Modelling Of Lightweight Three Layered Aluminium-Steel-Aluminium Composites Using Ansys Parametric Design Language

Munesh Singh Dangi[1], Dushyant Dwivedi[2]

[1] *Student, Mechanical Engg. Department, Vikrant Institute of Tech. & Management, Gwalior (M.P.) India*
[2] *Asstt. Prof., Mechanical Engg. Dept.t, Vikrant Institute of Tech. & Management, Gwalior (M.P.) India*

ABSTRACT

Layered 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 layered 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 stress and buckling characteristics of such structures subjected to static & dynamic loads in complex environmental conditions. The structural components made of composite materials such as aircraft wings, helicopter blades, vehicle axles and turbine blades can be approximated as layered composite beams, shells & plates. In this study, a three layered composite shell consisting of middle layer of High Strength Steel-4340 and outside layers of Aluminium Alloy 7075-76 is designed and analysed for complex aerodynamic loading. The analysis results are found for both elemental & nodal solution. The maximum elastic strain intensity is 0.00855 for elemental solution while the maximum value of Stress Intensity is 0.594e+09 for Nodal Solution, which indicates the variation in the stress intensities in different materials corresponding to their moduli of elasticity. The analysis results directly relate to the stress-strain characteristics of each material and need to be carefully considered keeping in view the variation in stress-strain characteristics of different grades of steel and numerous alloys of Aluminium. Further, the minimum & maximum elastic strain intensities are 0.172e-04 and 0.00855 respectively for both elemental & nodal solution. The behavior 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.

Keyword: - *Aluminium. Composites, Three Layered Composites, Ansys APDL, and Material Properties etc.*

---

1. Introduction

A metal matrix composite (MMC) is composite material with at least two constituent parts, one being a metal necessarily, the other material may be a different metal or another material, such as a ceramic or organic compound. When at least three materials are present, it is called a hybrid composite.

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.

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.

1.2 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.

1.2.1 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. 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.

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.

1.2.2 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.

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:

$$EC = ERVR + EMVM$$

where ER, EM and EC are the elastic moduli of the reinforcement, matrix and composite respectively, and V refers to the volume fraction.

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.

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.

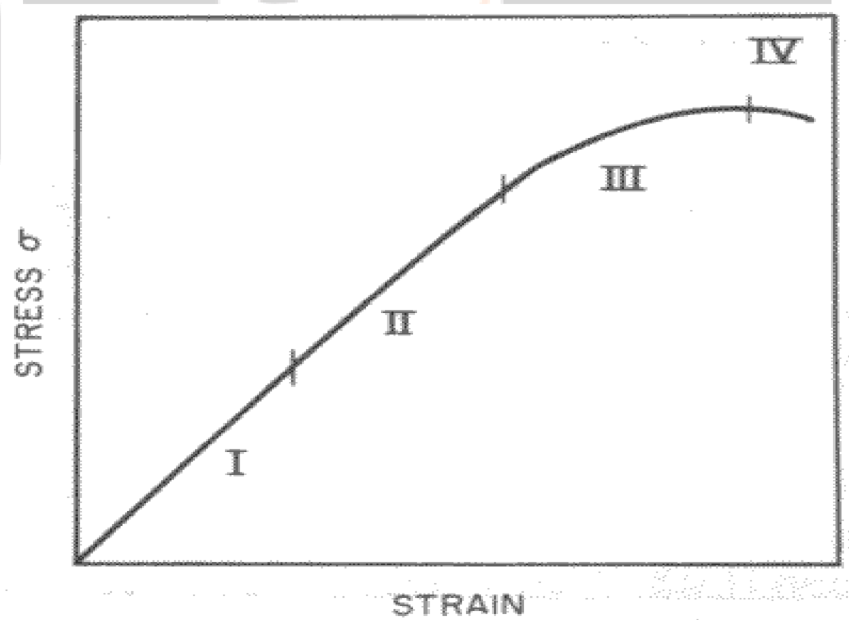


Fig. 1. Schematic curve showing the stress-strain behavior of a metal-matrix composite: (I) fiber elastic, matrix elastic; (II) fiber elastic, matrix plastic; (III) fiber plastic, matrix plastic; (IV) fiber fractured.

