# COMPARISON AND ANALYSIS OF SIMULATION OF COMPOSITES MATERIAL AL-STEEL-AL USING ANSYS

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## ABSTRACT

*The composite structures are made by addition of different materials which is subjected to stern vibrations which are adverse in many industries. A laminated composite structured metal consists of a number of layers of a composite mixture of the 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 desirable to describe about the dynamic characteristic and buckling characteristic of those structures which have subjected to dynamic loads in complicated environmental situations. For example, when the different stages of variation in the frequency of several loads match with one of the resonance frequencies of the structure and large translation/torsion deflections, internal stresses occur, this may lead to failure of structure components. About the research paper, three layered composite shell has been consisting of middle layer of HSS (High Strength Steel)-4340 and outside layers of Al Alloy 7075-76 is designed and analysed for complex aerodynamic loading. The analysis results are found for both elemental & nodal solution. The minimum & maximum total mechanical Strain Intensities are 0.174e-04 & 0.00855 respectively for elemental solution while in case of Nodal solution, the minimum & maximum values of Total Mechanical Strain Intensity are 0.170e-04 & 0.00855 respectively. This is directly linked to the stress and strain characteristics of the each material that is Al-Steel and has to carefully consider observance in the view of the variation in stress-strain characteristics of different grades of steel and numerous alloys of Aluminium.*

**Keyword**: - *Al Alloy, ANSYS, Composite Material, HSS, Total Mechanical Strain and Stress.*

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## 1. INTRODUCTION

The metal matrix composites have various advantages over other types of composites. Such as;

- High strength
- High modulus
- High toughness and impact properties
- Low sensitivity to changes in temperature or thermal shock
- High surface durability and low sensitivity to surface flaws
- High electrical conductivity
- Excellent reproducibility of properties
- Excellent technological background with respect to
  - ✓ Design
  - ✓ Manufacture
  - ✓ Shaping and forming
  - ✓ Joining and finishing
  - ✓ Service durability information

The high strength values of metal alloys, compared to structural ceramics or organic materials, which can be utilized in composite materials, make them attractive. This high strength is mostly important with respect to composite properties at a direction different from the reinforcement direction. Properties such as transverse strength, torsional strength and inter-laminar shear strength are examples of matrix strength controlled properties [31].

The high moduli of metal alloys compared to those of organic materials are particularly significant in high modulus composites. Figure below shows a comparison of several fiber-reinforced composite materials on the base of specific modulus (in inches).

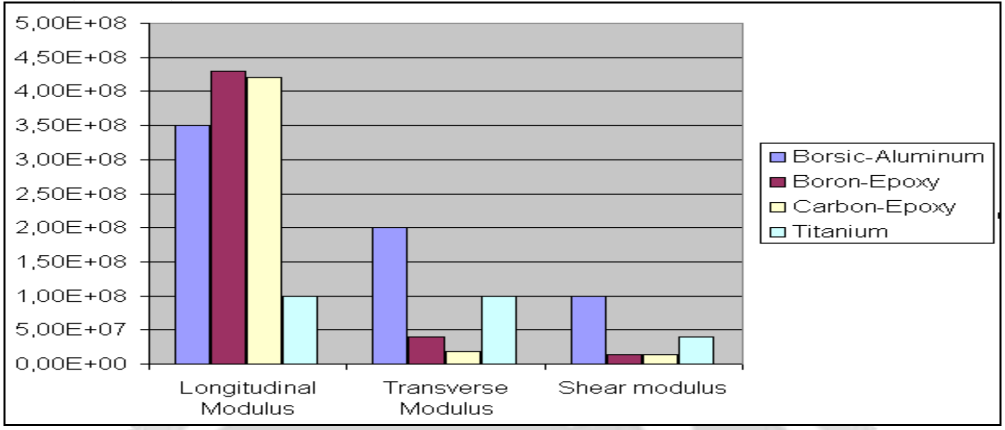


**Fig. 1.1.** Strength Values of various alloys

The high toughness and impact properties of metal alloys are very important, since the reinforcement is generally a linear elastic material and does not have good impact properties. Ductile metal matrix alloys such as aluminum, titanium or nickel-chromium alloys undergo energy-absorbing plastic deformation under impact, which is a desirable property for dynamic applications. The ductile metal matrix gives also improved fracture toughness [1].

The comparably low thermal sensitivity of metal matrices enhances their uses in high-modulus structural composites. Other organic matrix materials are quite sensitive to temperature changes. They are more resistant to thermal shocks the than ceramic matrices are. At elevated temperatures, not only do they tend to soften but also their resistance to oxidation, corrosion and erosion drops off significantly [13].

The metal matrices are generally less sensitive to surface flaws than ceramics or organic resins so their surfaces are more durable. The organic resins are more sensitive to small cracks because of various reasons such as low hardness and strength, moisture sensitivity, tendency of porosity, sensitivity to moderate temperature oxidation and ultraviolet radiation [2].

Another advantage of metal matrix alloys is their high thermal and electrical conductivity, which permits the diffusion and elimination of high thermal and electrical concentrations. Problems such as lightning strikes and hot-gas impingement are less severing if the impacting energy can be conducted away more rapidly [18].

