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Static Behaviour of Engine Mounting Bracket

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Abstract: In this work an attempt was made to analyse the engine mounting bracket. Design includes the modelling of the engine mounting brackets by taking into account all packaging constraints. Analysis includes Static Analysis of engine mounting bracket. The main purpose of this study is to examine the natural frequency of by analytically and through developing the model and self excitation frequency of engine bracket. An attempt was made to check whether the natural frequency of engine mounting bracket is less than self excitation frequency of engine bracket. Hence this work is carried by using ERW-1, ERW-2, aluminium and magnesium alloys for the engine mount bracket. The results are analysed for stresses and deformations.

Keywords: ANSYS, static structure, ERW-1 steels, ERW-2 steels.

1. INTRODUCTION

In an automotive vehicle, the engine rests on brackets which are connected to the main-frame or the skeleton of the car. Hence, during its operation, the undesired vibrations generated by the engine and road roughness can get directly transmitted to the frame through the brackets[1]. This may cause discomfort to the passenger(s) or might even damage the chassis. When the operating frequency or disturbance approaches the natural frequency of a body, the amplitude of Vibrations gets magnified. The first and the foremost function of an engine mounting bracket is to properly balance (mount) the power pack (engine & transmission) on the vehicle chassis for good motion control as well as good isolation[2].

The need for light weight structural materials in automotive applications is increasing as the pressure for improvement in emissions and fuel economy increases. The most effective way of increasing automobile mileage while decreasing emissions is to reduce vehicle weight. The strong emphasis on the cost has demanded the component manufacturers to improve the performance of their materials and to find the methods to deliver these materials at reduced cost[3]. There are a number of noise and vibration sources that affect the vehicle body. The noise and vibration occur because the power that is delivered through bumpy roads, the engine, and suspension result in the resonance effect in a broad frequency band. The ride and noise characteristics of a vehicle are significantly affected by vibration transferred to the body through the chassis mounting points from the engine and suspension[2-3]. Vibration damping can be either provided by using separate dampers (anti-vibration mounts) or by suitably deciding the material and dimensions of the brackets. Moreover, the brackets also undergo deflection under static and dynamic loads[1].

The mounting system is the primary interface between the power train and the frame therefore, it's vital to the determination of the vibration isolation characteristics. There are two major problems that engineers must deal with when it comes to vibration isolation. The first problem is force isolation, which is frequently encountered in rotating or reciprocating machinery with unbalanced masses. The main objective in this problem is to minimize the force transmitted from the machine to the supporting foundation[5]. The second problem is motion isolation. This is broadly achieved by mounting equipment on a resilient support or an isolator such that the natural frequency of the equipment-support system is lower than the frequency of the incoming vibrations to be isolated. The natural frequency of the mounting system should be lower than the engine disturbance frequency to avoid the excitation of the mounting system resonance. This will ensure a low transmissibility.

In diesel engines the engine mounting is one of the major problems. Due to the Un-throttled condition, and higher compression ratio of the diesel engine, the speed irregularities particularly at low Speed and Low load conditions and are significantly higher than gasoline engines. By optimizing the thickness and shape of major mounting points made it possible to design a vehicle with optimized weight and performance at initial designing stages[6]. Studies shows that the brackets saved 38% mass (0.86 kg the expected and resultant benefit is different for each application. Range of savings are 20% to 38% in the authors' experience to 0.53 kg) [7].

Engine-induced vibrations may be divided into to main categories: (a) low-frequency vibrations, in which the rigid body motion modes are engaged, and (b) high-frequency vibrations, in which structure-borne noises may alter the passenger's comfort. Almost all research performed so far in the field of optimal isolation of the engine-induced vibration has been restricted to the first category[7].

Some early works focusing on the engine-mount system optimization were developed by Kim and Singh (1995), Royston and Singh (1996), and Singh (2000). Singh (2000) studied the behaviours of vibro-acoustic models of passive and adaptive hydraulic engine mounts using quarter car models with discrete components. Bretl (1993) proposed a method to determine the minimal vibration response. His work was mainly focused on the effects of mount location changes on the lateral and vertical responses at the driver's hip using the rigid body modes. A literature review relevant to the analysis of the automotive vehicle engine mount systems was presented by Yu (2001). Lee et al. (2001) used the concept of the structure-borne acoustic transmission path of energy identification.

