FREE VIBRATION ANALYSIS OF THICK COMPOSITE PLATE BY USING ANSYS WORK BENCH

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Abstract: The main objective of vibration analysis is mostly utilized in aerospace applications to determine frequencies and strength in the structural components. The analysis is carried out for laminated composite plate under transverse loading condition. The mode shapes are observed in a laminate composite plate with different boundary conditions. It is found that the natural frequencies increase with increase in mode number and are more for Clamped -clamped boundary condition compared to remaining boundary conditions for the orthotropic plate. It was taken shell99 linear element for the propose of to study the vibration analysis. And it has six degrees of freedom and both are transitional and rotational along the x, y, and z directions. Those problems were solved by using the ANSYS 15.0 model. The ANSYS values are successfully executed and are given in tables. This analysis is useful in design of aerospace structures as the weight reduction is main criteria. the composite plate consists of aluminum alloys and polyethylene give better performance characters in design point of view in aerospace applications, the strength to weight ratio and stiffness to weight ratio are mainly considered while designing aero space structures.

Keywords: vibration analysis, composite plate, frequencies, structural components, ANSYS 15.0.

1.0 Introduction

In 3400 B.C the first composites were engineered by the Mesopotamians in Iraq. The ancient society glued wood strips on top of each other at different angles to create plywood. Following this, in around 2181 B.C the Egyptians started to make death masks out of linen or papyrus soaked in plaster. Later on, both of these societies started to reinforce their materials with straw to strengthen mud bricks, pottery and boats. In 1200 A.D, the Mongols began to engineer composite bows which were incredibly effective at the time. These were made out of wood, bamboo, bone, cattle tendons, horn and silk bonded with pine resin.

Following the industrial revolution, synthetic resins started to take a solid form by using polymerisation. In the 1900s this new-found knowledge about chemicals led to the creation of various plastics such as polyester, phenolic and vinyl. Synthetics then started to be developed, Bakelite was created by the chemist Leo Baekeland. The fact that it did not conduct electricity and was heat resistant meant it could be widely used across many industries. The 1930s was an incredibly important time for the advancement of composites. Glass fibre was introduced by Owens Corning who also started the first fibre reinforced polymer (FRP) industry. The resins engineered during this era are still used to this day and, in 1936, unsaturated polyester resins were patented. Two years later, higher performance resin systems became accessible.

The first carbon fibre was patented in 1961 and then became commercially available. Then, in the mid-1990s, composites were starting to become increasingly common in manufacturing and construction due to their relatively cheap cost compared to materials that had been used previously. The composites on a Boeing 787 Dreamliner in the mid-2000s substantiated their use for high strength applications. Definition a composite material is made by combining two or more materials – often ones that have very different properties. The two materials work together to give the composite unique properties.

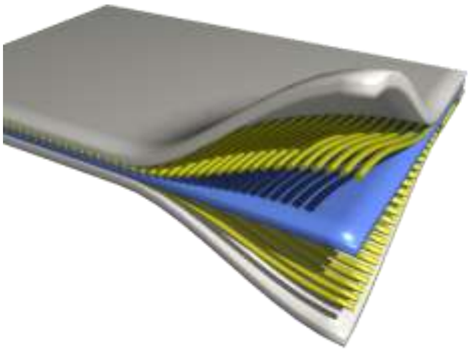


Fig.1 Examples of Composite Materials

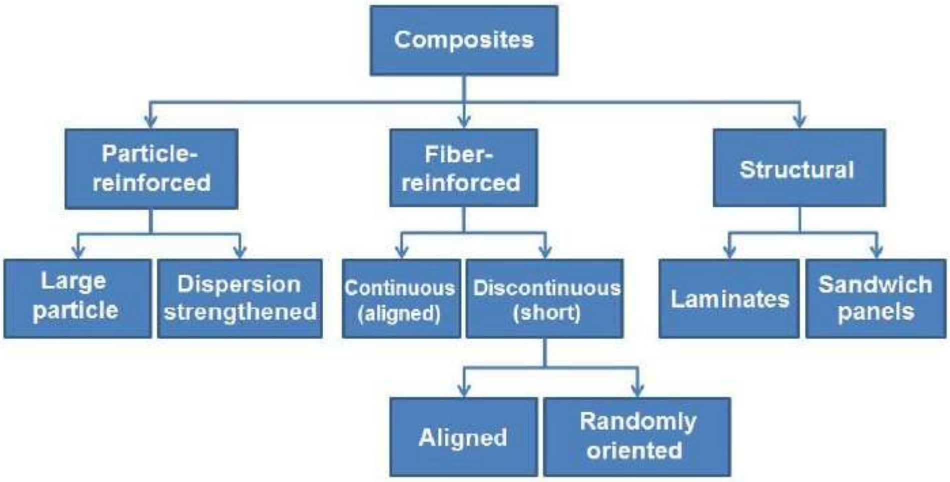


Fig.2 Classification of Composite Materials

Reasons Why Composites Are Replacing Traditional Materials

Composites unite many of the best qualities that traditional materials have to offer. The two components of a composite include reinforcement (often a high-performance fiber such as carbon or glass) and a matrix (such as epoxy polymer). The matrix binds the reinforcement together to merge the benefits of both original components.

