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Design & Analysis Of Polyethylene Terephthalate Based Sandwich Beam With Ansys

Rohit Kumar Singh
Student
Noida International University
rohitsinghkrj@gmail.com

Nidhi Sindhu
Assistant Professor
Noida International University
nidhisindhu15@gmail.com

Sushil Kumar Singh
Assistant Professor
ACET, ALIGARH
sushil.acet@gmail.com

Abstract: The present work aims to study the design and analysis of functionally graded layered sandwich beam with the viscoelastic core (Polyethylene terephthalate) in the high thermal environment. The top layer is functionally graded material (Ceramic S3N4) and stainless steel on the bottom. The report is divided into five chapters. First two chapters give Introduction and Literature survey of the various viscoelastic core with the Functionally graded material (FGM) that have unique and different properties from any other material. Materials and Methods used are given in chapter three. Chapter four provides details of ANSYS Software where the sandwich beam is subjected to axial dynamic loaded conditions. The viscoelastic core (Polyethylene terephthalate) layers are observed to be at high temperature but other layers of the beam are at normal conditions. The temperature variation is nonlinear in the viscoelastic core (Polyethylene terephthalate). The effect of various system parameters such as core thickness ratio, compression, expansion, modal structure test, thermal test is analysed using ANSYS software. The thickness of beam is responsible for their displacement and boundaries for the stable and unstable region are considered in this work. It is found that the buckling load of the beam decreases with increase in core thickness parameter and temperature of the top face of the functionally graded material. Temperature variation along thickness has a negligible effect on buckling load as well as on natural frequency. In this study as the frequency of the beam increases deformation starts first in Polyethylene terephthalate layer of the beam. The instability of the beam increases with increase in core thickness parameter and temperature of the top layer.

Keywords: Functionally Graded Material (FGM), Viscoelastic, Sandwich Beam, Stability, And Constraining Layer.

INTRODUCTION

Analytical and Modelling techniques for the stability behaviour of materials and structures facilitate the engineers and led to many applications. Sandwich materials really begin to be highly appreciated in the industry, and especially in the field of transport (automotive, aeronautics, shipbuilding and railroads) or in civil engineering. The traditional Sandwich construction includes a relatively thick core of low-density material, sandwiched between the top and bottom face sheets (face layers) of relatively thin size. A sandwich structure is composed of three layers are two edges made of rigid layers, working in the membrane, which represents the skins and the middle layer is a thick and soft central layer, the core, with low rigidity and density and essentially submitted to transverse shear loading, is sandwiched in between the edges. The thick core is Viscoelastic material (damping material) that exhibits both viscous fluid and elastic solid material characteristics. There are mainly two methods of treatment of viscoelastic material viz., constrained layer and an unconstrained layer or free layer treatment. In this case, the viscoelastic material sandwiched between the surface of the structure and thin facings of metallic material.

REVIEW OF LITERATURE

Brown Salama (2002) studied the dynamic stability of uniform bar using finite element method. He analysed the effect of support condition on dynamic stability of Timoshenko beam using finite element technique. His experiment based on dynamic stability problems of beams and frames using finite element method. Most of the recent works on dynamic stability of elastic systems have used finite element method. Kerwin (2003) was the first scientist to do a quantitative analysis of damping effectiveness of a constrained viscoelastic layer. In his work, he has formulated an expression for loss factor. He has formulated general expressions for the loss factor of uniform linear composites in terms of properties of its constituent materials. Asnani and Nakra (2004) has worked on multi-layer simply supported sandwich beams and found out the loss factors and displacement response for beams of different numbers of layers. Improved a theory for finding natural frequencies and loss factors for finite length sandwich beams.

