COMPARISON OF THE MECHANICAL PROPERTIES OF DIFFERENT MODELS OF AUTOMOTIVE ENGINE MOUNTING

Haval Kamal Asker
Mechanical Engineering, Faculty of Agriculture and Forestry, University of Duhok, Iraq
E-Mail: havaldosky78@yahoo.com

ABSTRACT

In this paper, a novel model was proposed to reduce the weight of the rib of the engine mounting. The suggested model is analyzed numerically and simulated using a computer program package (ANSYS 11) to perform the FEM computations. In addition, two more models for the engine mounting part have been and built and applied to the same boundary conditions as for the suggested model. The results of the stresses and deformations for the three models of the engine mount were compared to each other. The proposed model of the engine mount had a superior performance over the other the standard model in terms of weight reduction, whereas, 51.5% of the weight was reduced with the proposed model maintaining an acceptable level of yield stress.

Keywords: engine mount, von mises, FEM, weight reduction.

1. INTRODUCTION

Many efforts were conducted for the purpose of modification of the mechanical parts of vehicles in order to improve their performance and vibration response. These characteristics have a vital impact on the mechanical performance of the overall system balance.

In addition, redesigning the mechanical models play an important role in improving the sustainability of the system against the resultant stresses and strains, therefore, significant consideration should be taken for this when designed by engineers.

Engine mounts support the engine and dampen noise and vibration. Engine mounts isolate the vibrations of the engine from the chassis, thereby; impact forces are not transmitted to the rest of the vehicle. Engine mount could be defined as a device that reflects and absorbs waves of oscillatory energy.

The metal bracket part of the engine mount provides the mechanical support and attachment joints for the engine mounts. However, engine mounts are used to connect a vehicle engine to the car chassis. They are usually made of rubber and metal. The metal portion is connected to the engine on one side and to the chassis on the other side. The rubber is in-between to provide some flexibility.

Automotive engine mounts are one of the most important parts in the vehicle because they receive impact forces and disturbances from both the road and the reciprocating parts inside the I.C. engine. This consecutively produces torsion vibration that affects the engine mounting structure as well as the joints.

A dynamic design modeling issues for auto motives structures was studied; however, a focus was only on the illustration of the role of hydraulic engine mount [1].

This paper proposes three models for the engine mounting with different rib design. The theory of Hyper - Elastic material is introduced and the method of linear FEA (Finite Element Analysis) is studied [2]. The element type is chosen to be solid 3D (8 nodes) and the material mode behavior is structural linear elastic isotropic. The resulted stresses and deformations are analyzed to have an insight on the best design performance for engine mount in term of stress tolerance, size, and weight.

This paper has insight into comparing the stress, weight, and deformations for all models under the same boundary and loading conditions which applied to them in a homological manner to optimize the method of design.

2. METHODOLOGY

In this paper, Finite Element Analysis and Model analysis were used to determine the characteristics of the engine mounting. To obtain a comprehensive insight, the three models of the engine mounting were modeled using (ANSYS) software according to the original size of structures with various rib design. The purpose was to determine the stresses and deformations affect's on the engine mounting models during loading conditions and to optimize the design that make a reduction in the weight of the rib of the engine mounting models.

2.1. Finite element analysis of the engine mounting models

Finite element method has become an indispensible tool for the design of the vehicle structures [3]. In order to conduct a FE Analysis, it is necessary to create a solid model for an engine mounting as well as creating a FE model. In this paper, static analysis was carried out for the engine mounting considering load effects.

The main phases for finite element analysis are: 1-Preprocessing phase.2-Solution phase.3- Post-processing phase. In the preprocessing phase, the engine mounting models will be created, meshed and divided into nodes and elements. In addition to the abovementioned steps, preprocessing phase include developing equation for an element, defining the model material, applying boundary conditions, initial conditions and for applying loads. While, the analysis of the models is done in the solution

VOL. 8, NO. 6, JUNE 2013 ISSN 1819-6608
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phase according to the boundary conditions and load conditions that are applied on the models.

