Design and analysis of engine mount for biodegradable and non-biodegradable damping materials

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Abstract.

In the present automotive world high importance is given to the comfort and safety of the passenger. The comfort to the passenger signifies many terms such as the seating structure, leg space, air conditioning etc. The most important thing is that all the vehicles are subjected to vibrations such as from the engine or from external factors. The vibrations produced from the engine are transferred to the entire vehicle structure and this is reduced by placing engine mounts between the engine and the chassis. Designing the proper type of mount holds the key for effective reduction of vibrations. In this article a new design of the engine mount is proposed and taken into finite element analysis. Also, material for the mounts are considered to play a vital role. In this along with two regular materials, a biodegradable material is also used for the dampers. More importance is given to the frequency response of the mount for different materials and the finite element analysis is performed for a four-cylinder inline engine with two mounts on either side.

1. Introduction

There are many reasons due to which vibrations are produced from the engine such as unbalanced forces in the engine, worn out spark plugs etc. Since there is no perfectly balanced engine, engine mounts come into picture. There are usually two mounts for the engine and a mount for the transmission. The mounts at the engine are called engine mount while the mount at the transmission is called transmission mount. In a single engine mount, one part of the mount is connected to the vehicle frame and one mount is bolted to the engine. The mount is made up of rubber material as not to have direct metal to metal contact between the engine and chassis [1]. The major problem in terms of material is that the dampers used in present stages are most commonly polyurethane or neoprene which are non-biodegradable and thus replacing the dampers with biodegradable material based on the frequency behaviour would be considered as a feasible solution in terms of environmental basis. The vibrations are produced both from the road and engine, thus the engine mounting should be stiff and highly damped. In some of the engine mounts the rubber is covered with fluid or a metal. A fluid-filled mount can have leakage issues in the long run.

The objective is to develop a new design for the engine mount and to perform static and modal analysis for different materials and to select the optimum material for the proposed design. The two
most important variables that are to be considered are the design of the engine mount structure and the materials used. The material used in the present automotive sector are polyurethane or neoprene rubber and in addition to that in this paper a biodegradable material which refers to Bamboo vinyl ester is used [2]. Another factor that has a significant effect is the angle at which the mount is placed. It is observed that as the angle at which the mountings are placed are decreased the effectiveness of vibration reduction also increases. The optimum value for the mount angle is termed to be 30 degrees and might vary based on design of the entire structure of the mount or the space available [3]. The proposed design in this part has a mount angle of 50 degrees, this is because of the bracket design is in a L shaped manner and decreasing the angle of the mounting would result in lesser material of the lower bracket and hence becomes an area of higher stress concentration.

2. Methodology
Initially the entire structure of the engine mount has been developed in the CATIA software and it is taken into ANSYS software where it is being solved for static structural and modal analysis. The proposed engine mount structure is developed for 2.0 L and 4-cylinder inline engine. The exact structure of the engine is converted into a block of dimension 700*621*443mm and then solved [4]. The weight of the engine in the static analysis is taken to be 120 kg and solved for the deformation and stress. The modal analysis is solved for both free-free run and forced. Based on the frequency response conducted the best material among polyurethane, neoprene and Bamboo vinyl ester for the proposed design is determined [5].

2.1 Model setup

![Figure 1. Engine placed on mount](image1)
![Figure 2. Engine mount structure](image2)

| Component | Description |
|-----------|-------------|
| 1         | Engine bracket |
| 2         | Rubber (damper) |
| 3         | Rubber (damper) |
| 4         | Chassis bracket |

The figure 1 represents an engine block resting on the two engine mounts. While the figure 2 represents the highlighted view of the mounts. The table 1 represents the components present in the assembly of the engine and its mount. The engine bracket holds the engine via nuts and bolts and next to it has a slot in which the lower portion of it is covered with the damper material. The engine bracket
and the chassis bracket are connected via another damper that is 3 (as mentioned in figure 2) which is considered to be the main damper since it contributes more in the vibration reduction. Then the chassis bracket is connected to the chassis via nuts and bolts.

3. FEM Methodology

3.1 Material properties

| Material             | Young’s modulus (MPa) | Density (kg/m$^3$) | Poisson ratio |
|----------------------|-----------------------|--------------------|---------------|
| Structural steel     | 200000                | 7850               | 0.30          |
| Cast iron            | 110000                | 7200               | 0.28          |
| Neoprene             | 2                     | 1230               | 0.48          |
| Polyurethane         | 900                   | 1270               | 0.39          |
| Bamboo Vinyl Ester   | 2380                  | 1150               | 0.4           |

3.2 Mesh generation

The entire model was taken into tetragonal mesh and the element order was defined as program controlled and the relevance centre was set to be medium. The mesh that has been setup on the assembly is shown in figure 3. Solid 187 element is selected with 10-noded tetrahedron to optimally solve the model without much computational time and processor capability[6,7]. To converge the results an h-type method with element size variation process along with second order condition is considered[8,9].

