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Finite Element Analysis of Hybrid Single Lap Joints

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***Abstract*—A hybrid joint is a combination of mechanical fastening and adhesive bonding. Mechanical fastening in the joint is done by means of rivets. The work is aimed at analyzing single lap hybrid composite joints. In single lap hybrid joint, analyses are done by inserting a thin layer of composite between the plates. Analyses are done for different composite materials in ANSYS Workbench 16.2. The different composite materials used for both the joints are CFRP, GFRP, E- glass fibre and Aramid fibre. All the models have same cross-sectional area and are subjected to a tensile load within the elastic limit. The model with least deflection and least stress concentration is desirable. Results are compared and interpreted in terms of deflection and stresses.**

Keywords—hybrid joints, single lap joint, composite materials, ANSYS Workbench

I. INTRODUCTION

Commonly available types of load carrying joints are mechanically fastened joints and adhesively bonded joints. A novel method has been devised which is hybrid joint used in several applications like building elements, retrofitting and rehabilitation of structures .The advantages of such joints include large bond area for load transfer, low stress concentration, smooth external surfaces, less sensitivity to cyclic loading, time and cost saving, high strength to weight ratio, electrical insulation and thermal insulation, corrosion and fatigue resistance and crack retardation. Incorporating composite materials in such joints will further enhance their performance.

The type of joints incorporated in this study is single lap joints. The mechanical fasteners considered are rivets. Effect of composite materials like Carbon Fibre Reinforced Polymer (CFRP), E-glass fibre, Glass Fibre Reinforced Polymer (GFRP), and Aramid Fibre Reinforced Polymer (AFRP) on stress concentration and deflection in the joints is studied.

Noah M Salih and Mahesh J Patil [6], conducted a parametric on the relevant joint design parameters of hybrid composite, single lap bolted joints through finite element analysis. The load transfer mechanism is very complicated due to differences in load path and stiffness.

Amit P Wankhade, and Kiran K Sadhau [4] modeled a single lap bolted joint with PRO/E and analysed with ANSYS Workbench 14.5. Modeling and analysis were done for mild steel and E-glass fibre. Stresses were evaluated for both materials and it is observed that maximum stresses are for E-glass fibre and it may be a better replacement for mild steel.

Subramani and Senthil Kumar [2] made a finite element analysis for double riveted single lap joint for bonded, riveted and hybrid joints, which are subjected to tensile load. They concluded that stress induced by ANSYS is less than the material ultimate stress and ultimate limit. Also, hybrid joints are more efficient than bonded and riveted joints in the case of situations of repair.

Subramani and Arul [3] made a finite element analysis for stress distribution in bonded, riveted and hybrid joints. The hybrid joint used CFRP composite and they concluded that shear stress value for hybrid joints are less. The analyses were conducted using ANSYS. They also found out that efficiency of composite single lap shear joints can be increased using bonded inserts.

The objectives of the study include:

1. To model hybrid composite with rivets as mechanical fasteners and adhesive bonding in ANSYS Workbench 16.2.
2. To model hybrid composite joints namely, single lap joint of mild steel plates.
3. To study the effect of providing thin layer of composite materials such as CFRP, GFRP, E-glass and Aramid fibres in single lap joint under tensile load.
4. To compare deflections and stresses of the joints using the above mentioned composite materials.

II. TYPE OF JOINT ANALYSED

A. Hybrid Joints

Hybrid joining is the combination of two or more joining techniques to produce joints with properties additional to those obtained from a single technique. Here, the hybrid joint is a combination joint of mechanical fastening and adhesive bonding. The mechanical fastener used in the hybrid joint is rivet. The plates are bonded together by a thin layer of adhesive. A single lap hybrid joint of mild steel with and without the addition of composite layer is analyzed and the results are compared.

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B. Single Lap Joint

The most commonly used type of joint in a hybrid joint is a single lap joint. It is a relatively strong and simple method of joining two plates through an overlap. In this case, the joint is anti-symmetric with adhesive bonding and rivets. The two plates which are to be connected are overlapped. The loads in lap joints have eccentricity as the centre of gravity of the plates are not in the same line, which leads to a couple leading to bending in the connection. Stresses are unevenly distributed around the rivets. The adhesive bonding in the joint helps for even distribution of stresses and also reduces the effect of bending in the connection.

C. Rivets

A rivet is a type of permanent fastener used in joints. Rivets make a connection strong and tight. The rivet must be strong enough to prevent joint failure and tight enough to prevent leakage (as in the case of water tanks). Two rows of two rivets are considered for the hybrid single lap joint.

D. Adhesive Bonding

An adhesive is a polymeric material which is applied to surfaces to join them together to resist separation. The structural members of the joint are joined together by the adhesive, are the adherents. In these lap joints, a thin layer of adhesive is provided in between the plates as well as to connect the composite material with the plates.

III. FINITE ELEMENT MODELING

A total of five models of single lap joints namely mild steel hybrid composite joint and mild steel hybrid composite joints with a layer of composite materials in between. The composite materials used are CFRP, GFRP, E - Glass fibre and AFRP. The finite element modeling is done in ANSYS Workbench 16.2.