Finally, the results of the stresses, strains and deformations results from analyzing the redesigned rib of the engine mounting models can be listed and plotted through the post-processing phase [4].

2.2. Models of the engine mounting

In this paper, three models of the engine mounting have been studied and analyzed. The main body of the engine mounting is identical for all the three models with the base of the model has a width of 102 mm and a length of 129 mm and a height of 26 mm. The back of the engine mounting body is inclined with an angle equal to 54.73^{o} and the following dimensions; width of 102 mm, length of 180 mm, and a height of 26 mm. A hollow cylinder is attached to the back of the engine mounting which contains the rubber bush. The material properties are: Modulus of Elasticity (E=207 E^{3} MPa), Poisson's ratio (0.3), Yield Stress (550 MPa) [5].

2.2.1. First model

The three models differ from each other in terms of the rib design. The first model was built with the original engine mounting shape (standard rib design) as shown in Figure-1. The rib of the first model is extended from the front of the engine mounting base to the inclined back of the engine mounting (at a point rise about 65.8 mm from the base). Figure-2 shows the meshing of the first model in which the number of elements was (191386) and the number of nodes was (38698).

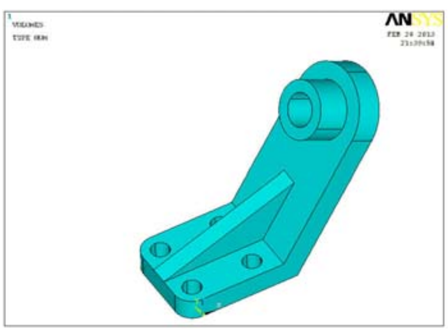

Figure-1. First model (engine mount with standard rib design).

Figure-2. Meshing of first model (engine mount with standard rib design).

2.2.2. Second model

The second model of the engine mount is shown in Figure-3 which was built with the suggested rib design. The rib of the engine mount in the second model has a lesser area and a reduction in the weight of the rib compared to the standard rib design in the first model. For this model, the number of elements was (180687) and the number of nodes was (36562). The meshed model is shown in Figure-4.

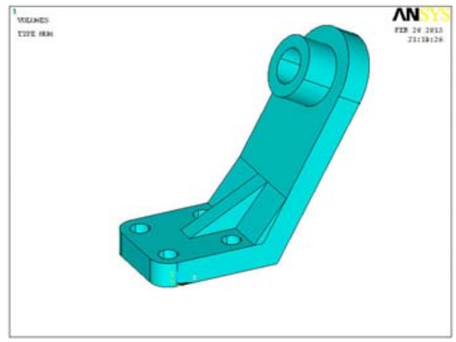

Figure-3. Second model (engine mount with suggested rib design).

Figure-4. Meshing of second model (engine mount with suggested rib design).

2.2.3. Third model

Figure-5 shows the third model of the engine mount. The base of the engine mount part in this model is similar to the base of the first model. In addition, the back of the engine mount has the same dimensions as for the first model. However, it was built without a rib to compare the effect of having a rib in the engine mount model in term of yield stress. Figure-6 set out the meshed model in which the number of elements was (172870) and the number of nodes was (35252). A stress and deformation analyses is required to be undertaken to compare the results of the three engine mounting models.

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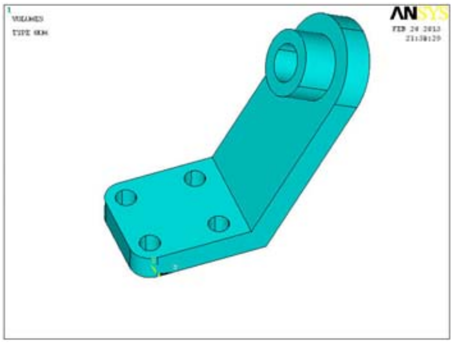

Figure-5. Third model (engine mount without rib).

