Analysis of Damping of Sandwich Materials by using Free Vibrations

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Article Info
Page Number: 796-806
Publication Issue:
Vol. 70 No. 1 (2021)

Article History
Article Received:*26 January 2021*
Revised: *07 February 2021*
Accepted: *25 February 2021*
Publication: *15 March 2021*

Abstract
Sandwich material panel is a structure made from three layers. A low density core is inserted in between two relatively thin skin layers. This sandwich material is used to achieve excellent mechanical performance at minimal weight. Sandwich panels with polygonal cores are widely used in different structural applications such as aircraft floor panels, control surfaces, civil engineering structures and many more. The main use of these panels is to reduce weight and material usage. These panels undergo various static and dynamic loading along with thermal environment. This project is a comparative study of PVC (Poly Vinyl Chloride), PU (Poly Urethane), GRF(Glass Reinforced fibre) all these sandwich materials. So there is requirement to develop the material which can be used easily for various engineering applications.
Keyword — sandwich Material, Ansys, Minimal weight, Dynamic loading

I. Introduction

Sandwich material panel is a structure made from three layers. A low density core is inserted in between two relatively thin skin layers. This sandwich material is used to achieve excellent mechanical performance at minimal weight. The very high rigidity of a sandwich panel is achieved by interaction of its components under flexural load applied to the panel. Core takes the shear loads and creates a distance between the skins which take the in-plane stresses, one skin in tension, the other in compression. Different sandwich core types are available and the potential with respect to weight savings.[2]
A sandwich-structured composite is a one of special class of composite materials that is made by attaching or joining two thin but stiff skins to a lightweight but thick core. The core material is normally low strength material, but its higher thickness provides the sandwich composite with high bending stiffness with overall low density.[3]Sandwich composite materials are increasingly being used in a variety of industrial applications such as, marine, aerospace, automobile industry etc. The use of sandwich construction is the result of an increasing demand for light and strong structures. Weight saving is a dominant factor in the transport sectors such as high speed trains, high speed boats, cars etc. The sandwich concept takes advantages over single skin laminated structures in terms of flexural properties with a reduced weight. Flexural stiffness and strength are just two of a variety of design criteria to be considered. Sandwich panels have the best stiffness over lightness ratio. Because of this ratio material made very useful in industrial applications for instance aerospace, transport and maritime fields. The multi-layer core is analyzed using a three-point bending test and the results correlated to the final properties of the composite sandwich composites with glass/polyester skins and polypropylene honeycomb cores are explored. From experimental study we founds that the multilayer structure is more rigid. A small increase of the final weight leads however to significant increase of the mechanical properties. The aim of the paper is to analyzing the damping of sandwich composites made of foam core and laminated skins. Damping parameters are found in the case of the bending vibrations of clamped-free beams. Modeling of the

damping of the sandwich materials is done by using a finite element analysis which is formulated on the sandwich material theory. Damping modelling is based on the evaluation of the different energies dissipated in the material directions of the core and the layers of the skins. The results obtained in the case of the bending vibrations of beams show a good agreement with the experimental results derived from an experimental investigation. A parametric study is implemented to identify the effect of the characteristics of the constituents on the damping of the sandwich composites.[5]

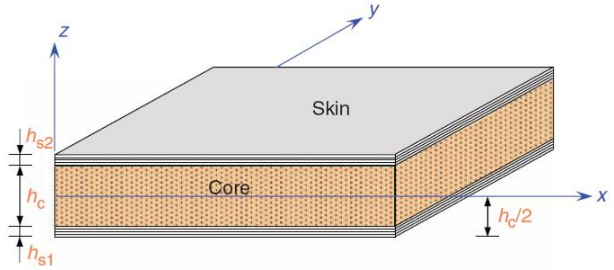


Fig 1 Sandwich plate

h_C-Thickness of core material.

h_{s1}-Thickenss of outer thin skin material.

h_{s2}- Thickness of outer thin skin material.