1.3 Manufacturing Techniques Of Metal-Matrix Composites

These methods can be divided into 4 broad senses:

1. powder processes
2. deposition processes
3. liquid processes
4. solid state processes

Problems vary with the particular matrix-fiber combination being considered but at least these three must always be kept in mind:

1. Reaction between fibers and matrix at elevated temperatures, either as the composite is being prepared or under service conditions
2. Obtaining sufficient bonding between the matrix and the fibers
3. Alignment of fibers within the material.

2. Modelling

Introduction related your research work Introduction related your research work Introduction related your research 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.
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.

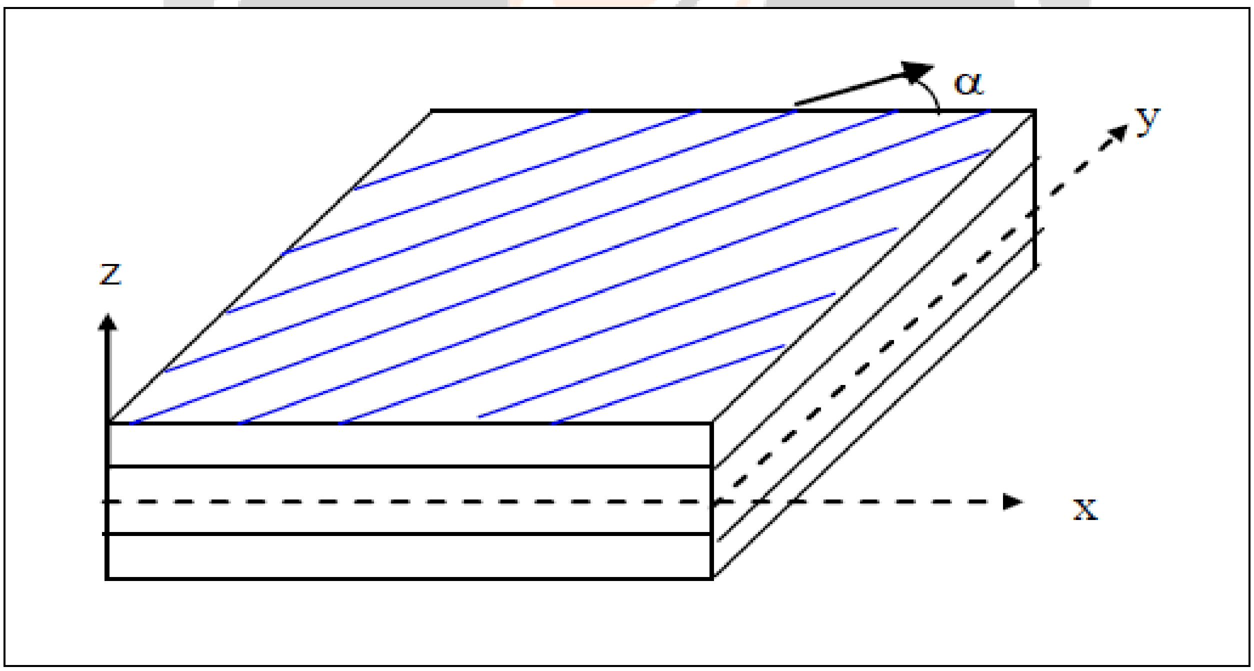


Fig. 2- Plate

2.1 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 thickness of the layered shells are given in Figure 3.

