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Design Optimization of Automotive Engine Mount System

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ABSTRACT: *The highly competitive automotive business industry requires manufacturers to pay more attention to passenger comfort and riding quality. This has forced designers to direct their attention to the development of high quality engine mountings. The energy absorption characteristics of the engine mount are mainly influenced by two variables, the material and the design. In real world automotive manufacturing there is a fewer chances of the material changes for any subsystem as the material procurement is bulk order process. Hence the design of the engine mount becomes the critical aspect in terms of vehicle crashworthiness. In this particular study, different designs of the engine mount system have been evaluated for damageability starting from the base model. In the process of optimizing the damageability, study has been performed repetitively on engine mount with design configurations. In this work, special attention is given to the accurate modeling of nonlinear effects on the dynamic behavior of the engine mount using LS-Dyna simulation. Based on the finite element model created, the mounts frequency response function curves are determined and multi-dimensional effects in the mounts response are observed. Also, the engine mounts time dependent response is compared to the ones obtained using a damping material model suggested by the automotive constructors. The overall results indicate that the modeled engine mount i.e. Four arm symmetry has an acceptable performance in both isolating engine induced vibration and suppressing high amplitude engine shake movement. Finally, some remarks are made about the use of parallel associated rubbers and nonlinear dynamic properties as a mean for improving the mounts dynamic behavior.*

Keywords: *Vehicle crashworthiness, Engine Mount, LS-Dyna Simulation, Vibration Isolation.*

I. INTRODUCTION

The highly competitive automotive business industry requires manufacturers to pay more attention to passenger comfort and riding quality. Resonant vibration of body panels arising from unbalanced loads existing in the engine body is intensified by frameless or unitary chassis construction. This has forced designers to direct their attention to the development of high quality engine mounting devices in order to ensure that improved comfort in riding and silencing shall not be offset by fatiguing vibration effects. An engine mount system is designed to reduce the transmission of engine vibration to the chassis. Engine mounts are used to connect a car engine to the car frame. They are usually made of rubber and metal. An engine mount must satisfy two essential but conflicting criteria. First, it should be stiff and highly damped to control the idle shake and engine mounting resonance. Also, it must be able to control, like a shock absorber, the motion resulting from load conditions such as travel on bumpy roads. Second, for a small amplitude excitation over the higher frequency range, a compliant but lightly damped mount is required for vibration isolation and passenger comfort.

II. METHODOLOGY AND APPROACH

The finite element model of engine mount is created using CAD & Hypermesh and simulation of the engine mount is carried out using LS-Dyna. A non linear steady-state dynamic analysis is performed using dynamic properties for six different designs of commercially available rubbers and the results compared to the ones obtained using a hysteretic damping material model suggested by the automotive constructor. The present work is focused on representing the engine mount components via 3-D finite element model and performing iterative analysis using a commercial package LS-DYNA. The analysis is run for 20 ms time frame which captures the complete deformation of the engine mount. During impact, the mounts are expected to fail so as to allow the engine to drop down and avoid injury in the passenger compartment. The rear mount is tested for different designs by applying force in the X (+ ve X and – ve X direction) and Z (+ ve Z and – ve Z directions) global directions to find its suitability towards the required Force-Displacement curves in the test results. The suitable design is determined using an iterative procedure.

(a) Model setup

The model set up is as shown in figure 1. The base model consists of the engine mount assembly made up of the outer aluminium bracket which is fixed and the rubber is press fitted but in between that a steel ring is fitted. Then another aluminium bracket (inner bracket) is fitted in that a steel ring is present. The assembly is fixed at one end with a fixed rigid wall which simulates the welded components attaching to the engine mount assembly. The impact is simulated using the moving rigid wall which crushes the rubber. The moving rigid wall is given motion by means of a prescribed boundary motion as indicated in load-curve, which is illustrated in Fig 2.

