Finite Element Analysis of Engine Mounting System

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Abstract— Engine is an important part of the of the vehicle, it is heart of the vehicle. it is important to in keep in right position in vehicle ,so that it cannot cause trouble to passenger and driver comfort. The main problem by engine is the generation of vibration effect by it , which caused noise and vibration problem to passenger and driver . For this engine mounting system is used to reduced this problem . Engine mounting system pass through several refinement in order to optimized it to better design .. one such refinement is done in this work ,by changing the cross section of supporting rod of engine mounting bracket and done finite element analysis on this design on the three metal hot rolled steel , aluminum ,magnesium . the reason for taking three metal for analysis , is to reduce the weight of design ,which result in reduced in the cost of making and, the lesser load applied to transmission system of vehicle.

Key words: Engine mounting, Finite element analysis, Ansys

I. INTRODUCTION

Engine mounting system is the basic part of vehicle whose main function is to give support to the engine . The engine mounting plays an vital role in reducing the noise, vibrations and harshness for improving vehicle ride comfort. The important function of an engine mounting bracket is to properly balance the power pack system of the vehicle chassis ,for good motion control as well as good isolation. Engine is one of the most important part of a road vehicle .The engine is the largest mass in a vehicle which will cause vibration if it is not properly isolated and constrained. An ideal engine mount system isolates engine vibration produced by engine unbalanced forces and prevents engine bounce caused from shock excitation. The modern engine mounting systems have been passes through many changes through research and testing so as used to isolate the driver and passenger from both noises and vibrations generated from the engine The main role of engine mounting system is that, it is used as one of the principal vehicle vibration isolating systems, besides suspension system, it is used to reduce the Noise, Vibration perceived by driver and also to improve the ride comfort. The main sources of noise and vibration in vehicle are low frequency road roughness and high frequency engine force. Thus, an engine mounts should be capable of adequate isolation in a wide range of frequency. One way of reducing vibration transmissions to the body structure is to adopt softer engine mountings Unfortunately, this will increases engine movement under drive torque reaction and so it requires greater space in the engine bay and more flexible hose and cable connections. Second disadvantage of soft mountings, especially in small vehicles, is that they produced an undesirable phenomenon termed shunt where movement of the engine is noticeable to the driver and can adversely affect drivability of the vehicle.

Automobile engine-chassis-body system undergoes undesirable vibrations due to disturbances from the road and engine. The vibrations induced by the road or the engine at idle are typically at the frequencies below 30Hz. In order to control the idle shake and the road-induced vibrations, the engine mount bracket should be stiff enough and highly damped. whereas, for a small amplitude excitation in which the higher frequency range (30- 250Hz) from the engine, a compliant and lightly damped mount bracket is required for vibration isolation and acoustic comfort. So, the engine mount bracket must satisfy these two essential criteria [4]. In motor vehicles engine mountings usually used with a rubber component to insulate the body structure from engine vibration. Front-engine front-wheel-drive vehicles usually uses the engine mountings to react final drive torque to the vehicle body. To make motor vehicle travel more comfortable, designers have been seeking to reduce the noise levels in the passenger compartment and particular attention has been given to engine mountings Thus engine mountings are presently used to perform two tasks, reaction of final drive torque which requires relatively hard mountings and reduction of vibration and noise transmissions which requires relatively soft mountings.

The present mounting is used for vibrating system and in particular to a mounting capable of eliminating or substantially reducing the transmission of vibration from a vibrating system to its support base.

II. MATERIAL SELECTION OF ENGINE MOUNTING

The necessity of 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 the emissions is to reduces vehicle weight. The magnitude of the production volumes has traditionally placed severe requirements on the robustness of the processes used in manufacturing process. The strong emphasis on the cost has pressurized the component manufacturers to improve the performance of their materials and to find the methods to deliver these materials at reduced cost. There are a number of sources of noise and vibration that affect the vehicle body [1].

The material generally used for manufacturing engine mounting are steel alloy, cast iron alloy , aluminum and magnesium alloy. The steel and iron alloy are used in generally used in heavy transport vehicle like truck , bus , small carriage vehicle like van ,whereas aluminum and magnesium alloy are used in light weighted vehicle like car and jeep. The aluminum has one third the density of steel and the most commercial aluminum alloys posses substantially higher specific strength than steel. Magnesium is the lightest of all metals known that is used as the basis for constructional alloys. This property make magnesium valuable 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.

III. Objective

The objective of this work is to compare properties of the various material used in the making of engine mounting system , to determine the better material for engine mounting system, in order to reduced its weight and increase its life and strength . Material used for analysis ,hot rolled steel which is used in existing design, other alternative metal for analysis ,aluminum and magnesium. And also to get better result, the analysis is done on proposed design that is rectangular section and compare the result with existing design.

IV. Methodology

A. Finite Element Analysis:

Finite element analysis is a numerical procedure that can be used to obtain solution to a variety of problems in engineering. It is used in stressed analysis for solving steady, transient, linear and non linear problems ,and also in heat transfer, fluid flow and electromagnetism problem. The origin of finite element method may be traced back to early 1900s when some investigators approximated and modeled elastic continua using discrete equivalent elastic bars. However courant in1943 is the first man to develop the finite element method. He used the piecewise polynomial interpolation over triangular sub region to investigate torsion problems.

