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Static and modal analysis of engine cover for different materials

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Abstract- The designed engine cover in this paper is made of different plastic materials, today's ever increasing demand for newer, lighter materials with higher strength, greater stiffness, and better reliability has led to wide research on development of thermo plastic materials. These materials offer a combination of strength and modulus that are either comparable to or better than many traditional materials such as metals. However, with the development need for materials with superior properties from the private sector, composites are now making their way into more common applications. However study on the static and dynamic mechanical behaviour, long term durability, and environmental stability of these materials are limited. Under-the-bonnet applications came later with the more widespread availability of high-performance thermoplastics (referred to as 'engineering plastics') and contributed significantly to cost and weight reduction in the engine compartment.

In the present work an attempt has been made to analyze the different composite materials for engine cover of vehicle with respect to static and modal analysis. Initially the engine cover model is prepared in catia software with actual dimensions. Analysis of engine cover model is done in ANSYS by importing the CATIA software model for 5 different materials and results for existing material are studied. The objective of present work is to suggest the best material for vehicle engine cover by comparing obtained results with present material. The various parameters of interest are natural frequency, total deformation and equivalent stress. Based on results obtained with the study of above parameters ideal material for engine cover is suggested.

The major objectives are outlined as follows:-

- Preparation of CAD model of engine cover using CATIA software.
- Carrying out static analysis and modal analysis using ANSYS for 5 different materials and to compare the obtained results with existing material.
- To obtain the mechanical properties viz equivalent stress, total deformation and modal frequencies of engine cover for different materials.
- To compare the various parameters of interest and draw conclusion.

Index Terms- Engine Cover, Deformation, Plastic Material.

I. Introduction

Today's ever increasing demand for newer, lighter materials with higher strength, greater stiffness, and better reliability has led to wide research on development of thermo plastic materials. These materials offer a combination of strength and modulus that are either comparable to or better than many traditional materials such as metals. Because of their low specific gravities, the strength-to-weight ratios as well as specific modulus make these materials more superior to those of metallic materials. In addition, fatigue strength-to-weight ratios as well as fatigue damage tolerances of many polymers are excellent and make them feasible candidates for many applications. The use of advanced materials has primarily been limited to high performance aerospace and sporting applications. However, with the development need for materials with superior properties from the private sector, composites are now making their way into more common applications. However study on the static and dynamic mechanical behaviour, long term durability, and environmental stability of these materials are limited.

Thermoplastics have been extensively used in automotive applications for the last few decades and are most visibly seen in automobile bumpers and interiors. Under-the-bonnet applications came later with the more widespread availability of high-performance thermoplastics (referred to as 'engineering plastics') and contributed significantly to cost and weight reduction in the engine compartment, initially in applications that could be regarded as less critical to performance and safety, such as cooling fans, shrouds and header tanks, fixations, radiator grills, etc.

Recently it has been seen engineering plastics are used in critical components on the vehicle itself as well as into safety critical components such as brakes, steering and air bag systems. The driving force behind this trend has been the growing confidence of automotive engineers in the capabilities of thermoplastics and engineering plastics. Engineering plastics have performed very well in each new demanding application. This successfully has raised awareness about plastic materials. Beyond this automotive engineers also studied different characters to judge the thermo plastic materials. They suggested that their characteristics are quite different to those of the metals that have been used for generations.

While this understanding has enabled innovation with thermoplastics, the drivers for change have been those familiar throughout the automotive industry: weight reduction, greater fuel economy and system cost reduction. The use of composite materials in various parts of automobile chassis component are shown in Fig1.1 .Thermoplastics are ideal materials to achieve these goals since they have specific gravities substantially lower than metals generally and the injection-moulding process lends itself to lower production costs through the ability to integrate complex parts into one component and the substantial reduction in finishing processes.

II. SIGNIFICANCE OF PROPOSED WORK

The introduction of plastics to replace the traditional materials in the vehicle industry do not only reduce product cost but also reduce production cost. Plastics are modern, synthetic materials. Plastics are oil and gas based, and consumes less our oil and gas reserves. The superior properties of plastics such as hygienic (clean or free from disease causing microorganisms) barrier properties, light weight, and durability contribute significantly to our health and quality of life. The factors that have contributed to this growth include the energy efficiency of plastic. All studies show that it takes less energy to make a product from plastics than just about any other material. As plastics continue to demonstrate that they are a safe and reliable alternative to traditional materials, new applications will emerge.

In the present work an attempt has been made to analyze the different composite materials for engine cover of Mahindra Scorpio vehicle with respect to static and modal analysis. Initially the engine cover model is prepared in catia software with actual dimensions. Analysis of engine cover model is done in ANSYS by importing the CATIA software model for 5 different materials viz Polypropylene with glass fiber, Nylon with glass fiber, Poly vinyl chloride(PVC) ,High density polyethylene(HDPE), Polybutylene terephthalate(PBT) and results for existing material poly propylene are studied. The objective of present work is to suggest the best material for Mahindra Scorpio vehicle engine cover by comparing obtained results with present material. The various parameters of interest are natural frequency, total deformation and equivalent stress. Based on results obtained with the study of above parameters ideal material for engine cover is suggested.

III. STATIC STRUCTURAL ANALYSIS

In the present work static structural analysis of engine cover of vehicle for five different alternative materials along with existing material of PP are studied. Initially measurements of engine cover are done and model is prepared in catia software. CAD model of engine cover is saved in the IGES format, and imported to ANSYS software for further analysis.