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The vibration power flow through an isolation system with multiple isolators was investigated to evaluate the effectiveness of each isolator. Test results were used instead of modelling the system. Kim and Lee (2008) and Kim et al. (2008) proposed a hybrid transfer path analysis to simulate interior noise caused by the vibration of the power train of the vehicle.

1.1. FINITE ELEMENT ANALYSIS:

Finite Element Analysis is a mathematical representation of a physical system comprising a part/assembly (model), material properties, and applicable boundary conditions (collectively referred to as pre-processing), the solution of that mathematical representation (solving), and the study of results of that solution (post-processing). Simple shapes and simple problems can be, and often are, done by hand. Most real world parts and assemblies are far too complex to do accurately, let alone quickly, without use of a computer and appropriate analysis software. The numerical technique has advantages of experimental as well as analytical method. This analysis requires less resources compared to that of experimental methods. Finite element analysis (FEA) is a powerful engineering tool that can solve many kinds of engineering problems to as high degree of precision as necessary. In essence, the finite element is a mathematical method for solving ordinary & partial differential equations. FEM is a computational technique used to obtain approximate solutions of boundary value problems in Engineering. This involves deciding what parts are important and what unnecessary detail can be omitted i.e. disregard any small geometric irregularities; consider load as concentrated, homogenized composite material properties. Then we choose the theory which best describes the behaviour of the model such as the behaviour best described by beam theory, plate bending theory, plane elasticity, plane strain or plane stress formulations. When modelling something in FEA attention must be paid to what you are actually trying to achieve.

1.1.1 ANSYS PACKAGE:

ANSYS is commercial finite-element analysis software with the capability to analyze a wide range of different problems. ANSYS runs under a variety of environments, like UNIX and Windows. ANSYS solves governing differential equations by breaking the problem into small elements. The governing equations of elasticity, fluid flow, heat transfer, and electromagnetism can all be solved by the finite-element method in ANSYS. The ANSYS has multiple windows incorporating Graphics user interface, pull down menus, dialog box and tool bars. There are three basic steps involved in ANSYS finite element analysis.

1. Pre-processing phase
2. Solution phase
3. Post processing phase

Fig 1 location of engine mounting bracket

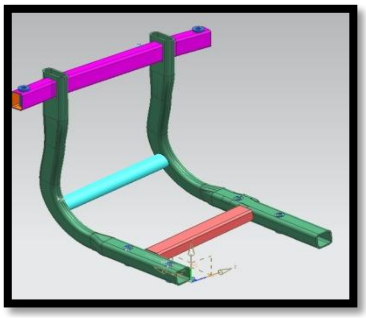

Fig 2: Isometric view of the mounting bracket

1.1.2 ISHIKAWA DIAGRAM

The study and analysis of the problem present here would be easy to visualize by adopting the Ishikawa method for fault finding. The Ishikawa diagram provides a visualization of a problem with respect to factors affecting it. Such as, equipment, process, people, materials, environment, etc. Arranging all such factors in the form of the Ishikawa diagram, provides a reasonable and logical guideline for analysis and fault finding. The diagram present here is the Ishikawa diagram constructed for the component being studied. Here following points are considered:

1) Methods: This point summarizes the setup and different manufacturing processes used for manufacturing the component. It deals with over viewing the production process. However, only mechanical attributes are considered in this point.

2) Materials: Here, materials being used for the production are checked. The quality and suitability of the material being used are two main factors contributing to the overall strength of the component.

3) Measurement: Measurement point deals with the different measuring systems used for the component metrology. Tolerances and allowances are studied in combination with the previous two points, i.e. Methods, Materials.

4) Environment: In this bit, the ambient conditions of production are studied. However, the component being analyzed does not require very high degree of precision, and hence this point has less significance in the overall fishbonediagram.

5) Man: This point deals with the labor and the skills of the workforce available for the production of this component. A worker with dissatisfactory skills can lead to a faulty end product.

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6) Mechanical Processes and Usage: This point studies specified mechanical operations done on the raw material, such as hydro forming, welding etc. Also the nature of usage is taken into account so as to precisely judge the cause of the problem.