Due to its diversity and flexibility as an analysis tool, it is receiving much attention in almost every industry. It consists of a computer model of design that is loaded and analyzed for specific results. It is used in new product design and also in existing product refinement. Basic concept is to make calculations at only limited (Finite) number of points and then interpolate the results for entire domain (surface or volume).

With the advances in computer technology and CAD systems, complex problems can be modeled easily. Several alternative configurations in shape can be tried out on a computer before the first prototype is built. In this method of analysis, a complex region defining a continuum is discretized into simple geometric shapes called finite elements and expressed in terms of unknown values at element corners. In assembly process, duly considering the loading and constraints, results in set of equations. Solution of these equations gives us the approximate behavior of the continuum.

B. Procedure for Finite Element Analysis:

Certain steps in formulating a finite element analysis of a physical problem are common to all such analyses, whether structural, heat transfer, fluid flow, or some other problem. The steps are described as follows:

1) Pre-processing
2) Processing or Solution
3) Post processing

1) Preprocessing:

The preprocessing steps are described as follows:

1) Define the geometric domain of the given problem.
2) Define the element type(s) for the element.
3) Define the material properties of elements.
4) Define the geometric properties of the elements (length, area, and the like) of the model.
5) Define the element connectivity i.e. meshing the model.
6) Define the boundary conditions.
7) Define the loadings on the model.

2) Processing or Solution:

During the solution phase, finite element software eg. Ansys assembles the governing algebraic equations in matrix form and computes the unknown values of the primary field variables. The computed values are then used by back substitution to compute additional, derived variables, such as reaction forces, element stresses, and heat flow. As it is not uncommon for a finite element model to be represented by tens of thousands of equations, special solution techniques are used to reduce data storage requirements and computation time During pre-processing phase ,user has to work hard while solution step is the turn of computer to do the job. Internally software carries out all process like matrix formation, inversion, multiplication and solution for unknown e.g. displacement and then find strain & stress for analysis

3) Post-Processing:

Analysis and evaluation of the solution results is indicated as post-processing. In postprocessor software contains sophisticated routines which are used for sorting, printing, and plotting selected results from a finite element solution. Examples of operations that can be accomplished include:

– Sort element stresses in order of magnitude.
– Check equilibrium condition.
– Plotting deformed structural shape to see various deffects.
– Animate dynamic model behavior of deformed structure.
– Produce a color-coded temperature plots which give temperature at different part of body

Post processing is main an analytical phase after viewing results, verifications, and conclusions and thinking about what steps could be taken to improve the design. While, solution data can be manipulated many ways in post-processing, the most important objective is to apply engineering judgment in determining whether the solution results are physically reasonable for use.

V. Modal Analysis

It is used to determine the vibration characteristics (natural frequency and mode shapes) of a structure or machine part ,while it is being designed. It can be also used as starting for other more detailed dynamic analysis like spectrum analysis, harmonic analysis, transient dynamic analysis. In this analysis all the process is same as in all ansys process but only difference is in applied loads . In modal analysis applied load are only zero value displacement constraint. These analysis are very helpful for approving or making some design changes in existing design during the post processing stage. The design changes mainly depend on the product life cycle and helps design analysts to finales dimensions and material of the any components.

A. Analysis of Engine Mounting System:

Here analysis of engine mounting system is done with the help of FEA software (Ansys). The objective of the analysis is to optimize the best design of engine mounting system by searching that material who reduce the weight of engine mounting , but not in cost of reduced strength. for this modal analysis is done on three metal ,hot rolled steel, aluminum, magnesium. Design of engine mounting system used here is, used in many transport vehicle like vikram auto, tata magic. In preprocessing phase , modeling is done, then defining the material properties, load, constraints and meshing the model. Since it is modal analysis no specific load is applied, but only zero value displacement constraint, fixed support to the model. Below are the mechanical properties of used metal.

B. Hot Rolled Steel:

Hot rolling is a mill process which involves rolling the steel at a high temperature (nearly at a temperature over 1700° F), which is above the steel's recrystallization temperature. When steel is heated above the recrystallization temperature, it can be shaped and formed easily, and the steel can be made in much larger sizes. Hot rolled steel is typically cheaper than cold rolled steel because it is often manufactured without any delays in the process, and therefore the reheating of the steel is not required as in case of cold rolled. When the steel cools off it will shrink slightly from its previous shape ,thus giving less control on the size and shape of the finished product when compared to cold rolled.

Young's modulus - 2e+011 N/mm^2 Poissons ratio – 0.29 Density – 7870 Kg/m3 Yield strength in tension & compression – 1.8e+8 N/m2

C. ALUMINUM:

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

But there are several obstacles in implementation of Aluminum directly in automotive industry. Some of these are,

The forming limits of Aluminum are significantly lower than the steel. There are several chances of Aluminum to tearing at bends. This limits the shapes that can be fabricated and slows die design, die tryout and applications.

Spring back problem is more in thicker sheets of Aluminum and it is hard to keep dimensional tolerances.