2.0 Plate Vibration Analysis

Thin plates are one of the most common components in engineering machines and structures. Examples of applications include building walls, large-span roofs, turbine disks, pressure vessels, and airplane wings. In general, shell structures are more advantageous in engineering applications than plates in term of resistance to load. The engineering components must resist not only static loads but also dynamic loads. For instance, buildings must be designed to withstand dynamic forces such as earthquake excitations. Much research has been conducted into plate behavior, using a wide range of methods. An excellent monograph of the early literature relating to vibration analysis of plates was published by Leissa . Among the methods utilized for plate vibration analysis, it is known that the Superposition Method developed by Gorman is very efficient and accurate for a range of geometric shapes.

A plate resists transverse loads by means of bending, exclusively. The flexural properties of a plate depend greatly upon its thickness in comparison with other dimensions. Plates may be classified into three groups according to length to thickness ratio. Where L is a typical dimension of a plate in a plane and h is a plate thickness. Thin if Łt> 100, moderately thin if 20 <Łt< 100, thick if 3 <Łt< 20, and very thick if Łt< 3. The “classical” theory of plates is applicable to very thin and moderately thin plates, while “higher order theories” for thick plates are useful. For the very thick plates, however, it becomes more difficult and less useful to view the structural element as a plate - a description based on the three-dimensional theory of elasticity is required.

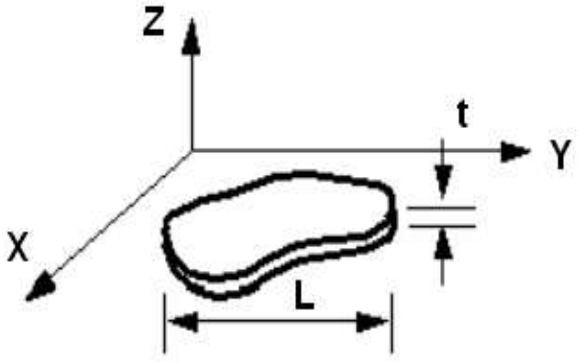


Fig.3 Thin and thick plate

Very thin if Length/ Thickness > 100
Moderately thin if 20 < Length/ Thickness < 100
Thick if 3 < Length/ Thickness < 20
Very thick if Length/ Thickness < 3

Free Vibration Analysis:

Laminated composites are increasingly used in various mechanical structures and industrial applications such as aircrafts, automobiles, marines, buildings and several house-hold appliances due to their, in particular, higher stiffness and higher strength-to-weight ratio compared to isotropic or wooden materials. In vibration engineering, modal parameters of a structure are primary design information, because they directly affect the forced response characteristics. Conventional methods for vibration analysis are generally based on either Theoretical solutions or experimental studies. However, in general, practical problems are either too difficult or impossible to deal with by analytical methods and experiments are rather expensive. Therefore, numerical simulations and algorithms are of significant role in modern vibration analysis. The finite element method (FEM) has been commonly used in the vibration analysis of composite plates

Dimensions	Cross-section
Length(a)=300mm Width(b)=150mm Thickness=10mm each	Rectangular

Table1.3: Parameters of free vibration of thick rectangular plate

First Order Shear Deformation Theory:
The following assumptions are considered in formulating the theory:
1) The layers are perfectly bonded
2) The material of each layer is linearly elastic and has two planes of material symmetry
3) The strains and displacements are small
4) Deflection is wholly due to bending strains only

5) Plane sections originally perpendicular to the longitudinal plane of the plate remain plane, but not necessarily perpendicular to longitudinal plane
6) The transverse shearing strains (stresses) are assumed to be constant along the plate thickness
The displacement field of the first-order theory is of the form:

$$u(x,y,z) = u_0(x,y) - z\theta_x(x,y)$$
$$v(x,y,z) = v_0(x,y) - z\theta_y(x,y)$$
$$w(x,y,z) = w_0(x,y)$$

Where (u_0,v_0,w_0,θ_x,θ_y)are unknown functions to be determined. As before (u_0;$v_0 w_0$) denote the displacements of a point on the plane z = 0. (θ_x, θ_y) are the rotation of a transverse normal with respect to unreformed middle plane.