3.3 Finite element analysis for polyurethane as the damping material

Figure 3. Mesh generated on assembly

Figure 4. Loading and boundary conditions

Figure 5. Equivalent stress for polyurethane
Static structural analysis has been done by considering 1200 N and it is distributed on either side of the engine bracket as shown in figure 4. Chassis bracket is fixed at the holes provided. The figure 5 and figure 6 represent the stress developed and deformation in the assembly. The result of equivalent stress (von-Mises) is nearly 1Mpa which is quite low. But when considered with all the tangential and radial loads that are generated in the engine the stress will increase to a certain extent but will not cross the yield limits. The deformation corresponding to the particular load is 0.0056mm.

3.3.1 Modal analysis using polyurethane
The frequency behaviour of the engine mount and the deformation at each frequency is shown below in the table for free-free run and forced analysis respectively.

| Mode | Frequency (Hz) | Deformation(mm) | Mode | Frequency (Hz) | Deformation(mm) |
|------|----------------|-----------------|------|----------------|-----------------|
| 1    | 1.58e-004      | 0.71921         | 1    | 4.095          | 1.258           |
| 2    | 3.24e-004      | 0.71921         | 2    | 42.255         | 1.2558          |
| 3    | 0.92122        | 0.79122         | 3    | 50.447         | 1.1772          |
| 4    | 2.5343         | 1.5709          | 4    | 56.364         | 1.1602          |
| 5    | 2.835          | 1.3305          | 5    | 59.584         | 1.4434          |
| 6    | 111.69         | 1.9894          | 6    | 74.495         | 1.3525          |
| 7    | 112.99         | 8.5227          | 7    | 998.02         | 1.5475          |
| 8    | 113.4          | 11.593          | 8    | 998.86         | 11.497          |
| 9    | 117.23         | 11.653          | 9    | 1359           | 11.498          |
| 10   | 129.08         | 14.0001         | 10   | 1378.6         | 7.2762          |
| 11   | 129.47         | 14.012          | 11   | 1389.7         | 13.23           |
| 12   | 403.41         | 10.881          | 12   | 1489.7         | 11.253          |

3.4 Finite elemental analysis for neoprene as the damping material

![Figure 7. Equivalent stress for Neoprene rubber](image1)

![Figure 8. Total deformation for Neoprene rubber](image2)
The slots and the main damper have been replaced with neoprene rubber whose properties are mentioned in Table 2. The figure 7 and figure 8 represent the stress developed and deformation for the boundary and loading conditions as mentioned in figure 4. For the same load of 1200N it is solved for static structural and is observed that the stress developed is 1.365 MPa which is slightly more compared to the polyurethane rubber.

3.4.1 Modal analysis using neoprene

Similar kind of response table as recorded in Table 3 and Table 4 is taken with the material replaced by neoprene rubber. The Table 5 and Table 6 indicates free-free and forced analysis respectively.

| Table 5. Free-free modal analysis |
|-----------------------------------|
| Mode | Frequency (Hz) | Deformation (mm) |
|------|----------------|------------------|
| 1    | 1.2313e-004    | 0.6407           |
| 2    | 2.5191e-004    | 1.5114           |
| 3    | 4.5874e-002    | 1.762            |
| 4    | 2.8026         | 2.7914           |
| 5    | 3.1671         | 8.9699           |
| 6    | 5.8204         | 8.1868           |
| 7    | 5.8287         | 8.307            |
| 8    | 5.8919         | 10.333           |
| 9    | 6.0723         | 10.252           |
| 10   | 6.0967         | 8.213            |
| 11   | 6.1899         | 9.5354           |
| 12   | 20.374         | 9.5343           |

| Table 6. Forced modal analysis |
|--------------------------------|
| Mode | Frequency (Hz) | Deformation (mm) |
|------|----------------|------------------|
| 1    | 0.37592        | 1.2416           |
| 2    | 2.2698         | 1.316            |
| 3    | 2.5226         | 1.3362           |
| 4    | 2.8521         | 1.4613           |
| 5    | 3.0858         | 1.191            |
| 6    | 3.7227         | 1.604            |
| 7    | 148.27         | 47.203           |
| 8    | 148.64         | 47.393           |
| 9    | 148.72         | 35.05            |
| 10   | 151.71         | 35.213           |
| 11   | 151.71         | 61.115           |
| 12   | 212.68         | 61.224           |