Traditional vehicle body manufacturing technology implementing stamped sheet steel component cannot be sufficiently improved to meet future vehicle requirements because of the higher weight of the steel and the high cost and more time required for stamping tool development.

Young's modulus – 7.1e+10 N/m2 Poisson's ratio – 0.33 Density – 2770 Kg/m3 Yield strength in tension & compression – 2.8e+8 N/m2

D. 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 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.

Young's modulus -4.5e+011 Poisson's ratio – 0.35 Density – 1800 Kg/m3 Yield strength in tension & compression – 1.9+8 N/m2

E. Procedure

After modeling the existing design the material property ,first on hot rolled steel ,then on aluminum and magnesium respectively. Then meshing the model , and the applying the load here zero value displacement constraint, the fixed support to the model.

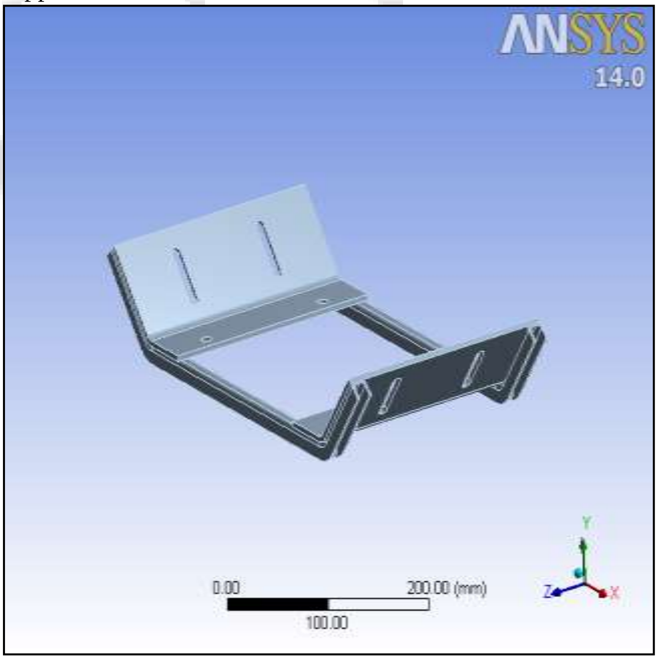

Fig. 1: Existing Design

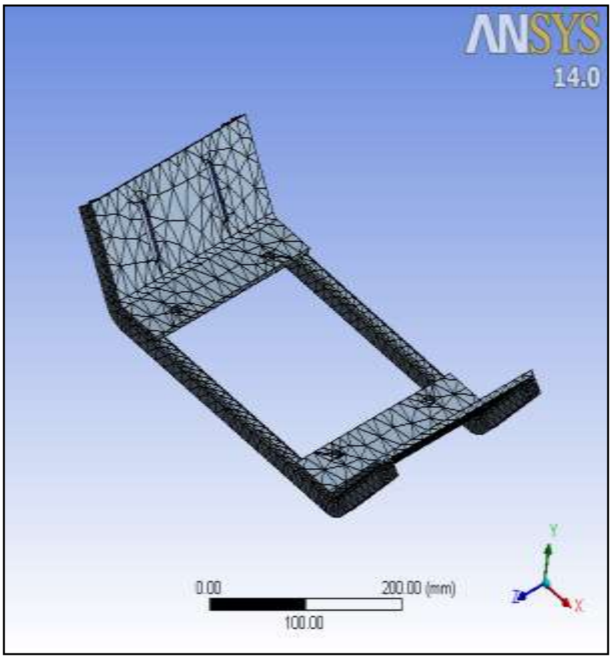

Fig. 2: Meshed Model

After doing the solution ,various mode of natural frequency is obtained with corresponding deformation ,which shows the deformation of design when natural frequency is increased , here first mode is important because it shows the deformation in the existing design , when natural frequency is increased. In hot rolled steel ,first mode of deformation of 53.88 mm takes place at the 918.77 Hz. Here it is clearly seen that maximum deformation is takes place in the right side of design.