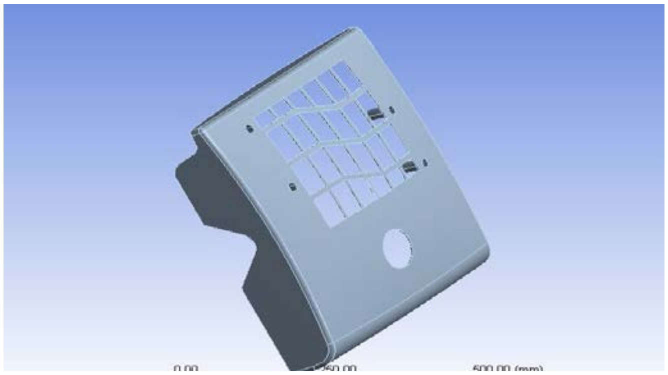

Fig 4.1 CATIA Model of engine cover

Meshing of the engine cover is carried out using ANSYS software for imported model by using tetrahedral elements. The global model is descritized with element size of 2.5mm. Similar kind of element and size are used in the work of Laxmikant D. Rangari et al., 2012 and Umesh S. Ghorpade et al., 2012.

Tetrahedral element is robust and efficient element, with unique capabilities, can be used as a majority element in a mesh because it overcomes problems of volumetric locking for explicit dynamic problems, including those involving extreme strain, fragmentation and failure. Tetrahedral meshes are widely used in computer graphics for physically based modeling, in particular realistic simulation of deformable objects [Muller and Dorsey, 2002 and McMillan et al., 2002]. Figure 4.2 shows the mesh of the engine cover and details of mesh are indicted in Table. 4.1.

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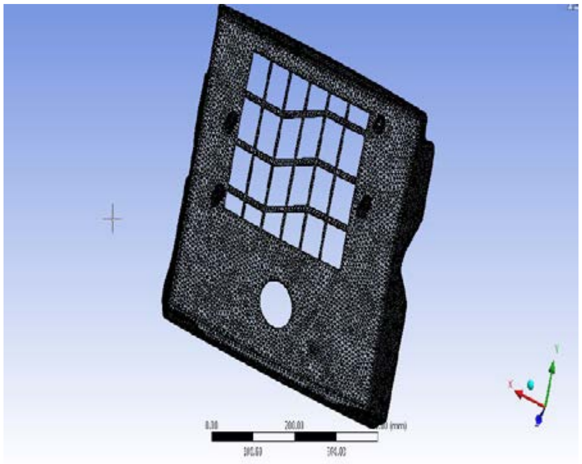

Fig.4.2 Mesh of engine cover model

Details of "Mesh"	
Relevance	0
Sizing	
Inflation	
Advanced	
Defeaturing	
Statistics	
Nodes	906736
Elements	526255
Mesh Metric	Skewness
Min	5.93901969756838E-04
Max	0.877320832776415
Average	0.353333950993138
Standard Devi...	0.138586074584772

Table.4.1 Mesh details

The FEM model is having 6 degrees of freedoms: translations in the nodal x, y, and z directions and rotations about the nodal x, y, and z axes.

In the present work static structural analysis has been done for 5 different materials viz, Glass reinforced polypropylene, Glass reinforced nylon, Poly vinyl chloride, High density polyethylene, and Polybutylene terephthalate and results are compared with results of existing cover of Poly Propylene. The various material properties of material used for the present work are shown in Table 4.2.

Table.4.2 Material properties

Material	E,(GPa)	Poission's ratio	Density(g/cm3)	Yield Stress(MPa)
Glass reinforced pp	3.553	0.40	1.12	40
Glass reinforced nylon	7.5	0.40	1.4	48
PVC	1.5	0.42	1.4	53
HDPE	0.7	0.42	0.95	25
PBT	5	0.41	1.31	50
PP	0.9	0.40	0.89	35

The above material properties are assigned to the mesh of the engine cover and the bolt holes are fixed. This kind of boundary condition is in accordance with the work of Beomkeun Kim et al., 2007. The only load comes on the engine is Self weight of engine cover and all other kind of loads are neglected in the analysis. In the postprocessor of the software maximum equivalent stress and deformations are obtained. These two kinds of parameter are used in the earlier work [Umesh S. Ghorpade et al., 2012].

IV. RESULTS AND DISCUSSION

Equivalent stresses, total deformation for 6 different materials as stated above are discussed in detail in the following section.

Equivalent stress And Total elongation

Equivalent stress and total deformation from the postprocessor of ANSYS are obtained for 6 different materials and are shown in Fig.4.3 and Fig. 4.4.