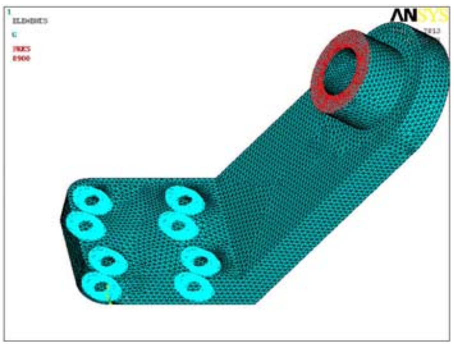

Figure-6. Meshing of third model (engine mount without rib).

2.3. Boundary conditions

The same boundary and load conditions are applied to the three models of the engine mounting to ensure providing the same environments for all models. The four bolts holes in the base of the engine mounting are considered fixed in all directions. A pressure of 10 MPa was applied on the bush hole which located in the back of the engine mounting [6].

3. RESULTS AND DISCUSSIONS

The three models of engine mounting (with standard rib, with suggested rib and without rib) were built and analyzed numerically using the (ANSYS 11) package program. Table-1 remarks all the results obtained from the numerical analysis for the three models. The following results were taken into consideration when designing the model; Von Misses stresses, weight reduction, and the deformations happen to the models. However, the results can be summarized into three patterns:

a) Maximum von - misses stresses

Figure-7 shows Von-Mises stress of the model with standard rib which was (108.26 MPa). The Von Mises stress reach (19.7 %) out of the value of the Yield stress. This model has been built exactly with the engine mounting dimensions with standard rib.

Von Mises stress for the second model (engine mounting with suggested rib design) is shown in Figure-8. It records (159.64 MPa). When comparing the value of Von Mises stress with the value of the Yield stress, it gives a value of 29% from the value of the Yield stress.

The effect of the rib existence in the engine mounting model was depicted clearly in Figure-9. The Von Mises stress for the third model which was designed without rib was (239.16 MPa). It hits a value of (43.48%) from the Yield stress value. It was concluded that the lowest value for the Von Mises stress was for the first model and the greatest value was for the third model.

b) The reduction in the rib weight

One of the main objectives of this paper is to make a reduction in the weight of the rib. Three models were taken into consideration in the study. Nevertheless the comparison was among the first model (engine mounting with standard rib design) and the second model (engine mounting with suggested rib design). However, the third model was built without rib just to illustrate the effect of rib existence on the stress. The second model (engine mount with suggested rib design) made a net reduction in the rib weight of (51.5%). Figure-1 and Figure-3 show the first model (engine mounting with standard rib design) and second model (engine mount with suggested rib design) respectively.

c) Nodal deformations

Figures 10, 11 and 12 show the deformation in X direction for the first, second, and third models, respectively. The deformation in X direction for the engine mount with standard rib design (first model) was (0.083 mm); while the deformation in X direction for the engine mount with suggested rib design (second model) was (0.123 mm). The deformation in X direction for the engine mount without rib (third model) was (0.198 mm). The greatest deformation was in the engine mount without rib. It was clear from Figures 10, 11 and 12 that the deformations in X direction for the three models make approximately the same behavior.

The deformation in Y direction for the first, second, and third models is depicted in Figures 13, 14 and 15, respectively. For the engine mount with standard rib design (first model), the deformation in Y direction was (0.529 E^{-3} mm) and it was (0.827 E^{-3} mm) for the engine mount with suggested rib design (second model), while it mark (0.00123 mm) for the engine mount without rib. The lowest value for the deformation in Y direction was for the first model while the greatest value was for the third model.

Figures 16, 17 and 18 express the deformations in Z direction for the three models respectively. It was noticed that the deformation in Z direction for engine mount with standard rib design (first model) was (0.828 E^{-3} mm) while the deformation in Z direction for engine mount with suggested rib design (second model) was (0.001 mm). In addition, it was shown that the deformation in Z direction for engine mount (third model) without rib was (0.661 E^{-3} mm).

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Figures 20, 21, and 22 are showing a comparison between the three models in terms of deformations in X, Y, and Z directions, respectively.