Another important advantage of metal matrix alloys is the availability of an excellent technological background of their present use in the design of engineering structures, manufacturing techniques and a comprehensive information on service durability [15].

Although metal matrix composites have a lot of advantages, they have some important disadvantages. One of the most important disadvantages is that the metal matrices are poor in chemical and mechanical compatibility with the reinforcements. In other words, the chemical inertness of the reinforcement (usually a fiber) at modest resin-fabrication temperatures and large elastic compliance of the matrix are the chemical and mechanical incompatibility problems [11].

## 1.1 TYPES OF METAL MATRIX COMPOSITES

Metal matrix composites can be reinforced by strong second phases of three-dimensional shapes (particulate), two-dimensional shapes (laminar), or one-dimensional shapes (fibrous). All these three types differ in both the mechanical properties and the fabrication techniques.

### 1.1.1 Particle-Reinforced Composites

Particle reinforced composites although having a hard reinforcing dispersed phase differ from the dispersion hardened materials in the sense that they have a higher volume fraction of dispersoid, smaller sizes of particles and interparticle spacing [19]. With particle based reinforced composites such as tungsten-carbide-cobalt, the reinforcing phase is the principal load-bearing phase and the matrix is used for transferring the load and for ease of fabrication. High matrix-constraint factors produced by the hard reinforcement are used to prevent yielding in the matrix and the composite strength generally increases linearly with decreasing volume fraction of the matrix [20].

The three-dimensional reinforcement can lead to isotropic properties, since the material is symmetrical across the three orthogonal planes. Strength of the particulate composites normally depends on the diameter of the particles, interparticle spacing and volume fraction of the reinforcement. Matrix properties, including the work-hardening coefficient, which increases the effectiveness of the reinforcement constraint, are also important [7].

### 1.1.2 Laminated Composites

Laminated composite materials are considered to be reinforced by a repeating lamellar reinforcement of high modulus and strength, which is contained in the more ductile and formable metallic matrix material. Boron-carbide-titanium composites, in which the repeating reinforcing structural constituent consists of chemical-vapor-deposited boron carbide films of 5-25mm thickness, can be an example of the laminated composite materials; another kind of example can be the eutectoid composites of Ni-Mo and Al-Cu, in which two phases solidify in a lamellar array [9].

The elastic constants of a structural lamellar composite have been predicted by laminate theory. In either of the directions of the reinforcing plates is given by the rule of mixture: $E_C = E_R V_R + E_M V_M$

where $E_R$, $E_M$ and $E_C$ are the elastic moduli of the reinforcement, matrix and composite respectively, and V refers to the volume fraction [38].

The strength of laminated composite materials relate more closely to the properties of the bulk reinforcement. Since the reinforcing lamellae can have two dimensions that are comparable in size to the structural part, flaws in the reinforcement can nucleate cracks of lengths to that of the part. Since the most important reinforcing materials are brittle in nature, their strength is related to the population of their flaw density and intensity [37].

The reinforcements of strength in all directions of the plane is a good advantage but their strength, elongation and ductility is lower than the fiber reinforced composites, since the corresponding values of films are lower than the values for fibers.

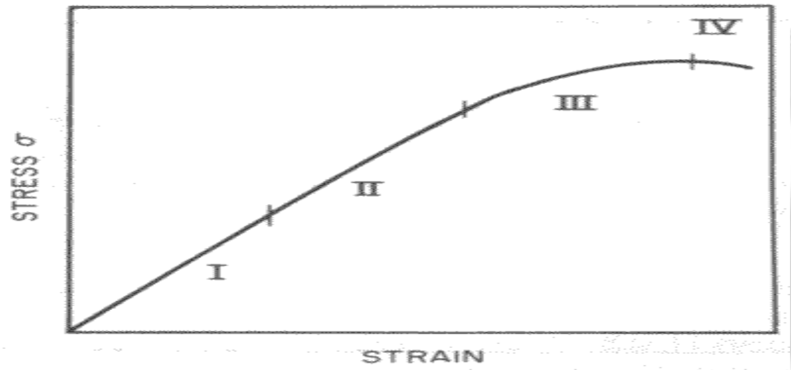


**Fig. 1.2.** Schematic curve showing the stress-strain behavior of a metal-matrix composite: (I) fiber elastic, matrix elastic; (II) fiber elastic, matrix plastic; (III) fiber plastic, matrix plastic; (IV) fiber fractured [36].

## 2. LITERATURE SURVEY

**Anil kumar et al [10]** investigated the mechanical properties of fly ash reinforced aluminum alloy (Al 6061) composites fabricated by stir casting. Three sets of composites with fly ash particle sizes of 75-100, 45-50 and 4-25 μm were used. Each set had three types of composite samples with the reinforcement weight fractions of 10%, 15% and 20%. The mechanical properties studied were compressive strength, tensile strength, ductility and hardness.