II. LITERATURE REVIEW

Mustapha Assarar, Abderrahim El Mahi (2013) The analysis the damping of sandwich composite material made from foam core and laminated skins. Damping parameters are find out for the bending vibrations of clamped-free beams. Modelling of the damping of the sandwich materials is created using a finite element analysis which is formulated based on the sandwich material theory. Damping modelling is based on the evaluation of the different energies dissipated in the material directions of the core and the layers of the skins. The results obtained for the bending vibrations of beams show a good agreement with the experimental results derived from an experimentation. Parametric study is done to identify the effect of the characteristics of the constituents on the damping of sandwich materials. [1]

B. Saraswathy, R. Ramesh Kumar (2012) Analytical formulation is done using the split beam theory for the evaluation of frequency of sandwich beam with debonds. Considering honeycomb core stiffness and validated the range of debond size through 3D nonlinear transient analysis. Honeycomb core is structured with the contact element introduced between the core and the skin during vibration. Fast Fourier transform analysis to obtain the Frequency Response Functions. T

est analysis is used for Comparison of fundamental frequencies of a cantilever beam with a single debond obtained, and numerical method show a reasonably good agreement between them up to a debond length of 15% of beam length. Analytical model has also been validated for the case of double debonds and it is observed that reduction in frequency of the sandwich beam is only as much as with the presence of single debond when two debonds (of sum total length up to 30% of beam length) are separated by three times single-debond size. However, when the double-debond size is very small up to a value of 5% of the beam length, then the distance in between can be retained to 1.5 time the debond size to obtain a value corresponding to a single debond.[2]

M.D. Theobald, G.S. Langdon, G.N. Nurick, (2010) metallic sheets are used for Sandwich panels construction. Core is composed by energy absorbing material. It have shown potential as an effective blast resistant structure. The air-blast tests are carried out on sandwich panels composed steel face sheets which is unbonded aluminium foam (Alporas, Cymat) or hexagonal honeycomb cores. Honeycomb cores with small and large aspect ratios are investigated. For any core materials, tests are conducted using two different face sheet thicknesses. The results show that the performance affected by face thickness. The thick core honeycomb panels show the greatest increase in blast resistance under the majority of the loading conditions investigated of the core materials. The Cymat core panels do not show any significant increase in performance over monolithic plates.[3]

Hozhabr Mozafari, Habibollah Molatefi, Vincenzo Crupi (2014) The crushing properties is investigated of foam filled aluminum structure . Polyurethane foam is used with densities of 65, 90, and 145 kg/m^3 for foam filled honeycomb panels. Experimental quasi-static compression tests were performed. Finite element model, is created based on the conducted tests. In the finite element analyses, three different polyurethane foams were used to fill three different honeycomb cores. Mechanical properties are effected by foam filling of aluminum honeycomb core on its in-plane were analyzed experimentally and numerically. Finally results get that the foam filling of honeycomb core can increase the plane crushing strength up to 208 times. Its specific absorbed energy increased up to 20 times. It was found that the effect of foam filling decreases in heavier honeycombs, producing an increment of the above mentioned properties only up to 36 and 6 times, respectively.[4]

LIU Ting, MAO Liangliang, LIU Fuwei, (2011) polyurethane (PU) foams with different loading mass fraction (0%-2.0%) of fumed silica were synthesized by free-rising foaming method. The addition of 1.4% fumed silica makes the cells diffuse more uniform in the PU foam. the temperature of degradation occurring with a maximum weight loss rate is about 7 ℃ higher than that of pure PU foam. Most significantly, the sound absorption peaks of the filled PU foams shift to the low frequency region (from 997 Hz to 711 Hz) with increasing fumed silica content (0%-2.0%). The average sound absorption coefficients of filled PU foams increase except the content of 0.35% fumed silica. The experimental results show that flexible PU foams filled with fumed silica have excellent sound absorption characteristics in low-frequency regions.[5]