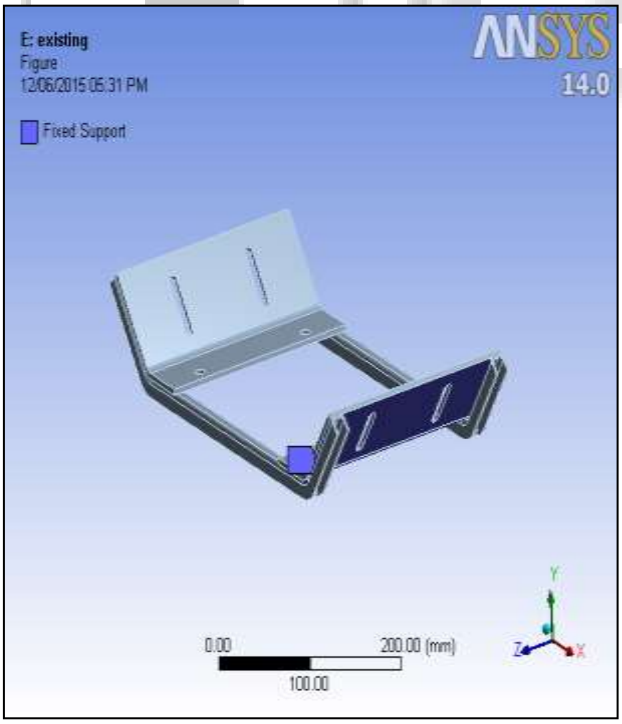

Fig. 3: Load

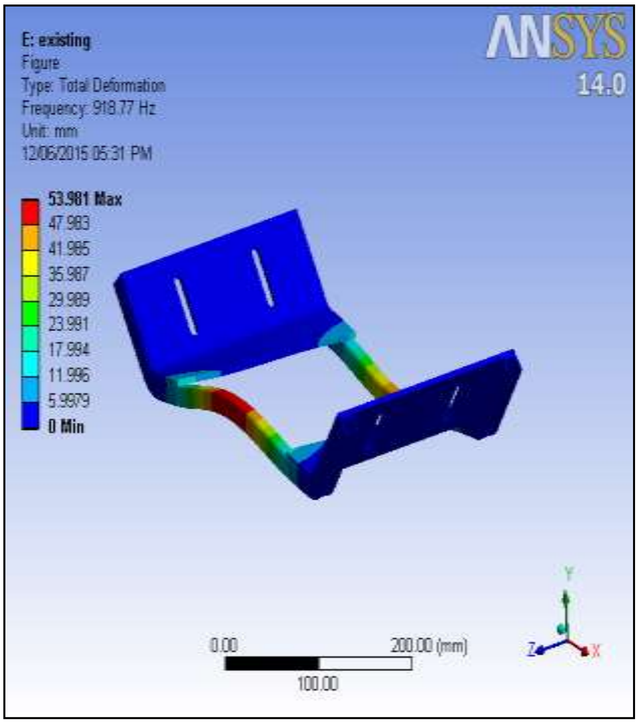

Fig. 4: 1st mode

In , second mode of deformation the maximum deformation of 53.992 mm takes place at left side of design ,at natural frequency of 99.6 Hz. Whereas, in third and fourth mode of deformation the maximum deformation of 77.604 mm and 77.621mm takes place respectively at natural frequency of 1284.2 Hz and 1285.2 Hz, and deformation takes down side of design. Since bracket is fixed there is not much deformation in this.