Unreinforced Al6061 samples were also tested for determining the mechanical properties. It was found that the compressive strength, tensile strength and hardness of the aluminum alloy composites decreased with the increase in particle size of reinforced fly ash. With an increase in the weight fractions of the fly ash particles, the ultimate tensile strength, compressive strength, hardness and the ductility of the composite decreases. The SEM of the samples indicated uniform distribution of the fly ash particles in the matrix without any voids.

**AzamTafreshi et al [1]** analyzed that the composite cylindrical shells and panels are widely used in aerospace structures. These are often subjected to defects and damage from both in-service and manufacturing events. Delamination is the most important of these defects. This paper deals with the computational modelling of delamination in isotropic and laminated composite cylindrical shells. The use of three-dimensional finite elements for predicting the delamination buckling of these structures is computationally expensive. Here combined double-layer and single-layer of shell elements are employed to study the effect of delamination on the global load-carrying capacity of such systems under axial compressive load. It is shown that through-the-thickness delamination can be modelled and analysed effectively without requiring a great deal of computing time and memory. A parametric study is carried out to study the influence of the delamination size, orientation and through-the-width position of a series of laminated cylinders. The effect of material properties is also investigated. Some of the results are compared with the corresponding analytical results. It is shown that ignoring the contact between the delaminated layers can result in wrong estimations of the critical buckling loads in cylindrical shells under compressive load.

**AzamTafreshi and Tobias Oswald [2]** investigated that the finite element models were developed to study global, local and mixed mode buckling behaviour of composite plates with embedded delaminations under compression. The global modelling results were compared with corresponding experimental results. It is shown that the numerical results for embedded delaminations agree very well with the experimental results, whereas the difference between the results was high for delaminations located at the edge of the plates. It is also shown that at lower loading levels the interaction of global and local buckling is negligible. At higher loading levels the strain energy release rate distribution and the delamination growth potential at the delamination front strongly depend on the shape of the debonded region and the local buckling mode. It was observed that the local buckling mode was highly influenced by the laminate stacking sequence. In the course of global buckling a parametric study was carried out to investigate the influence of the delamination size, shape and alignment of a series of composite plates.

**C.Roos et al [3]** studied that the Flexible matrix composites (FMCs) 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. In the present investigation, an optimization tool using a genetic algorithm approach is developed to determine the best combination of stacking sequence, number of plies and number of in-span bearings for a minimum-weight, spinning, 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.The analysis assures that the material does not overheat and that allowables are not exceeded. The challenge is that the analysis needs to address several physical processes such as self-heating in the presence of material damping, conduction and surface convection, ply-level stresses and strains, buckling and dynamic stability. Quasi-static and dynamic temperature- and frequency-dependent material properties for a carbon-polyurethane composite are embedded within the 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.

**C.s.ramesh et al [4]** studied the Al6061 matrix composite reinforced with nickel coated silicon nitride particles were manufactured by liquid metallurgy route. Microstructure and tribological properties of both matrix alloy and developed composites have been evaluated. Dry sliding friction and wear tests were carried out using pin on disk type machine over a load range of 20–100 N and sliding velocities of range 0.31–1.57 m/s. Results revealed that, nickel coated silicon nitride particles are uniformly distributed throughout the matrix alloy. Al6061–Ni–P–$Si_3N_4$ composite exhibited lower coefficient of friction and wear rate compared to matrix alloy. The coefficient of friction of both matrix alloy and developed composite decreased with increase in load up to 80 N. Beyond this, with further increase in the load, the coefficient of friction increased slightly. However, with increase in sliding velocity coefficient of friction of both matrix alloy and developed composite increases continuously. Wear rates of both matrix alloy and developed composites increased with increase in both load and sliding velocity. Worn surfaces and wear debris was examined using scanning electron microscopy (SEM) for possible wear mechanisms. Energy dispersive spectroscope (EDS), X-ray diffraction (XRD) and X-ray photoelectron spectroscope (XPS) techniques were used to identify the oxides formed on the worn surfaces and wear debris.

**BalasivanandhaPrabu et al [29]** investigated that the better stir process and stir time. The high silicon content aluminum alloy –silicon carbide MMC material, with 10% Si-C by using a variance of stirring speeds and stirring times. The microstructure of the produced composite was examined by optical microscope and scanning electron microscope. The results with respect to that stirring speed and stirring time influenced the microstructure and the hardness of composite also. They investigated that at lower stirring speed with lower stirring time, the particle group was more.

**Bienias et al [12]** studied the microstructure characteristics of aluminium matrix Ak12 composites containing of fly ash particles, obtained by gravity and squeeze costing techniques followed by the study of pitting corrosion behaviour and corrosion kinetics. It was found that in comparison to squeeze casting, gravity casting technology is advantageous for obtaining higher structural homogeneity with minimum possible porosity levels, good interfacial bonding and quite a uniform distribution of reinforcement. The fly ash particles lead to an enhanced potting corrosion of the Ak12/9%flyash (75-100 μm fraction) composite in comparison with unreinforced matrix (Ak12 alloy), and further the presence of nobler second phase of fly ash particles, cast defects like pores, and higher silicon content formed as a result of reaction between aluminum and silica in Ak12 alloy and aluminum fly ash composite determining the pitting corrosion behaviour and the properties of oxide film forming on the corroding surface.