Free Vibration:
By free vibration we mean the motion of a structure without any dynamic external forces or support motion. The motion of the linear SDF systems without damping specializes to

$$m\frac{d^2u}{dt^2} + ku = 0$$

Free vibration is initiated by disturbing the system from its static equilibrium position by imparting the mass some displacement u(0) and velocity ů (0) at time zero, defined as the instant the motion is initiated :

u = u(0), ů = ů(0)

So, solution to the equation is obtained by standard methods:

$$u(t) = u(0)\cos\omega_n t + \frac{\dot{u}(0)}{\omega_n}\sin\omega_n t$$

Where natural circular frequency of vibration in unit radians per second=

$$T_n = \frac{2\pi}{\omega_n}$$

Natural cyclic frequency of vibration is denoted by $f_n = \frac{1}{T_n}$unit in Hz (cycles per second)

3.0 Finite Element Analysis:

Finite element analysis (FEA) has become commonplace in recent years, and is now the basis of a multibillion dollar per year industry. Numerical solutions to even very complicated stress problems can now be obtained routinely using FEA, and the method is so important that even introductory treatments of Mechanics of Materials - such as these modules - should outline its principal features. In spite of the great power of FEA, the disadvantages of computer solutions must be kept in mind when using this and similar methods: they do not necessarily reveal how the stresses are influenced by important problem variables such as materials properties and geometrical features, and errors in input data can produce wildly incorrect results that may be overlooked by the analyst. Perhaps the most important function of theoretical modeling is that of sharpening the designer's intuition; users of finite element codes should plan their strategy toward this end, supplementing the computer simulation with as much closed-form and experimental analysis as possible.

Finite element analysis usually consists of three principal steps:

(a) Preprocessing
(b) Analysis
(c) Post processing.

(a)Preprocessing:
A thin rectangular plate is modeled whose geometry is divided into a number of discrete sub regions, or “elements," connected at discrete points called “nodes." Certain of these nodes willhave fixed displacements, and others will have prescribed loads. These models can be extremely time consuming to prepare, and commercial codes vie with one another to have the most user-friendly graphical “preprocessor" to assist in this rather tedious chore. Some of these preprocessors can overlay a mesh on a preexisting CAD file, so that finite element analysis can be done conveniently as part of the computerized drafting-and-design process. The following commands used in ANSYS

(b)Analysis:
The dataset prepared by the preprocessor is used as input to the finite element code itself, which constructs and solves a system of linear or nonlinear algebraic equations $K_{ij}u_j = F_i$Where u and f are the displacements and externally applied forces at the nodal points. The formation of the K matrix is dependent on the type of problem being attacked, and this module will outline the approach for truss and linear elastic stress analyses. Commercial codes may have very large element libraries, with elements appropriate to a wide range of 13 problem types. One of FEA's principal advantages is that many problem types can be addressed with the same code, merely by specifying the appropriate element types from the library.

(c) Post-processing:
In the earlier days of finite element analysis, the user would pore through reams of numbers generated by the code, listing displacements and stresses at discrete positions within the model. It is easy to miss important trends and hot spots this way, and modern codes use graphical displays to assist in visualizing the results. A typical postprocessor display overlay colored contours representing stress levels on the model, showing a full-field picture similar to that of photo elastic or more experimental results.

4.0 Modeling and Analysis of Thick Composite Plate

Modeling of plate is done by using solid edge and creo software’s and analysis is done by using ANSYS Work bench. Rectangular plates are formed by the above mentioned (in table 1.3) dimensions and are shown below.

Properties of Outline Row 3: Aluminum Alloy

	A	B	C
1	Property	Value	Unit
2	Density	2770	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's M...	
8	Young's Modulus	71000	MPa
9	Poisson's Ratio	0.33	

Table.1 Mechanical properties of Aluminum alloy material

Properties of Outline Row 4: Polyethylene

	A	B	C
1	Property	Value	Unit
2	Density	950	kg m^-3
3	Isotropic Secant Coefficient of Thermal Expansion		
6	Isotropic Elasticity		
7	Derive from	Young's M...	
8	Young's Modulus	1100	MPa
9	Poisson's Ratio	0.42	

Table.2 Mechanical properties of Polyethylene material

modeling of plate is done by using solid edge and creo softwares and analysis is done by using ANSYS Work bench. A rectangular plate is formed by the above mentioned (in table 1.3)dimensions and are shown below.

