Investigation of Stress Analysis of Al-Glass Fiber Sandwich Plate for Riveted Double Lap Joint

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Abstract— This work deals with Find the tensile strength of Al-Glass Fiber Sandwich Plate having double lap rivet joint with different fiber orientation. The commercial finite element analysis (FEA) software, ANSYS has been used to create and analyze the models. The laminates (adherend) were made of glass/epoxy composite with different fibre orientation and the adhesive used was epoxy-based standard resin. The width of all the members was 50 mm. The thickness of adherents was taken to be 2 mm, and the thickness of adhesive layer was 0.2 mm. A 4 aluminium rivets was used for mechanical fastening from design calculations. The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is (200x50x5)mm. Typical points of interest when testing a material include: ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) Instron 1195 and results are analyzed to calculate the tensile strength of composite plate having double lap riveted joint.

Key words: Riveted Double Lap Joint, Al-Glass Fiber Sandwich Plate

I. INTRODUCTION

Fiber-reinforced polymer (FRP) elements are commonly joined with mechanical connections such as steel profiles. However, the use of bolts and rivets is not material-adapted due to the anisotropic character and brittle behavior of FRP materials, and usually leads to over-sizing of components. Adhesively bonded connection is far more appropriate and allows better load transfer. Nevertheless the stiff and relatively brittle epoxy adhesives currently used cause shear and through thickness peaks at joint edges. The use of ductile and/or flexible adhesives reduces shear and through-thickness stress concentrations and creates even distribution, increasing the joint's robustness. In addition, ductile and flexible adhesives allow large deformations and develop elastoplastic or elastic hinges in the structures, which for compensate the lack of ductility of FRP materials. Bonded joints with ductile and flexible adhesives are adapted to FRP elements.

Laminated composite sheets of aluminum-epoxy with a double lap riveted joints, which find applications in the fuselage type structure used in aircrafts are subjected to high stresses. Hence it is necessary to investigate thoroughly the strength aspects of such structures. the stress concentration at the joint in the composite laminates contribute towards failure and delamination phenomenon. In this regard, it becomes vital to analyze the behavior of the laminate under tensile loading conditions.

Rivets are considered to be permanent fasteners. Riveted joints are therefore similar to welded and adhesive joints. When considering the strength of riveted joints similar calculations are used as for bolted joints. Rivets have been used in many large scales applications including ship building, boilers, pressure vessels, bridges and building. Riveted joints are very effective in designs subjected to pronounced vibration loads where welded joints are less reliable. A riveted joint, in larger quantities is sometimes cheaper than the other options but it requires higher skill levels and more access to both sides of the joint.

II. THEORETICAL ANALYSIS & EXPERIMENTAL ANALYSIS

A. *Theoretical Analysis*

- Detailed 3-D modeling of the double lap riveted joint of composite plate of aluminium-epoxy sheets.
- Finite element analysis of double lap riveted joint of composite plate using commercial CAE software ANSYS. This work will involve stress analysis to determine the strength of the joint and also to locate the peak stress counters.

B. *Experimental Analysis*

1) The manufacturing of riveted and bonded double lap joint of composite plate of Aluminium-epoxy sheets will be carried out.
2) Experimental analysis of these joints will be carried out on the universal testing machine, with relevant fixture adjustment to obtain the load vs. deflection relation. The pattern of the failure will be observed in both the joints and limiting value of the strength (load) will be obtained prior to failure.
3) The DOE will indulge a parametric study to understand the effect of Fiber Orientation.