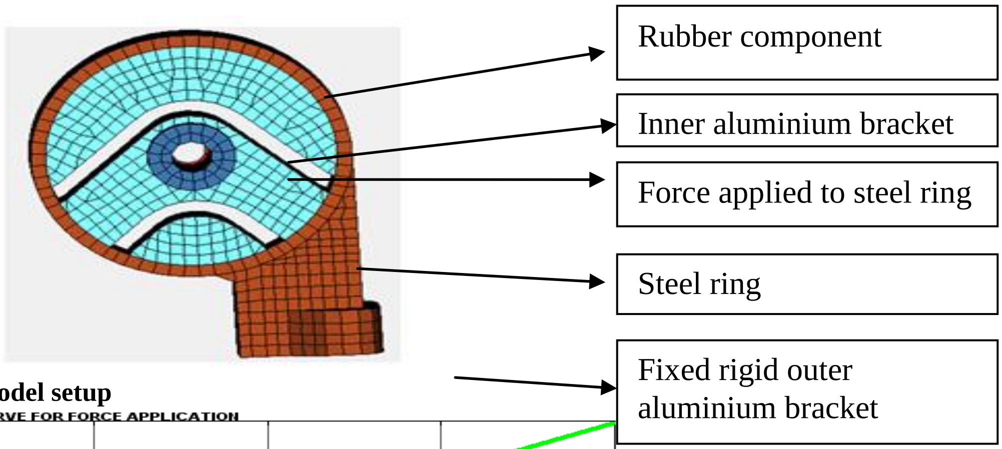


Fig.1: Base Model setup

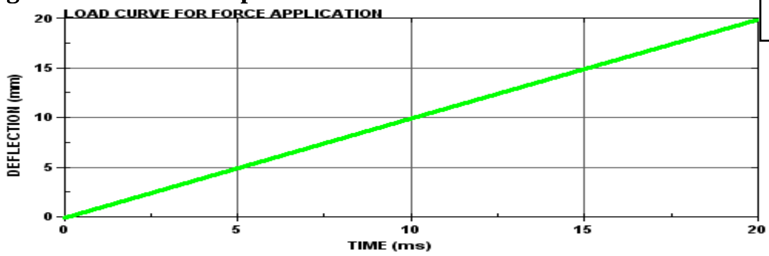
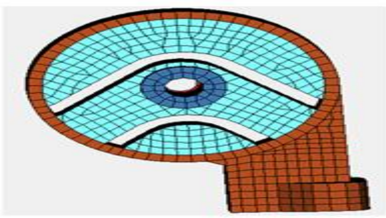


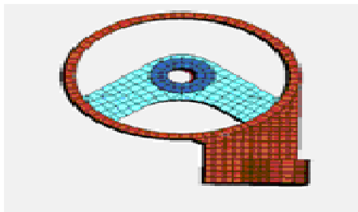
Fig.2: Load Application curve

(b) Different engine mount designs:

