DYNAMIC BEHAVIOR OF SANDWICH BEAM WITH PIEZOELECTRIC LAYERS BY USING ANSYS

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ABSTRACT

Sandwich beams with composite face sheets and foam core are widely employed as lightweight components in many of the industries that extend from automotive, marine to aerospace applications due to its high bending stiffness and strength combined with low weight factor. Therefore, it is important for us to gain insight about their flexural or bending behavior under static as well as dynamic loads. Extensive research has been carried out on the flexural behavior of composite laminates. The flexural and bending behavior of sandwich structures is quite and obviously different. Several works treating the dynamic flexural behavior of sandwich beams have also confirmed the marked susceptibility of sandwich structures to damage caused by the impact of low velocity foreign objects. Impacts can certainly damage the face sheets, the core material, and the core face interface. The type of damage found in the faces is similar to that observed after impacts on monolithic composites. However, the damage initiation thresholds and damage area depend on the properties of the core material and the relationship between the properties of the core and those of the face sheets. A finite element model is proposed and developed based on first order shear deformation theory (FSDT). The element formulated is an 8-noded. The design is developed either using CAD. Where a program is written and then by using APDL code analysis is done in ANSYS. The free vibrations are computed using Block Lanczos and Gauss elimination method / steps. The responses like transverse deflections, normal and shear stress and frequencies of composite laminates that are obtained will be compared with available literature. Parametric effects (modular ratio, number of layers, thickness ratio etc….) on composite plate will be further discussed in detail.

Keywords: *Composite plate, different material, by using software's like ANSYS and others.*

INTRODUCTION

Today, composite laminates have many applications as advanced engineering materials, primarily as components in power plants, aircrafts, ships, civil engineering structures, cars, robots, rail vehicles, sports equipment, prosthetic devices, etc. The major attribute of composite material is capability of the controllability of fiber alignment. By arranging layers and fiber direction, laminated material with required stiffness and strength properties to specific design conditions, can possibly be achieved, Laminated composite materials are extensively used in aerospace, defense, marine, automobile, and many other industries. They are generally lighter and stiffer than other structural materials. A laminated composite material consists of several layers of a composite mixture consisting of matrix and fibers. Each layer may have similar or dissimilar material properties with different fiber orientations under varying stacking sequence. Because, composite materials are produced in many combinations and forms, the design engineer must consider many design alternatives. It is essential to know the dynamic and buckling characteristics of such structures subjected to dynamic loads in complex environmental conditions. For example, when the frequency of the loads matches with one of the resonance frequencies of the structure, large translation/torsion deflections and internal stresses occur, which may lead to failure of structure components. The structural components made of composite materials such as aircraft wings, helicopter blades, vehicle axles and turbine blades can be approximated as laminated composite beams.

LAMINATED COMPOSITE STRUCTURES

A laminate is constructed by stacking a number of laminas in the thickness (z) direction. Each layer is thin and may have different fiber orientation. The fiber orientation, stacking arrangements and material properties influence the response from the laminate. The theory of lamination is same whether the composite structure may be a plate, a beam or a shell. Fig.1.1 shows a laminated plate or panel considered in most of the analysis. The following assumptions are made in formulations:

(i) The middle plane of the plate is taken as the reference plane.

(ii) The laminated plate consists of arbitrary number of homogeneous, linearly elastic orthotropic layers perfectly bonded to each other.

(iii) The analysis follows linear constitutive relations i.e. beys generalized Hooke's law for the material.

(iv) The lateral displacements are small compared to plate thickness.