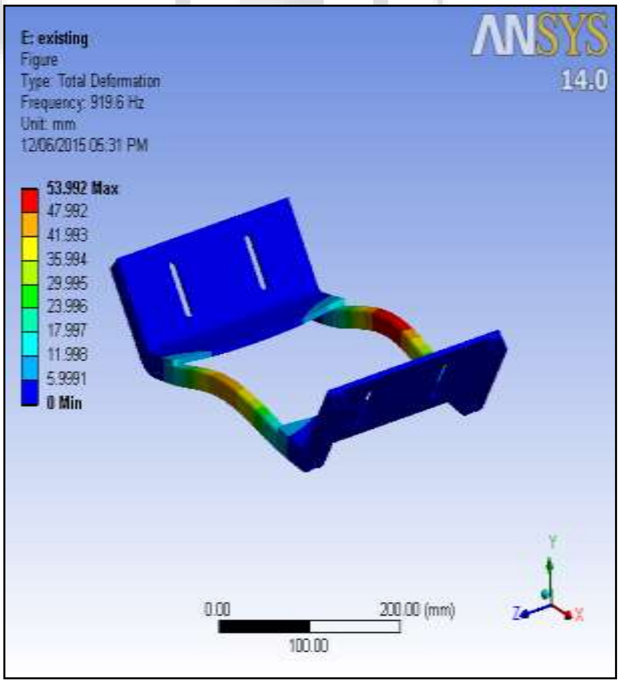

Fig. 5: 2nd mode

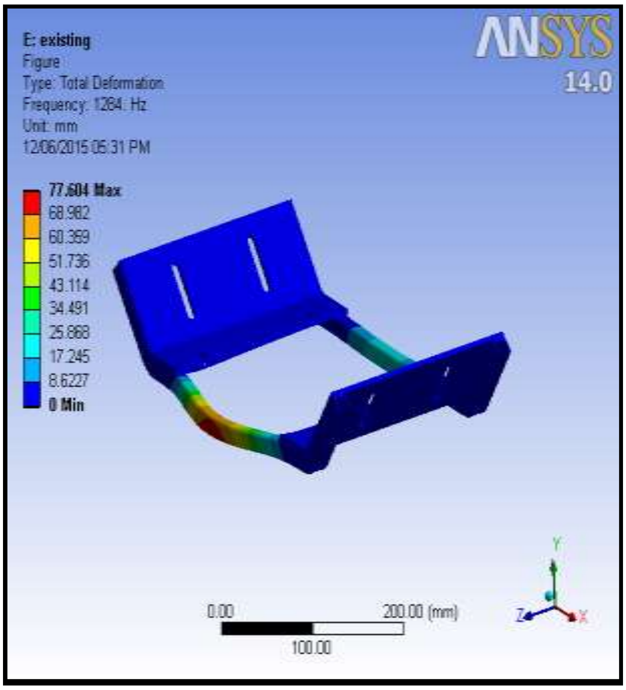

Fig. 6: 3rd Mode

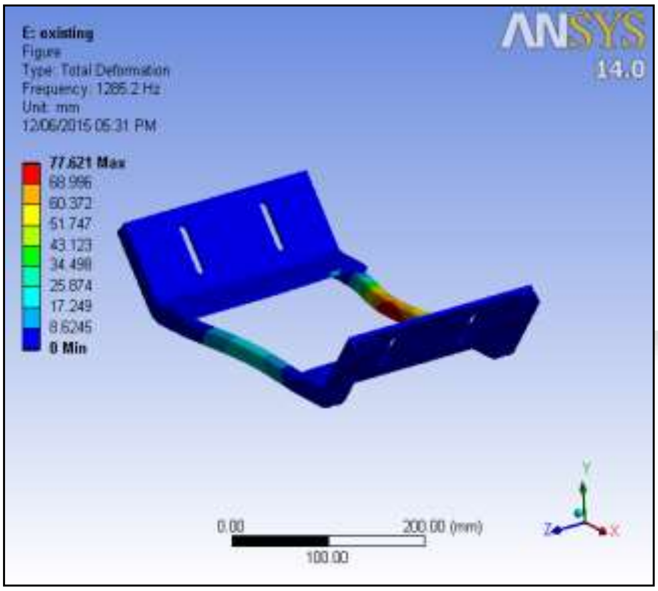

Fig. 7: 4th mode

After modification in cross section of bar into the rectangular cross section and applying the same procedure as in the above existing design. After solving the solution, it is found that when changing the cross section , the deformation is reduced to 52.817 mm at 978.06 Hz in 1st mode , 52.812 mm at 979.13 Hz in 2nd mode, 59.268 mm at 1453.9 Hz in 3rd mode , 59.27mm at 1455.9 Hz. it is clearly seen that there is considerable reduction in deformation in size at higher frequency , so we can used in place of existing design.

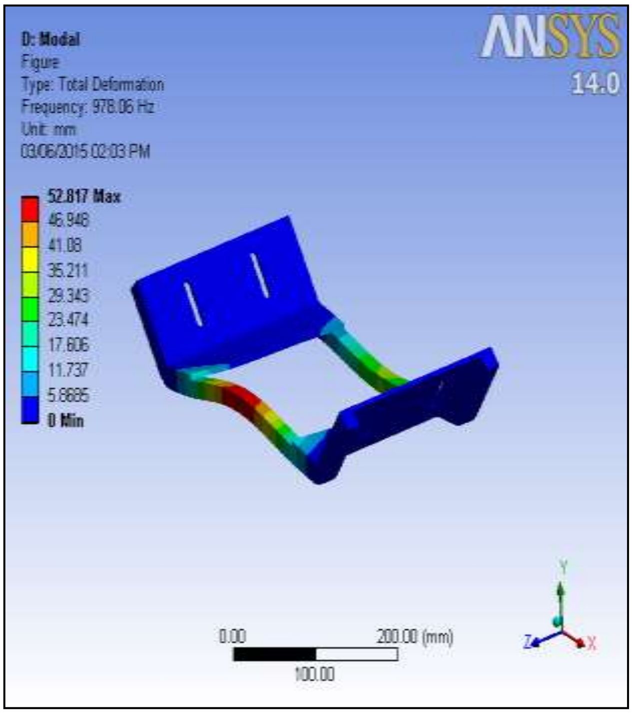

Fig. 8: 1st mode, rectangular

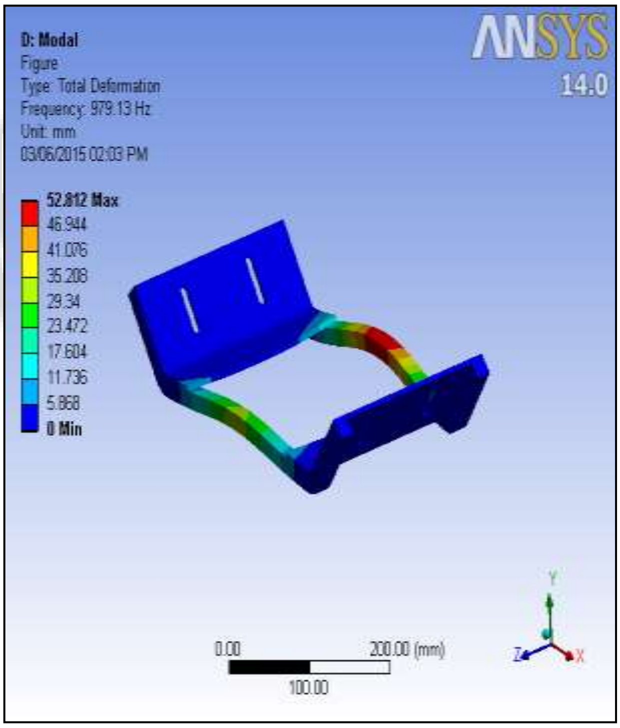

Fig. 9: 2nd Mode, Rectangular

F. Analysis on Alternative Metal:

In this section ,analysis is done on same model of rectangular cross section as it give better result in previous section, but by changing the metal to aluminum and magnesium alloy. As both are lighter metal so making design lighter they can be used for analysis. Here first is done on aluminum, Process is same as before , after post processing , it is found that first mode of deformation is takes place at 982.73 hz of 88.373 mm second mode at 983.57hz of 88.372 mm , third mode at 1459 hz at 97.88 mm and fourth mode at 1459 hz of 97.90 mm . it is clearly seen that there is not much difference in first and second mode deformation is almost same , same in third and fourth mode of deformation.