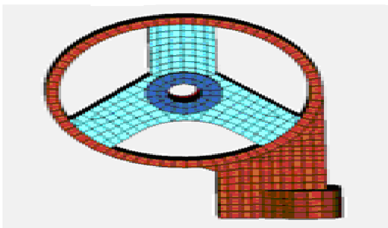
3(a) Basic Design of Engine Mount



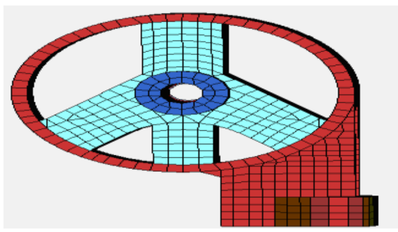
3(b) Design of Two Arm Engine Mount



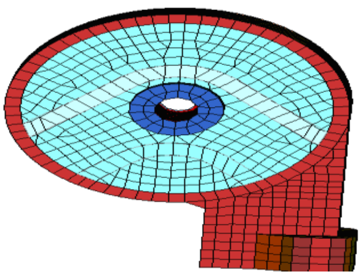
3(c) Design of Three Arm Engine Mount



3(d) Design of Four Arm Engine Mount



3(e) Design of Filler Arm Engine Mount



3(f) Design of Four Arm Symmetry Engine Mount

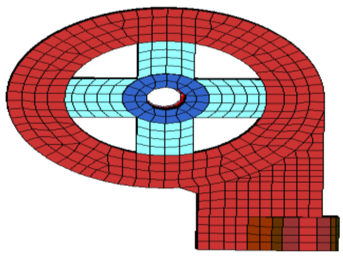


Fig.3: Different engine mount designs

III. Results and Discussion

(a) Basic Design of Engine Mount

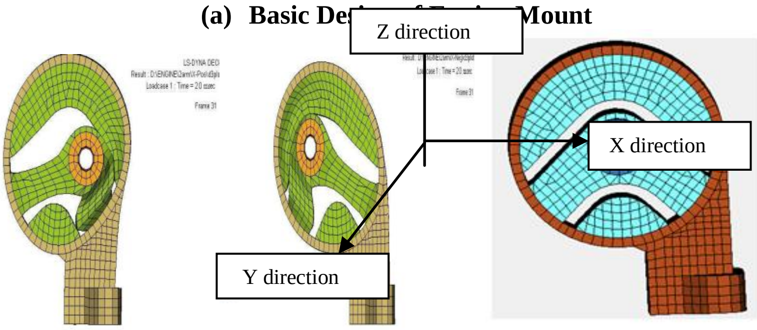


Fig.4 (a): Displacement of model in X-directions at 20 ms

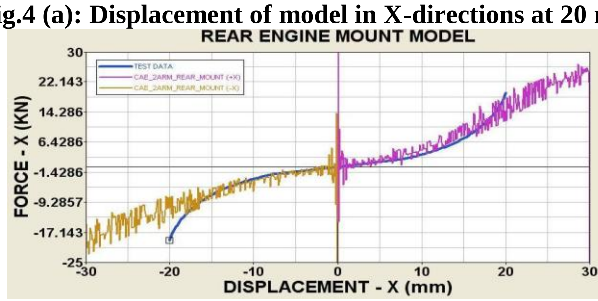
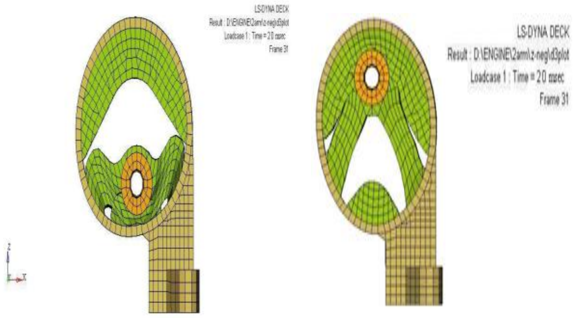


Fig.4 (b): Force Vs Displacement curve in positive and negative X directions (Energy Absorbed by Material)

To carry out the analysis a force of 30kN is applied to the rigid pin of engine mount in positive and negative X directions and positive and negative Z directions. The Force displacement curve which is a measure of the energy absorbed by the engine mount is obtained and this curve needs to match with experimental set up curve within 20 ms for representing the better energy absorption. During impact, the mounts are designed to fail within 20 ms so as to allow the engine to drop down and avoid injury in the passenger compartment but in this design the curve obtained from LS-Dyna approach does not follows the experimental test curve within 20 ms so this design is not suitable. Analysis is carried out for engine mount. Fig 4(a) and Fig 4(b) shows the basic design of engine mount and force v/s displacement curve in positive and negative X-direction curve for basic model of engine mount respectively. Similarly the results are obtained for two arm, three arm, four arm, filler arm and four arm symmetry engine mounts and they are illustrated in Fig.5 to Fig.13. Among all iteration the design of four arm symmetry engine mount curve obtained from LS-Dyna approach follows exactly the experimental test curve within 20ms and also this design has the highest natural frequency as illustrated in table.1.