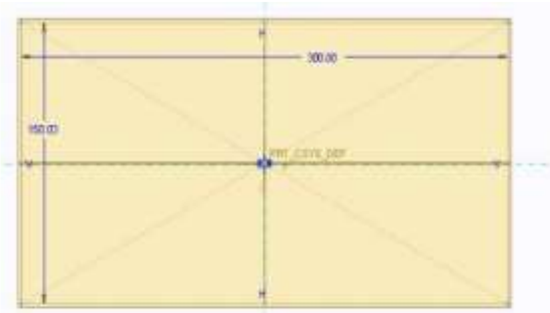


Fig.4 Dimensions of the plate

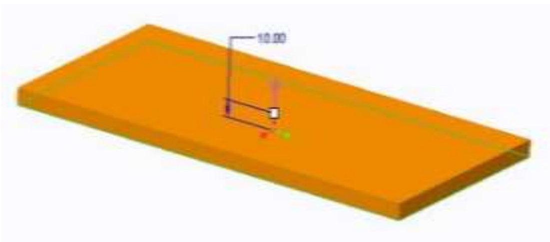


Fig.5 Thickness of plate

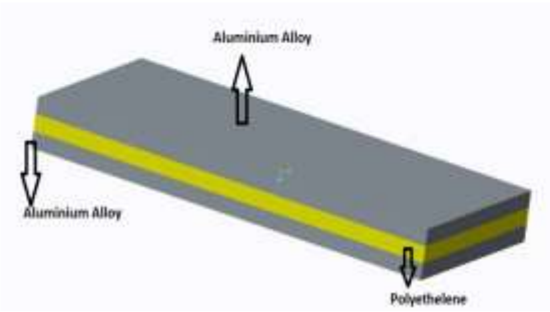
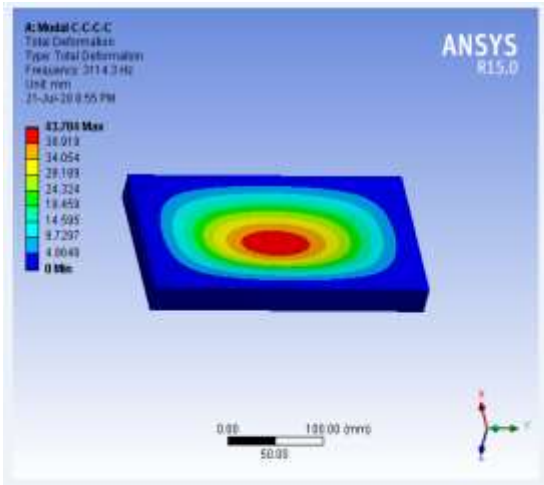
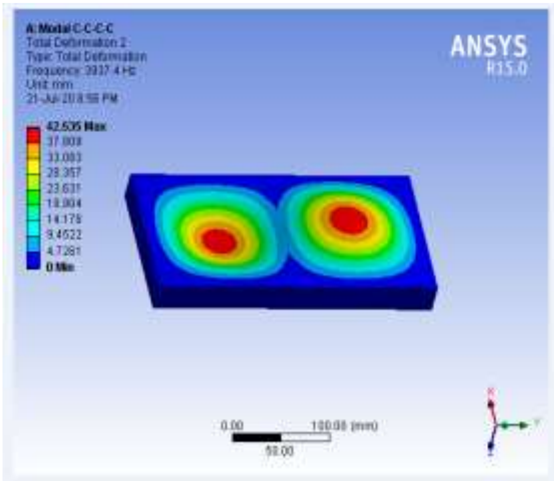