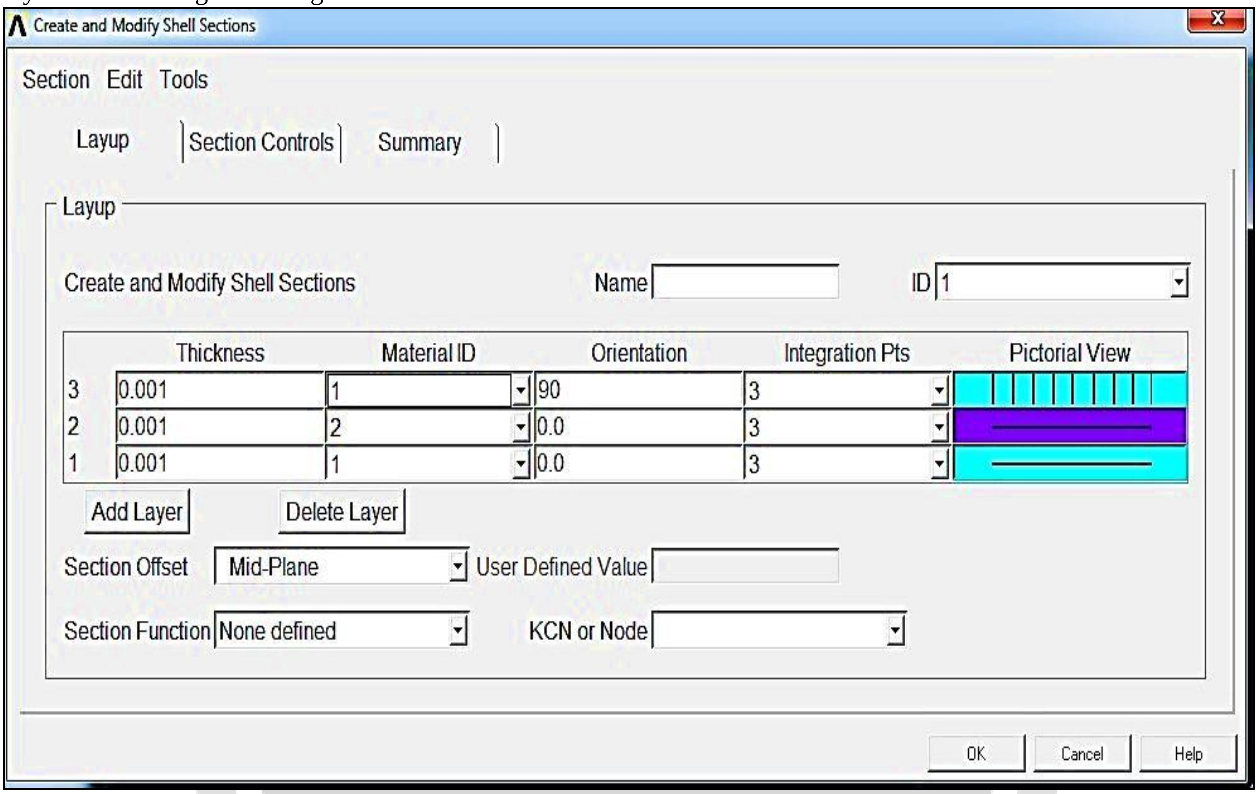


Fig -3: Dimensions of Layered Shells

The Material properties of Steel & Aluminium alloy used in this study are given in Table 1.

Table -1: Material properties of Steel & Aluminium

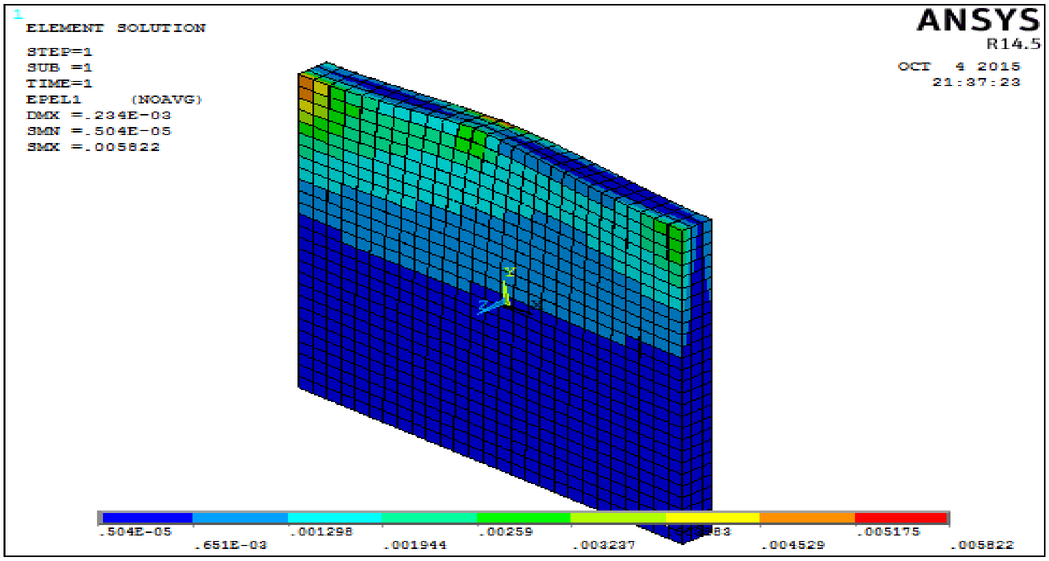
Table 3.1.					
Material	***Young's Modulus, E***	***Modulus of Rigidity, G***	***Density***	***Poisson's Ratio***	***Co-eff. of Thermal Expansion***
High Strength Steel 4340	210GPa	76Gpa	$7.8 Mg/m^3$	0.26	$14*10^6$
Aluminium Alloy 7075-76	70GPa	28Gpa	$2.7 Mg/m^3$	0.34	$33*10^6$