Analysed the effect of a number of layers and thickness ratio of layers on loss factor of a multi-layer simply supported beam. Rao and Y.V.K.S (2006) study including the rotary and longitudinal inertia terms. Studied the effect of free vibration of a short sandwich beam considering higher order effects such as inertia, extension, and shear of all layers. He found out that if these higher terms are not considered, then there is an error in the values of loss factor and natural frequencies as high as 45%.in his other work formulated equations for calculating frequencies and loss factor for sandwich beams under different end conditions. Imaino and Harrison (2007) used modal strain energy technique and finite element technique to study the damping of first and second bending resonance of a sandwich beam with constrained damping layer.in his model of a simply supported beam with a constraining damping layer has considered the continuity of displacements and transverse shear stresses across the interface of layers and found out the resonant frequencies and loss factors. Sakiyama (2008) has worked on three layers continuous sandwich beam and studied the effect of the shear parameter and core thickness on the resonant frequencies and loss factors. He used Rayleigh-Ritz method and found out the frequencies, loss factors and mode shapes for sandwich beams. They used polynomials which satisfied the boundary conditions. Mead and Markus (2008) analysed the forced vibration of a three layered sandwich beam with visco-elastic core by using the method of Di Taranto. He worked on forced vibration of a sandwich beam with viscoelastic core for fixed-fixed and cantilever type end conditions. Used finite element method to do modal analysis and calculate the response in time domain. Chonan (2009) worked on the stability of two layered sandwich cantilever beam with imperfect loading. He analysed the dynamic stability of a sandwich beam on which a direction-controlled non-conservative force was acting. Ray and Kar (2010) have studied the dynamic stability of sandwich beams under different boundary conditions. They have used Hamilton's principle for deriving the equations of motion and converted those equations into a set of coupled Hill's equation in the time domain by Galerkin's method. They have assumed approximate series solution which satisfies most of the boundary conditions. Kapuria (2011) using zigzag theory analysed the static and dynamic response of FGM with constituent materials as Al/SiC and Ni for various boundary conditions. He analysed static and dynamic response in high-temperature environment. Simsek.M. (2012) using higher order theories worked on a dynamic study of functionally graded beams. He studied axial displacements of the viscoelastic layer by the kinematic relationships between the constraining layers. Sagar R Dharmadhikari, (2013) Have worked "Design and Analysis of Composite Drive Shaft using ANSYS and Genetic Algorithm". Chakraborty (2014) have worked on the thermo-elastic behaviour of functionally graded beams using finite element technique. They have considered both exponential law and power law variation of material properties. Mohanty (2014) have worked on a static and dynamic study of a functionally graded Timoshenko beams using finite element method. Studied general equations for solving the primary unknowns by using an elimination method or an iterative method. Liu Jiec. (2015) have worked Stress Distribution on Composite Honeycomb Sandwich Structure Suffered from Bending Load. Mechanical performance of the Composite Honeycomb Sandwich was characterized using finite element analysis (FEA) and three points bending performance. Rupesh N. Kalwaghe (2015) Design and Analysis of Composite Leaf Spring by Using FEA and ANSYS. The objective of this paper describes the design and FEA analysis of composite leaf spring made of glass fiber reinforced polymer. The dimension of an existing conventional steel leaf spring of commercial vehicle is taken for evaluation of result.

METHOD AND METHODOLOGY

Ceramic material constituents take care of high-temperature conditions by providing heat shield as its thermal conductivity is low. The other one i.e. metal material constituent's arrests fracture originated by stresses due to the high thermal gradient.Our analysis is based on ANSYS of PET based on sandwich beam graded material.

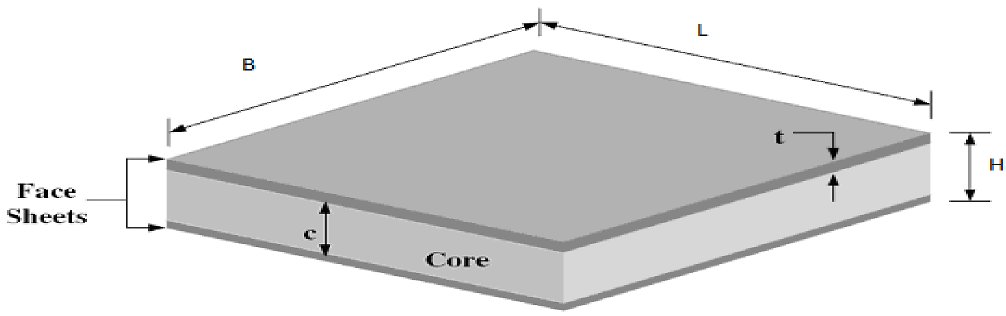

Fig: 1 Sandwich Beam Structure

Dimensions of Sandwich Beam, Length of sandwich Beam(600mm), Width of Sandwich Beam(25.4mm), Face sheet Thickness(30mm), Core Thickness(15mm), Beam Thickness(75mm).

Table 1: Mechanical Properties of Different Materials Used in Sandwich Beam.