**G.Sharifishourabi et al [9]** Studied the composition of the beam varies gradually from ceramic to metal along both the thickness and width directions. Continuous gradations according to both the power law and exponential law variations are considered. In the presence of a thermal gradient and transverse distributed loads an analytical solution based on the Euler-Bernoulli beam theory is presented

**Rama Rao et al [30]** examined that aluminum alloy-boron carbide composites were fabricated by liquid metallurgy techniques with different particulate weight fraction (2.5, 5 and 7.5%). Phase identification was carried out on boron carbide by x-ray diffraction studies microstructure analysis was done with SEM a composites were characterized by hardness and compression tests. The result shows that with an increase in the amount of the boron carbide, the density of the composites decreased whereas the hardness is increased.

**Rohatgi et al [23]** analysed the A356-fly ash composites which can be synthesized using gas pressure infiltration technique over a wide range of reinforcement volume fraction from 20 to 65%. The densities of Al356-fly ash composites, made under various experimental conditions, are in the range of 1250-2180 kg/m3 corresponding to the volume fraction of cenosphere in the range 20-65%. The density of composites increased for the same cenosphere volume fraction with increasing size of particles, applied pressure and melt temperature.

**Siva Prasad et al [6**], this investigation, studied the dry sliding wear behavior of aluminum (Al) matrix hybrid composites reinforced with rice husk ash (RHA) and silicon carbide (SiC) particulates up to 8% (in equal proportions) fabricated by vortex method. Pin-on disk wear test was carried out for both unreinforced alloy and hybrid composites. Scanning electron microscopy is used to study the wear characteristics of the unreinforced Al alloy and the hybrid composites. The results showed that the hybrid composites exhibits higher wear resistance than the unreinforced alloy. The wear mechanisms in the unreinforced alloy and the hybrid composites are analyzed and presented.

## 3. RESEARCH OBJECTIVE

The following are the objectives of the present work:

1. To predict the overall elastic properties of multilayer composite material of given number of layers, stacking sequence and elastic constants of each layer.
2. Validate the elastic data with finite element modeling.
3. Analyse the program in a graphic user interface.
4. using equivalent modulus beam theory, estimate the total mechanical strain properties, Displacement, Stresses and load of beams.
5. Comparison and analysis of total mechanical properties, material behavior of composite material Al-Steel-Al and its characteristics with the uses of analytical tool: ANSYS

### 3.1 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. Figure 3.1 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. obeys 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.

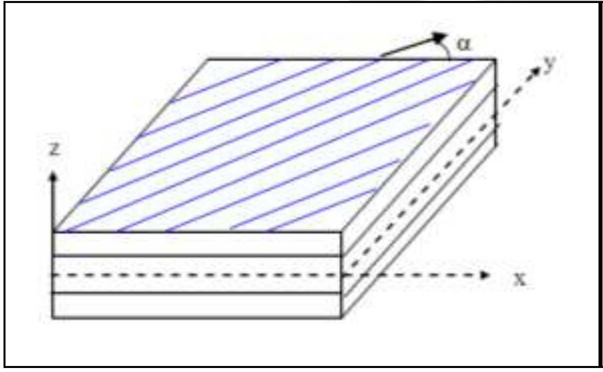


**Figure 3.1 Plate**

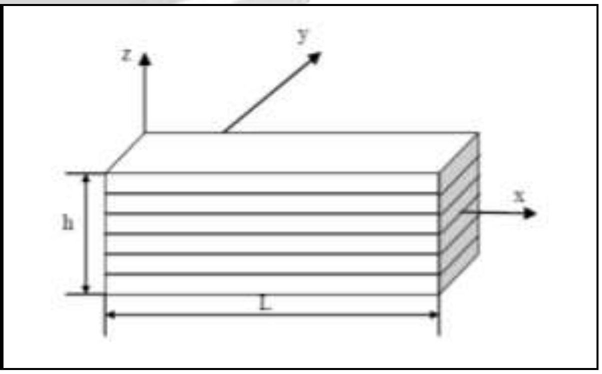


**Figure 3.2 Beams**

As shown in Figure 3.1, 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 x-axis. 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.

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 Figure 3.3 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.