Vyacheslav N.Burlayenko, Tomasz Sadowski (2010), The study of dynamic behavior of partially delaminated at the skin/core sandwich plates with flexible cores is done. The ABAQUS is finite element code which is used to calculate natural frequencies and mode shapes of the sandwich plates containing a debonding zone. The debonding size, debonding location and types of debonding are the modal parameters of damaged sandwich plates. Parameters are investigated with various boundary conditions. The results of dynamic analysis illustrated that they can be useful for analyzing practical problems related to the non-destructive damage detection of partially debonded sandwich plates. [6]
Nayak AK, Satapathy AK (2016) stochastic damped free vibration analysis of composite sandwich plates has been carried out using a nine node Heterosis plate bending element based on a first order shear deformation theory with a-priori shear correction factors. The plate bending element contains one transverse displacement and two rotations of the normals about the plate’s mid-plane. Selective reduced integration scheme is adopted to integrate terms associated with the stiffness matrix formulations. Both lumped and consistent mass matrices are considered in the analysis. The accuracy and reliability of the present finite element formulation is verified with previously published results in the literature. New results are presented which are beneficial for designers of composite structures.[7]

C. Cai, H. Zheng, M. S. Khan and K. C. Hung (2002) comprehensive review of vibration damping in vibration and acoustics analysis is presented. The treatment of damping material is an important measure for vibration and acoustics control in engineering. The simulation-based results on vibration and acoustics analysis are very sensitive to the description and input methods of damping properties. In this paper, the consideration of vibration damping using software ANSYS for harmonic and modal analysis is addressed. Several key points are summarized.[8]

III. Methodology

Experimental analysis:

The purpose/aim behind experimentation is to find out the comparison of in the frequencies of three sandwich materials and mild steel.

Experimentation is performed to measure the natural frequencies of a uniform cantilever beam for various materials by modal analysis technique. The basic requirement of the method is to determine reproducibly the first six natural frequencies of the structure under consideration. It does not matter whether the boundary conditions are exactly same as those assumed in the dynamic analysis, if they are reproducible and the mode shapes are not greatly altered from those predicted by the theoretical model. In order to achieve this, experimental modal analysis is carried out which enables the determination of dynamic properties such as frequency mode shapes.

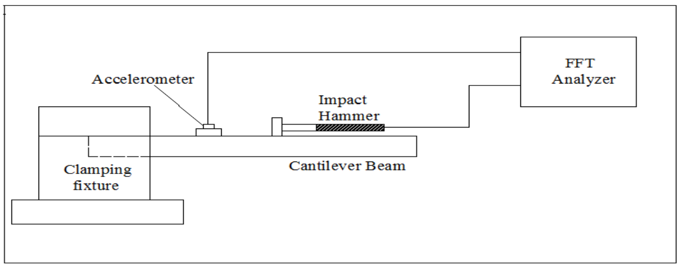
Specimen specification:

Mild steel, PVC(Poly Vinyl Chloride), PU(Poly Urethane) ,GRF(Glass Reinforced fibre) beams will be used for this experimental investigation. The beam consisted with the fixed-free ends.It has the following properties:

Table 1. Geometric and Material Properties

Material	Mild steel	PVC	PU	GRF
Length	300mm	300mm	300mm	300mm
Width	100mm	100mm	100mm	100mm
Height	24mm	20mm	20mm	20mm

Experimental set up



Experimental Study

Fig 2 Block diagram of experimental set up

The experimental set up consists of the test instruments as shown in block diagram, the test specimen and a clamping fixture. The whole experimentation is based on the cantilever condition of the rectangular cross section beam under investigation. The requirement of the cantilever condition is that the deflection as well as slope at the fixed end should be zero. A T-slotted machine bed is used as a foundation for the clamping fixture to have very low frequencies. Modal analysis involves fixing the accelerometer at one location and impacting the structure at one point and moving the accelerometer to other points of interest. The hammer impulse consists of a nearly constant force over a broad frequency range and is therefore capable of exciting all resonances in that range. The resulting Frequency Response Function (FRF) obtained imparts the modal parameters.