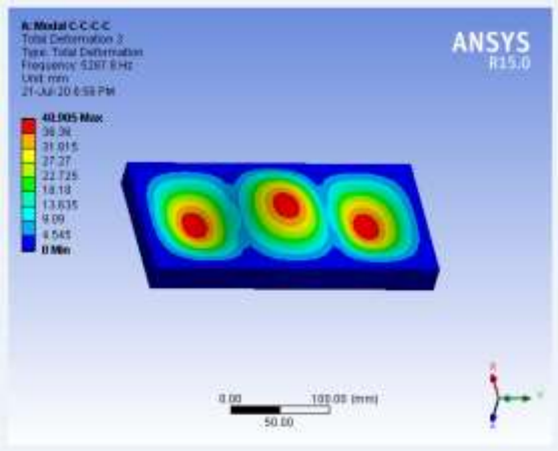
Fig.6 Thick Composite plate



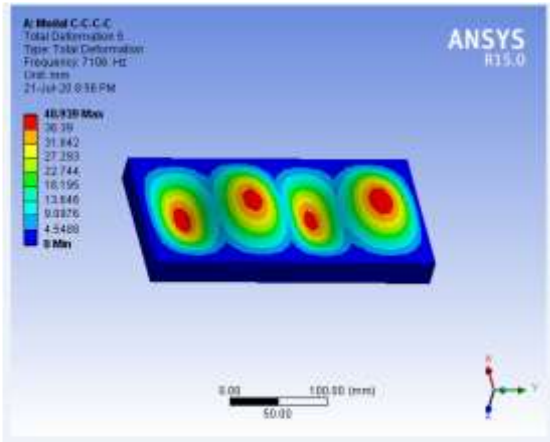
(a) 1st mode



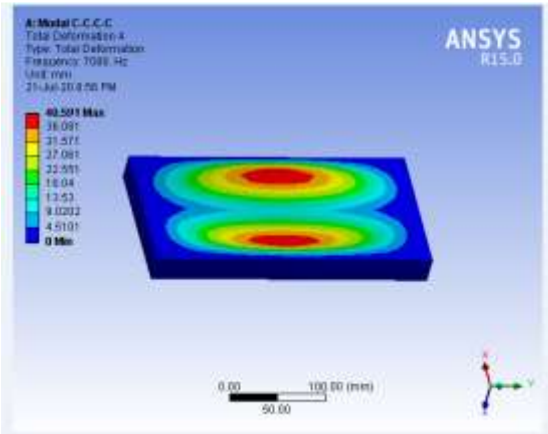
(b) 2nd mode



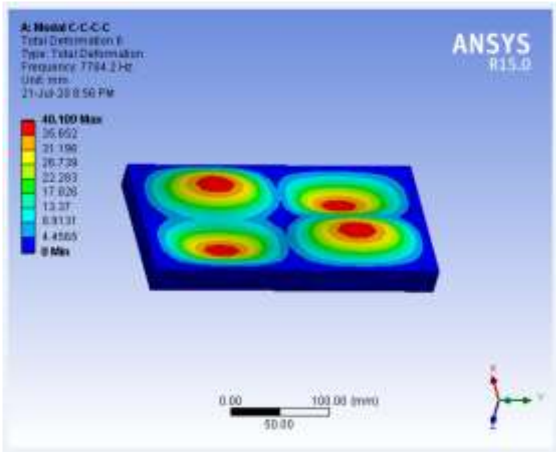
(c) 3rd mode



(e) 5th mode

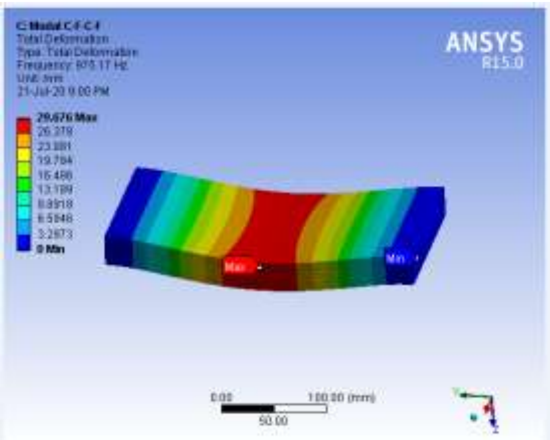


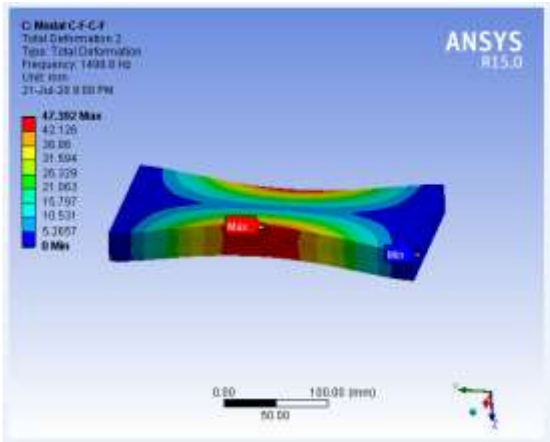
(d) 4th mode



(f) 6th mode

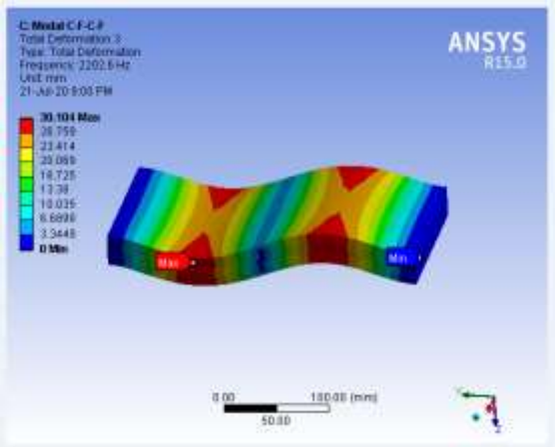
Fig.7 Deformation of C-C-C-C thick Composite plate at (a) 1st mode, (b) 2nd mode, (c) 3rd mode, (d) 4th mode, (e) 5th mode and (f) 6th mode



