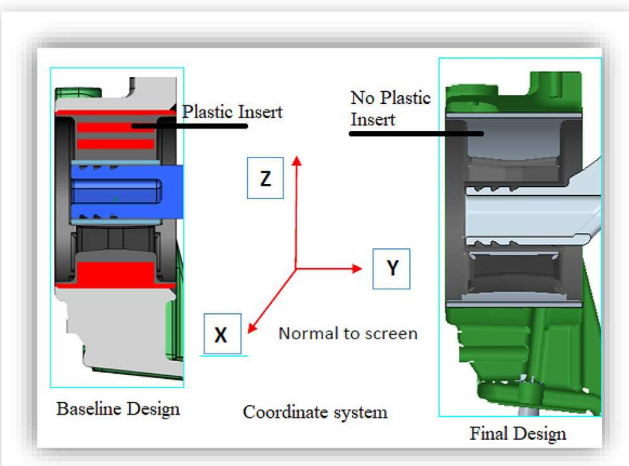


TABLE 5 BSR score baseline vs final design

BSR score -Acceptable limit	BSR score -Baseline design	BSR score -Final design
<100	450	0 (No noise)

Conclusions

We have explained the critical difference in powertrain mount related NVH and its modal map for ICE vs EV. In EV, the mount progressivity plays an essential role due to lighter powertrain weight w.r.t same platform ICE.

As a result, due to the different preload setting point, the progressivity in rebound direction comes into action early in EV, which results in BSR issue. By changing the progressivity through mount rubber internal structure, the travel increased, and BSR issue was resolved.

This paper has described a case study by presenting the mount progressivity phenomenon and its effect on BSR noise with baseline vs final mount L-d characteristics. It is done through internal stopper design change without changing the dynamic stiffness. It shows the progressivity effect of an engine mount to be addressed adequately in advance stage of development for a modified cradle type EV to achieve BSR performance.

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Definitions/Abbreviations

BSR - Buzz, squeak and rattle
DOF - Degree of Freedom
DSR - Driver seat rail
EV - Electric vehicle