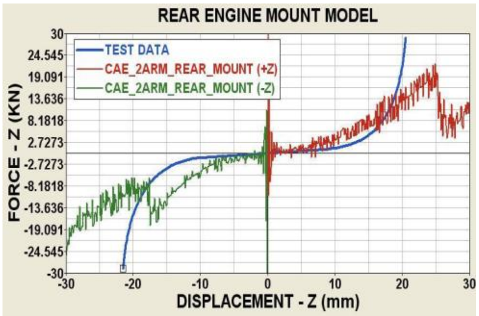
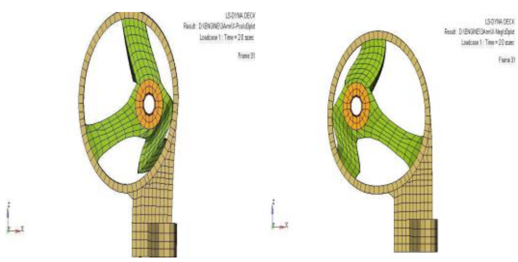


Fig.5 (a): Displacement of model in Z-directions at 20 ms Fig.5 (b): Force Vs Displacement curve in Positive and Negative Z directions

(b) Design of Three Arm Engine Mount



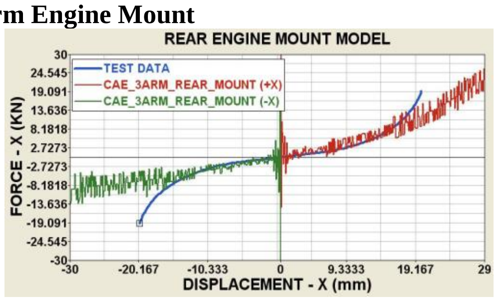


Fig.6 (a): Displacement of model in X-directions at 20 ms Fig.6 (b): Force Vs Displacement curve in Positive and Negative X directions

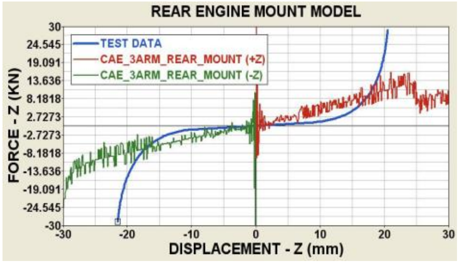
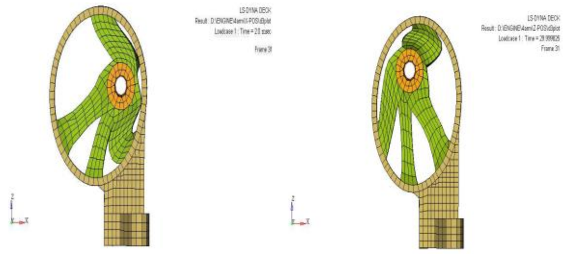


Fig.7 (a): Displacement of model in Z-directions at 20 ms Fig.7 (b): Force Vs Displacement curve in Positive and Negative Z directions

(c) Design of Four Arm Engine Mount



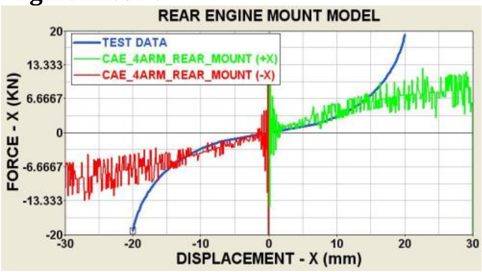
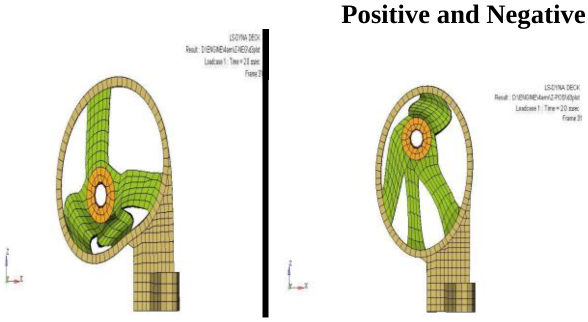