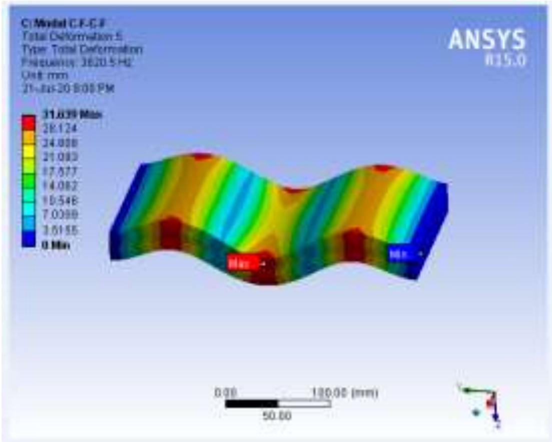


(b) 2nd mode

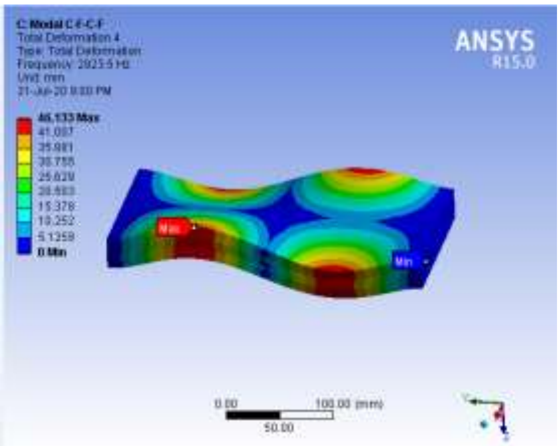
(a) 1st mode



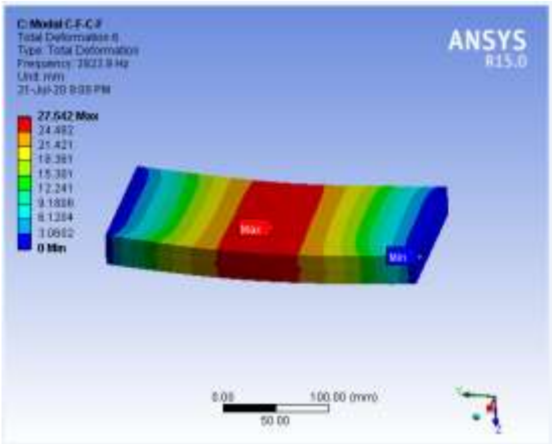
(c) 3rd mode



(e) 5th mode

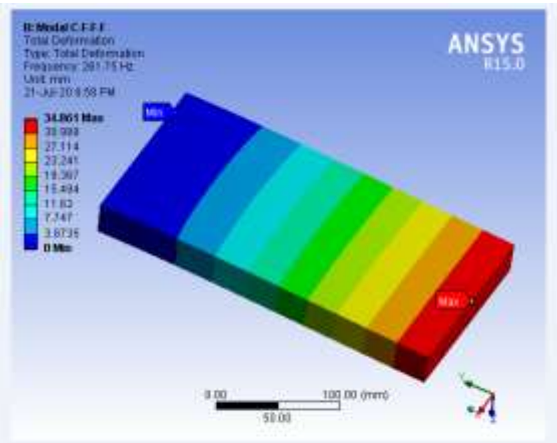


(d) 4th mode

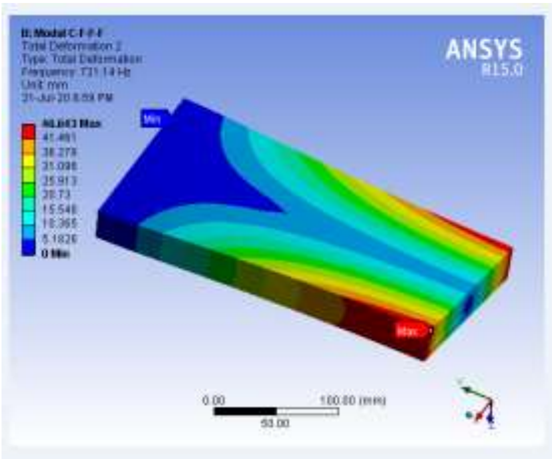


(f) 6th mode

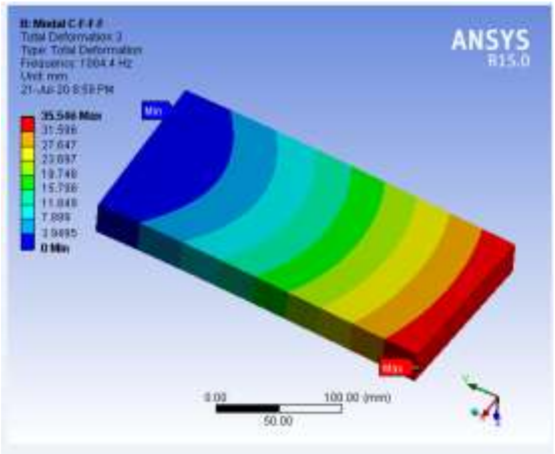
Fig.8 Deformation of of C-F-C-F thick Composite plate at (a) 1st mode, (b) 2nd mode, (c) 3rd mode, (d) 4th mode, (e) 5th mode and (f) 6th mode