3. Results & Discussions

The chosen composite was subjected to various loads as described and various results were obtained which are discussed below. In this paper only elemental Solutions are discussed.

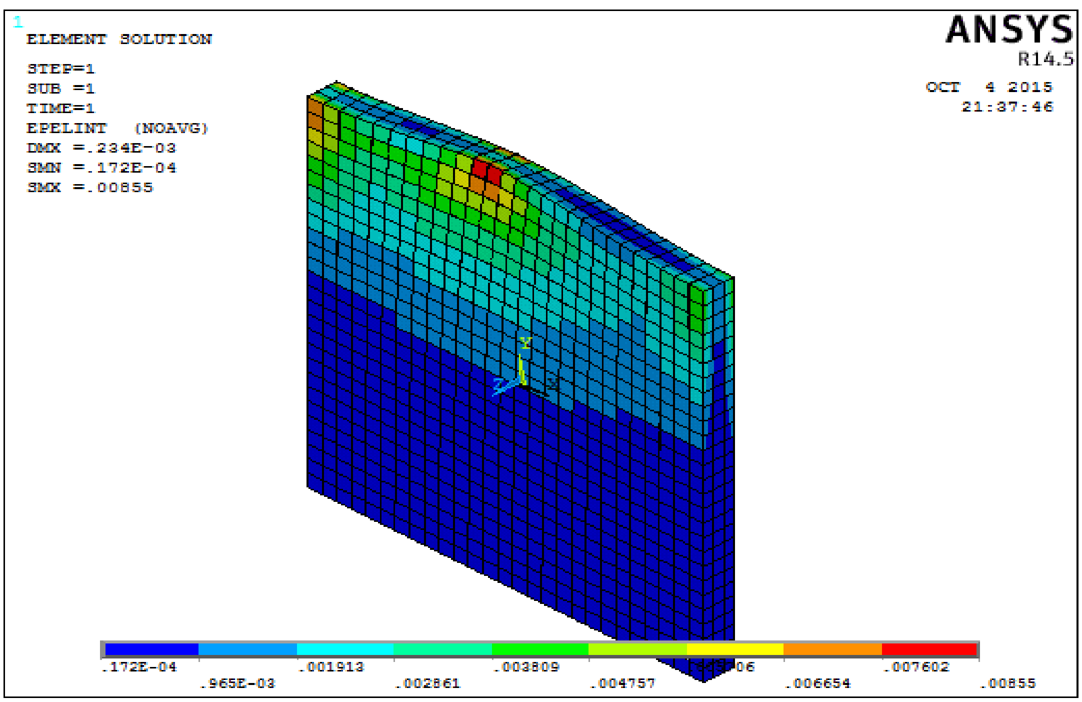
3.1 Elemental Solutions

3.1.1 1st Principal Elastic Strain