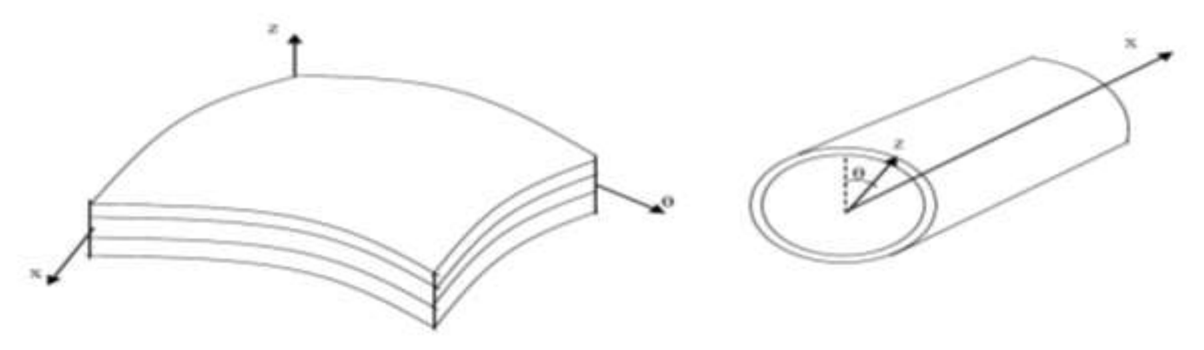
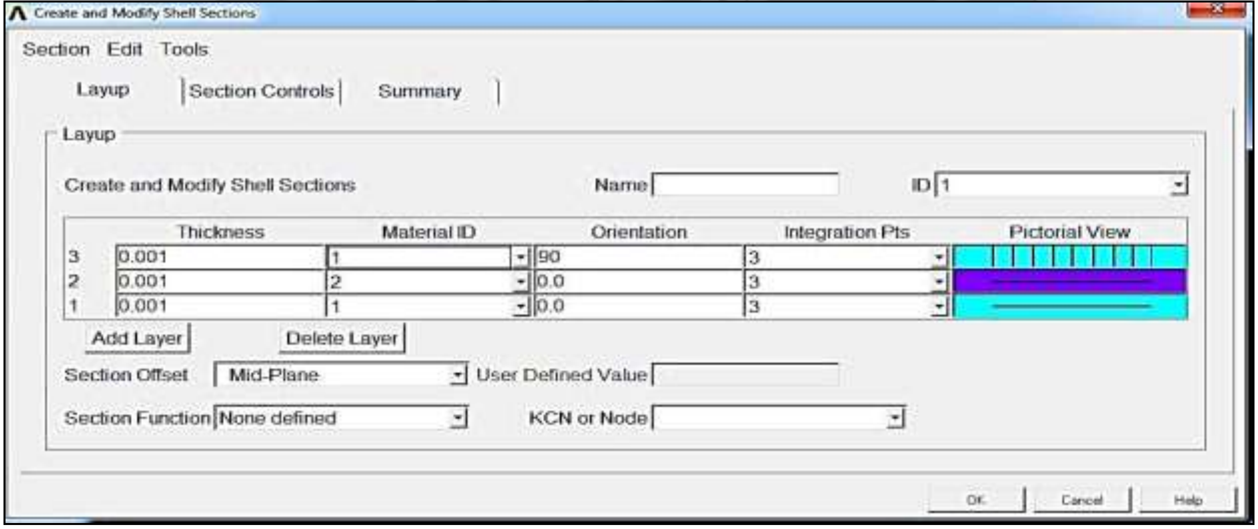


**Figure 3.3 Shell (cylindrical)**

### 3.2 MODELLING OF THE Al-Steel-Al COMPOSITE

The Modelling of three layered composite has been done using ANSYS 14.5. The layers are modeled as SHELL181. It is suitable for analyzing thin to moderately-thick shell structures. It is a four-node element with six degrees of freedom at each node: translations in the x, y, and z directions, and rotations about the x, y, and z-axes. (If the membrane option is used, the element has translational degrees of freedom only). The degenerate triangular option should only be used as filler elements in mesh generation. SHELL181 is well-suited for linear, large rotation, and/or large strain nonlinear applications. Change in shell thickness is accounted for in nonlinear analyses. In the element domain, both full and reduced integration schemes are supported. SHELL181 accounts for follower (load stiffness) effects of distributed pressures. SHELL181 can be used for layered applications for modeling composite shells or sandwich construction. The accuracy in modeling composite shells is governed by the first-order shear-deformation theory (usually referred to as Mindlin-Reissner shell theory). The element formulation is based on logarithmic strain and true stress measures. The element kinematics allow for finite membrane strains (stretching). However, the curvature changes within a time increment are assumed to be small.

The Material model used in this study is Linear Isotropic Structural Static model. Further, the properties of the layered shells are given in Figure 3.4.



Create and Modify Shell Sections

Name

ID 1

| | Thickness | Material ID | Orientation | Integration Pts | Pictorial View |
|---|---|---|---|---|---|
| 3 | 0.001 | 1 | 90 | 3 | |
| 2 | 0.001 | 2 | 0.0 | 3 | |
| 1 | 0.001 | 1 | 0.0 | 3 | |

Section Offset Mid-Plane

User Defined Value

Section Function None defined

KCN or Node

The Material properties of Steel & Aluminium alloy used in this study are given in Table 3.1.