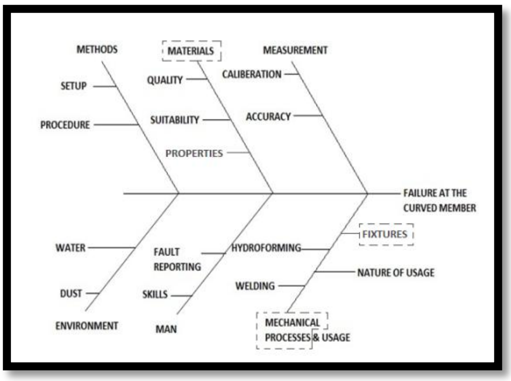


Fig 3: Ishikawa diagram

2. EXPERIMENTATION:

2.1. METHODOLOGY:

1) Static structural Analysis is the analysis in which displacements, stresses, strains and forces on structure or a component due to load distribution can be find out.
2) Modal Analysis of engine mounting bracket to determine whether the current design has a natural frequency which is lower than the excitation frequency.
3) Shape Optimization: The design will be changed by changing the cross section i.e. square cross section to circular cross section.
4) Material Optimization: The design will be tested for different materials, ERW-2, Aluminium, and magnesium and suitability of material will be tested.
5) Study the effect of seam weld on engine mounting bracket.

2.2Experiment

2.2.1 - Static structural Analysis of engine mounting

Static Analysis deals with the conditions of the equilibrium of the bodies acted upon by forces. A Static analysis is used to determine the displacements, stresses, strains and forces in structures and components caused by loads that do not induce significant inertia and damping effects. The kind of loading that can be applied in static analysis includes External applied forces, pressures and moments Steady state inertial forces such as gravity and spinning imposed non-zero displacements.

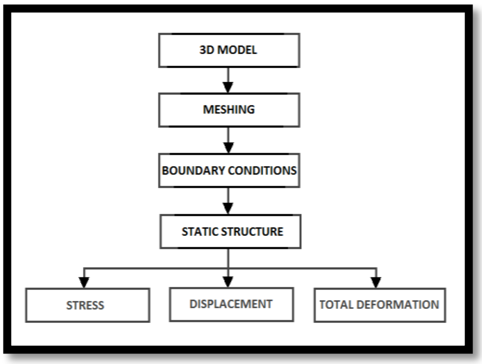
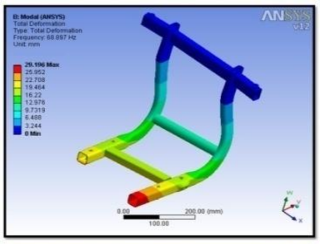


Fig 4: Flow chart for Static Structural analysis

2.2.2 Modal Analysis

Modal analysis determines the vibration characteristics of a structure or a particular component in the form of natural frequencies and mode shapes. From this analysis we can do more detailed dynamic analysis such as transient dynamic analysis, harmonic analysis or spectrum analysis. The natural frequencies and mode shapes are important in the design of a structure for dynamic loading conditions. In this analysis, only linear behaviour is valid. Damping is not considered and applied loads are ignored in modal analysis. A static structural analysis is required first for performing pre stressed modal analysis.

Modal analysis for ERW-1



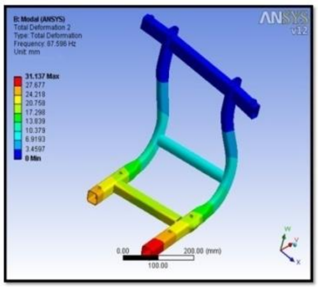


Figure 5: Mode 1 for ERW-1
Figure 6: Mode 2 for ERW-1

The deformation for the other side which is fixed to the body of the vehicle is almost zero for some part of it. The frequency of vibration for this particular mode of the bracket is 87.596 Hz. And the deflection is 31.137 mm Max.

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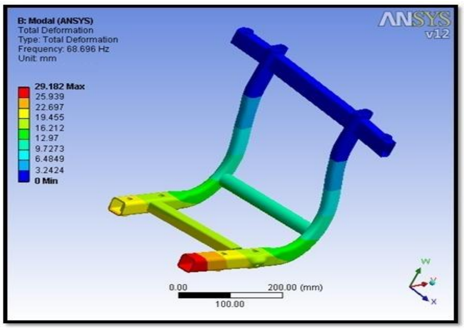

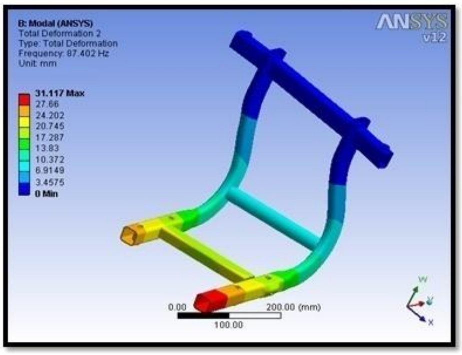

Figure 7: Mode 1 for ERW-2
Figure 8: Mode 2 for ERW-2

The deformation for the other side which is fixed to the body of the vehicle is almost zero for some part of it. The frequency of vibration for this particular mode of the bracket is 87.402 Hz. And the deflection is 31.117 mm Max.