The results of the deformations in Z direction were interesting. After analyzing the results it was concluded that the lowest value for the deformation in Z direction was for the engine mount without rib (third model) followed by the engine mount with standard rib design (first model) then the engine mount with suggested rib design (second model). This may be caused due to the existence of the rib in the engine mount in addition to the contact area of the rib.

Table-1. Comparing the numerical results for the three models.

Stresses and deformations	Engine mounting with standard rib design	Engine mounting with suggested rib design	Engine mounting without rib
Von Mises stress (MPa)	108.26	159.684	239.161
S x (stress in X dir.) MPa)	94.1	142.116	259.794
S y (stress in Y dir.) MPa)	48.0	61.446	107.424
S z (stress in Z dir.) (MPa)	66.64	62.121	97.137
S xy (stress in XY dir.) (MPa)	30.99	41.079	50.11
S yz (stress in YZ dir.) (MPa)	18.15	18.959	20.518
S xz (stress in XZ dir.) (MPa)	13.9	15.704	20.338
U x (deform. In X dir.) mm	0.083	0.123	0.198
U y (deform. In Y dir.) mm	0.529 E^{-3}	0.827 E^{-3}	0.00123
U z (deform. In Z dir.) mm	0.828 E^{-3}	0.001	0.661 E^{-3}

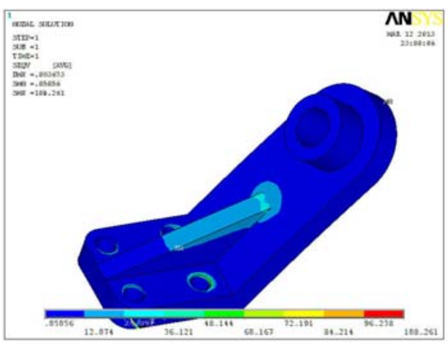

Figure-7. Von Mises stress for engine mount with standard rib design.

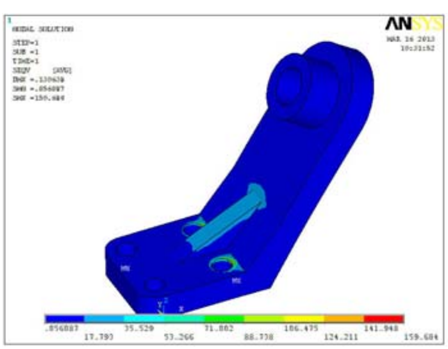

Figure-8. Von Mises stress for engine mount with suggested rib design.

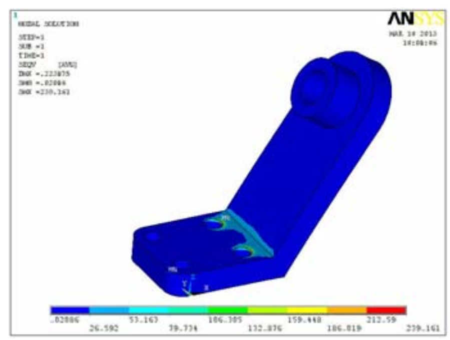

Figure-9. Von Mises stress for engine mount without rib.

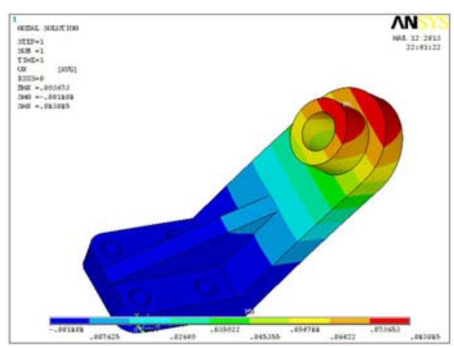

Figure-10. Deformation in X direction for engine mounts with standard rib design.

VOL. 8, NO. 6, JUNE 2013 ISSN 1819-6608
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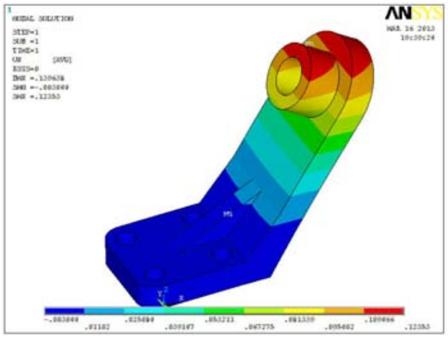

Figure-11. Deformation in X direction for engine mount with suggested rib design.