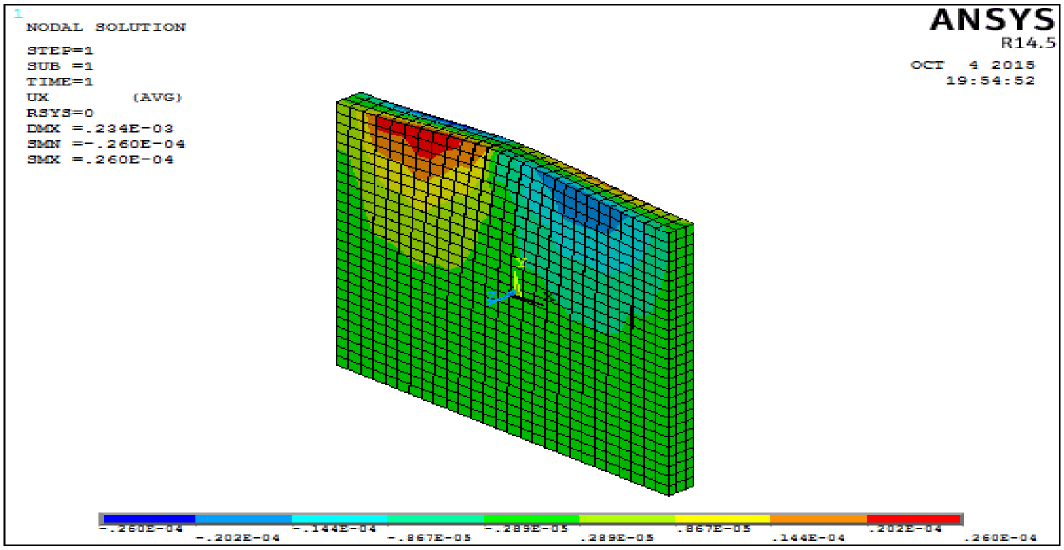
| Material | **Young's Modulus, E** | **Modulus of Rigidity, G** | **Density** | **Poisson's Ratio** | **Co-eff. of Thermal Expansion** |
|---|---|---|---|---|---|
| High Strength Steel 4340 | 210GPa | 76Gpa | 7.8Mg/m$^3$ | 0.26 | $14*10^6$ |
| Aluminium Alloy 7075-76 | 70GPa | 28Gpa | 2.7Mg/m$^3$ | 0.34 | $33*10^6$ |

Table 3.1.

# 4. RESULTS

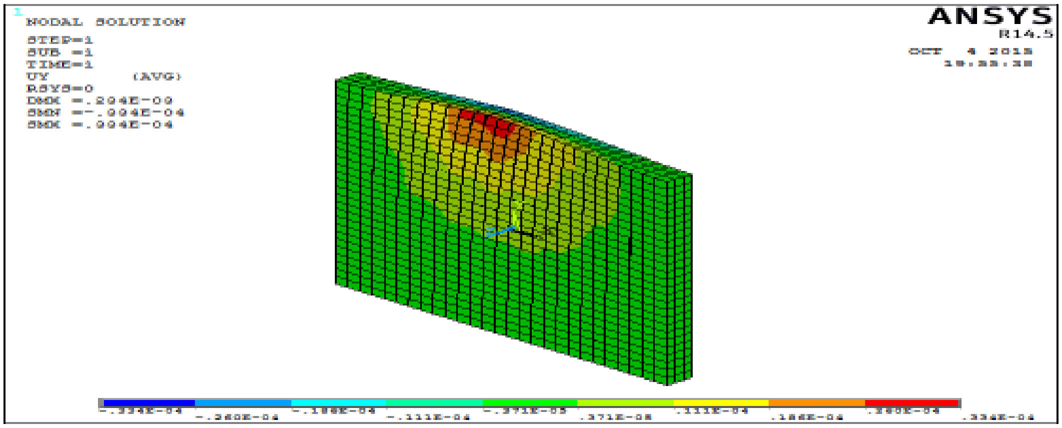
## 4.1 Nodal Solution/Degrees of Freedom Solution/Displacement

### (a) X- Component of Displacement



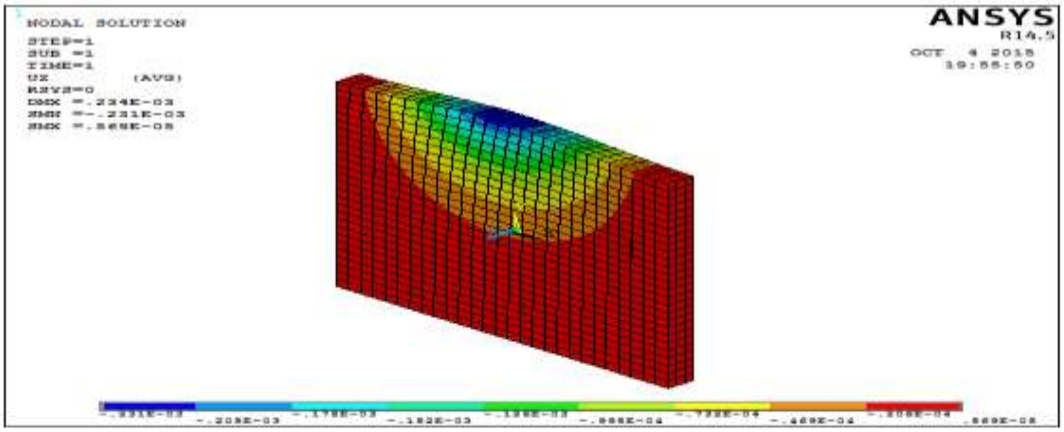
The minimum & maximum values of X-component of displacement are -0.260e-04 & 0.260e-04 respectively.