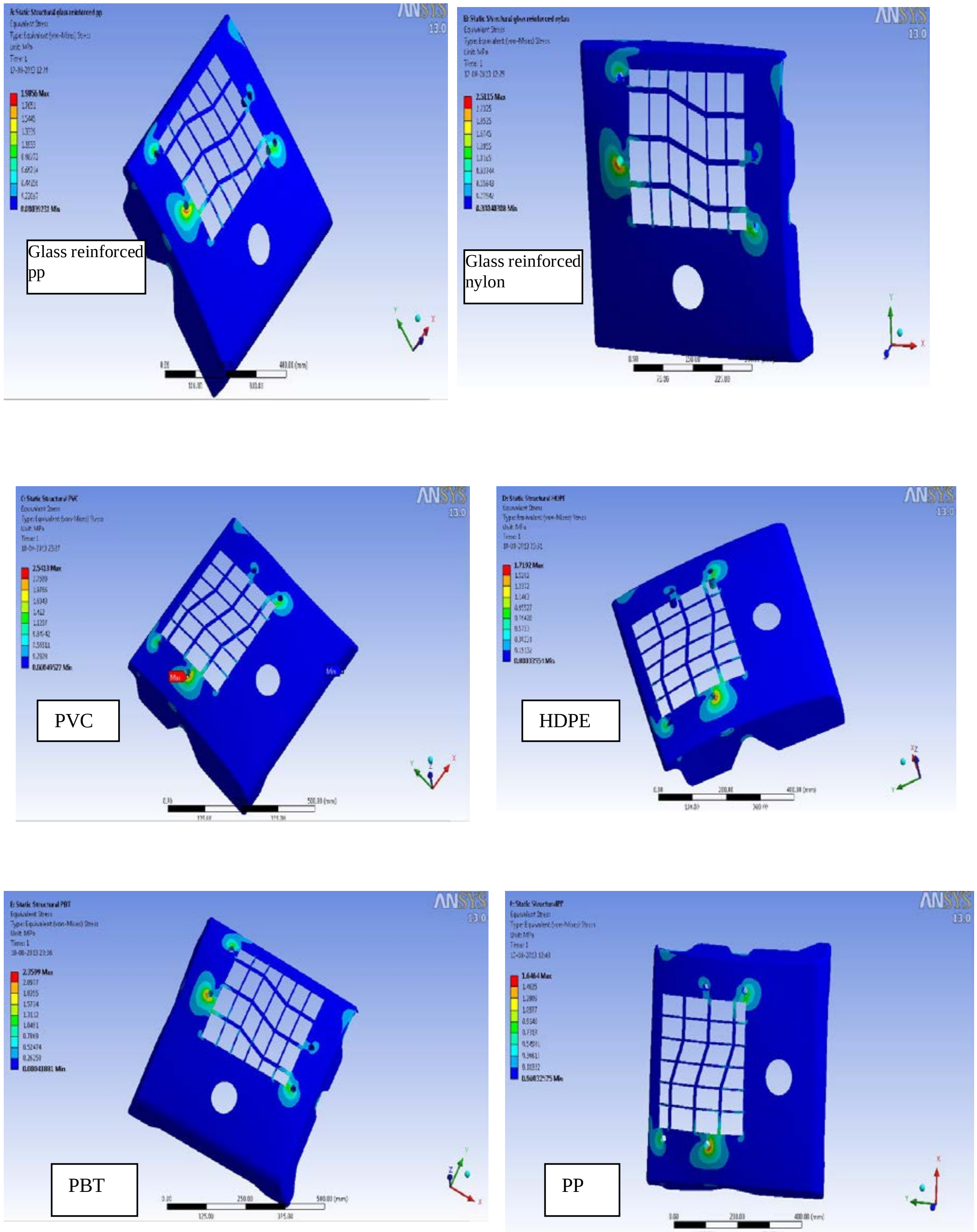

Fig 4.3 Pictorial view of equivalent stress of PVC, HDPE, PBT, PP, Glass reinforced PP and Glass reinforced nylon

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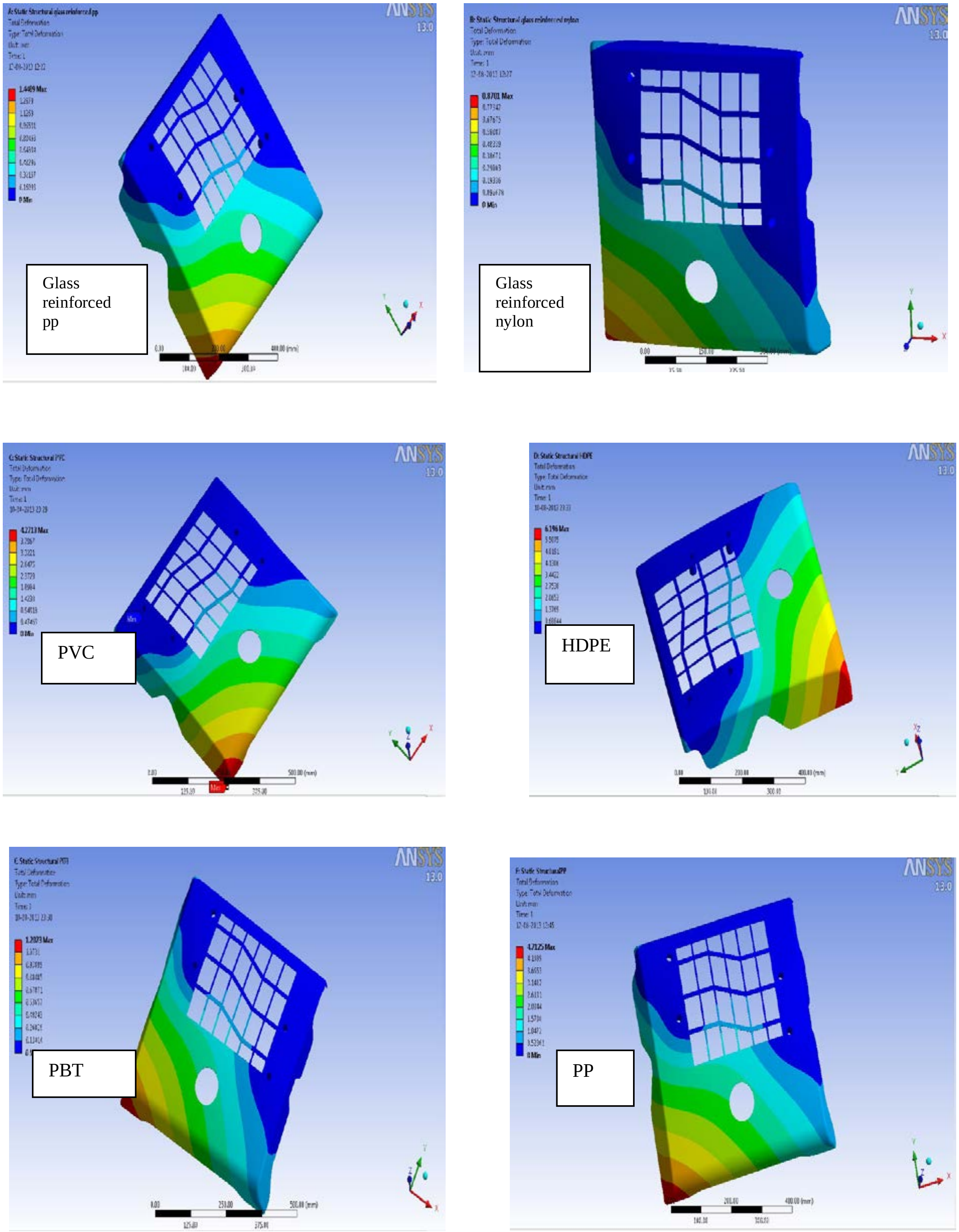