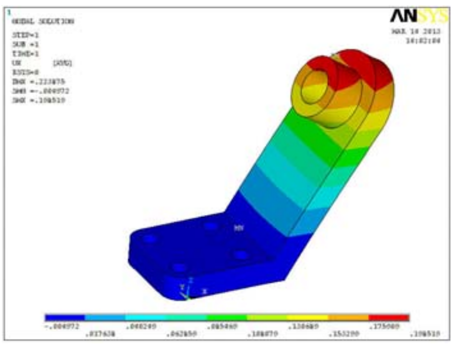

Figure-12. Deformation in X direction for engine mounts without rib.

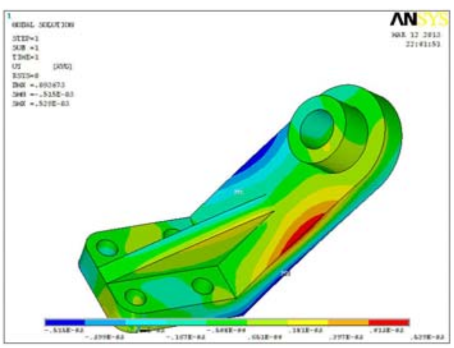

Figure-13. Deformation in Y direction for engine mounts with standard rib design.

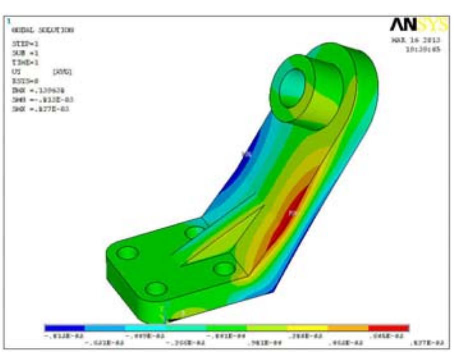

Figure-14. Deformation in Y direction for engine mount with suggested rib design.

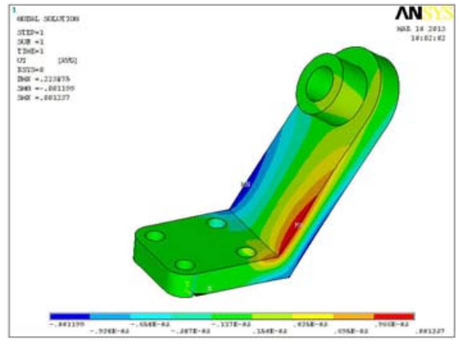

Figure-15. Deformation in Y direction for engine mounts without rib.

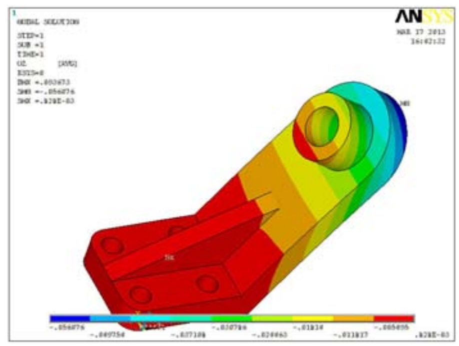

Figure-16. Deformation in Z direction for engine mounts with standard rib design.

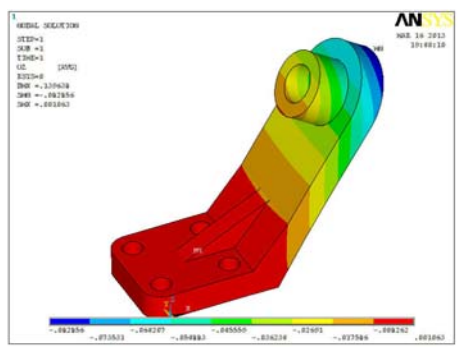

Figure-17. Deformation in Z direction for engine mount with suggested rib design.