A. Dimensioning of the Model

The plates to be connected are of size 100 mm x 25 mm x 5 mm. the overlap length of the plates is 20 mm. The thickness of the composite layer is 1 mm. the size of the rivet is 8 mm. the rivets are placed in two rows with two rivets in each row. The model with composite layer is shown in Figure 1.

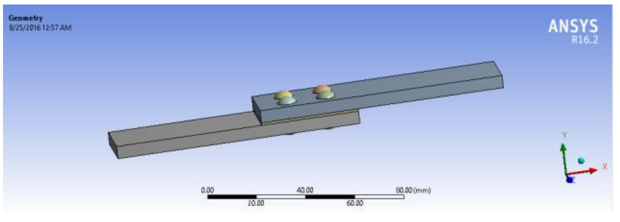

Figure 1: Finite Element Model with a layer of composite material in between

B. Materials

- The materials used in the Finite Element Model are mild steel, CFRP, GRRP, E-Glass fibre and AFRP.
- The plates in the hybrid composite single lap joint are made of mild steel. The material properties of the plates are as that of structural steel provided in the Material Library in ANSYS Workbench 16.2.
- The material properties of the composite layer provided in the other models other than in AFRP are shown in Table 1. The composites CFRP, GFRP and E-Glass fibre have orthotropic behavior whereas in AFRP, the fibres behave in an isotropic manner.

TABLE 1: MATERIAL PROPERTIES OF COMPOSITES

Material Properties	CFRP	GFRP	E-Glass Fibre
Ex (MPa)	62000	20700	119000
E_Y (MPa)	4830	6890	9280
E_z (MPa)	4830	6890	9280
μ_{xy}	0.22	0.26	0.34
μ_{xz}	0.22	0.26	0.34
μ_{yz}	0.3	0.3	0.18
G_{xy}	3270	1520	4640
G_{xz}	3270	1520	4640
Gyz	1860	2650	3930
Density (kg/m^3)	1600	1900	2000

- The material properties of AFRP are Young's modulus (E) is 83000MPa, Poisson's ratio (μ) is 0.31 and Density is 1430 kg/m^3.

C. Meshing

The models are meshed with an element size of 0.1 mm. Figure 2 shows the meshing.

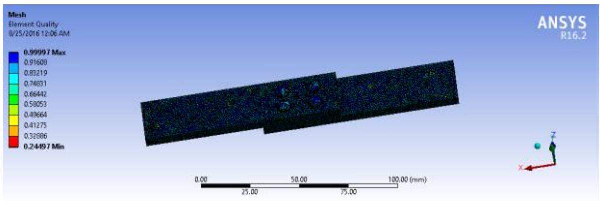

Figure 2 Meshing

D. Loading

A tensile load of 31250 N is provided from one end, keeping the other end fixed. Same load is provided for all the five models, since all the plates are mild steel and have same area of cross-section. Figure 3 shows the loading in the model with a layer CFRP in between. The load is calculated in such a manner that the material is not loaded beyond the elastic limit.

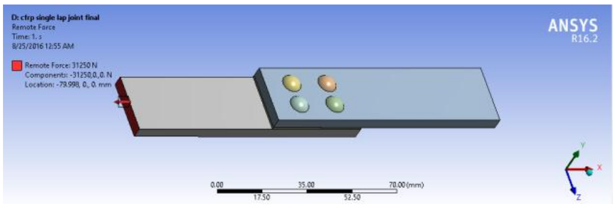

Figure 3 Loading Diagram

IV. ANALYSIS

A finite element analysis is done for all the five models using ANSYS Workbench 16.2. The analysis is done within the elastic limit. The load applied on the model is calculated from the following equation:

$$\sigma = L/A \qquad (1)$$

where 'σ' is the yield strength of mild steel which is 250 MPa. 'A' is the cross sectional area of mild steel on which the load is applied.

$$A = 25\ \text{mm} \times 5\ \text{mm}$$

$$= 125\ \text{mm}^2$$

$$L = 250 \times 25 \times 5$$

$$= 31250\ \text{N}$$

V. RESULTS

The results of the finite element analysis done on all the five models are found in terms of deflection and von-mises stresses. All the results are shown in the following figures.