Comparative Performance of All-Metal structure with Sandwich Structures

Criteria	**Steel**	**Aluminum**	**Sandwich**
Weight saving	Low	High	Low-High
Price per m2 of panel	Medium	High	Medium
Resistance to transverse loads	High	Medium	High
Risk of corrosion	Medium	Low	Low
Robustness	Medium	High	Medium
Fire resistance	Medium	High	Low-high

Finite Element Analysis

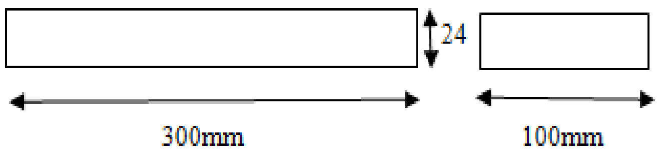


Fig 4 Mild steel plate dimension

Fig 5 Sandwich material plate dimension

Different sandwich material analysis is done in ANSYS.
A compression test experiment is to be carried out and the result obtained can be compared to FEA result.

Sandwich panels with polygonal cores are widely used in different structural applications such as aircraft floor panels, control surfaces, civil engineering structures and many more. The main use of these panels is to reduce weight and material usage. These panels undergo various static and dynamic loading along with thermal environment. This project is a comparative study of PVC(Poly Vinyl Chloride), PU(Poly Urethane) ,GRF(Glass Reinforced fibre) all these sandwich materials. So there is requirement to develop the material which can be used easily for various engineering applications.

Ordinary or traditional materials which are used for various engineering applications are replaced by sandwich materials. Here the sandwich material panel is taken to carryout damping analysis. Comparing with ordinary material damping analysis, good material for various applications selected. By using this analysis the low lost material, high strength material, Low weight material is selected for required application.

Finite element model of a cantilevers beam developed in ANSYS environment. The dimensions of the beam are shown in Fig. In order to perform numerical experiment, modal and structural analysis of the beam is performed. Following the steps outlines below.

Define Materials

- Set preferences. (Structural)
- Define constant material properties.

Model the Geometry

- Create the geometry

Generate Mesh

- Define element type.
- Mesh the area.

Apply Boundary Conditions

- Apply constraints to the model.

Obtain Solution

- Specify analysis types and options.
- Solve

FEA Analysis Result of Mild steel-

The natural frequencies which go as input to the analytical model are determined using Ansys software. A cantilever beam of the dimension shown in the figure is taken for the evaluation. As specified above, in preprocessing step meshing is done with v mesh element with appropriate material. Appropriate boundary conditions are applied for the beam. Once the FE model is ready, following analysis are performed,

- Normal Mode Analysis: output of this analysis is used as input to analytical model.
- Frequency Response Analysis: This analysis is done to study the response of the beam. In this analysis external exaltation ranges from 1Hz to 400 Hz.