### (b)Y- Component of Displacement



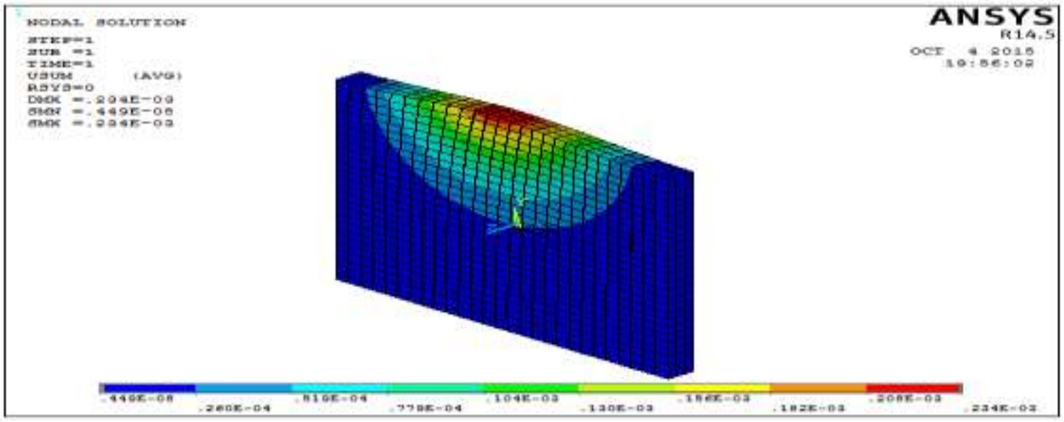
The minimum & maximum values of Y-component of displacement are -0.334e-04 & 0.334e-04 respectively.

### (c)Z- Component of Displacement



The minimum & maximum values of Z-component of displacement are -0.231e-02 & 0.569e-05 respectively.

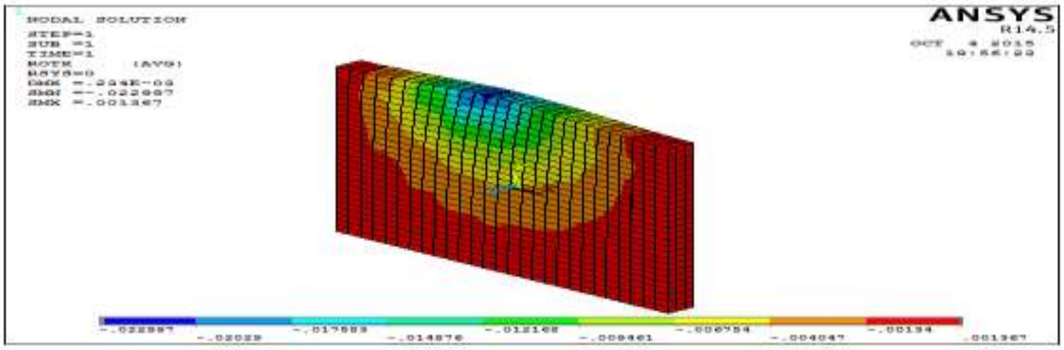
### (d)Vector Sum of Displacement



The minimum & maximum values of Vector sum of displacement are 0.449e-08 & 0.234e-03 respectively.