2.2.3 Alternative Material for Engine Mounting Bracket

A]ALUMINUM:

Aluminum has only about one third the density of steel and the most commercial aluminum alloys posses substantially higher specific strength than steel. A vehicle weight reduction would not only result in higher oil savings, but also gives a significant reduction in emission. For these reasons there is preference to use more aluminium and replace steel in automotive applications.

Aluminium alloy under consideration has following material properties:

Young's modulus – 7.1e+10 N/m^2
Poisson's ratio – 0.33
Density – 2770 Kg/m^3
Yield strength in tension & compression – 2.8e+8 N/m^2

B] MAGNESIUM ALLOY:

Magnesium is the lightest of all metals used as the basis for constructional alloys. It is this property due to which automobile manufactures has to replace denser materials, not only steels, cast irons and copper base alloys but even aluminum alloys by magnesium base alloys. The requirement to reduce the weight of car components as a result in part of the introduction of legislation limiting emission has triggered renewed interest in magnesium. A wider use of magnesium base alloys necessitates several parallel programs. These can be classified as alloy development, process development improvement and design considerations. The requirement to reduce the weight of car components as a result in part of the introductions of legislation limiting emission has triggered renewed interest in magnesium.

The advantages of magnesium alloys are listed as follows, lowest density of all metallic constructional materials. It posses high specific strength, good cast ability, which suitable for high pressure die casting good welding properties, higher corrosion resistance. Also compared with polymeric materials it posses better mechanical properties, better electrical and thermal conductivity and it is recyclable.

3. RESULTS AND DISCUSSIONS

3.1 STATIC STRUCTURAL ANALYSIS

Table No. 1: Optimal design values of static structural analysis

Particulars	**ERW-1**	**ERW-2**
Von-Mises stress(max)	331.92 MPA	82.96 MPA
Total deformation (max)	4.37m	1.86 mm

1) From the static structural analysis, it is found that the centre of gravity of the component is improper thus the load distribution of the component is unbalanced and the stress concentrates only at a particular location which is very near to our target area.
2) From the experiment, it is found that equivalent stress induced for existing material (i.e. ERW-1) at the target area exceeds the permissible yield stress which is 160 MPa. Hence the component fails as per the Von-Mises Criterion
3) Due to the design constraint provided by the industry, the design of the component cannot be changed hence the only option available is to change the material for the component. So ERW-2 material which contains high percentage of carbon (i.e.0.04%) can be used and same static structural analysis will be performed.
4) From the above results, it is found that the equivalent stress induced for ERW-2 material at the target area is within permissible yield stress which is 160 MPa, Hence the component using ERW-2 material is safe for the application.
5) Total Deformation of ERW -2 is very less as compared with ERW-1 material.
6) Due to presence high percentage of carbon in ERW-2 Material i.e 0.04 %. Stress induced in Engine mounting bracket is less as compared with ERW-1 Material which contains 0.02 % carbon.
7) The main cause of crack initiation is stress concentration near the target area which is more in ERW-1 material, hence the component fails.

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8) Whereas Stress induced in the ERW-2 material is within permissible

3.2 MODAL ANALYSIS

Table 2: Frequency ERW-1 v/s ERW-2

Frequency	**ERW-1 in Hz**	**ERW-2 in Hz**
First Frequency	68.897	68.696
Second Frequency	87.596	87.407
Third Frequency	165.05	165.05
Fourth Frequency	195.83	195.79
Fifth Frequency	266.74	266.69
Sixth Frequency	520.41	520.28

Table 3 Maximum displacement ERW1 v/s ERW2

Maximum Displacement	**ERW-1 in mm**	**ERW-2 in mm**
First Mode	29.196	29.182
Second Mode	31.137	31.117
Third Mode	33.223	33.263
Fourth Mode	34.844	34.827
Fifth Mode	47.385	47.380
Sixth Mode	35.510	35.496

1) From above results we can conclude
2) The convergence of frequencies for ERW-2 material is good.
3) The first excitation frequency value for ERW-2 is higher than that of excitation frequency range of engine.
4) The first excitation frequency value for ERW-2 is higher than that of excitation frequency range of engine (1-150 HZ).
5) The values of frequencies are nearly same for ERW-1 and ERW-2 bracket.