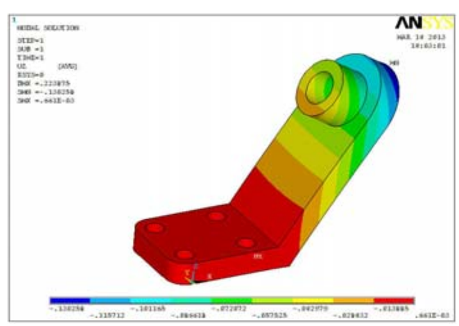

Figure-18. Deformation in Z direction for engine mounts without rib.

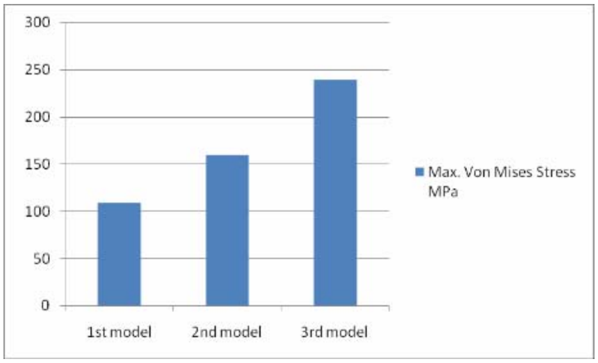

Figure-19. Comparing the numerical results of the maximum Von Mises Stresses.

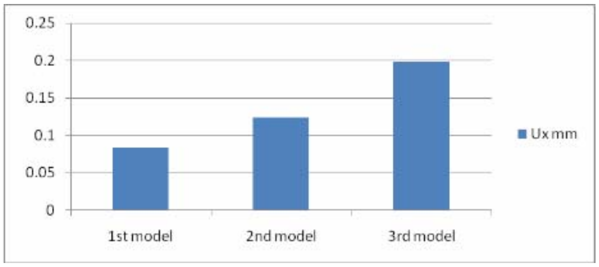

Figure-20. Comparing the numerical results of the maximum Def. in X direction.

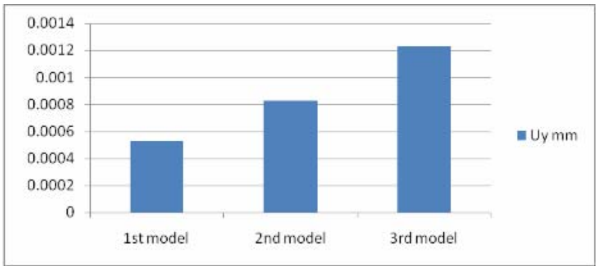

Figure-21. Comparing the numerical results of the maximum Def. in Y direction.

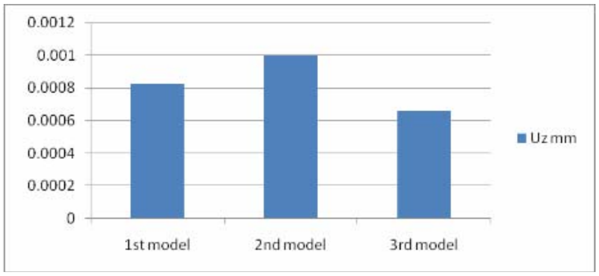

Figure-22. Comparing the numerical results of the maximum Def. in Z direction.

4. CONCLUSIONS

In this paper, three models of the engine mounting part were built, numerically simulated, and analyzed. The aim of this paper is to propose a novel rib design for the engine mount part which ensures a reduction in the rib weight without exceeding the allowable Von Mises stresses. The numerical results showed a reduction of 51.5% in the rib weight of the suggested model. In terms of stresses, Von Mises stress in the engine mount with the suggested rib design remains within the allowable values of the Yield stress. The proportion of Von Mises stress in the engine mount with standard rib design was (19.7%) with respect to the Yield stress value. On the other hand the proportion of Von Mises stress was (29%) with respect to the Yield stress value in the engine mount with suggested rib design which means that the Von Mises stress maintained within an allowable value.

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