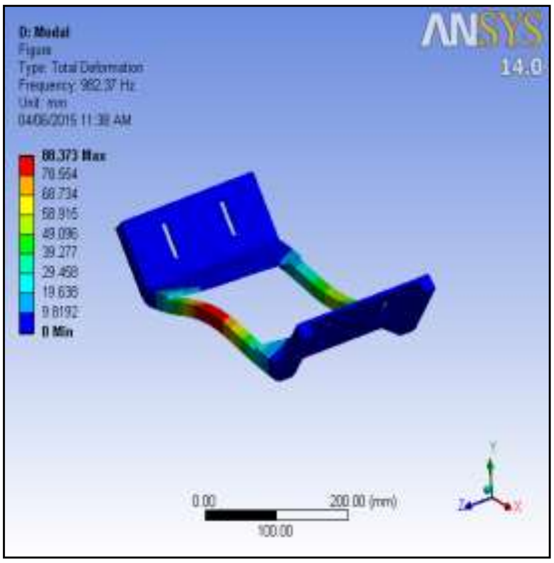

Fig. 12: 1st mode Al

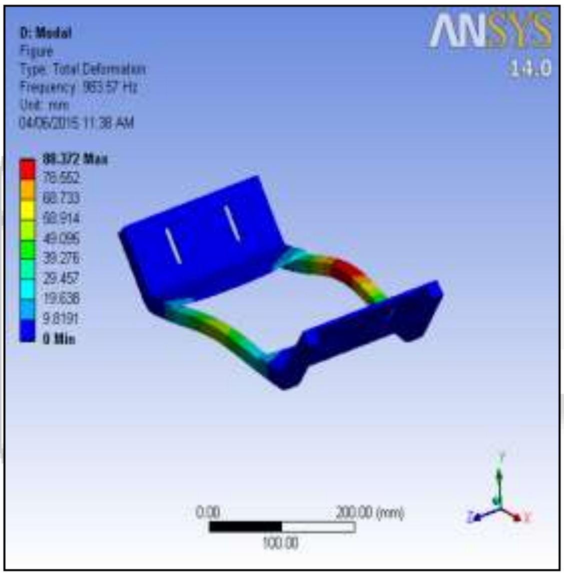

Fig. 13: 2nd Mode Al

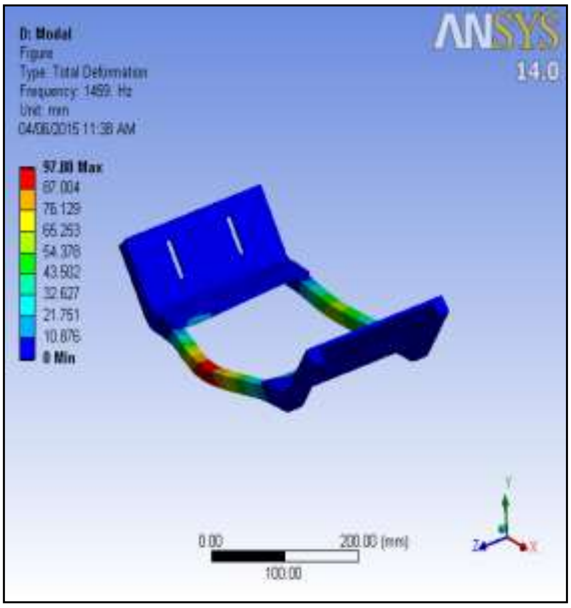

Fig. 14: 3rd mode Al

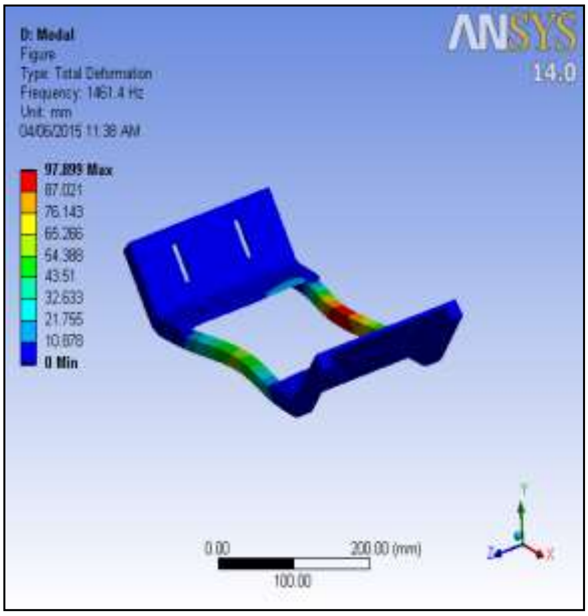

Fig. 15: 4th Mode, Al

Now, same analysis is done by taking magnesium alloy metal and rectangular section design. reason for taking magnesium metal is that it is lightest metal of all used metal in industrial application, and also its noncorrosive property make it valuable , it has also 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. Make it very effective metal and costly.