3.3 OPTIMIZATION BY CHANGING CROSS-SECTION FROM SQUARE TO CIRCULAR

Table 4: Square section V/s Circular Stress

	Square c/s	**Circular Cross Section**
Stress Induced	331.92 MPa	149.3 MPa
Total Deformation	4.37 mm	1.537mm

1) The engine cradle being analyzed used square shaped cross section at the base to support the engine.
2) The modified the design using circular cross section members instead of square shape.
3) The same FEM analysis process was repeated over the modified design. The outcome showed reduced total deformation, and reduced Von Mises stresses.
4) The above result results show the decreased stresses and deformation in the new modified design.
5) The analysis results as evident from the above table show reduced maximum stresses; the value for maximum Von Mises stress is 149.3 MPa.
6) The same stress had a maximum value of 331.92 MPa for the previous design.

3.4 ALTERNATIVE MATERIAL FOR ENGINE MOUNTING BRACKET

Table 5: Stress Distribution among ERW-2, Aluminum and Magnesium

	ERW-2	**Aluminum alloy**	**Magnesium alloy**
Von-Mises stress(max)	82.96 MPA	64.588 MPA	67.089 MPA
Total deformation	1.086 mm	3.8855 mm	1.5672mm

1) The results obtained for the static structural have shown that the magnesium is better than aluminum and ERW-2 material.
2) From the results it can be seen that the magnesium bracket is safe for the required application.
3) The main advantage of the magnesium engine mounting bracket is its light weight.
4) It will help in decreasing the weight of the power train assembly, which can increase fuel efficiency. Magnesium is recyclable; therefore it is an eco friendly material.
5) The magnesium bracket is less susceptible to corrosion; therefore they are better for the application of bracket.
6) The magnesium bracket can be manufactured with less amount of time and it possesses longer life compared to an aluminum bracket and ERW-2.
7) The main problem of using magnesium instead of aluminum is its higher cost; but recent studies have shown

that the difference between costs of aluminum and magnesium is decreasing. Thus magnesium can be preferred over aluminum and ERW-2 as a material for an engine mounting bracket.

4. CONCLUSION

The finite element analysis tool, ANSYS has been used to analyze the engine mounting bracket. The results obtained from the static structural and modal analysis shows that ERW-2 steel is better than ERW-1 steel. From the results it can be seen that the ERW-2 steel bracket is safe for the required application.

It is noted that the modified design i.e. Circular cross section showed less equivalent stress being developed, as well as less deflection but it can be practically implemented as square cross-section gives a better base for engine to rest on its top surface.

During this work, study of manufacturing process of engine mounting bracket was also considered and it was found that the ERW tubes are manufactured with the help of through seam weld and after this the tubes are hydro-formed to the desired shape where the orientation of seam weld was not taken into consideration. Hence if the hole is drilled on seam weld position it causes initiation of crack. Thus to prevent this we need to mark the seam position and ensure that hole drilled is not on the seam weld position.

This work also contributes to the defining alternative material engine mounting bracket, in which magnesium alloy and aluminium alloy were studied along with ERW-2 steel. After analyzing the results, it was found that magnesium can be proffered over Aluminium and ERW-2. The main advantage of the magnesium engine mounting bracket is its light weight. It will help in decreasing the weight of the power train assembly, which can increase fuelefficiency.

Magnesium is recyclable; therefore it is an eco friendly material. The magnesium bracket can be manufactured with less amount of time and it posses longer life compared to an aluminium and ERW-2 bracket. The magnesium bracket is less susceptible to corrosion; therefore they are better for the application of bracket. The main problem of using magnesium instead of aluminum is its higher cost; but recent studies have shown that the difference between costs of aluminum and magnesium is decreasing. Also manufacturing cost for magnesium is more as compared to Aluminium and ERW-2. Thus it can be concluded that ERW-2 can be preferred over ERW-1 as a material for an engine mounting bracket.

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