Fig 4.4 Pictorial view of total deformation of PVC, HDPE, PBT, PP, Glass reinforced PP and Glass reinforced nylon

The maximum values of equivalent stress and total elongation are shown in the Table 4.3 and plot of the same is shown in Fig. 4.5

Table.4.3 Equivalent stress and total deformation

Material	Equivalent stress(MPa)	Total deformation(mm)
PP	1.6464	4.7125
HDPE	1.7192	6.196
Glass reinforced pp	1.9856	1.1513
PBT	2.3599	1.2073
Glass reinforced nylon	2.5115	0.68363
PVC	2.5413	4.2713

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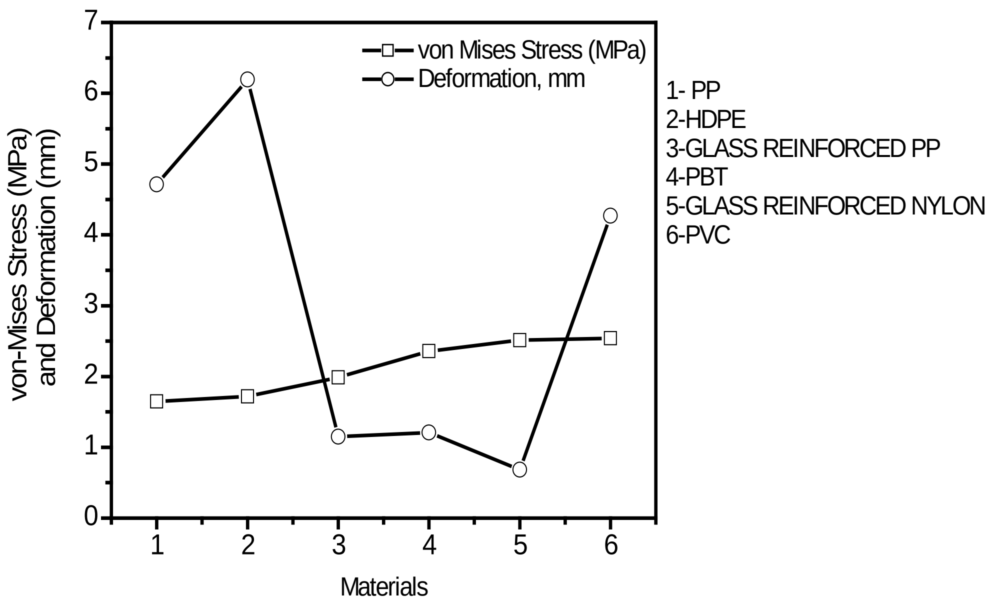


Fig 4.5 Plot of Equivalent stresses and Total deformation v/s Different materials

From the Fig. 4.5 it is clear that the variations of equivalent stresses for different material are found to be almost equal and they are ranging from 1.642 to 2.54MPa. The developed stresses are well within the limits (Compared to yield Stress). At this level of analysis the optimization is not possible. The constraint is that the minimum thickness to be taken is 3mm. But, unlike stresses the deformations are not same for different materials when analysis is done using self-weight. The deformation is found to be maximum for HDPE material and minimum is found to be for Glass reinforced PP. This clearly indicates that such variation is attributed to different values of Young's modulus and Poission's ratio. At this moment with static analysis using self-weight as a parameter, Glass Reinforced PP is an alternate material to present existing material (PP) for the engine cover.