(v) Normal strain in z-direction is neglected

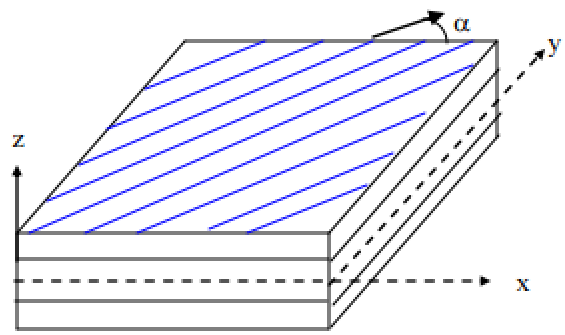


Fig.1.1 Plate

As shown in Fig.1.2, laminated beams are made-up of many plies of orthotropic materials and the principal material axes of a ply may be oriented at an arbitrary angle with respect to the xaxis. In the right-handed Cartesian coordinate system, the x-axis coincides with the beam axis and its origin is on the mid-plane of the beam. The length, breadth and thickness of the beam are represented by L, b and h, respectively.

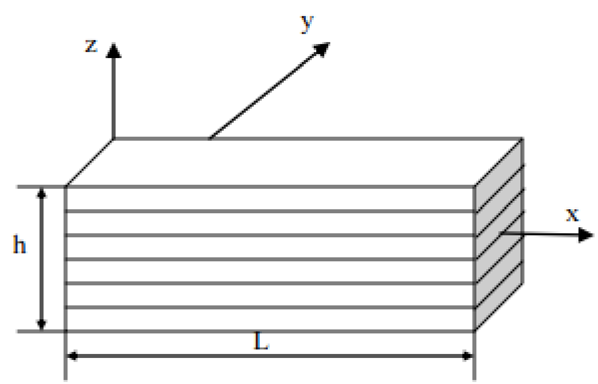
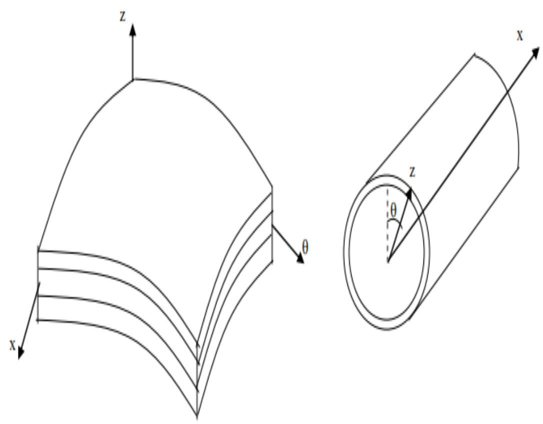


Fig.1.2 Beams

In practical engineering applications, laminated shells of revolution may have different geometries based mainly on their curvature characteristics such as cylindrical shells, spherical shells and conical shells. The composite shell of revolution is composed of orthotropic layers of uniform thickness as shown in Fig.1.3. A differential element of a laminated shell shown with orthogonal curvilinear coordinate system located on the middle surface of the shell. The total thickness of the shell is h.



Shell (cylindrical)

LITERATURE REVIEW

This section brief-outs the various earlier works done in the area of laminated composite material. These are grouped under four broad headings. More recently, HajianmalekI presented a review of analysis of laminated composite structures used in recent decades.

Laminated Beams

Yildirim used stiffness method for the solution of the purely in-plane free vibration problem of symmetric cross-ply laminated beams. The rotary inertia, axial and transverse shear deformation effects are considered in the mathematical model by the first-order shear deformation theory. A total of six degrees of freedom, four displacements and two rotations are defined for an element. The exact in-plane element stiffness matrix of 6×6 is obtained based on the transfer matrix method. The element inertia matrix consists of the concentrated masses. The sub-space iteration and Jacobi"s methods are employed in the solution of the large-scale general eigenvalue problem.

Jun et al. introduced a dynamic finite element method for free vibration analysis of generally laminated composite beams on the basis of first-order shear deformation theory. The influences of Poisson effect, couplings among extensional, bending and torsional deformations, shear deformation and rotary inertia are incorporated in the formulation. The dynamic stiffness matrix is formulated based on the exact solutions of the differential equations of motion governing the free vibration of generally laminated composite beam.