Material	Density(ρ) (kg/mm³)	Coefficient of thermal expansion (α)(/℃)	Thermal Conductivity(k) (W/mm℃)	Yield Strength(σ_y) (MPa)	Ultimate Strength(σ_{ut}) (MPa)	Young's Modulus(E) (MPa)	Poisson's Ratio(μ)	Bulk modulus(K) (MPa)	Shear Modulus(G) (MPa)
Ceramic	3.29e-06	2.8e-06	3e-02	250	800	2.8978e+05	0.25	1.9319e+05	1.1591e+05
PET	1.38e+06	1.1e-04	2.4e-04	53	55	3100	0.41	5740.7	10999.3
Stainless steel (SUS304)	7.75e-6	1.7e-05	28e+3	207	586	1.93e+05	0.31	1.693e+05	7366.4

Buckling test:

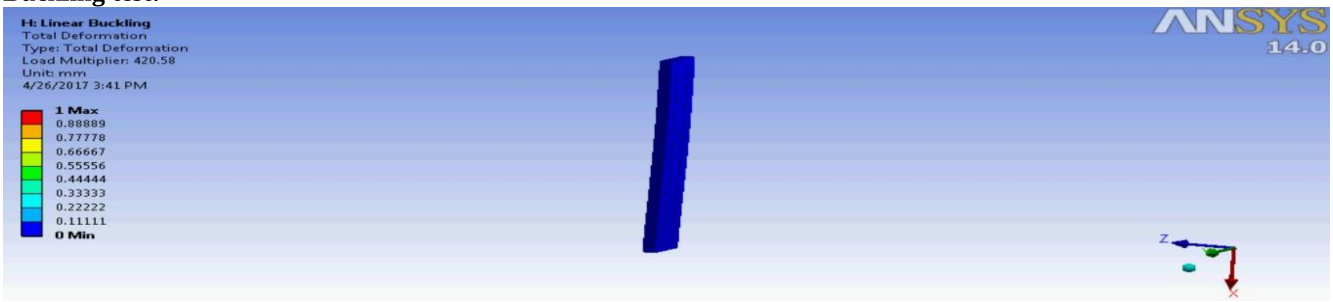

Fig:2 First stage in buckling

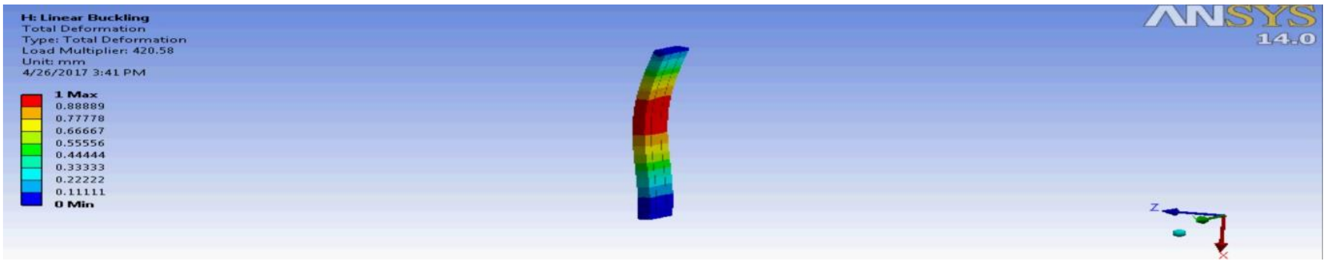

Fig: 3 Last stage in buckling

Buckling test is performed on sandwich beam by using ANSYS software in six stages. In first stage, an axial and compression load is applied to sandwich beam whose both ends are fixed. As the value of load is increased beam starts to buckle and buckling vary linearly with load. When the value of load becomes 420.58 MPa then buckling of the sandwich beam is maximum.

Modal structure test:

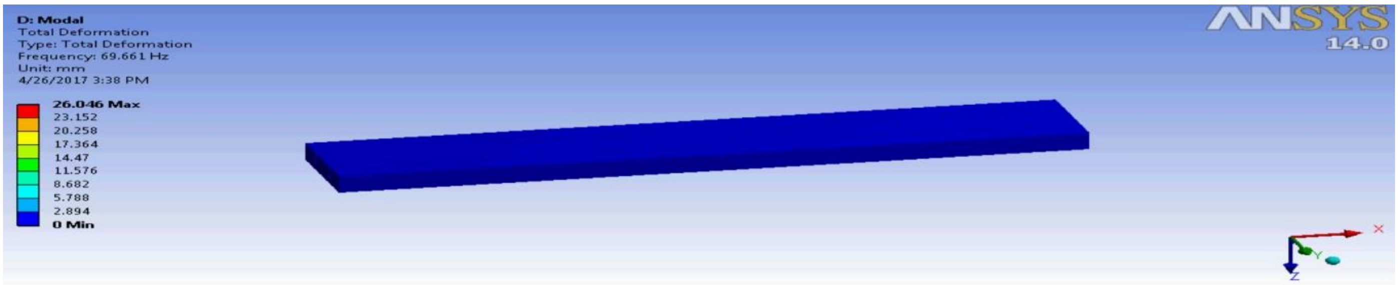

Fig: 4 First stage in Modal structure.