Fig.8 (a): Displacement of model in X-directions at 20 ms Fig.8 (b): Force Vs Displacement curve in Positive and Negative X directions



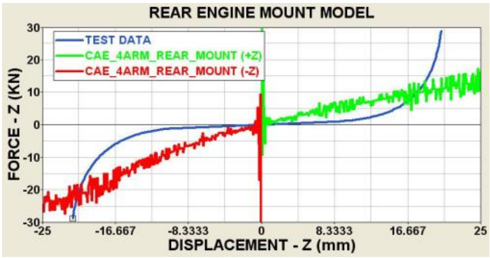
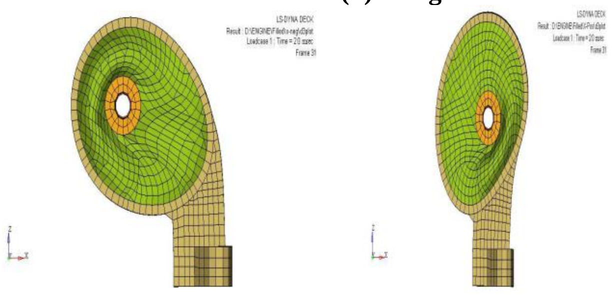


Fig.9 (a): Displacement of model in Z-directions at 20 ms Fig.9 (b): Force Vs Displacement curve in Positive and Negative Z directions

(d) Design of Filler Arm Engine Mount



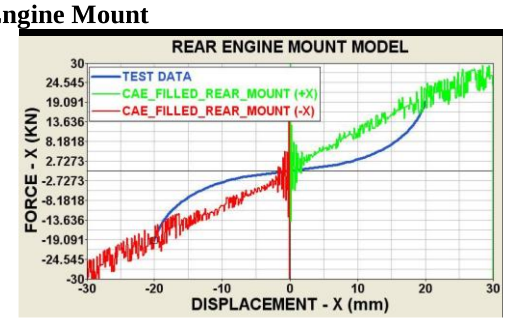
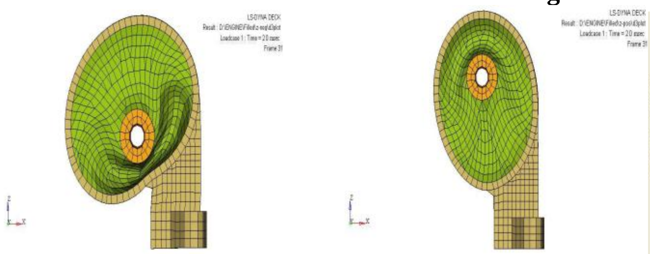


Fig.10 (a): Displacement of model in X-directions at 20 ms Fig.10 (b): Force Vs Displacement curve in Positive and Negative X directions



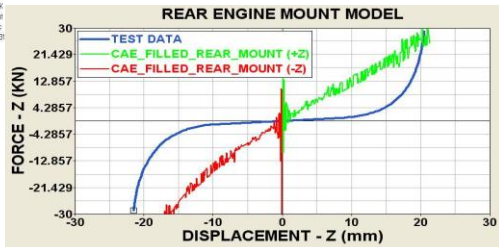


Fig.11 (a): Displacement of model in Z-directions at 20 ms Fig.11 (b): Force Vs Displacement curve in Positive and Negative Z directions