Gurban and Gupta analyzed the natural frequencies of composite tubular shafts using equivalent modulus beam theory (EMBT) with shear deformation, rotary inertia and gyroscopic effects has been modified and used for the analysis. The modifications take into account effects of stacking sequence and different coupling mechanisms present in composite materials. Results obtained have been compared with that available in the literature using different modeling. The close agreement in the results obtained clearly show that, in spite of its simplicity, modified EMBT can be used effectively for rotor-dynamic analysis of tubular composite shafts.

Yegao et al. presented a general formulation for free and transient vibration analysis of composite laminated beams with arbitrary lay ups and any boundary conditions. A modified variational principle combined with a multi-segment partitioning technique is employed to derive the formulation based on a general higher order shear defomation theory. The material coupling for bending-stretching, bending-twist, and stretching twist as well as the poison"s effect are taken into account.

Shell Structures

Qu et al. introduced a variational formulation for predicting the free, steady-state and transient vibrations of composite laminated shells of revolution subjected to various combinations of classical and non-classical boundary conditions. A modified variational principle in conjunction with a multi-segment partitioning technique was employed to derive the formulation based on the first-order shear deformation theory.

Xiang et al. studied a simple yet accurate solution procedure based on the Haar wavelet discretization method (HWDM) is applied to the free vibration analysis of composite laminated cylindrical shells subjected to various boundary conditions. The Reissner–Naghdi"s shell theory is adopted to formulate the theoretical model. The initial partial differential equations (PDE) are first converted into system of ordinal differential equations by the separation of variables. Then the discretizations of governing equations and corresponding boundary conditions are implemented by means of the HWDM, which leads to a standard linear eigenvalue problem.

Plates

Sahoo and Singh proposed a new trigonometric zigzag theory for the static analysis of laminated composite and sandwich plates. This theory considers shear strain shape function assuming the non-linear distribution of in-plane displacement across the thickness. It satisfies the shear-stress-free boundary conditions at top and bottom surfaces of the plate as well as the continuity of transverse shear stress at the layer interfaces obviating the need of an artificial shear correction factor.

Rarani et al. used analytical and finite element methods for prediction of buckling behavior, including critical buckling load and modes of failure of thin laminated composites with different stacking sequences. A semi-analytical Rayleigh–Ritz approach is first developed to calculate the critical buckling loads of square composite laminates with SFSF (S: simply-support, F: free) boundary conditions. Then, these laminates are simulated under axially compression loading using the commercial finite element software, ABAQUS. Critical buckling loads and failure modes are predicted by both eigenvalue linear and nonlinear analysis.

Alnefaie developed a 3D-FE model of delaminated fiber reinforced composite plates to analyse their dynamics. Natural frequencies and modal displacements are calculated for various case studies for different dimensions and delamination characteristics. Numerical results showed a good agreement with available experimental data. A new proposed model shows enhancement of the accuracy of the results.

Sino et al. worked on the dynamic instability of an internally damped rotating composite shaft. A homogenized finite element beam model, which takes into account internal damping, is introduced and then used to evaluate natural frequencies and instability thresholds. The influence of laminate parameters: stacking sequences, fiber orientation, transversal shear effect on natural frequencies and instability thresholds of the shaft are studied. The results are compared to those obtained by using equivalent modulus beam theory (EMBT), modified EMBT and layerwise beam theory (LBT).

OPTIMIZATION ISSUES AND DYNAMICS

Topal presented a multiobjective optimization of laminated cylindrical shells to maximize a weighted sum of the frequency and buckling load under external load. The layer fiber orientation is used as the design variable and the multi-objective optimization is formulated as the weighted combinations of the frequency and buckling under external load. The first order shear deformation theory is used for the finite element formulation of the laminated shells. Five shell configurations with eight layers are considered as candidate designs. The modified feasible direction method (MFD) is used as optimization routine. Finally, the effect of different weighting ratios, shell aspect ratio, shell thickness-to-radius ratios and boundary conditions on the optimal designs is investigated and the results are compared.