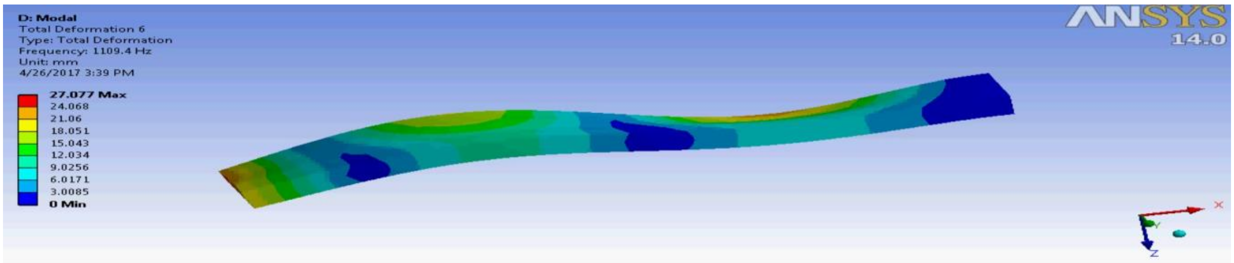

Fig: 5 Last stage in modal structure.

Modal structure test is performed on sandwich beam by using ANSYS software in six stages. In first mode, beam is in cantilever position and a frequency of 69.661 Hz is applied on beam and waviness is formed first towards where the beam is fixed. As values of frequency increase the waviness of beam is increases and becomes maximum when the value of frequency is 1109.4 Hz and sandwich beam starts failure at the fixed end and the position where waviness in maximum in the beam.

Compression test:

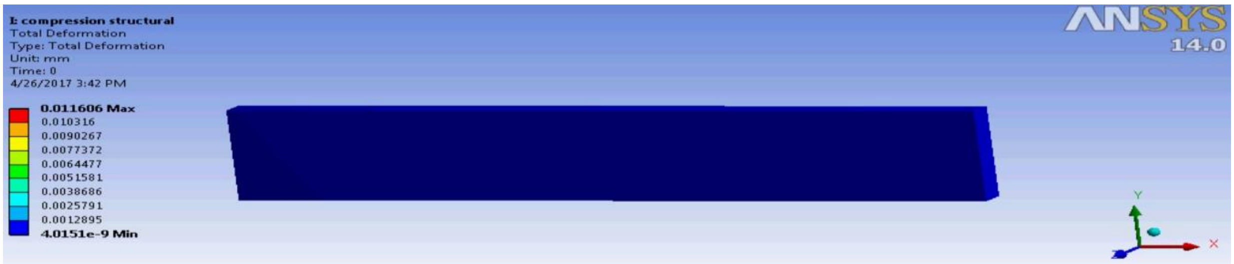

Fig: 6 First stage in compression.

Fig: 7 Last stage in compression.

Compression test is performed on sandwich beam by using ANSYS software in seven stages. The axial and compressive load is applied to sandwich beam whose both end is fixed. As the load is applied on the beam deformation starts first in PET and layers of stainless steel and ceramic remain same. After the application of maximum load maximum deformation obtained in PET, then stainless steel and minimum in ceramic layer.

Expansion test:

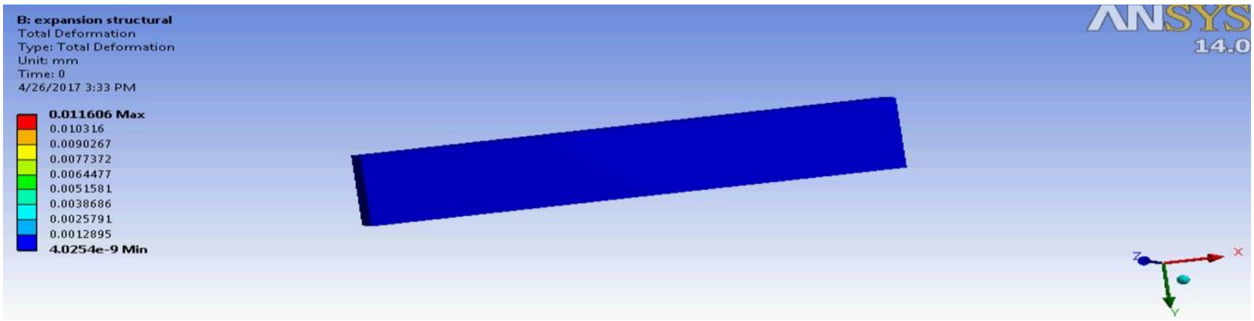

Fig: 8 Frist stage in expansion

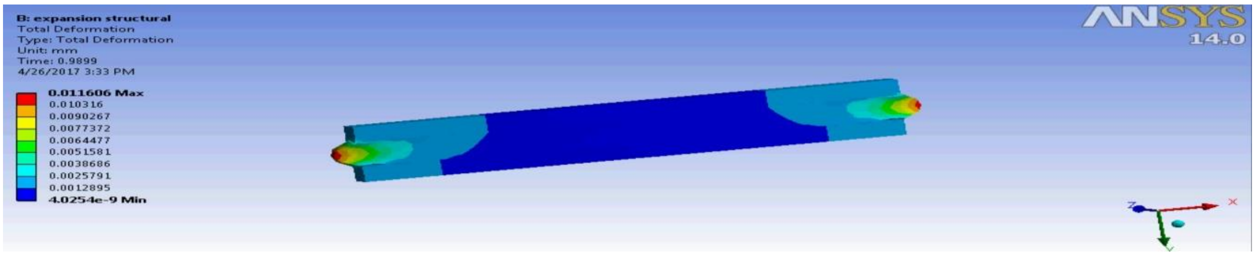

Fig: 9 Last stage in expansion

Expansion test is performed on sandwich beam by using ANSYS software in seven stages. Axial and tensile load is applied on sandwich beam whose both ends are fixed. As the load is applied to the beam expansion starts first in PET and layers of stainless steel and ceramic remain same. After the application of maximum load maximum expansion obtained in PET, then stainless steel and minimum in ceramic layer.

Thermal test:

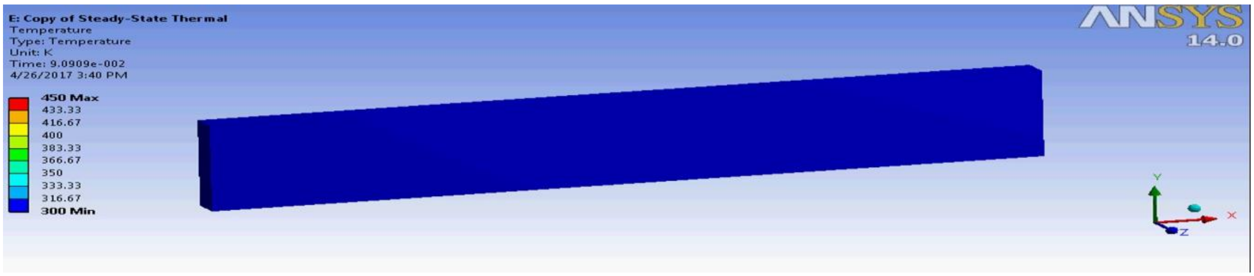

Fig: 10 frist stage in thermal test.

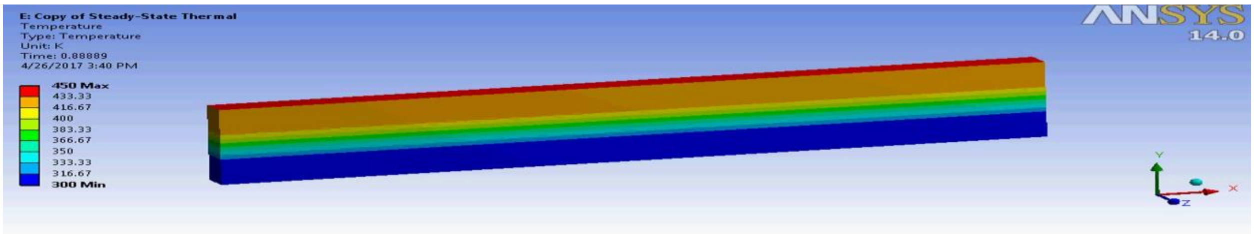

Fig: 11 Last stage in the thermal test.

The thermal test is performed on sandwich beam by using ANSYS software in six stages. Initial temperature given to the sandwich beam is 180.65K and convection coefficient is calculated which is 3.78e-6 W/mm^{2}K. As the value of temperature is increases convection coefficient is also increased. At 1415.7K the value of convection coefficient is 7.99e-6W/mm^{2}K.