3.5 Finite element analysis for bamboo vinyl ester damping material

The material has been replaced with the biodegradable material termed as bamboo vinyl ester and is subjected for static structural analysis. The figure 9 and figure 10 represent the stress developed and the deformation in the assembly. The stress developed is 0.065 MPa and the total deformation corresponds to 3.4*10^-5 mm which is equivalent to zero.

| Figure 9. Equivalent stress for bamboo vinyl ester |
|---------------------------------------------------|
| Figure 10. Total deformation for bamboo vinyl ester |

3.5.1 Modal analysis for bamboo vinyl ester

Frequency response is taken from the modal analysis as shown below in the table 7 and 8 [10].
4. Conclusion

The analysis for the materials that is neoprene, polyurethane and bamboo vinyl ester had been carried out and from the structural point of view in terms of both deformation and stress developed in the mounts bamboo vinyl ester has yielded better results than neoprene and polyurethane rubber. From modal point of view, the resulting frequency plays the deciding role for selection of the material for the proposed design. In case of polyurethane the maximum frequency is 403.41 Hz and 1489.7 Hz for free and forced analysis respectively. While in case of neoprene the maximum vibration is determined as 20.374 Hz and 212.68 Hz for free and forced analysis respectively. For bamboo vinyl ester the maximum frequency corresponds to 1512.6 Hz and 1997.7 Hz in free and forced modal analysis respectively. Since the amplitude is lesser for higher frequency, which intern means that the effectiveness of vibration reduction is higher for Bamboo vinyl ester. As considered for deformation, it is higher on the side of neoprene in the modal analysis. Hence, the proposed design of the engine mount structure is better with the biodegradable material that is bamboo vinyl polymer. This material also accounts for the environmental safety too.

Remark

With additional factors coming into picture selection of material again becomes more difficult. Factors such as cost, temperature, weight etc. plays a vital role. The proposed design has damping on two sides for a single mount. It has a slot wherein a material with lesser cost and a low damping property can be filled and another material with good damping properties can be accommodated i.e. in the position of main damper. Nevertheless, both the material will contribute in reduction of vibrations produced from the engine and transfer lesser amplitude and high frequency patterns to the chassis.

References

[1]. https://www.carsdirect.com/car-repair/5-causes-of-engine-vibration
[2]. https://www.isuzu.co.jp/world/product/industrial/motive/s3a.html
[3]. Phadnis, Vrushank S., Jimmie Harris, Shile Ding, Chen Arambula, Ben Collins, Mark Jeunnette, and Amos Winter. Engine Mount Design Strategies to Mitigate Linear Vibrations in a Tata Nano volume 3: 20th International Conference on Advanced Vehicle
Technologies; 15th International Conference on Design Education, 26-29 August, 2018, Quebec City, Quebec, Canada, ASME, 2018. © 2018 ASME.

[4]. https://www.isuzu.co.jp/world/product/industrial/motive/s3a.html

[5]. James J. Sargianis, Hyung-Ick K, Erik A and Jonghwan S. Sound and vibration damping characteristics in natural material based sandwich composites 17 September 2012

[6]. Hallad S A, Banapurmath N R, Patil A Y, Hunashyal A M and Shettar A S 2015. Studies on the effect of multi-walled carbon nano tube–reinforced polymer based nano-composites using finite element analysis software tool, Journal of Nano engineering and Nano systems, SAGE Publications, DOI:10.1177, 13, 122015.

[7]. Kohli A, Ishwar S, Charan M J, C M Adarsha, Patil A Y and Kotturshettar B B, Design and Simulation study of pineapple leaf reinforced fiber glass as an alternative material for prosthetic limb, IOP Conf. Ser.: Mater. Sci. Eng. Volume 872, 2020, 012118, doi.org/10.1088/1757-899X/872/1/012118.

[8]. D N Yashasvi, Badkar J, Kalburgi J, Koppulkar K, Purohit K, Patil A Y., Fattepur G and Kotturshettar B B, Simulation study on mechanical properties of a sustainable alternative material for electric cable cover, IOP Conf. Ser.: Mater. Sci. Eng. Volume 872, 2020, 012016, doi.org/10.1088/1757-899X/872/1/012016.

[9]. Kandekar P, Acharaya A, Chatta A, Kamat A, Patil A Y. and Kotturshettar B B, A feasibility study of plastic as an alternative to air package in performance vehicle, IOP Conf. Ser.: Mater. Sci. Eng. Volume 872, 2020, 012076, doi.org/10.1088/1757-899X/872/1/012076.

[10]. Patil A Y., Banapurmath N. R., Shivangi U S, Feasibility study of Epoxy coated Poly Lactic Acid as a sustainable replacement for River sand, Journal of Cleaner Production, Elsevier publications, IF: 7.24, Volume 267, 2020. doi.org/10.1016/j.jclepro.2020.121750,