Topal and Uzman proposed a multiobjective optimization of symmetrically angle-ply square laminated plates subjected to biaxial compressive and uniform thermal loads. The design objective is the maximization of the buckling load for weighted sum of the biaxial compressive and thermal loads. The design variable is the fiber orientations in the layers. The performance index is formulated as the weighted sum of individual objectives in order to obtain optimal solutions of the design problem. The first-order shear deformation theory (FSDT) is used in the mathematical formulation of buckling analysis of laminated plates.

Roos and Bakis analysed the flexible matrix composites which consist of low modulus elastomers such as polyurethanes which are reinforced with high-stiffness continuous fibers such as carbon. This fiber–resin system is more compliant compared to typical rigid matrix composites and hence allows for higher design flexibility. Continuous, single-piece FMC driveshafts can be used for helicopter applications. Authors employed an optimization tool using a genetic algorithm approach to determine the best combination of stacking sequence, number of plies and number of in-span bearings for a minimum-weight, spinning, and misaligned FMC helicopter driveshaft. In order to gain more insight into designing driveshafts, various loading scenarios are analyzed and the effect of misalignment of the shaft is investigated. This is the first time that a self-heating analysis of a driveshaft with frequency- and temperature-dependent material properties is incorporated within a design optimization model. For two different helicopter drivelines, weight savings of about 20% are shown to be possible by replacing existing multi-segmented metallic drivelines with FMC drivelines.

Sadr and Bargh studied the fundamental

frequency optimization of symmetrically laminated composite plates using the combination of Elitist- Genetic algorithm(E-GA) and finite strip method(FSM). The design variables are the number of layers, the fiber orientation angles, edge conditions and plate length/width ratios.

Kayikci and Sonmez studied and optimized the natural frequency response of symmetrically laminated composite plates. An analytical model accounting for bending–twisting effects was used to determine the laminate natural frequency. Two different problems, fundamental frequency maximization and frequency separation maximization, were considered. Fiber orientation angles were chosen as design variables. Because of the existence of numerous local optimums, a global search algorithm, a variant of simulated annealing, was utilized to find the optimal designs. Results were obtained for different plate aspect ratios. Effects of the number of design variables and the range of values they may take on the optimal frequency were investigated. Problems in which fiber angles showed uncertainty were considered. Optimal frequency response of laminates subjected to static loads was also investigated.

Khandan et al. researched and added an extra term to the optimisation penalty function in order to consider the transverse shear effect. This modified penalty function leads to a new methodology whereby the thickness of laminated plate is minimised by optimizing the fiber orientations for different load cases. Therefore the effect of transverse shear forces is considered in this study.

Montagnier and Hochard studied the optimisation of hybrid composite drive shafts operating at subcritical or supercritical speeds, using a genetic algorithm. A formulation for the flexural vibrations of a composite drive shaft mounted on viscoelastic supports including shear effects is developed. In particular, an analytic stability criterion is developed to ensure the integrity of the system in the supercritical regime. Then it is shown that the torsional strength can be computed with the maximum stress criterion. A shell method is developed for computing drive shaft torsional buckling. The optimisation of a helicopter tail rotor driveline is then performed. This study yielded some general rules for designing an optimum composite shaft without any need for optimisation algorithms.

Rocha et al. presented a genetic algorithm combining two types of computational parallelization methods, resulting in a hybrid shared/distributed memory algorithm based on the island model using both Open MP and MPI libraries. In order to take further advantage of the island configuration, different genetic parameters are used in each one, allowing the consideration of multiple evolution environments concurrently. To specifically treat composite structures, a three-chromosome variable encoding and special laminate operators are used. The resulting gains in execution time due to the parallel implementation allow the use of high fidelity analysis procedures based on the Finite Element Method in the optimization of composite laminate plates and shells. Two numerical examples are presented in order to assess the performance and reliability of the proposed algorithm.