RESULT ANALYSIS AND CONCLUSION

Buckling test result:

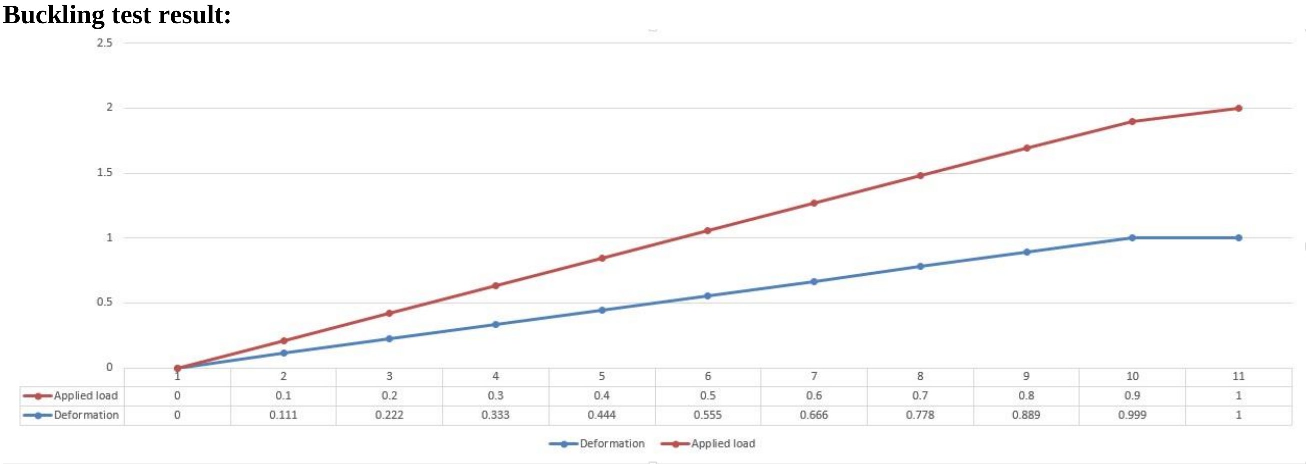

Fig: 11 Graph between applied load and deformation.

A graph is plotted between applied load and deformation by using values of buckling test on ANSYS software. Deformation varies linearly with applied load, as load increases deformation increases and becomes constant at maximum load condition.

Modal structure test result

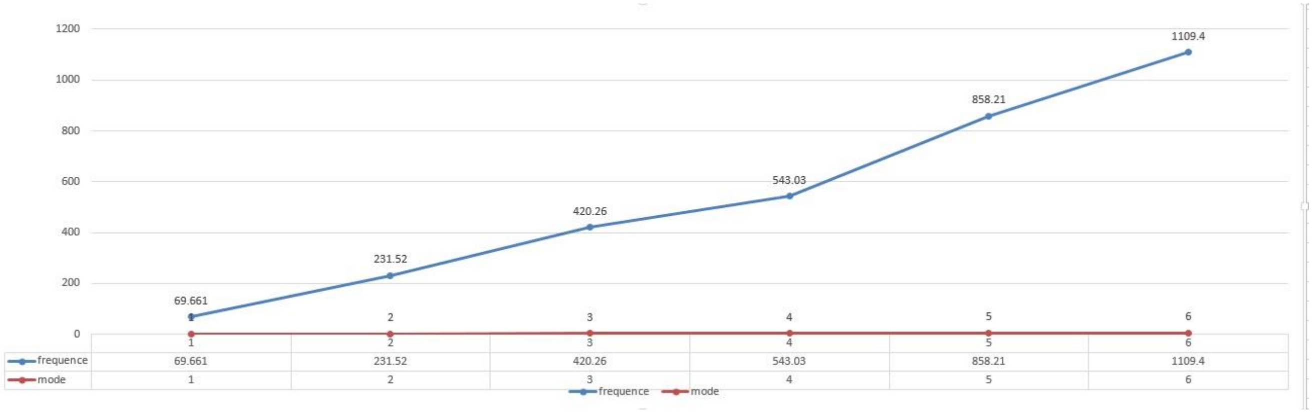

Fig: 12 Graph plotted between frequency and mode.

The graph is plotted between frequency and mode by using values of modal structure test on ANSYS software. Sandwich beam held in cantilever position at low-frequency beam remains undeformed. As the value of frequency increases beam seems like wavy layer and failure occurs at fixed end.