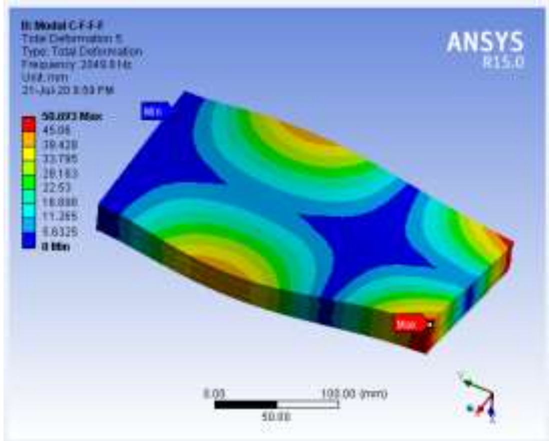
(a) 1st mode



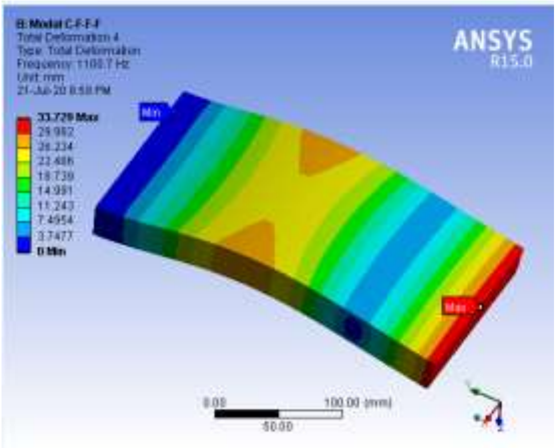
(b) 2nd mode



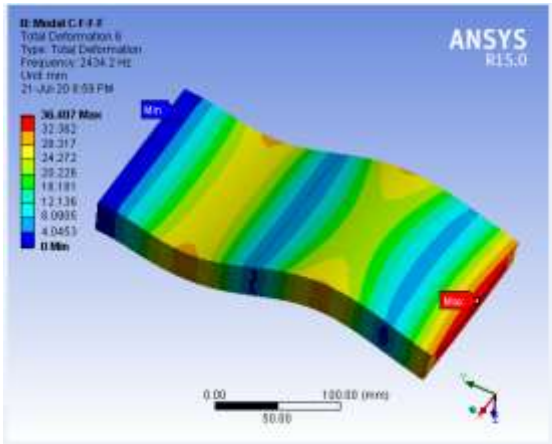
(c) 3rd mode



(e) 5th mode

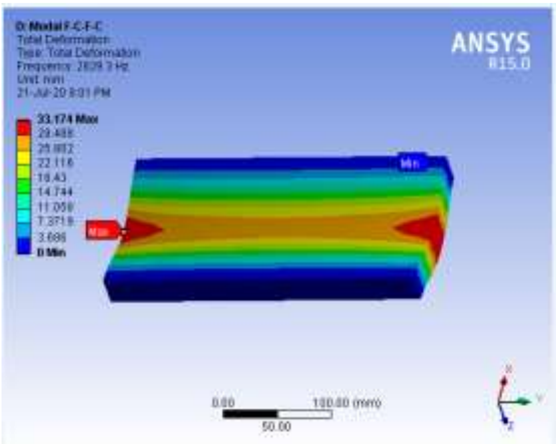


(d) 4th mode

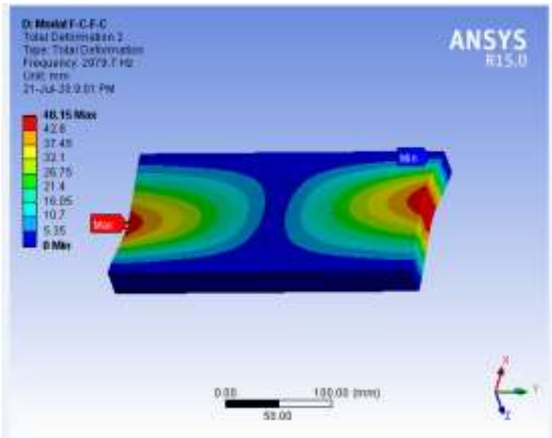


(f) 6th mode

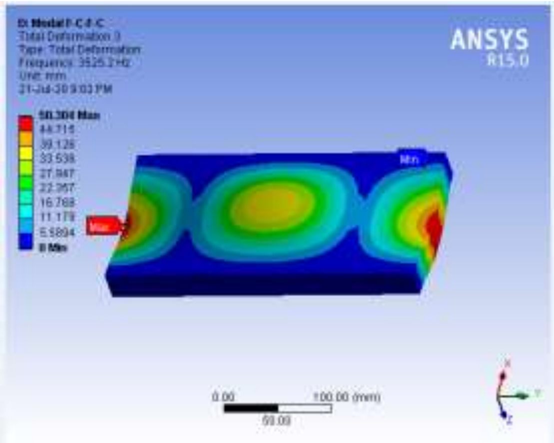
Fig.9 Deformation of of C-F-F-F thick Composite plate at (a) 1st mode, (b) 2nd mode, (c) 3rd mode, (d) 4th mode, (e) 5th mode and (f) 6th mode