Abadi and Daneshmehr developed the buckling analysis of composite laminated beams based on modified coupled stress theory. By applying principle of minimum potential energy and considering two different beam theories ,i.e, Euler-Bernouli and Timoshinko beam theories, governing equations, boundary and initial conditions are derived for micro composite laminated beam.

Apalak et al. carried-out the layer optimization for achieving maximum fundamental frequency of laminated composite plates under any combination of the three classical edge conditions. The optimal stacking sequences of laminated composite plates were searched by means of Genetic Algorithm. The first natural frequencies of the laminated composite plates with various stacking sequences were calculated using the finite element method. Genetic Algorithm maximizes the first natural frequency of the laminated composite plate defined as a fitness function (objective function).

In addition to above, numerous conference articles and textbooks emphasize the analysis issues of composite laminated structures.

OBJECTIVES

1. Excitation of a composite laminate plate by patch type piezoelectric actuators surface bonded to the structure.

2. Model has been applied to a simply supported cross-ply composite laminate plate excited by two piezoelectric actuators symmetrically bonded to both sides of the plate with time harmonic electric loading.

3. Analytical expression of the harmonic vibration of the simply supported composite laminate induced by the piezoelectric actuators.

4. Three-dimensional finite element analysis is to conduct using the commercial software ANSYS.

MATERIALS AND METHODS

- The finite element method is a widely used and powerful tool for analyzing complex structures. Many researchers have modelled the piezoelectric actuation using the finite element method. The commercially available finite element software ANSYS has the ability to analyze piezoelectric materials. In this study, ANSYS is adopted to investigate the harmonic vibration of a simply supported composite plate excited by the surface bonded piezoelectric actuators.

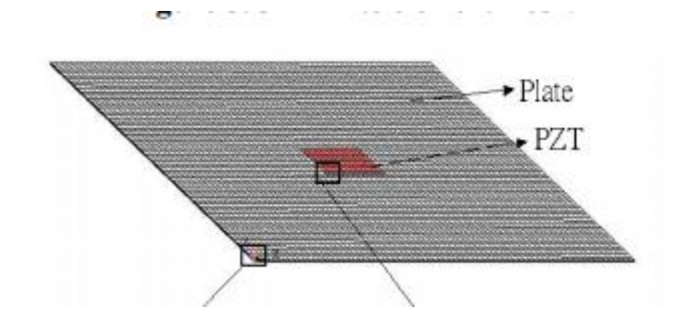


Figure shows the model of composite plate.

METHODOLOGY FLOW CHART

Study about the composite plates

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Design consideration of composite plate for piezoelectric materials

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Study on properties of piezoelectric materials used in preparation of heat sensors

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Selection of materials for testing and design in software

Theoretical and numerical analysis of piezoelectric materials

Thermal properties consideration and preparation of simulations by using ANSYS 15.0 work bench

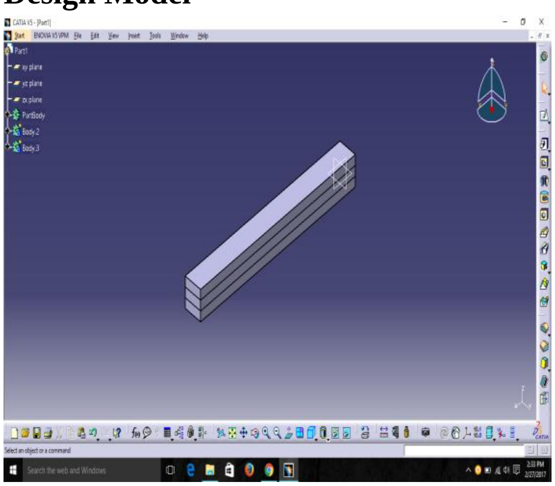
Comparisons of theoretical and analyzed calculations