Compression test result:

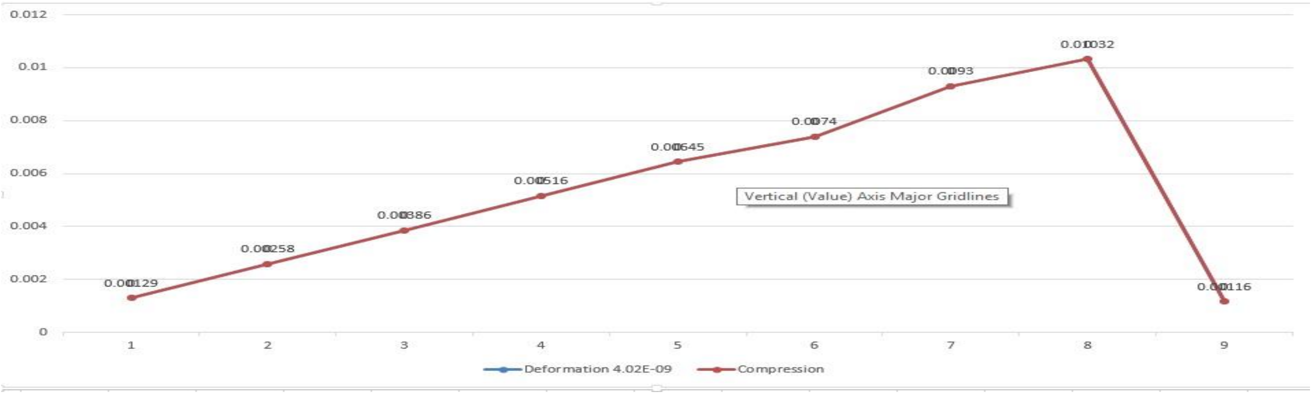

Fig: 13 Graph plotted between Deformation and compressive load.

The graph is plotted between deformation and compressive load by using values of compression test on ANSYS software. An axial compressive load is applied to sandwich beam maximum deformation occurs in PET than in stainless steel and minimum in ceramic. Failure starts first in PET.

Expansion test result:

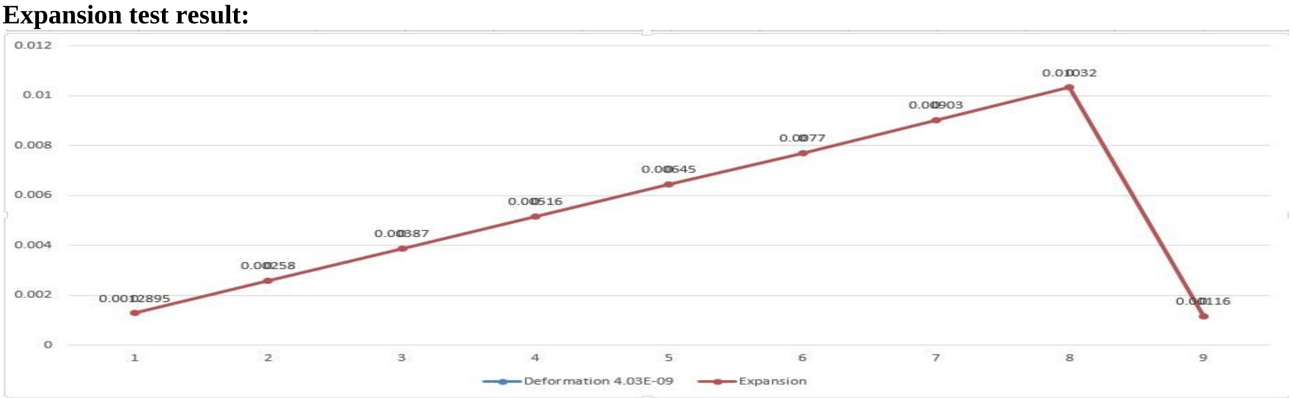

Fig: 14. The graph plotted between deformation and tensile load.

The graph is plotted between deformation and tensile load by using values of expansion test on ANSYS software. An axial tensile load is applied to sandwich beam maximum expansion occurs in PET than in stainless steel and minimum in ceramic. Failure starts first in PET.