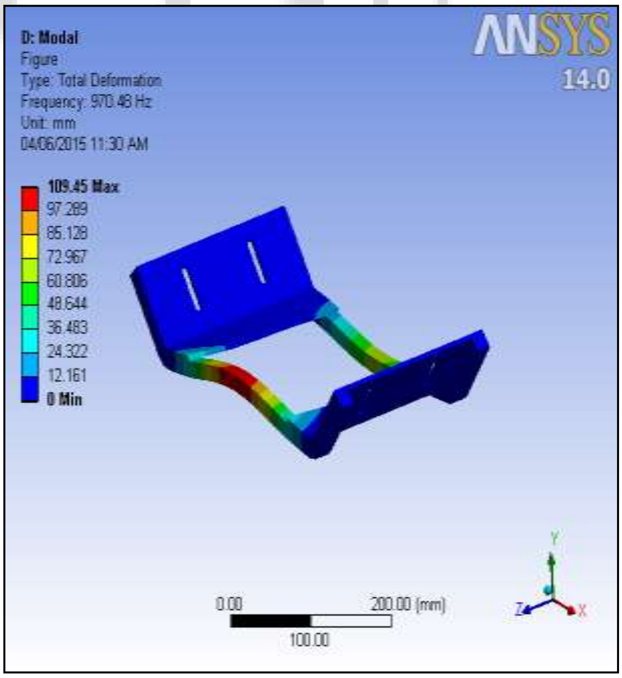

Fig. 16: 1st Mode Mg

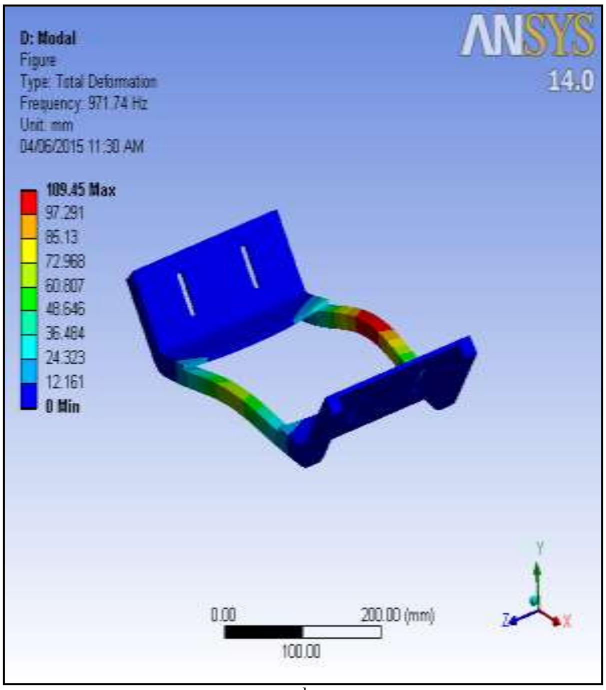

Fig. 17: 2nd Mode Mg

In above two figure first and second mode of deformation with natural frequency is represented for magnesium metal. It is clearly seen that in first and second mode of deformation , the deformation of 109.45 mm is same ,at different natural frequency of 970.48 Hz and 971,74 Hz. Whereas, the third and fourth mode of deformation of 120.42 mm and 120.46mm at natural frequency of 1440.7 Hz and 1443.3 Hz ,respectively. The deformation is more in rod bar as it is it not given any support , it is first deform upward in first and second mode , then down ward in next two mode as shown below.