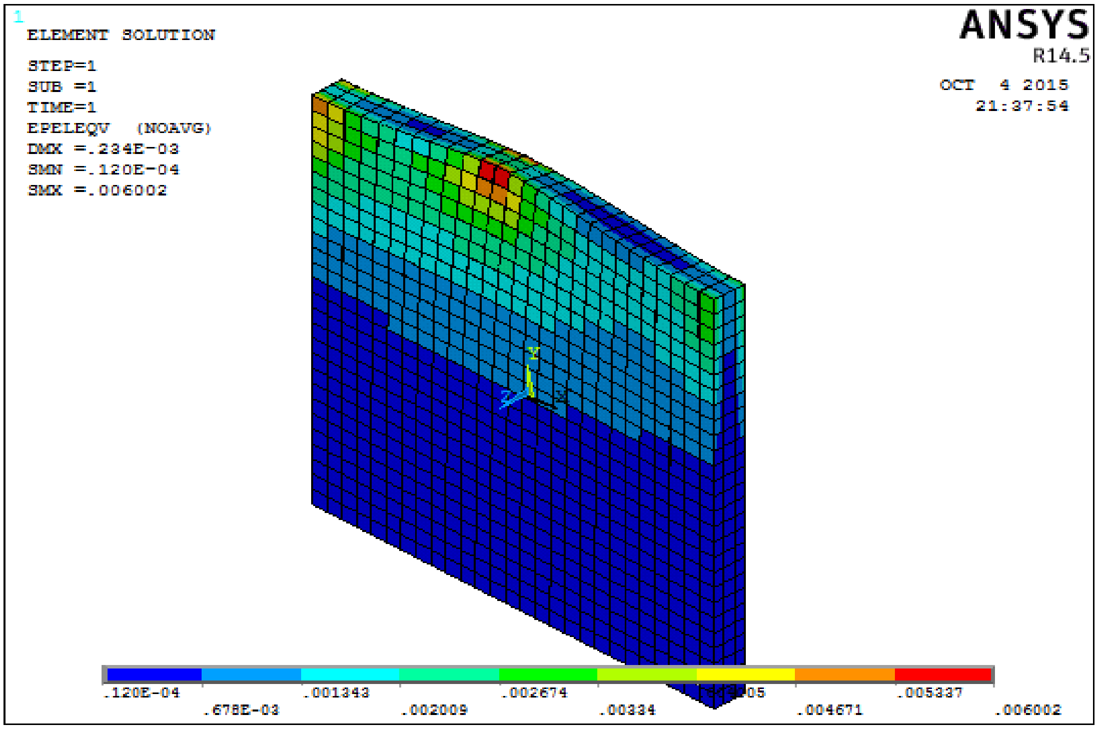
The maximum 1st principal elastic strain is 0.005822 and the minimum is 0.50e-05.

3.1.2 Elastic Strain Intensity



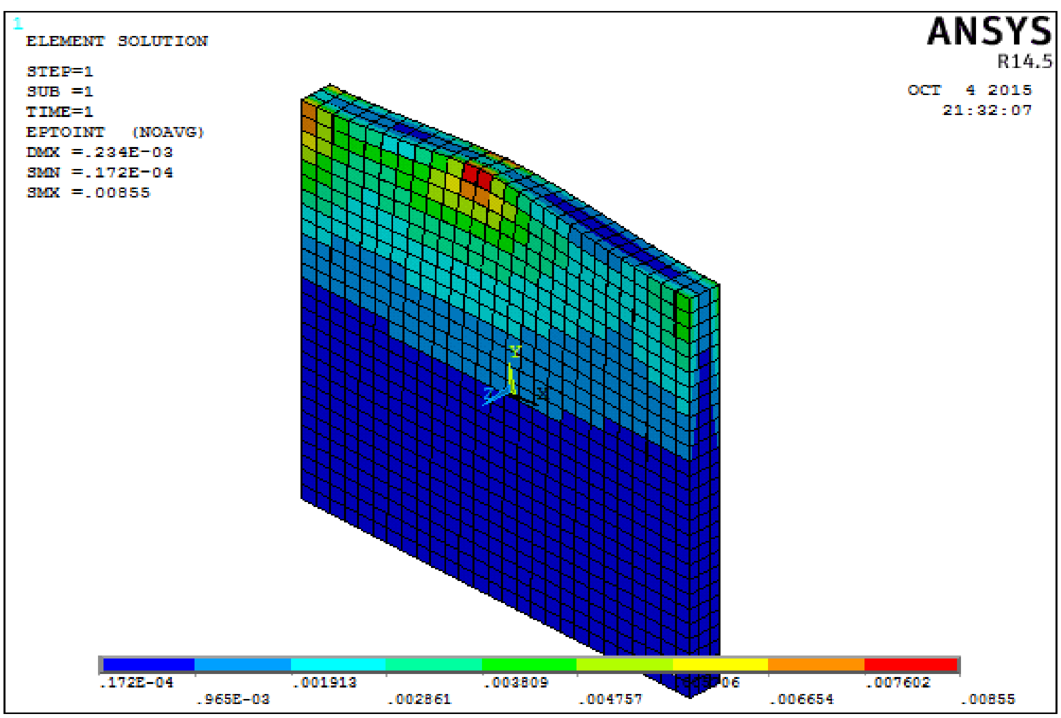
The minimum & maximum elastic strain intensities are 0.172e-04 and .00855 respectively.