- 0^0
- 30
- 45
- 90
- -30
- -45

III. DESIGN CALCULATIONS FOR RIVET

$\sigma_t = 90$ MPa, $\tau = 60$ MPa and $\sigma_c = 60$MPa
b = 50mm, L= 200mm, t=5mm

A. *Diameter of Rivet*

We know that the diameter of rivet hole,
$d = 6\sqrt{t} = 6\sqrt{5} = 13.41$
d = 12mm

B. Number of Rivets

n= Number of rivets
Maximum pull acting on the joint
$P_t = (b - d)\ t \times \sigma_t$
= (50 - 12)× 5 × 90
= 17100 N
Shearing resistance of one rivet
$= 1.05 \times \pi/4 \times d^2 \times \tau$
$= 1.05 \times \pi/4 \times 12^2 \times 60$
= 7121.52N
Crushing resistance of one rivet
$P_c = d \text{ x } t \text{ x } \sigma_c$
= 12 x 5 x 60
= 3600N
Number of rivets
n = Pt / Pc
= 17100 / 3600
= 4.56 ≈ 4

C. Weight Calculation

1) For Composite laminate Plate

Weight = M × g
Mass = Density x Volume
= 2350x l x b x t
= 2350 x 0.200 x 0.050 x 0.005
= 0.1175kg

2) For Mild Steel Plate

Weight = M × g
Mass = Density × Volume
= 7845 x l x b x t
= 7845 x 0.200 x 0.050 x 0.005
= 0.39225 kg
Weight Reduction %
= [(0.39225−0.1175) / 0.39225] ×100 = 70.04%

IV. SAMPLE PREPARATION

The specimens of composite plates are created using hand layup method.6 samples are used for experimental tensile testing. The specimens consist of number of layers. Sequentially layers are of aluminium then glass fiber and again an aluminium. The dimensions of the specimen are 50*200mm.The thickness of aluminium plate is 1.5mm.The fiber orientation of the glass fiber are 0^0, 30^0, 45^0, 90^0, -30^0,-45^0 unidirectional.

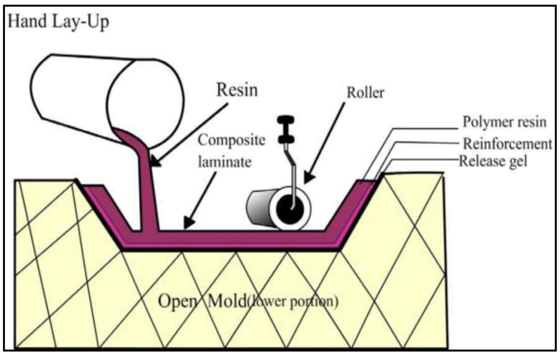

Fig. 1: Hand Lay-Up Process

Hand laminating is a primitive but effective method that is still widely used for prototyping and small batch production. The most common materials are E glass fiber and polyester resin, although higher performance materials can also be used. The single sided mold is invariably operated at room temperature using an ambient curing resin. The reinforcement may be in the form of chopped strand mat or an aligned fabric such as woven rovings. The usual feature of hand laminating is a single sided female mold, which is often itself made of glass fiber reinforced plastics (GRP), by taking a reversal from a male pattern. Thin plastic sheets are used at the top and bottom of the mold plate to get good surface finish of the product. Reinforcement in the form of woven mats or chopped strand mats are cut as per the mold size and placed at the surface of mold after perspex sheet. Then thermosetting polymer in liquid form is mixed thoroughly in suitable proportion with a prescribed hardner (curing agent) and poured onto the surface of mat already placed in the mold. The polymer is uniformly spread with the help of brush. Second layer of mat is then placed on the polymer surface and a roller is moved with a mild pressure on the mat-polymer layer to remove any air trapped as well as the excess polymer present. The process is repeated for each layer of polymer and mat, till the required layers are stacked. After placing the plastic sheet, release gel is sprayed on the inner surface of the top mold plate which is then kept on the stacked layers and the pressure is applied. After curing either at room temperature or at some specific temperature, mold is opened and the developed composite part is taken out and further processed. The schematic of hand lay-up is shown in figure.