Conclusions & Future scope

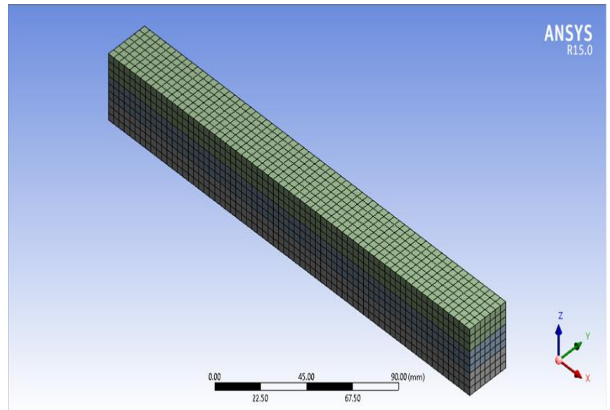
ANALYTICAL WORK

After designing of Sandwich Beam in Ansys design software, with specific material with Aluminum with zirconia ceramics and Aluminum with Polymer piezio layers on the meshed node of the beam to study the stress-strain distribution along the Sandwich beam. After analysis procedure, Results are found out in the form of Stress-Strain graphs are plotted for different loads.

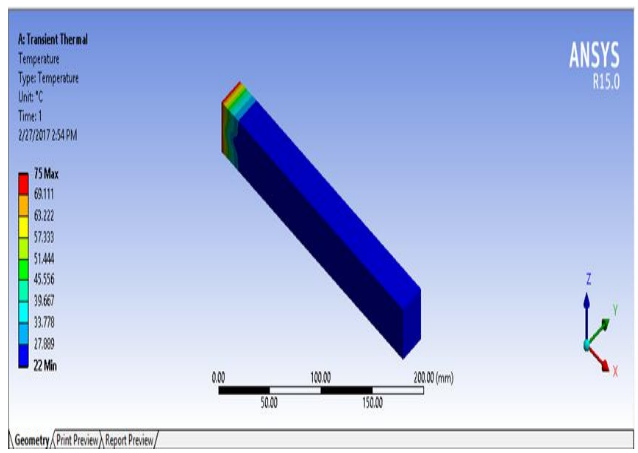
Design Model



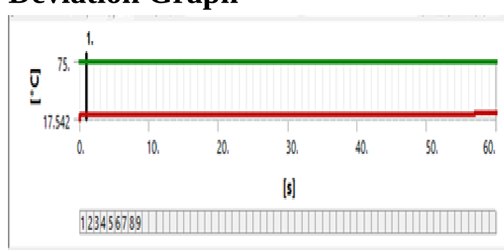
Meshing



Transient Thermal Analysis using material Aluminum with zirconia ceramics on the Sandwich beam