3.1.3 Von Mises Elastic Strain



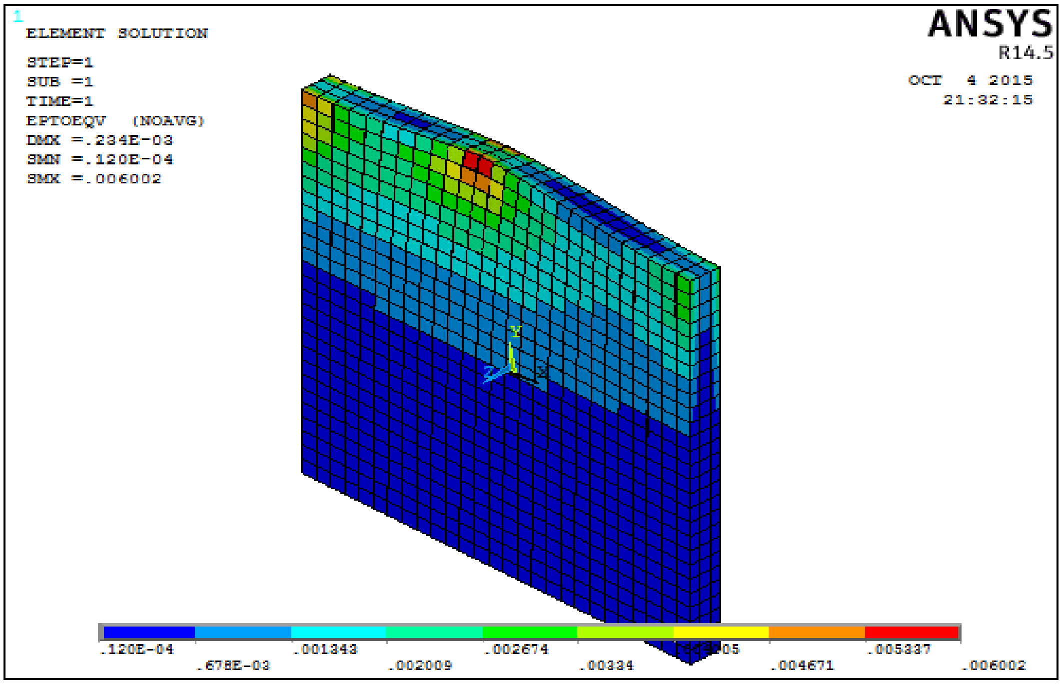
The minimum & maximum Von-Mises Elastic strains are 0.12e-04 & 0.006002 resp.