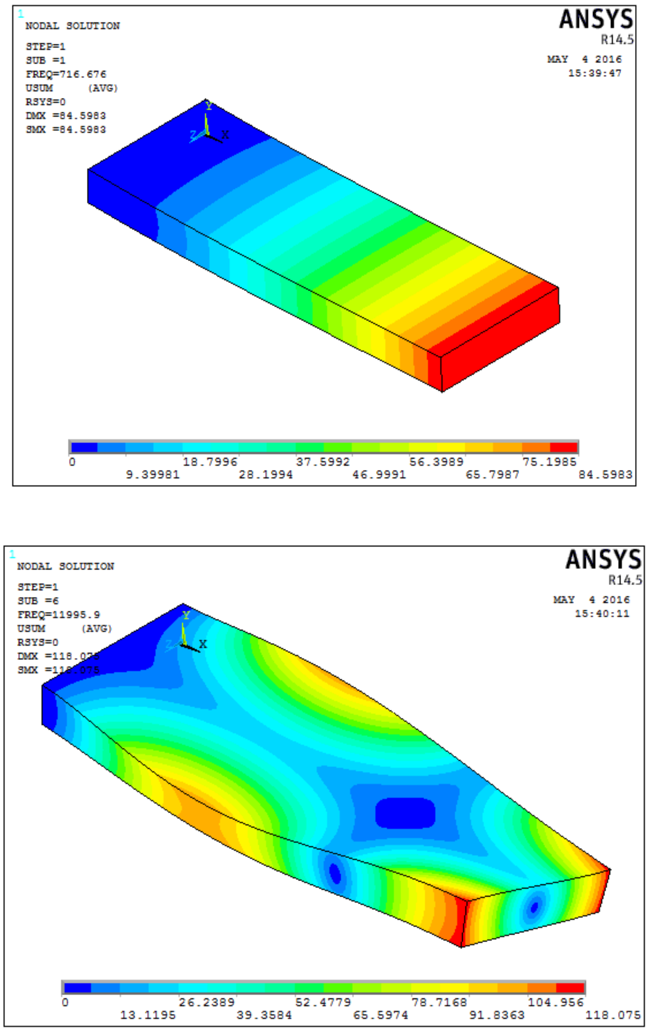
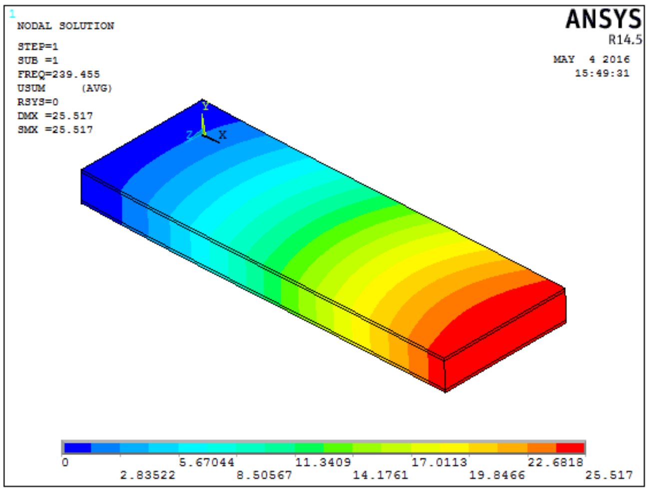


Figure 5: Mode shape 1 & 6 for mild steel.

FEA Analysis Result of Poly urethane-

Above mentioned procedure is repeated for sandwich materials.



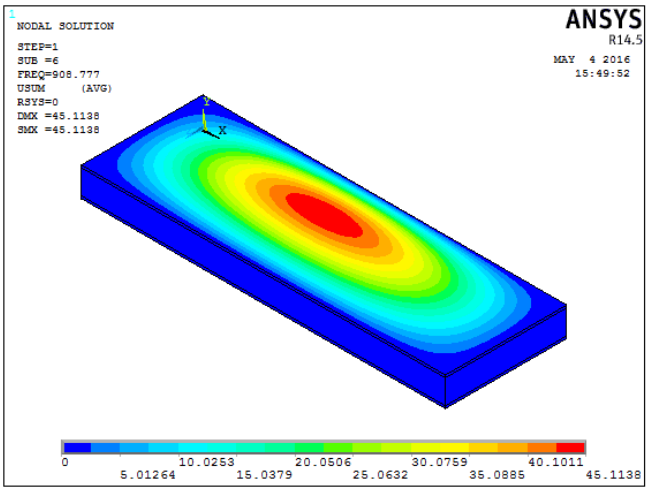


Figure 6 Mode shape 1 & 6 for PU.