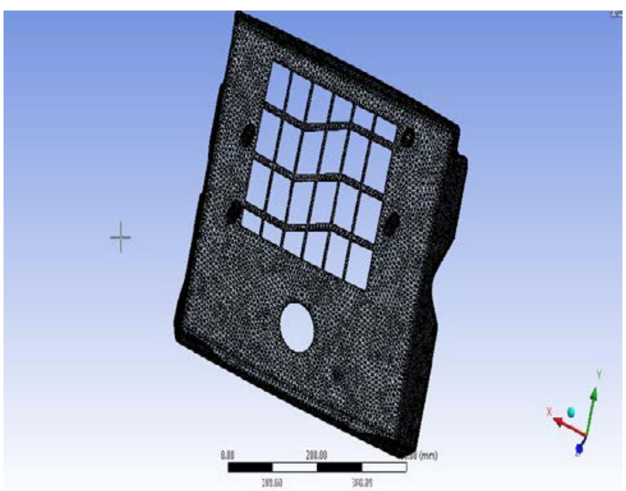
Modal analysis of engine cover using finite element method

The objective of the present work is to estimate the natural frequencies and mode shapes of engine cover using different materials of interest. The details of the material used in the analysis are given in Table 5.1. The obtained mode shapes and frequencies are used to compare with the present existing material (PP) of the engine cover.

Table.5.1 Material properties

Material	E,(GPa)	Poission's ratio	Density(g/cm^3)
Glass reinforced pp	3.553	0.40	1.12
Glass reinforced nylon	7.5	0.40	1.4
PVC	1.5	0.42	1.4
HDPE	0.7	0.42	0.95
PBT	5	0.41	1.31
PP	0.9	0.42	0.89

Engine cover model as per the dimension is prepared in CATIA software and is saved as IGES format. The model thus prepared is imported to ANSYS software through IGES format to carry out further analysis. Mesh is generated in ANSYS software with tetrahedral element with element size 2.5mm, same as discussed in section 4.2. Number of elements and nodes are shown in Table .5.2.



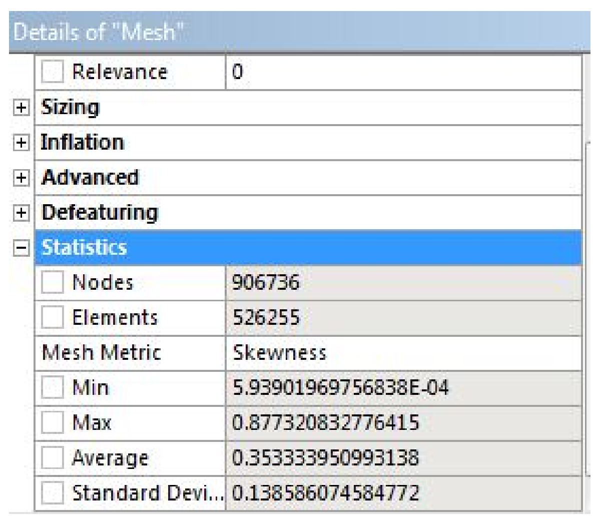


Fig.5.1 Meshed engine cover

Modal analysis is carried out on engine cover model for 5 different materials viz. Glass reinforced polypropylene, Glass reinforced nylon, Poly vinyl chloride, High density polyethylene, and Polybutylene terephthalate and mode shapes of different materials are studied and compared with existing material PP by fixing four bolt holes which is the major constraint/boundary condition in this analysis. The results of modal analysis are explained in detail in section 5.3 along with pictorial views and various plots.

Results and discussion

In order to check the correctness of methodology and validation purpose the analysis is carried out using the data provided in the earlier paper [Beomkeun Kim et al., 2007]. The plot of our results is superimposed with the results of Beomkeun Kim et al., 2007 and is shown in Fig. 5.2. The plots clearly demonstrate excellent match and hence validation of our present methodology. Similar approach is used further to analyse with other materials. The 3 mode shapes along with their frequencies of 6 different materials are shown pictorially below in Fig.5.3 (a), Fig5.3 (b) and Fig5.3(c).