3.1.4 Total Mechanical Strain intensity



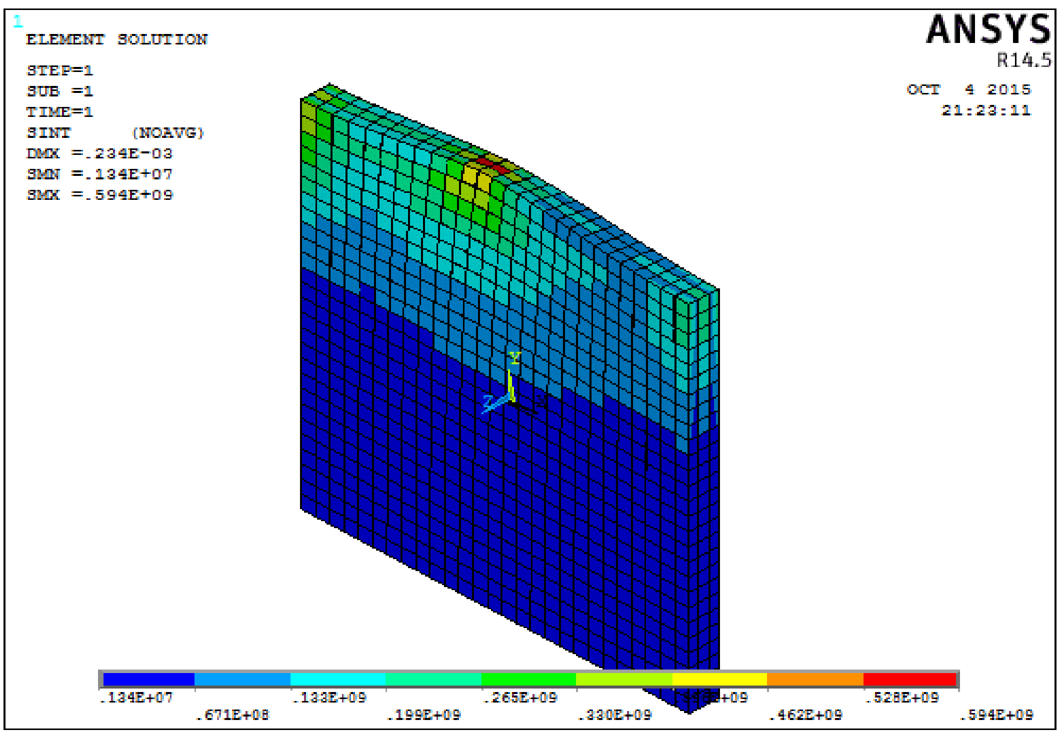
The minimum & maximum total mechanical Strain Intensities are 0.174e-04 & 0.00855 respectively.

3.1.5 Von-Mises Total Mechanical Strain



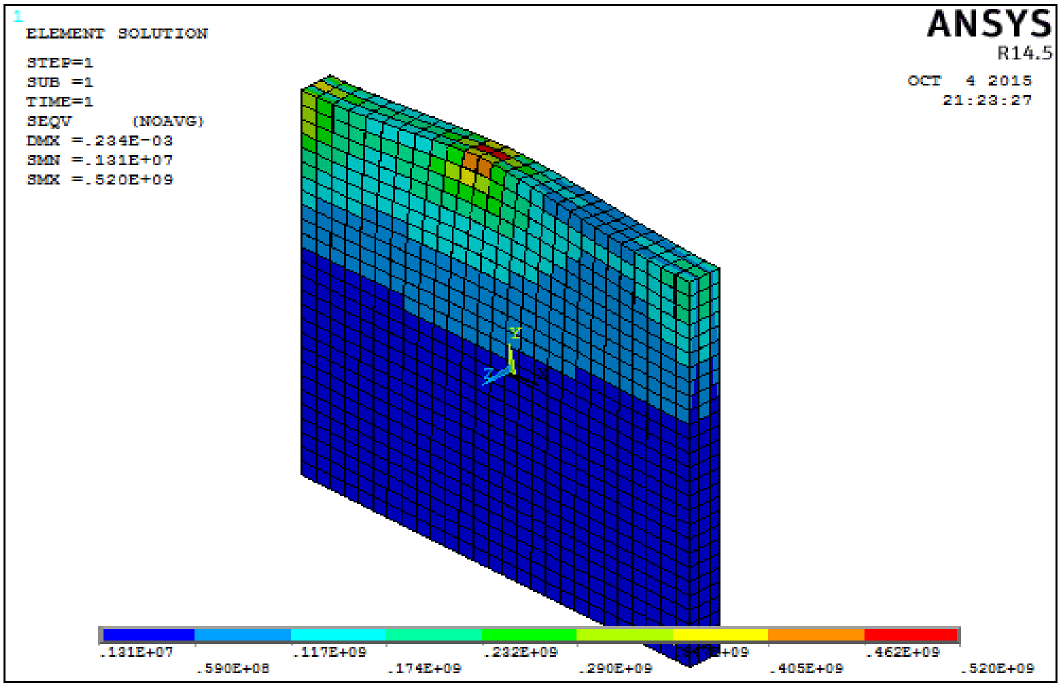
The minimum & maximum values of Von-Mises total mechanical strain are 0.120e-04 & 0.006002 respectively.