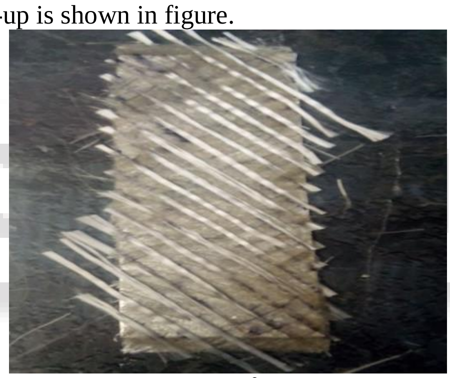
Fig. 2: Fibre at 30^0 Orientations


Fig. 3: Fibre at 90^0 Orientation


Fig. 4: Six nos. of Al-Glass fiber composite plate

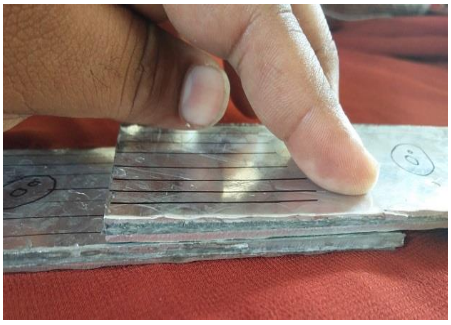

Fig. 5: Preparation for Double Lap Joint

Fig. 6: Preparation for Riveted Joint

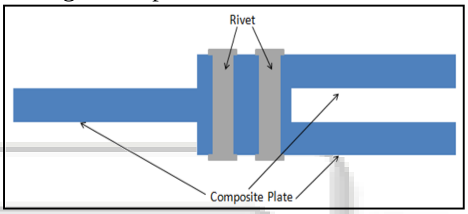

Fig. 7: Composite Plate With Rivet Joint

V. Experimental Testing

The tensile strength of a material is the maximum amount of tensile stress that it can take before failure. The commonly used specimen for tensile test is the dog-bone type. During the test a uniaxial load is applied through both the ends of the specimen. The dimension of specimen is (150x10x5)mm. Typical points of interest when testing a material include: ultimate tensile strength (UTS) or peak stress; offset yield strength (OYS) which represents a point just beyond the onset of permanent deformation; and the rupture (R) or fracture point where the specimen separates into pieces. The tensile test is performed in the universal testing machine (UTM) Instron 1195 and results are analyzed to calculate the tensile strength of composite double lap riveted joint.

Fig. 8: UTM machine Sample loaded condition for tensile testing

A. *Testing Report*

Fiber orientation	Load at Peak in KN	Tensile Strength in KN/mm^2
0^0	23.81	31.74
30^0	22.42	29.89
45^0	23.46	31.28
90^0	21.56	28.74
-30^0	22.72	30.29
-45^0	23.22	29.64

Table 1: Tensile Stress for all Glass Fiber Orientation

VI. FEA Results

The commercial finite element analysis (FEA) software, ANSYS has been used to create and analyze the models. The laminates (adherend) were made of glass/epoxy composite with different fiber orientation and the adhesive used was epoxy-based standard resin. The width of all the members was 50 mm. The thickness of adherents was taken to be 2 mm, and the thickness of adhesive layer was 0.2 mm. An 4 aluminium rivets was used for mechanical fastening from design calculations.

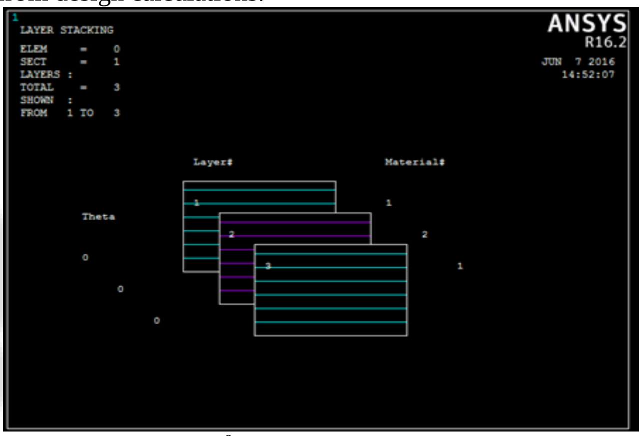

Fig. 9: 0^0 Degree Fiber Orientation

Above fig. green colour orientation shows aluminium material and dark colour shows glass fiber orientation. In this analysis all fiber are orient 0^0. Aluminium plate thickness is 1.5 mm and glass fiber epoxy plate thickness is 2mm.