(d) Design of Four Arm Symmetry Engine Mount

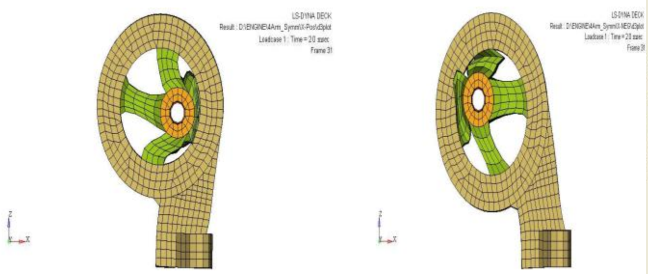
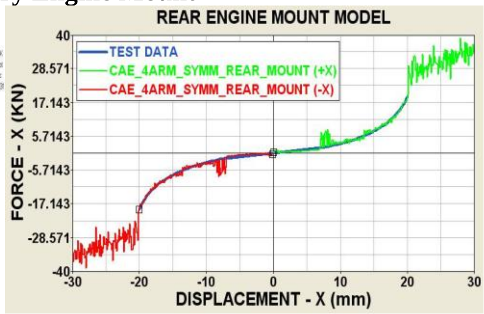



Fig.12 (a): Displacement of model in X-directions at 20 ms Fig.12 (b): Force Vs Displacement curve in Positive and Negative X directions

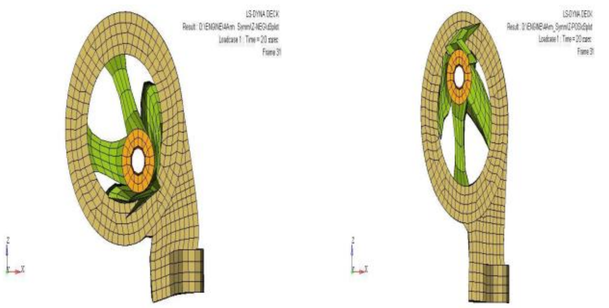
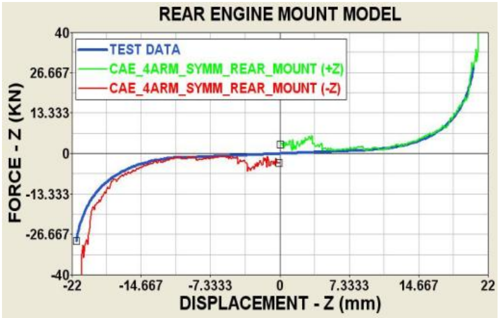



Fig.13 (a): Displacement of model in Z-directions at 20 ms Fig.13 (b): Force Vs Displacement curve in Positive and Negative Z directions

In this design the curve obtained from LS-Dyna approach follows the experimental test curve within 20 ms and also this design has the highest natural frequency amongst all design iterations. Hence we conclude that this design is best suited.

Table 1: Comparison of Frequency of all various iterations

ITERATIONS	Mode 1 in Hz	Mode 2 in Hz	Mode 3 in Hz	Mode 4 in Hz	Mode 5 in Hz	Mode 6 in Hz
2 Arm	1.1227	1.1308	1.1423	1.1455	1.1505	1.1517
3 Arm	1.0022	1.0265	1.1437	1.1493	1.1861	1.2516
4 ARM	1.0613	1.0663	1.1375	1.1794	1.2132	1.2356
FILLER ARM	1.0058	1.0159	1.0265	1.0289	1.0386	1.0388
4 ARM SYMMETRY	1.8035	2.0037	2.1348	2.1941	2.3245	2.3721

IV. CONCLUSIONS

The finite element model of engine mount is created using CAD & Hypermesh and simulation of the engine mount is carried out using LS-Dyna. The analysis results which are obtained from two arm, three arm, four arm, filler arm and four arm symmetry engine mounts in which the design of four arm symmetry engine mount curve obtained from LS-Dyna approach follows exactly the experimental test curve and also this design has the highest natural frequency amongst all design iterations.

The results indicated that the rubber used in the engine mount had increased the frequency from 1.2Hz (basic design) to 1.8Hz (four arm symmetry). As the design is changing in rubber, the mode of frequency increases and it has found that 1.8Hz is the frequency for the four arm symmetry mount design.

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