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A Comparative Study of Source Vibration Between the Electric Motor and Internal Combustion Engine Application for Passenger Vehicles

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Abstract

In an electric vehicle, internal combustion engines are replaced by the electric motor. As a result, the signature of source vibration changes. The noise, vibration and harshness (NVH) issues are entirely different in electric vehicle (EV) compared to internal combustion engine (ICE) due to the change in source vibration. The outline of this paper is a comparative study of source vibration, the challenges to address various noise issues related to source vibration and the isolation methodology. A case study is presented to show the different methods of treatment required to mitigate source vibration issues during the electric vehicle development program.

Keywords

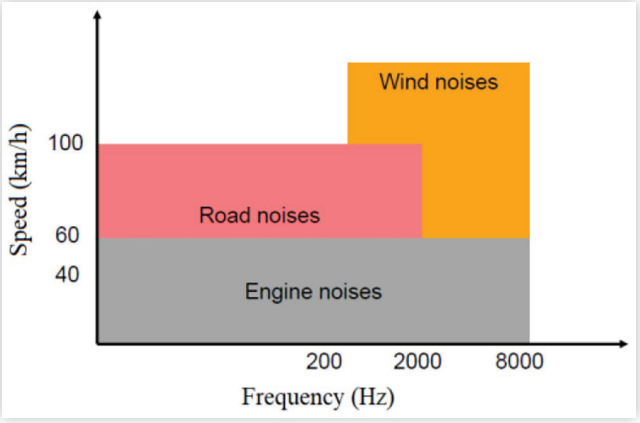
Engine, Motor, vibration

Introduction

The automotive industry has various challenges for safety, fuel economy and environmental norms. One of such challenges is to reduce pollution and improve carbon footprints. For minimization of the carbon footprint, there is an increasing trend of electric vehicle introduction. More and more original equipment manufacturers(OEM's) are focussing on their product portfolio for the development of EVs and faster launch in the market. The shortest lead-time adopted by almost all OEM are modified EV. An electric powertrain replaces the current Internal combustion engine (ICE), and a battery replaces the exhaust and fuel system. We all know the noise, vibration and harshness(NVH) is a mechanism of interaction among source, transfer path and receiver. Here, the transfer path is the same, but the source is getting changed as we are replacing ICE with EV. The customer comfort requirement is also getting changed due to the increased quietness of EV compared to gasoline or diesel engine.

A typical representation of the Noise profile of EV and ICE are shown in Figure 1a) and 1b: The engine noise in ICE would be replaced by ancillary noise and motor noise in EV. The aerodynamic and road noise in EV is more than ICE as there is no masking effect in EV compared to ICE. So, a little noise is experienced by a user called buzz, squeak and rattle (BSR) noise in a quiet an objectionable in EV car.

FIGURE 1A The noise profile of an ICE vehicle



The identification and treatment of each noise source are essential for EV. Due to motor resonance in high frequency, sometimes, EV has a high-frequency resonance issue not present in ICE. So, it is essential to understand the source noise difference between ICE and EV to further work on the treatment mechanism of various noise issues during development.

There is a significant difference in forcing function between ICE and EV powertrains. In ICE, the engine's sound masks many other noises and is shown in Figure 1a: Due to

References

1. Liang, J., Qian, K., Wang, J., Gao, Y. et al., "Interior Noise and Vibration Prediction of Permanent Magnet Synchronous Motor," *Journal of Vibroengineering* 20, no. 5 (2018): 2225-2236, doi:10.21595/jve.2018.18605.
2. Diez-Ibarbia, A., Battarra, M., Palenzuela, J., Cervantes, G. et al., "Comparison Between Transfer Path Analysis Methods on an Electric Vehicle," *Applied Acoustics* 118 (2017): 83-101, doi:10.1016/j.apacoust.2016.11.015.
3. Sakhaei, B. and Durali, M., "Vibration Transfer Patanalysis and Path Ranking for NVH Optimization of a Vehicle Interior," *Shock and Vibration* 2014 (2014): 1-5, doi:10.1155/2014/697450.
4. Cao, Y., Wang, D., Zhao, T., Liu, X. et al., "Electric Vehicle Interior Noise Contribution Analysis," SAE Technical Paper Series (2016), https://doi.org/10.4271/2016-01-1296.
5. Ravi, V., Jentz, R., Kumar, V. et al., "Assessment of Exhaust Actuator Control at Low Ambient Temperature Conditions," SAE Technical Paper 2021-01-0681 (2021), https://doi.org/10.4271/2021-01-0681.
6. Ravi, V.K., and Dadam, S.R., "Methods and Systems for an Active Exhaust Valve," U.S. Patent number: 11,002,166.
7. Rong, G., Xiao-Kang, W., and Jun, G., "Experimental NVH Evaluates a Pure Electric Vehicle in Transient Operation Modes," *Vibroengineering Procedia* 10 (2016): 364-368.
8. Xin, F., Qian, L., Du, H., and Li, W., "Multi-objective Robust Optimization Design for Powertrain Mount System of Electric Vehicles," *Journal of Low-Frequency Noise, Vibration and Active Control* 36, no. 3 (2017): 243-260, doi:10.1177/0263092317719635.
9. Courteille, E., Mortier, F., Leotoing, L., and Ragneau, E., "Multi-objective Robust Design Optimization of an Engine Mounting System," SAE Technical Paper 2005-01-2412 (2005), https://doi.org/10.4271/2005-01-2412.
10. Gunti, R.S., Bodla, M., and Venugopal, S., "Experimental NVH Studies on Electric Powered and IC Engine Powered Passenger Vehicles - A Comparative Study for NVH Target Setting," in *2019 IEEE Transportation Electrification Conference (ITEC-India)*, 2019, 10.1109/itec-india48457.2019.itecindia2019-277.
11. Genuit, K., "The Future of NVH Research - A Challenge by New Powertrains," SAE Technical Paper 2010-36-0515 (2010), https://doi.org/10.4271/2010-36-0515.
12. Hazra, S., "Study of Dynamics Stiffness and Shape Factor of Rubber Mounts to Address High-Frequency Resonance Issue in Electric Powertrain Mounting System," *SAE Int. J. Adv. & Curr. Prac. in Mobility* 3, no. 2: 773-779. https://doi.org/10.4271/2020-28-0341.
13. Zeng, X., Liette, J., Noll, S., and Singh, R., "Analysis of Motor Vibration Isolation System with Focus on Mount Resonances for Application to Electric Vehicles," *SAE International 2015-01-2364* (2015), https://doi.org/10.4271/2015-01-2364.

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Definitions/Abbreviations

CoG - Center of gravity
DSR - Driver's seat rail
DOF - Degrees of freedom
DEL - Driver ear level
EV - Electric vehicle
ICE - Internal combustion engine
LHS - Left Hand mount
NVH - Noise vibration and harshness
NTF - Noise transfer function
OEM - Original equipment manufacturer
PT - Powertrain
RHS - Right Hand Side

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