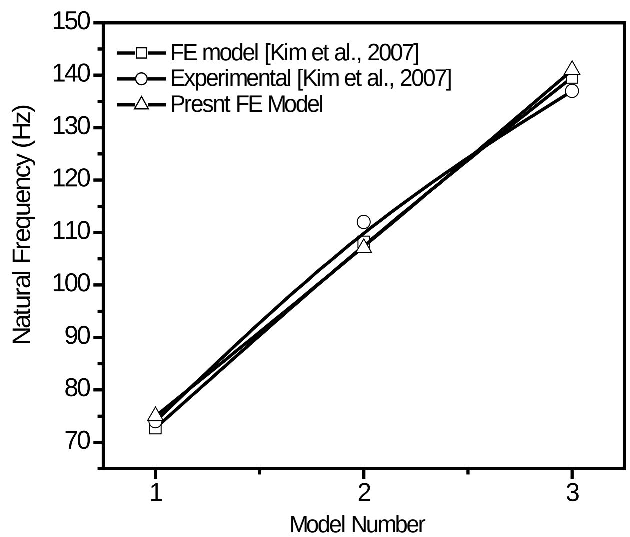


Fig 5.2 Plot of mode number Vs Natural frequency

5.3.1 Mode 1

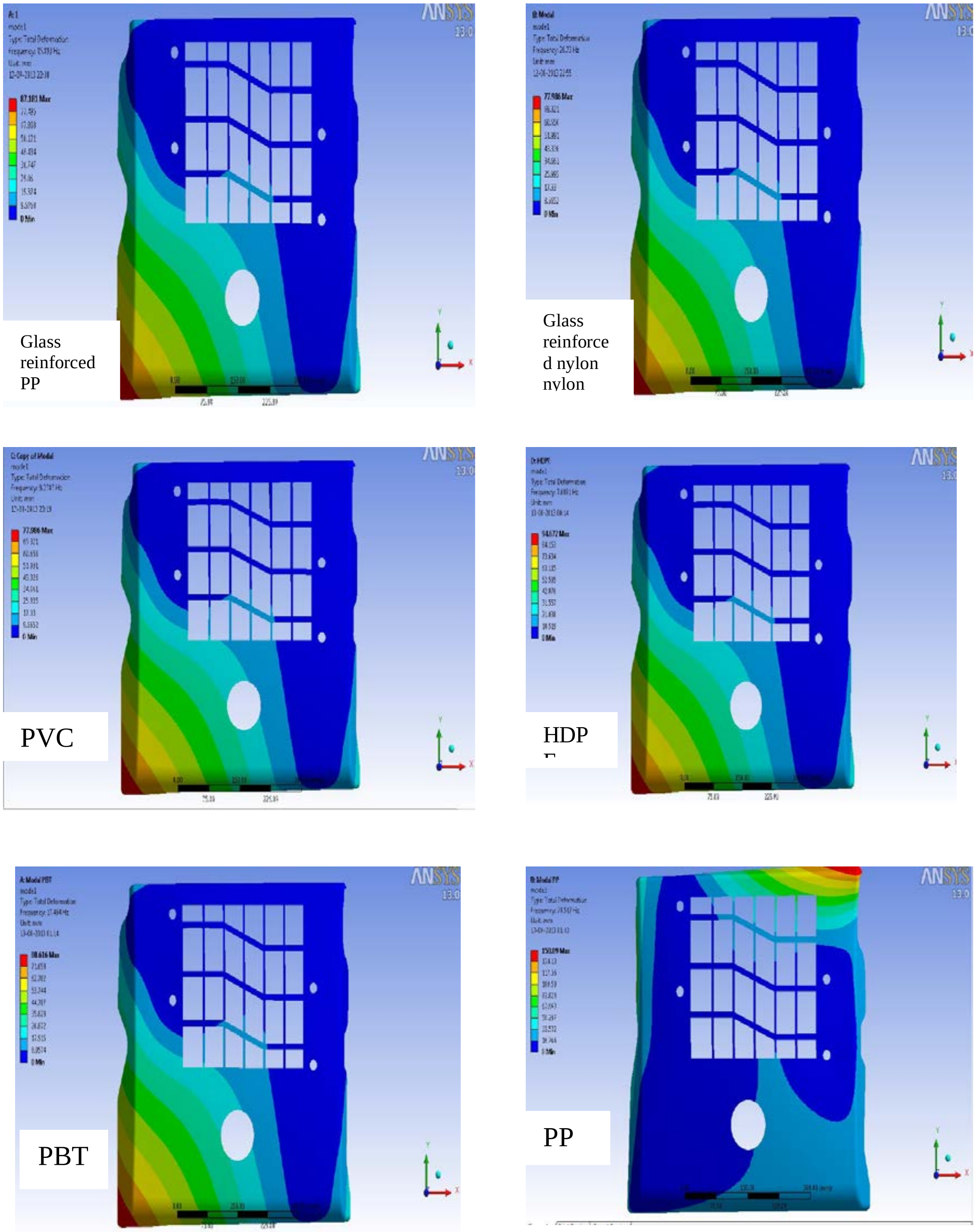


Fig.5.3 (a) Pictorial view of first mode shape of 6 different materials

5.3.2 Mode 2

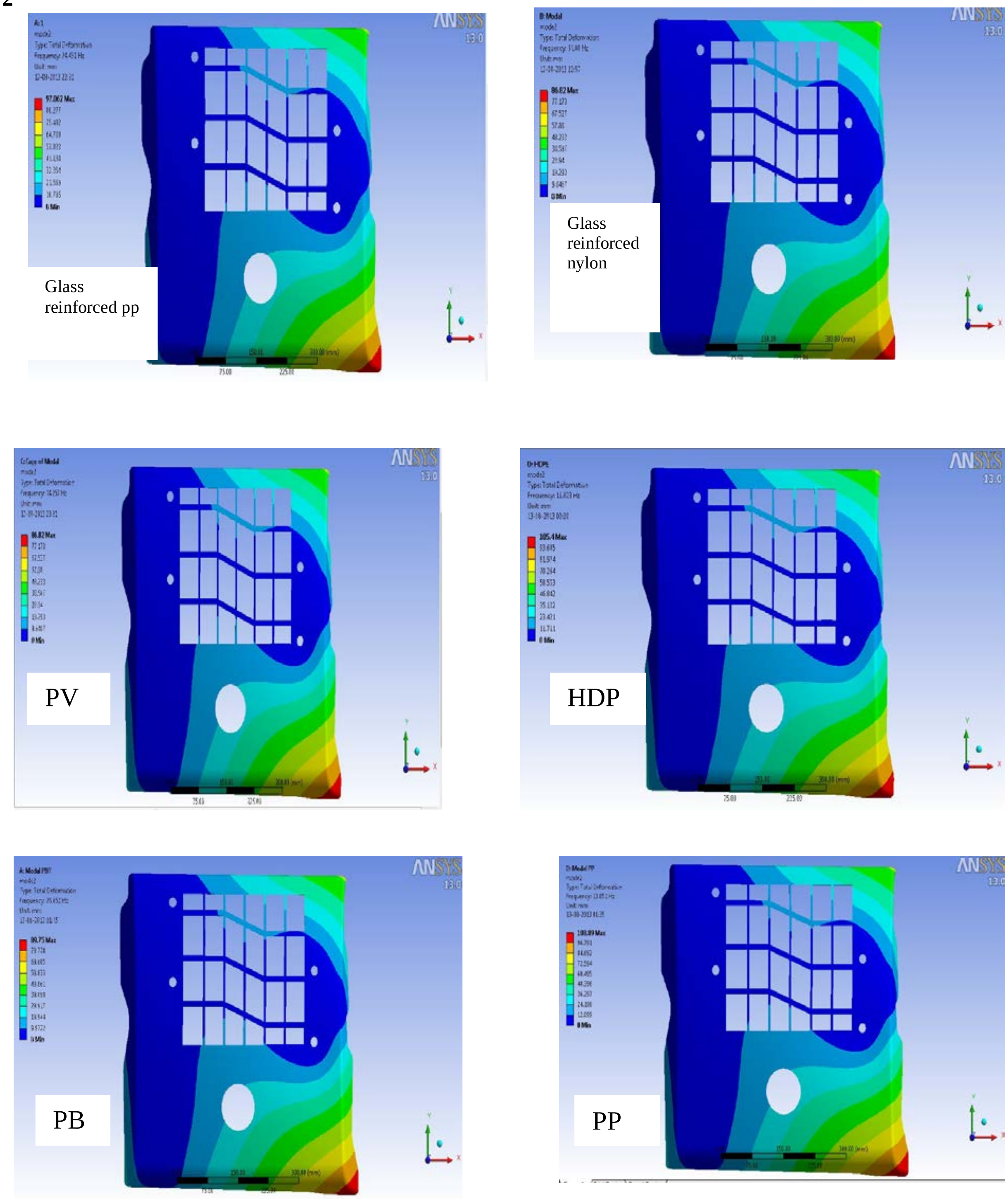


Fig.5.3 (b) Pictorial view of second mode shape of 6 different materials

5.3.3 Mode 3

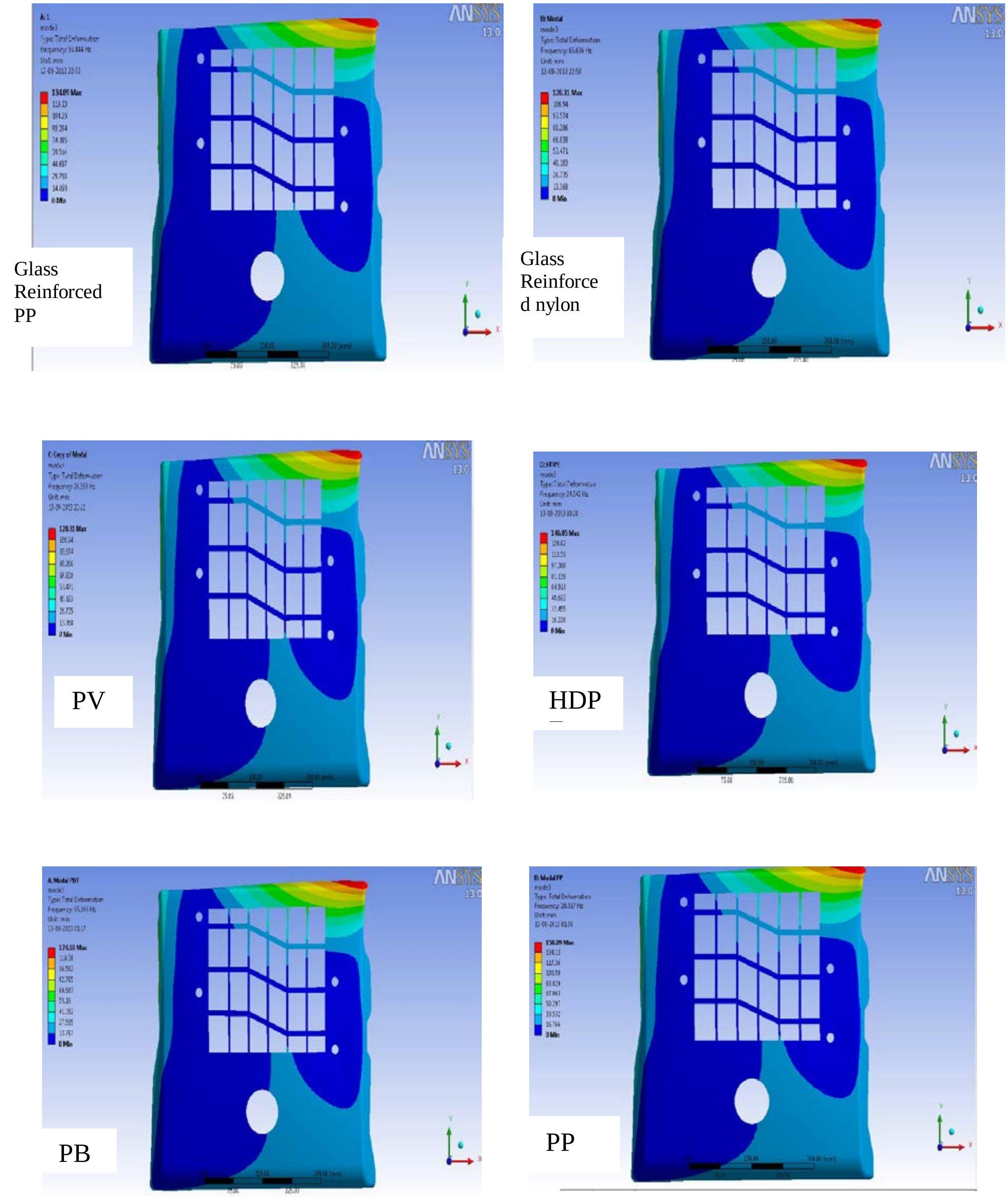


Fig.5.3 (c) Pictorial view of third mode shape of 6 different materials

The initial three mode shape frequencies of engine cover vibration for 6 different materials are shown in Table 5.3. A plot of the same is shown in Fig. 5.4.

Table.5.3 Mode shape frequencies

Material	Mode 1(Hz)	Mode 2(Hz)	Mode 3(Hz)	Specific Modulus
HDPE	7.6881	11.823	24.342	0.00074
PP	8.9734	13.794	28.48	0.00101
PVC	9.2707	14.257	29.353	0.00107
PBT	17.464	26.852	55.365	0.00382
Glass Reinforced PP	15.893	24.431	50.444	0.0317
Glass Reinforced nylon	20.73	31.88	65.636	0.0536

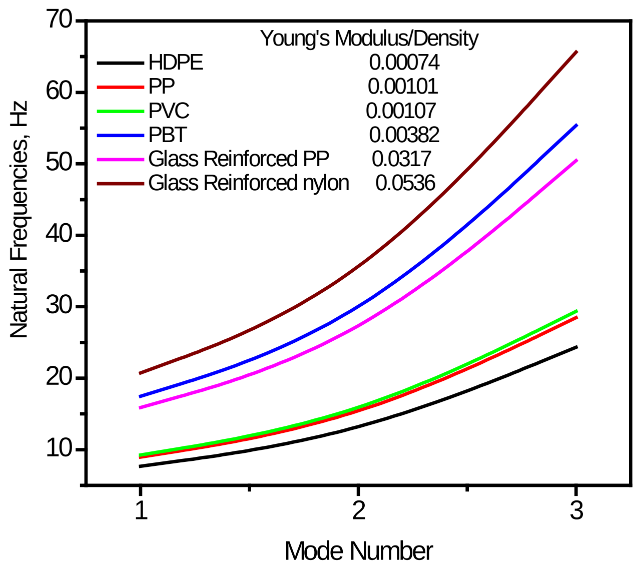


Fig.5.4 Variation of mode shape frequencies of different materials with respect to Specific modulus

Figure 5.4 clearly indicates that the natural frequencies are dependent on the specific modulus. Similar kind of variation is found in the work of Patil and Barjibhe [2013]. As specific modulus increases natural frequencies also increase and vice versa. This is in accordance with the work of Bondok, [2013]. The