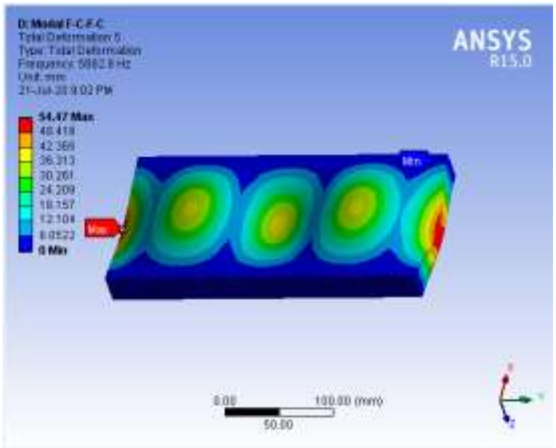
(a) 1st mode



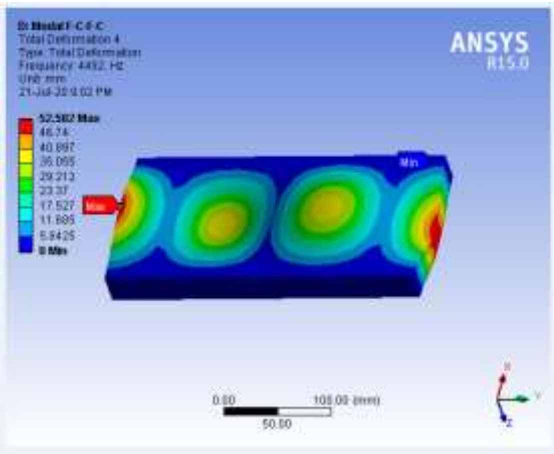
(b) 2nd mode



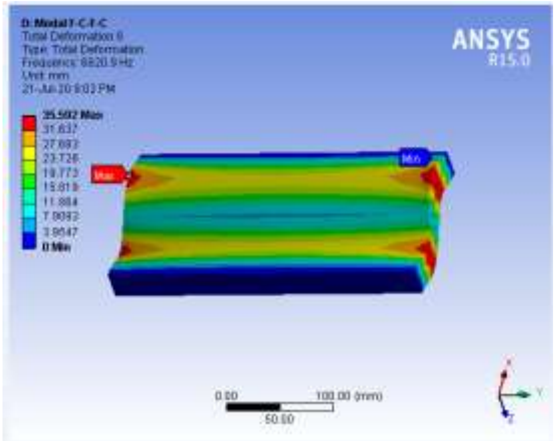
(c) 3rd mode



(e) 5th mode



(d) 4th mode



(f) 6th mode

Fig.10 Deformation of of F-C-F-C thick Composite plate at (a) 1st mode, (b) 2nd mode, (c) 3rd mode, (d) 4th mode, (e) 5th mode and (f) 6th mode

Numerical Analysis:

The deflections and frequencies for the thick plate for different boundary conditions are calculated for first 6 modes with given dimensions and are placed in corresponding tables.

Table.3 Deformations and frequencies of C--C-C-C Thick Plate

Mode Number	Boundary condition	Deformations (mm)	Frequency(HZ)
1	C-C-C-C	43.78	3113
2		42.53	3937
3		40.90	5287
4		40.59	7080
5		40.33	7106
6		40.10	7764

From the table 3, it is observed that for the C-C-C-C boundary condition, the deformation decreases as the mode number increases. it is also concluded that the frequency increase with increase in mode number.

Table.4 Deformations and frequencies of C--F-C-F Thick Plate

Mode Number	Boundary condition	Deformations	Frequency
1	C-F-C-F	29.67	975
2		47.39	1498
3		30.10	2202
4		46.13	2923
5		31.63	3820
6		27.54	3923

From the table 4, it is observed that for the C-F-C-F boundary condition, the deformation is maximum in 2nd mode. it is also concluded that the frequency increase with increase in mode number.

Table.5 Deformations and frequencies of C--F-F-F Thick Plate

Mode Number	Boundary condition	Deformations	Frequency
1	C-F-F-F	34.86	261
2		46.64	721
3		35.54	1084
4		33.72	1100
5		50.69	2049
6		36.40	2434

From the table 5, it is observed that for the C-F-F-F boundary condition, the deformation is maximum for 5th mode. it is also concluded that the frequency increase with increase in mode number.

Table.6 Deformations and frequencies of F-C-F-C Thick Plate

Mode Number	Boundary condition	Deformations	Frequency
1	F-C-F-C	33.17	2829
2		48.15	2979
3		50.30	3525
4		52.58	4492
5		54.47	5882
6		35.59	6820

From the table 6, it is observed that for the F-C-F-C boundary condition, the deformation is maximum for 5th mode. it is also concluded that the frequency increase with increase in mode number.

5.0 CONCLUSIONS

This study considers the free vibration response of thick composite plate consists of aluminum alloy and polyethylene composite thick Plate with all edges clamped, opposites edges clamped and free and one edge clamped and remaining edges free boundary conditions. From the present analysis, the following conclusions are made.

1. The deflection for clamped boundary condition is less than the remaining boundary conditions.
2. From C-C-C-C boundary condition, the deformation decreases as the mode number increases.
3. The frequency increase with increase in mode number.
4. The C-F-C-F boundary condition, the deformation is maximum in 2nd mode.
5. The C-F-F-F boundary condition, the deformation is maximum for 5th mode.
6. The F-C-F-C boundary condition, the deformation is maximum for 5th mode.

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