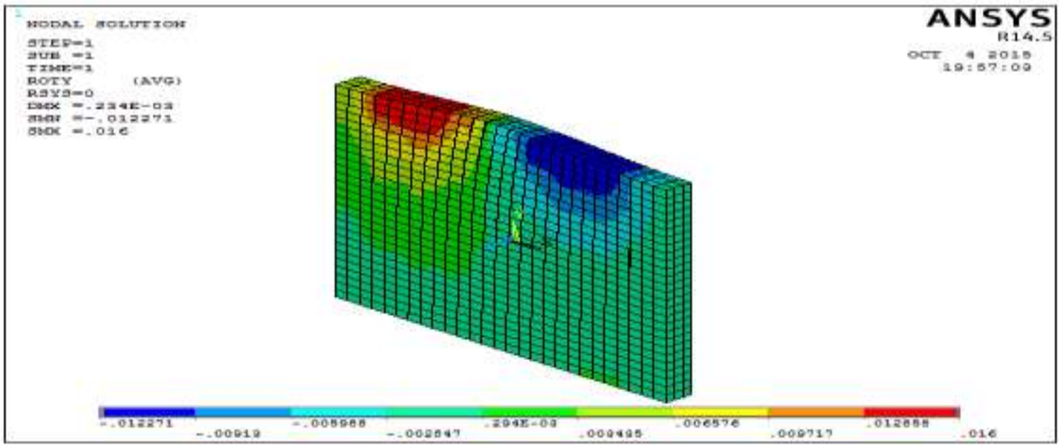
## 4.2 Rotation

### (a) X- Component of Rotation



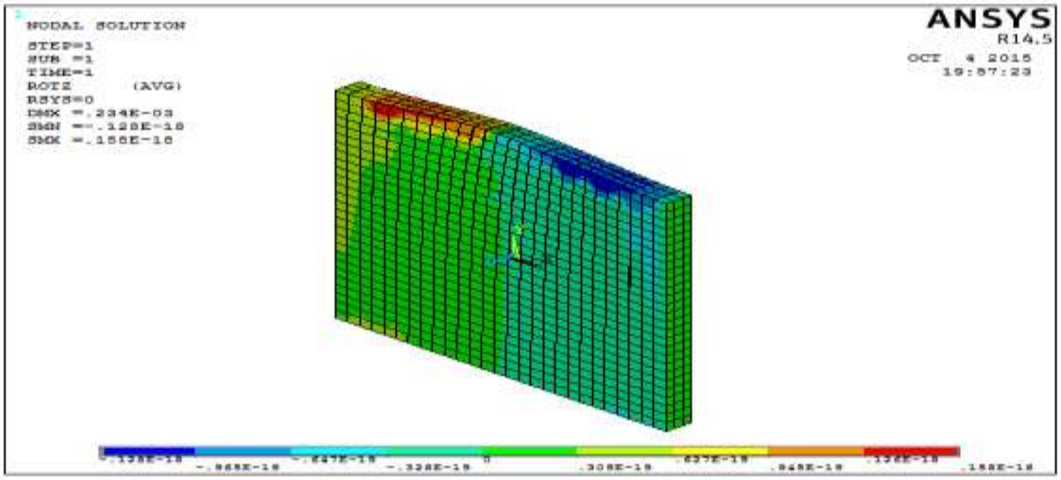
The minimum & maximum values of X-component of Rotation are -0.022997 & 0.001367 respectively.

### (b)Y- Component of Rotation



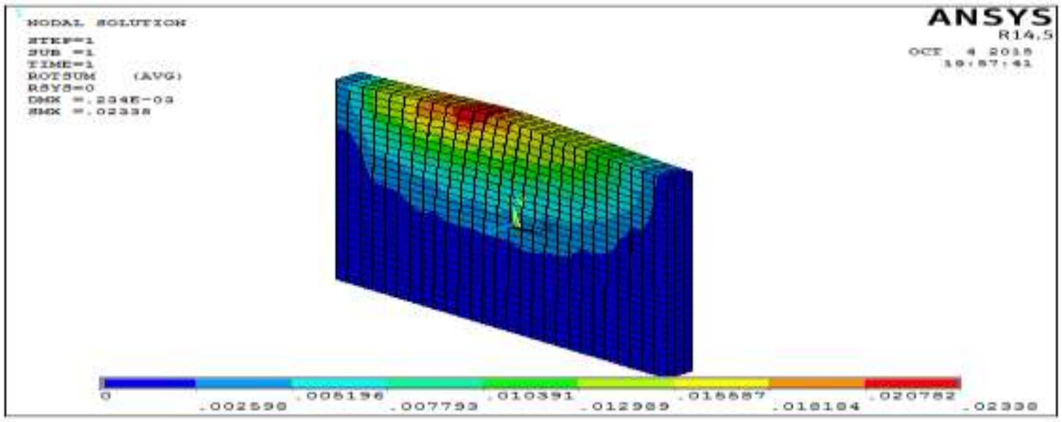
The minimum & maximum values of Y-component of Rotation are -0.012271 & 0.016 respectively.

**(c)Z- Component of Rotation**



The minimum & maximum values of Y-component of Rotation are -0.128e-18 & 0.158e-18 respectively.

**(d) Vector sum of Rotation**



The minimum & maximum values of Vector Sum of Rotation are 0.234e-03 & 0.02336 respectively.

## 5. CONCLUSIONS

From the analysis of the three layered Al-Steel-Al composites, following conclusions can be drawn:

1. The minimum & maximum total mechanical Strain Intensities are 0.174e-04 & 0.00855 respectively for elemental solution while in case of Nodal solution, the minimum & maximum values of Total

Mechanical Strain Intensity are 0.170e-04 & 0.00855 respectively. This is directly related to the stress-strain characteristics of each material that is Aluminium & Steel and need to carefully consider keeping in view the variation in stress-strain characteristics of different grades of steel and numerous alloys of Aluminium.

2. The minimum & maximum elastic strain intensities are 0.172e-04 and .00855 respectively for elemental solution while in case of nodal solution, the minimum & maximum values of Elastic Strain Intensity are 0.170e-04 & 0.00855 respectively. The behaviour of each material subject to axial & biaxial tensile as well as compressive loading up to elastic limit is taken into account in the analysis of composites for point loads. The effect due to pure bending & pure torsion is considered to be negligible and thereby not considered in the analysis.

**Future Scope:**

The analysis of three layered Al-Steel-Al composites has yielded sufficient analytical results necessary for the design of such composites. However, there is a potential future scope of further studies as given under:

1. Samples from the experimental testing should be analysed under Scanning Electron Microscopes as well at nano-scales to observe the micro-deformations, micro-fractures as well as micro-cracks.
2. More alloys of Aluminium should be used with altering combinations of steel and the optimum combination should be found out based on the principles of linear & complex programming

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