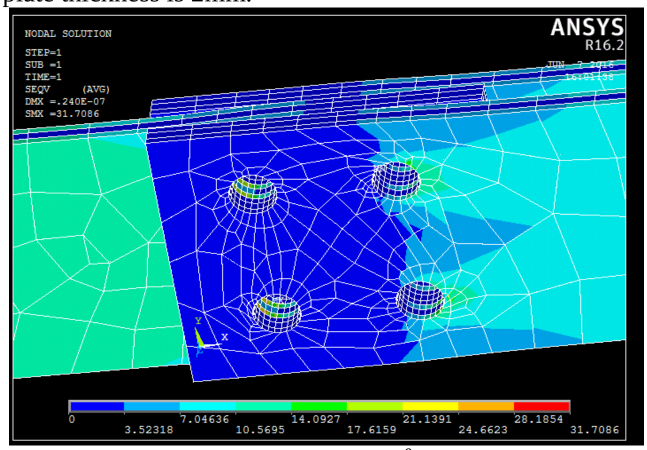

Fig. 10: Max. Stress Induce for 0^0 Fiber Orientation

Maximum stress shown around the hole area. Red colour shows maximum value of stress and fails the plate at this particular section. Maximum stress value is 31.708 MPa.

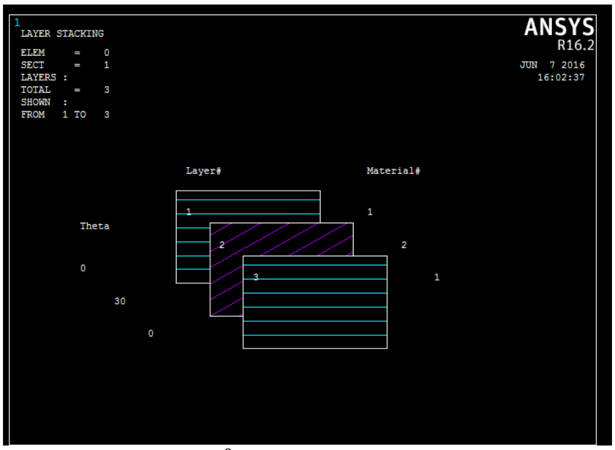

Fig. 11: 30^0 Degree Fiber Orientation

In this analysis all fibre are orient 30^0

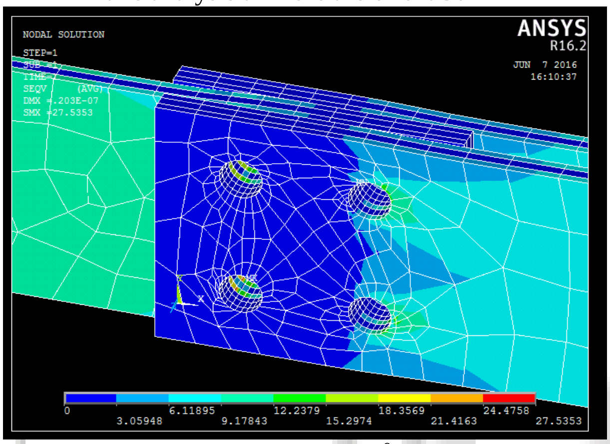

Fig. 12: Max stress Induce for 30^0 Fiber Orientation

A. Maximum Stress Value is 27:53 MPa

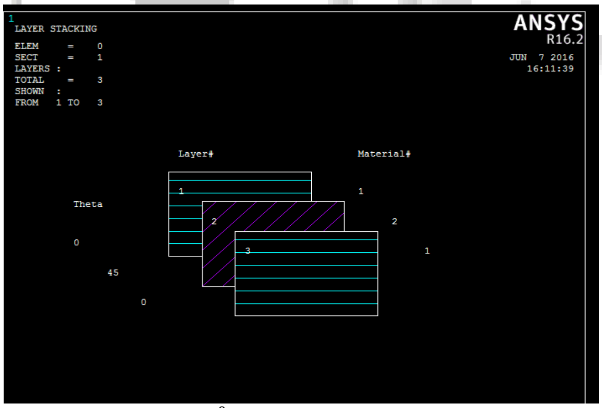

Fig. 13: 45^0 Degree Fibre Orientation

In this analysis all fiber are orient 45^0

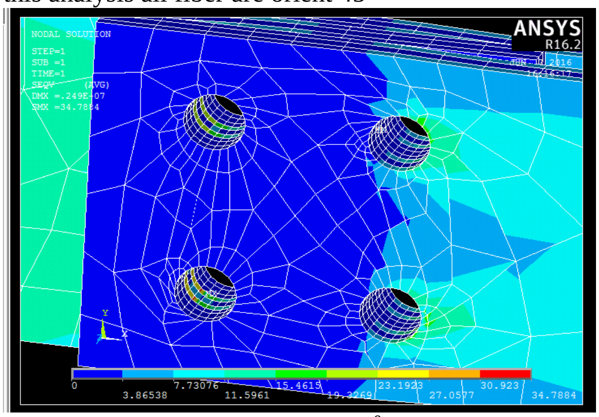

Fig. 14: Max Stress Induce at 45^0 Fiber Orientation

B. Maximum stress value is 34:78 MPa

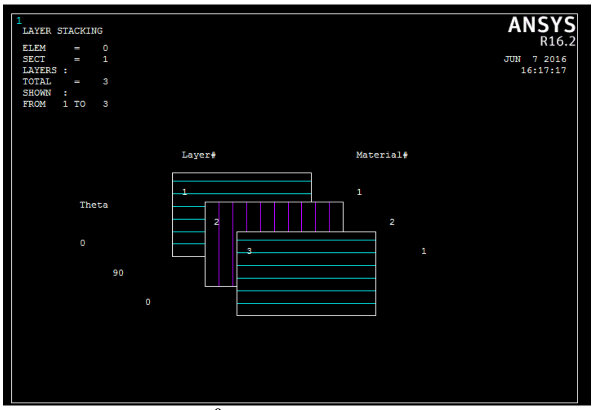

Fig. 15: 90^0 Degree Fibre Orientation