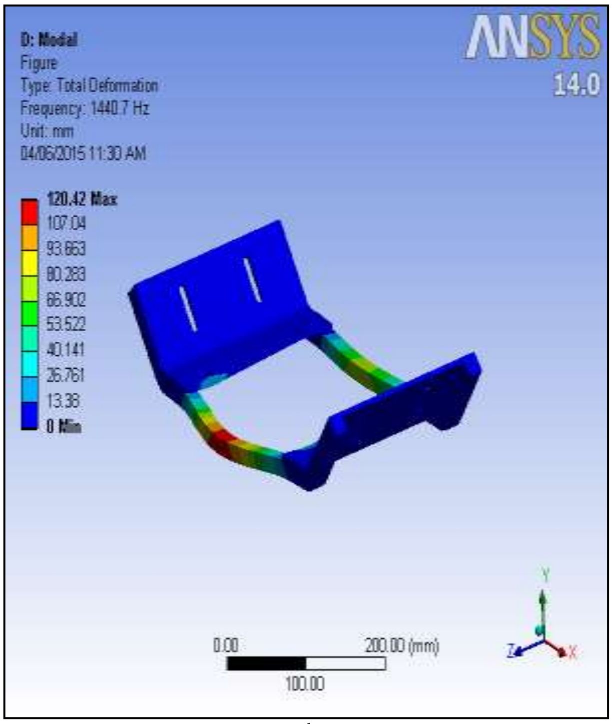

Fig. 18: 3rd mode Mg

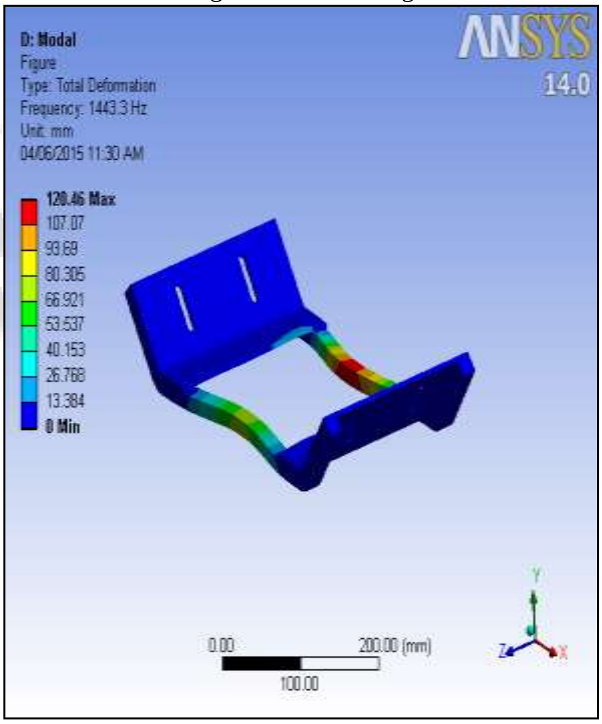

Fig. 19: 4th mode Mg

VI. RESULTS AND FINDING

On the basis of above analysis of three metal following tables is obtained

MODE	EXISTING DESIGN		RECTANGULAR CROSS SECTION		TRAPEZOIDAL CROSS SECTION	
	Deform. In mm	Frequency In hz	Deform. In mm	Frequency In hz	Deform. In mm	Frequency In hz
1ST MODE	53.981	918.77	52.812	979.13	55.753	975.48
2ND MODE	53.992	919.6	52.818	978	55.757	972.79

3RD MODE	77.604	1284	59.268	1453.9	55.276	1413
4TH MODE	77.622	1285.2	59.27	1455.62	55.263	1414.4

Table 1: Hot Rolled Steel

MODE	EXISTING DESIGN		RECTANGULAR CROSS SECTION		TRAPEZOIDAL CROSS SECTION	
	Deform. In mm	Frequency In Hz	Deform. In mm	Frequency In Hz	Deform. In mm	Frequency In Hz
1ST MODE	90.42	922.55	88.373	982.37	92.233	975.27
2ND MODE	90.431	923.431	88.37	983.55	92.29	976.69
3RD MODE	128.68	1287.5	97.88	1459	91.792	1418.2
4TH MODE	128.71	1288.5	97.90	1461.4	91.781	1420.4

Table 3: Aluminum Alloy

MODE	EXISTING DESIGN		RECTANGULAR CROSS SECTION		TRAPEZOIDAL CROSS SECTION	
	Deform. In mm	Frequency In Hz	Deform. In mm	Frequency In Hz	Deform. In mm	Frequency In Hz
1ST MODE	112.1	911.23	109.45	970.48	113.44	963.49
2ND MODE	112.13	912.22	109.45	970.71	113.42	964.85
3RD MODE	158.47	1270	120.42	1440.7	113.23	1400.5
4TH MODE	158.51	1271.5	120.46	1443.33	113.24	1402.5

Table 4: Magnesium Alloy

On basis of above tables, In case of hot rolled steel maximum deformation is 77.622 at 1285.5 Hz in existing design and minimum is 52.812 mm at 979.13 Hz in rectangular cross section. Whereas in 1st mode of deformation the minimum value is 52.812 mm at 979.13 Hz in rectangular cross section , which can be preferred.

in Aluminum the maximum deformation is 128.71 mm at 1288.5 Hz in existing design and minimum deformation is 88.373 mm at 982.37 Hz in rectangular cross section , but most important is 1st mode of deformation of material because permanent deformation initiate from here which is also 88.373 mm at 982 .373 Hz in rectangular cross section ,so in aluminum rectangular cross section is preferred

Similarly, in magnesium the maximum deformation is 158.51 mm at 911.23 Hz in existing design, whereas minimum deformation 109.45 mm at 970.48 Hz in rectangular cross section which is also in 1st mode of deformation ,so it can be preferred.

VII. CONCLUSION

In all of the three metals, in terms of lighter and non corrosive property magnesium is best of all but it is costly than all of three ,whereas aluminum is in second position in lighter and non corrosive parameters so magnesium and aluminum can used as engine mounting material if possible. Also the natural frequency of all metal used is more than the first excitation frequency range(1-250 Hz), so all the metal can be used as base metal on the basis of modal analysis in all of the metal rectangular cross section give better result as its first mode of deformation give less value of deformation at sufficiently high natural frequency so, it can be used.

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