nature of variation is found to be same in all materials. The lowest natural frequency is found in HDPE and the highest is in Glass Reinforced nylon. The only material having lesser natural frequency is HDPE as compared to existing material of engine cover. The suitability of the material for the engine cover with reference to frequencies cannot be clearly indicated at this juncture unless further investigation is made. This kind of analysis helps practicing design engineers to safety design critical engine components. The present investigation also indicates that there is a need for a further experimentation for estimation of strength and frequencies. Future research on this area needs to be focused in these directions.

IV. CONCLUSION AND FUTURE SCOPE

In the present work engine cover of vehical has been modeled in CATIA software. Mesh is generated using ANSYS software with solid tetrahedron four node elements. Five different materials are used for the analysis. The static analysis clearly shows that minimum total deformation was found in Glass reinforced PP material and was lower than existing PP material. Hence it is better material as far as deformation is concerned. The deformation is found to be higher for HDPE material. It clearly infers that it is better to avoid HDPE material if deformation produced in engine cover is major design criterion. In order to study the vibrational behavior Modal analysis was carried out. The results have been presented for comparative study of different materials and comparing with existing PP material. The mode shape frequencies are found to be very less for HDPE material as compared to existing material. Hence the use of HDPE is better option for engine cover as far as modal analysis concerned. Finite element analysis results indicated that the natural frequency increases as the specific modulus increases.

These natural frequencies and mode shapes gives designer/engineers an idea of how the design will respond to different types of dynamic loads. This allows to designer/engineer to change the design to avoid resonant vibrations or to vibrate at a specified frequency. Also helps in calculating solution controls (time steps, etc.) for other dynamic analyses. The suitability of material cannot be decided at this juncture.

An investigation of this kind requiring extensive FEA is naturally limited in a restrained time axis to probe several features of scientific interest in depth. It is considered that future work in this area of research should attempt to quantify other factors and experimental work. Fillet areas near the boss, where bolts are tightened, were found structurally critical. For complete structural analysis, fatigue life analysis of engine cover would be necessary to predict critical area.

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