PET deformation analysis with variation in thickness result:

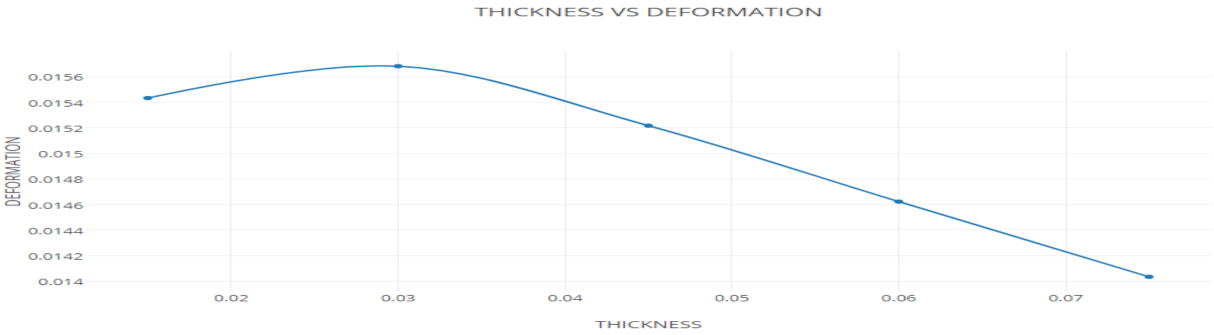

Fig: 15. The graph plotted between deformation and thickness.

A graph is plotted between deformation and thickness on PET layer by using ANSYS software. It is found that the deformation of the beam increases up to a certain thickness value and then decreases gradually. Hence we can calculate an optimal value of PET layer thickness for minimum deformation in the beam.

Thermal test result:

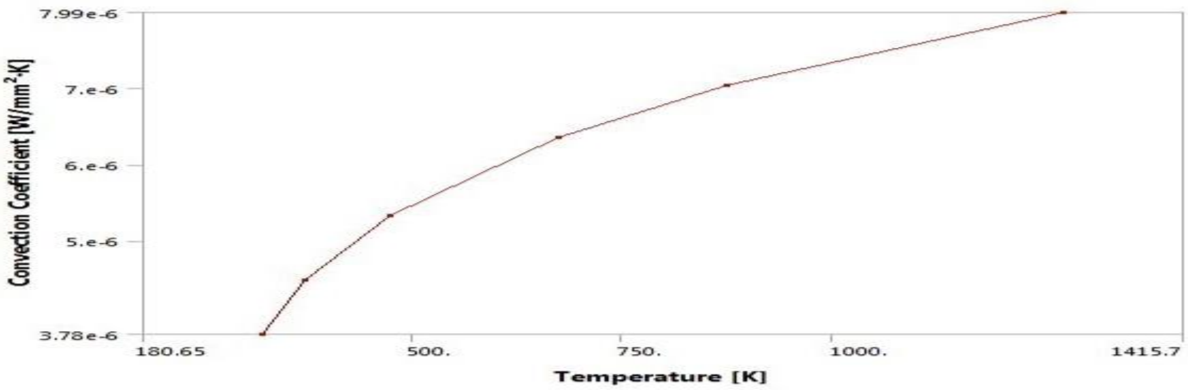

Fig: 16 Graph plotted between convection coefficient and temperature.

A graph is plotted between convection coefficient and temperature on sandwich beam by using ANSYS software. It is found that the convection coefficient of the beam increases as temperature of beam increases and maximum convection coefficient is obtained at a temperature of 1415.7K
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CONCLUSION AND FUTURE SCOPE

The objective of design and analysis of functionally graded layered sandwich beam with the viscoelastic core (Polyethylene terephthalate) in the high thermal environment is successfully carried using ANSYS software. The top layer is functionally graded material (Ceramic S3N4) and stainless steel on the bottom. The sandwich beam is subjected to axial dynamic loaded conditions. The viscoelastic core (Polyethylene terephthalate) layers are observed to be at high temperature but other layers of the beam are at normal conditions. The temperature variation is nonlinear in the viscoelastic core (Polyethylene terephthalate). The effect of various system parameters such as core thickness ratio, compression, expansion, modal structure test, thermal test is analysed using ANSYS software. Buckling load factor is 420.58MPa. Expansion test is performed on sandwich beam by using ANSYS software in seven stages. Axial and tensile load (1KN) is applied on sandwich beam whose both ends are fixed. As the load is applied to the beam expansion starts first in PET and layers of stainless steel and ceramic remain same. After the application of maximum load maximum expansion obtained in PET, then stainless steel and minimum in ceramic layer. It is found that the convection coefficient of the beam increases as the temperature of beam increases and maximum convection coefficient is obtained at a temperature of 1415.7K. The present work can be extended to study the stability of structural elements like plates, shells, and Stability of multi-layered sandwich beams.

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