FEA Analysis Result of Poly Vinyl Chloride-

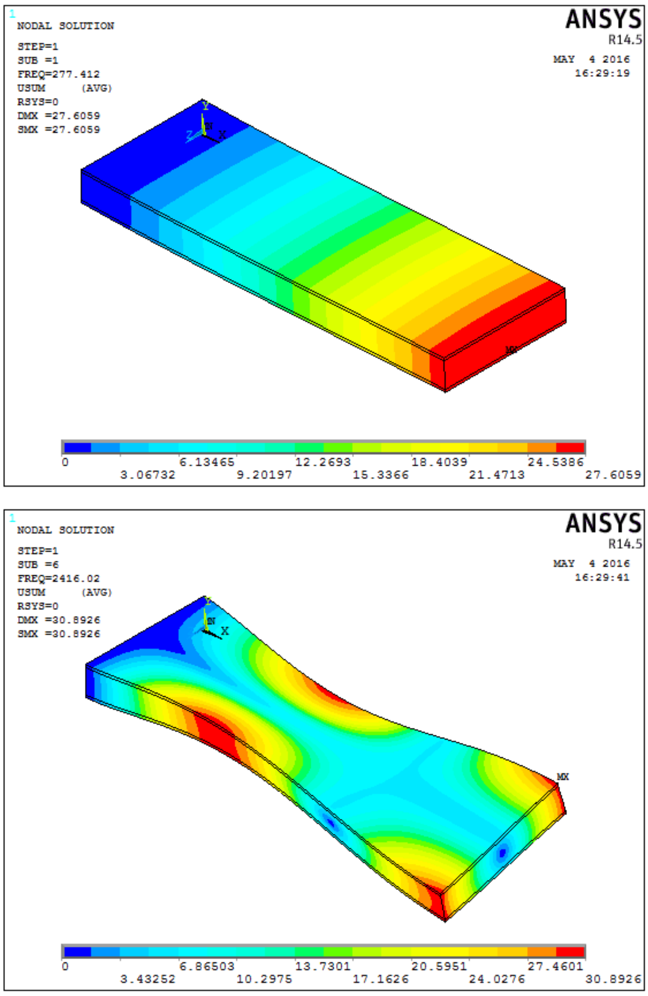
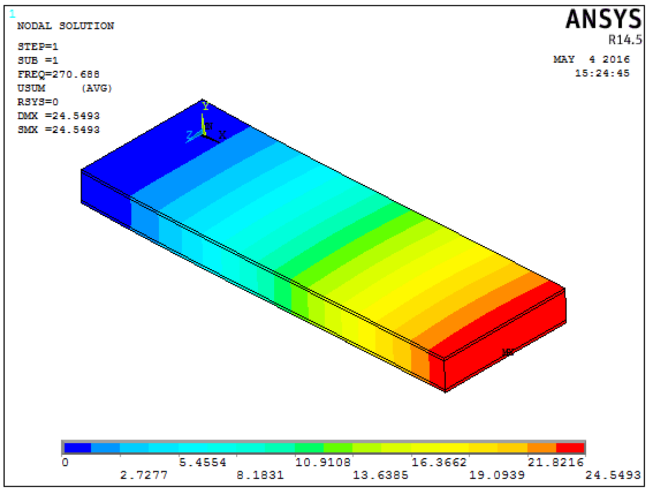


Figure 7: Mode shape 1 & 6 for PVC.

FEA Analysis Result of Glass Reinforced fibre-



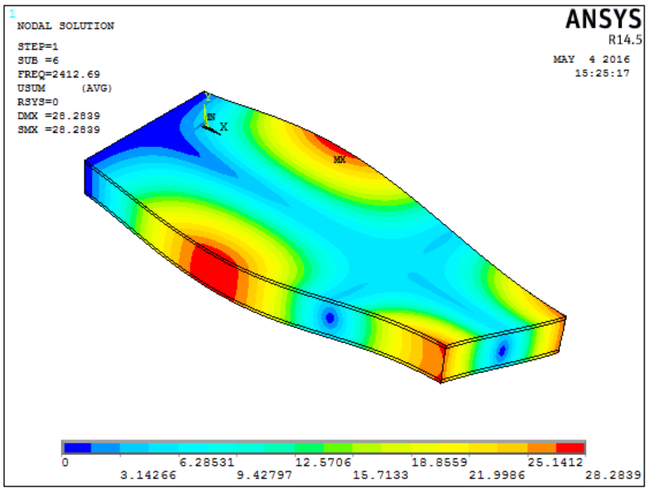


Figure 8: Mode shape 1 & 6 for GRF.