3.1.6 Stress Intensity



The minimum & maximum values of stress intensity are 0.134e+07 & 0.594e+09 respectively.

3.1.7 Von-Mises Stress



The minimum & maximum values of Von-Mises Stress are 0.131e+07 & 0.520e+09 respectively.

4. CONCLUSIONS

From the analysis of the three layered Al-Steel-Al composites, following conclusions can be drawn:
The minimum & maximum elastic strain intensities are 0.172e-04 and 0.00855 respectively for elemental solution while the minimum & maximum values of stress Intensity are 0.140e+07 & 0.594e+09 respectively in case of Nodal Solution, which indicates the variation in the stress intensities in different materials corresponding to their moduli of elasticity.

1. The Z-component of stress tensors is uniform & almost equal to zero as the applied external point loads have no component along Z-axis which indicates that in isotropic materials, the force resultants are directly governed by applied loads. However, in actual practice ideally isotropic materials do not exist as such there will be always stress components in all directions irrespective of the direction of applied loads.
2. 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 Aluminum & Steel and need to carefully consider keeping in view the variation in stress-strain characteristics of different grades of steel and numerous alloys of Aluminum.
3. 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 behavior 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.
4. The non-linear behavior is considered concerning only material & geometric nonlinearities while the structural non-linearity is not considered.

REFERENCES

1] S.Rama rao. G. Padmanabhan, Fabrication and mechanical properties of aluminium-boron carbide composites, international journal of materials and biomaterials applications 2(2012) 15-18

[2] S.balasivanandha prabu, Karunamoorthy, s. Kathiresan, b. Mohan, Influence of stirring speed and stirring time on distribution of particles in cast metal matrix composite. Journal of materials processing technology 171(2006) 268-273

[3] S. Balasivanandha prabu, Karunamoorthy Microstructure- based finite element analysis of failure prediction in particle-reinforced metal-matrix composite, journal of materials processing technology 207(2008)53-62

[4] G.g. sozhamannan. S. Balasivanandha prabu, r. Paskaramoorthy. Failures analysis of particle reinforced metal matrix composites by microstructure based models, materials and design, 31(2010) 3785-3790

[5] P.k. rohatgi , j.k. kim, N.gupta, simonalaraj, A.Daoud Compressive characteristics of A356/fly ash cenospehere composites synthesized by pressure infiltration technique, science direct 37(2006) 430-437

[6] N.Radhia, r. Subramanian, sivenkat prasat, Tribological behaviour of aluminium/alumina/graphite hybrid metal matrix composite using taguchi's techniques, journal of minerals and materials characterization and engineering 10(2011) 427-443

[7] C.s.ramesh, r. Keshavamurthy, b.h. channabasappa, s. Pramod, Friction and wear behaviour of Ni-P coated Si3N4 reinforced Al6061composites, tribology international 43(2010)623-634

[8] Mahendra boopathi, k.p. arulshri N. Iyandurai, Evaluation of mechanical properties of aluminium alloy 2024 reinforced with silicon carbide and fly ash metal matrix composites, American journal of applied sciences, 10(2013),219-229

[9] J. Bienias, m. Walczak, b. Surowska,j.Sobczak,Microstructure and corrosion behaviour of aluminium fly ash composites, journal of optoelectronics and advanced materials, 5(2003), 493-502

[10] H.c. anilkumar, h.s. hebbar and k.s. ravishankar, Mechanical properties of fly ash reinforced aluminium alloy (Al6061) composites, international journal of mechanical and materials engineering 6(2011) 41-45

[11] Dora siva Prasad, chintada shoba, nallu ramanainah, Investigations on mechanical properties of aluminium hybrid composite, mater res technol. 3(2014) 79-85

[12] D.J. Smith , G. Zheng, P.R. Hurrell , C.M. Gill, B.M.E. Pellereau , K. Ayres D. Goudar c, E. Kingston, Measured and predicted residual stresses in thick section electron beam welded steels, International Journal of Pressure Vessels and Piping 120-121 (2014) 66-79

[13] W. Weglewski , M. Basista , A. Manescu , M. Chmielewski , K. Pietrzak Th. Schubert , Effect of grain size on thermal residual stresses and damage in sintered chromium–alumina composites, Composites: Part B 67 (2014) 119–12.