In this analysis all fibre are orient 90^0

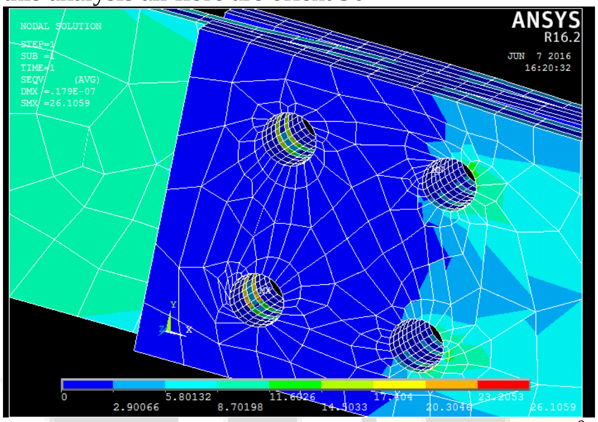

Fig. 16: Max Stress Induce at Fiber Orientation at 90^0

C. Maximum stress value is 26:10 MPa

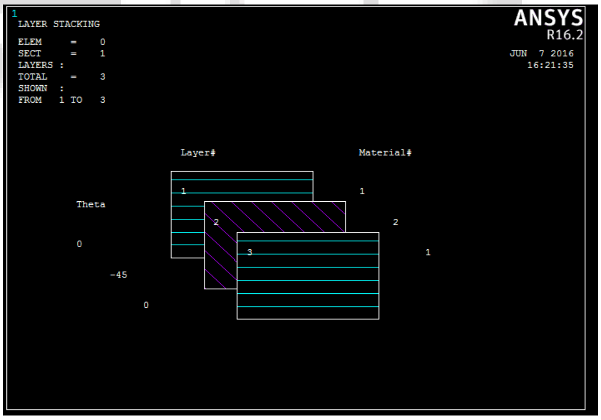

Fig. 17: -45^0 Degree Fibre Orientation

In this analysis all fibre are orient - 45^0

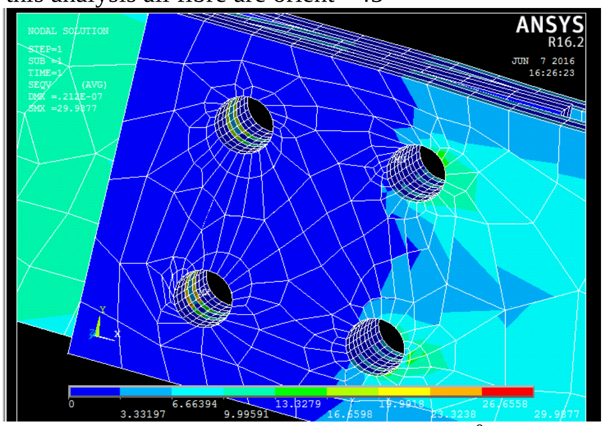

Fig. 18: Max Stress Induce at -45^0

D. Maximum stress value is 29:98MPa

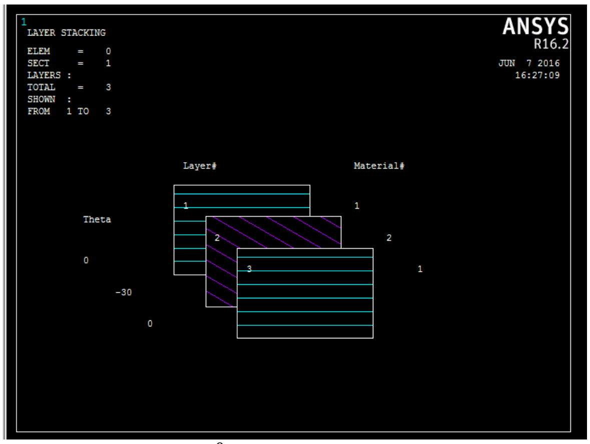

Fig. 19: -30^0 Degree Fibre Orientation

In this analysis all fibre are orient -30^0

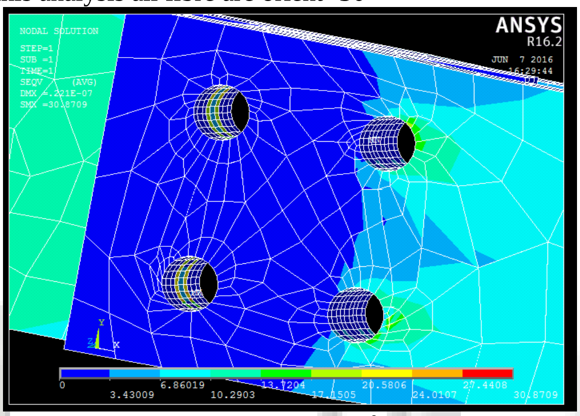

Fig. 20: Max Stress Induce at -45^0 Fiber Orientation

Maximum stress value is 30:87 MPa

VII. Compare the Result Experimental Vs FEA

Fibre Orientation	Thickness of Fibre Plate	Experimental Result in MPa	ANSYS Result in Mpa
0^0	2mm	31:74	31:708
30^0	2 mm	29:89	27:53
45^0	**2 mm**	**31:28**	**34:78**
90^0	2 mm	28:74	26:10
-45^0	2 mm	29:64	29:98
-30^0	2 mm	30:29	30:87

Table 2: Comparison of Experimental and FEA Results

VIII. Conclusion

FE model of a double lap sandwich composite riveted joint, under static tensile load: The model comprises a high level of geometrical details in the plates and rivets (such as the geometric clearance in between hole and rivet), the simulation of the sandwich plate with different orientation was done in ANSYS:

The following conclusions drawn from the present Study

1) The best ply orientation was seen 450 in single direction of fibre with maximum thickness (2mm)
2) Design the sandwich composite joint for lightweight application and this purpose is fulfill, 74% weight reduction achieved in composite plate than steel plate:

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