Table 2 Comparison of frequencies from ansys result-

Materials/ Frequencies	MS	PU	PVC	GRF
Mode 1	716.67	239.45	277.41	270.69
Mode 2	2738.72	710.62	764.32	755.08
Mode 3	38886.86	726.4	1028.79	982.13
Mode 4	4354.1	731.51	1110.89	1082.1
Mode 5	11701.7	891.12	2251.54	2233.9
Mode 6	11995.9	908.77	2416.02	2412.7

Table 3 Comparison of frequencies from FFT result-

Materials/ Frequencies	MS	PU	PVC	GRF
Mode 1	9.77	19.53	9.77	29.30
Mode 2	39.06	68.36	19.53	78.13
Mode 3	127	136.7	127.0	156.3

Mode 4	224.5	166.0	175.8	195.3
Mode 5	478.5	185.5	214.8	293.0
Mode 6	644	410.2	468.8	419.9

Advantages Of Sandwich Material-

- In comparison to other sandwich technologies, all-metal structures are not particularly "lightweight". If lightweighting is a primary design driver, composite material sandwich structures might be a better option.
- The main advantages of all-metal structures are space savings, increased unsupported spans and high pre-manufacturing accuracy.
- Other significant advantages of all-metal structures (in comparison to other sandwich technologies) are their relatively low cost and their ease of joining to conventional ship structures by welding.
- For reasons of robustness in the shipyard production process (e.g. handling of material, welding, etc.) it is recommended that the facings of all-metal sandwich panels should be at least 2 mm thick.
- Experience has shown that such panels can be handled within shipyards without them incurring significant damage. Thinner facings can be used, but these need to be handled more carefully.

Conclusion-

From the analytical and experimental results it is observed that sandwich material is having advantages than traditional materials. The first three natural frequencies are generally sufficient for analysis and smaller frequencies are easier to measure experimentally.
It is observed that the presence of crack Material affect the natural frequency, as a result the natural frequency decreases with the decrease in vibrations. So it is concluded that the analysis of change of natural frequencies is effective for prediction of vibration.
Experimental results shows that the vibrations in sandwich material is minimum as compared with traditional materials. So there is scope for sandwich materials in vibrating machines like Lathe, Drilling Machines for reducing their vibrations.

Acknowledgments

Thanks to my project guide Prof. D. P. Kamble, Head of Department Prof. G. E. Kondhalkar and ME coordinator Prof. Munde for their valuable contribution in carrying out this project.

References

[1]Mustapha Assarar, Abderrahim El Mahi, Jean-Marie Berthelot, Analysis of the Damping of Sandwich Materials and Effect of the Characteristics of the Constituents, International Journal of Material Science (IJMSCI), 2013, Vol. 3, No. 2, 61-71
[2]B. Saraswathy, R. Ramesh Kumar, and LaluMangal, Dynamic Analysis of Honeycomb Sandwich Beam with Multiple Debonds, International Scholarly Research Network,ISRN Mechanical Engineering, Vol. 3, No. 7 2010, 2465-2475.
[3]M.D. Theobald *, G.S. Langdon, G.N. Nurick, S. Pillay, A. Heyns, R.P. Merrett , Large inelastic response of unbonded metallic foam and honeycomb core sandwich panels to blast loading, Blast Impact and Survivability Research Unit (BISRU),Vol. 1, No. 4, December 2008.
[4]HozhabrMozafari, HabibollahMolatefi, Vincenzo Crupi,GabriellaEpasto and Eugenio Guglielmino, In plane compressive response and crushing of foam filled aluminum honeycombs, Journal of Composite Materials2012, 1-14.

[5]LIU Ting, MAO Liangliang, LIU Fuwei, JIANG Wuzhou, HE Zhaobo, FANG Pengfei, Preparation, Structure, and Properties of Flexible Polyurethane Foams Filled with Fumed Silica, Wuhan University journals of natural science, Vol. 16, No. 1 (2011) 29–32.
[6]VyacheslavN.Burlayenko, TomaszSadowski, Matrix Influence of skin/core debonding on free vibration behavior of foam and honeycomb cored sandwich plates, International Journal of Non-Linear Mechanics, Vol. 16, (2010), 959-968.
[7] Nayak AK, Satapathy AK, "Stochastic Damped Free Vibration Analysis of Composite Sandwich Plates", 12th International Conference on Vibration Problems, ICOVP 2015.
[8] C. Cai, H. Zheng, M. S. Khan, K. C. Hung, "Modeling of Material Damping Properties in ANSYS", Institute of High Performance Computing, 2002.