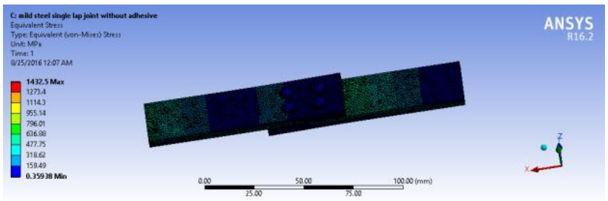

Figure 4 Von-mises stresses in the model without composite

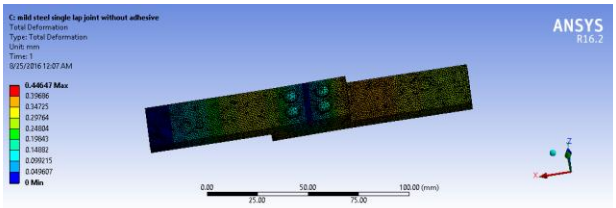

Figure 5 Deflection in the model without composite

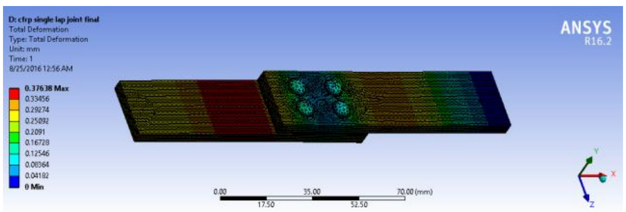

Figure 6 Deflection in the model with CFRP as composite material

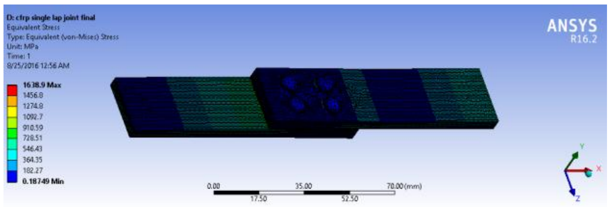

Figure 7 Von-mises stress in the model with CFRP as composite

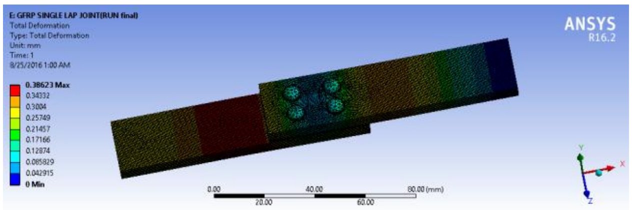

Figure 8 Deflection in the model with GFRP as composite

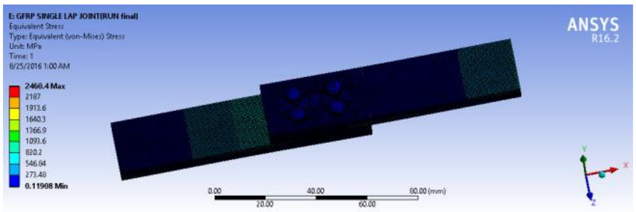

Figure 9 Von-mises stress in the model with GFRP as composite

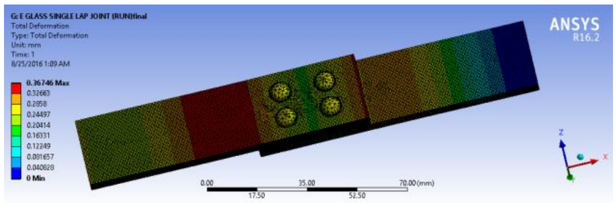

Figure 10 Deflection in the model with E Glass fibre as composite

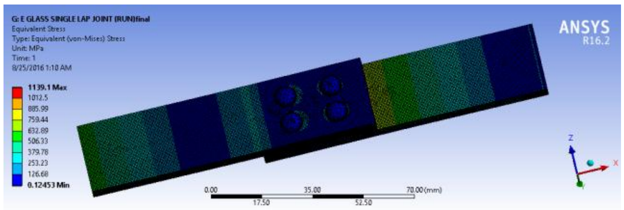

Figure 11 Von-mises stress in the model with E Glass fibre as composite

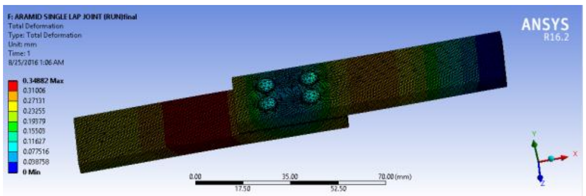

Figure 12 Deflection in the model with AFRP as composite

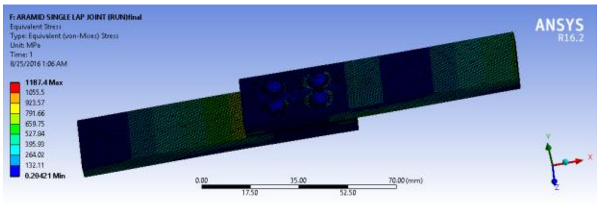

Figure 13 Von-mises stress in the model with AFRP as composite

TABLE 2 Results of Finite Element Analysis

Joint	Deflection (mm)	Von-mises stress (MPa)
Mild steel	0.44647	1432.5
Mild steel with CFRP	0.37638	1638.9
Mild steel with GFRP	0.38623	2460.4
Mild steel with E Glass	0.36746	1139.1
Mild steel with AFRP	0.34882.	1187.4

VI. CONCLUSION

In this work, five models of single lap joint with and without different composite materials were analysed by applying same tensile load. Following are the conclusions obtained from the work:

a) Linear analysis has been done within the elastic limit.

b) Deflection and equivalent stress in terms of von-mises stress are obtained from the finite element analysis done in ANSYS Workbench 16.2.

c) The model having least deflection is mild steel single lap joint with AFRP as the composite material.

d) The equivalent stress is least for mild steel single lap joint with E Glass fibre as composite material.

e) From the values obtained we can conclude that mild steel single lap joint with AFRP as composite material shows better performance.

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