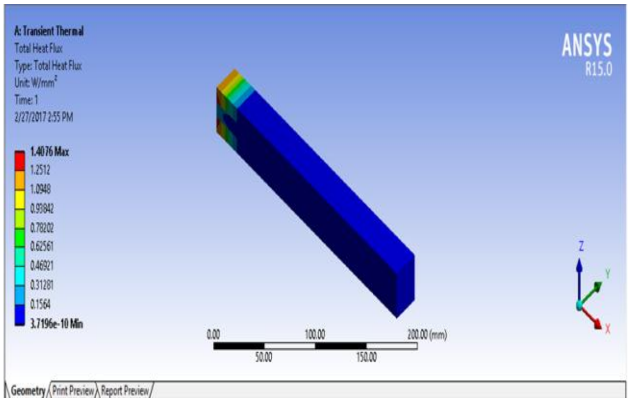


Deviation Graph

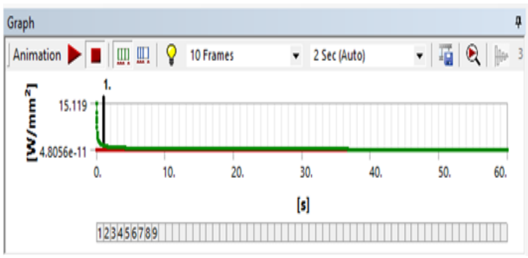


Total Heat Flux analysis

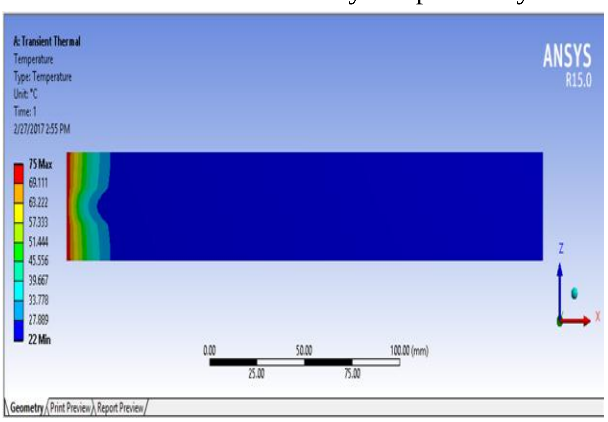
Material Aluminum with zirconia ceramics on the Sandwich beam



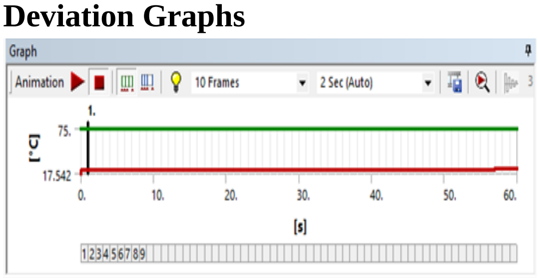
Deviation Graph



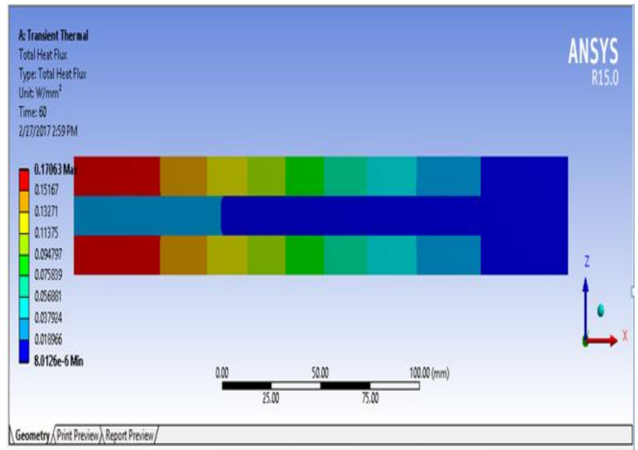
Transient Thermal Analysis using the material Aluminum with Polymer piezio layers



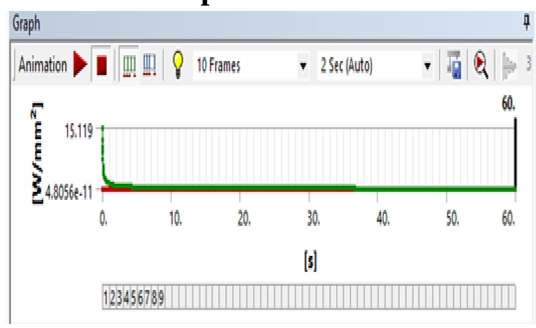
Deviation Graphs



Total Heat Flux in Transient Thermal Analysis using material Aluminum with Polymer piezio layers on the sandwich beam



Deviation Graphs



CONCLUSION

Sandwich cross sections are composite and consist of a low to moderate stiffness core which is connected with two stiff exterior face-sheets and it has a considerably higher shear stiffness to weight ratio compared to an equivalent beam made of only the core material or the face sheet material. By continuing transient thermal analysis of both the layers these found that ceramic layers are more efficient than Polymer layers. Transient thermal analysis shows the optimization results than normal thermal analysis under the time variation heat flux shows scope of future work practically.

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