

# **FEA and Experimental Evaluation of Bonded, Riveted and Hybrid Joints in Glass Fibre Epoxy Composite Laminates**

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**ABSTRACT:** The composite structural members are highly used in the following applications such as aerospace, automobiles, robotic arms, architecture etc., has attracted extensive attention in the past decades. One of the important issues in the composite technology is the repairing of aging aircraft structures. In such applications and also for joining various composite parts together, they are fastened together either using adhesives or mechanical fasteners. Modelling, static analysis of 3D models and Manufacturing of the composite joints (bonded, riveted and hybrid) were carried out using FEA software. The results were interpreted in terms of Von Misses stress. To utilize the full potential of composite materials like Glass Fibre - epoxy as structural elements, the strength and stress distribution of these joints namely, bonded, riveted and hybrid joints must be understood while conducting experimental works. Various joint like bonded, riveted and hybrid joint were prepared by glass fibre epoxy composite laminates. And then undergo for tensile test by universal testing machine with data acquisition system. The results will then be compared with the joints. The Best Joint is identified by their load Bearing Capacity.

## **I. INTRODUCTION**

Over the past three decades, application of composite materials are continuously increasing from traditional application areas such as military aircraft, commercial aircraft to various engineering fields including automobiles, robotic arms and even architecture. Due to its superior properties, composites have been one of the materials used for repairing the existing structures. In such applications and also for joining various composite parts together, they are fastened together either using adhesives or mechanical fasteners. Nowadays, a novel method called hybrid joint is also being employed, where a combination of both adhesive and mechanical fasteners is used.

## **II. OBJECTIVE**

In the present project, an attempt is made to analyze the stress distribution in 3-D models of three configurations of single lap joint, namely, bonded, riveted and hybrid joints.

## **III. METHODOLOGY**

Modeling and static analysis of 3-D models of the joints (bonded, riveted and hybrid) were carried out using ANSYS 13 FEA software. The results were interpreted in terms of Von Mises stress.

## **IV. IMPORTANCE OF THE WORK**

Composite materials have been widely used as structural elements in aircraft structures due to their superior properties. Aircraft structure is a huge assembly of skins, spars, frames etc. The structure consists of an assembly of sub-structures properly arranged and connected to form a load transmission path. Such load transmission path is achieved using joints.

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Joints constitute the weakest zones in the structure. Failure may occur due to various reasons such as stress concentrations, excessive deflections etc. or a combination of these. Therefore, to utilize the full potential of composite materials, the strength and stress distribution in the joints has to be understood so that suitable configuration can be chosen for various applications.

Analysis using FEA tool is necessary to standardize the experimental procedures and testing sequence.

### V.COMPOSITE MATERIALS – AN OVERVIEW

A composite is a structural material which consists of two or more constituents combined at a

macroscopic level. The constituents of a composite material are a continuous phase called matrix and a discontinuous phase called reinforcement.

Matrix gives shape and protects the reinforcement from the environment. It also makes the individual fibers of the reinforcement act together and provides transverse shear strength and stiffness to the laminated composites. The matrix factors which contribute to the mechanical performance of composites are transverse modulus and strength, shear modulus and strength, compressive strength, inter-laminar shear strength, thermal expansion co-efficient, thermal resistance and fatigue strength.

Reinforcement provides strength and stiffness and controls thermal expansion co-efficient. It also helps to achieve directional properties. Reinforcements may be in the form of fibers, particles or flakes. The fiber factors which contribute to the mechanical performance of a composite are length, orientation, shape and material.

The factor which influences the mechanical performance of composites other than the fiber and the matrix is the fiber-matrix interface. It predicts how well the matrix transfers load to the fibers.

Composites are classified by

1. the geometry of the reinforcement as particulate, flakes and fibers
2. the type of matrix as polymer, metal, ceramic and carbon

The most commonly used advanced composites are polymer matrix composites. These composites consists of a polymer such as epoxy, polyester, urethane etc., reinforced by thindiameter fibers such as carbon, graphite, aramids, boron, glass etc.

The building block of a laminate is a single lamina. Therefore the mechanical analysis of a lamina precedes that of a laminate. A lamina is an anisotropic and non-homogeneous material. But for approximate macro-mechanical analysis, a lamina is assumed to be homogeneous where the calculation of the average properties are based on individual mechanical properties of fiber and matrix, as well as content, packing geometry and shape of fibers. The lamina is considered as orthotropic, so it can be characterized by nine independent elastic constants: three Young's moduli along each material axis, three Poisson's ratio for each plane and three shear moduli for each plane. Once the properties for each lamina are obtained, properties of a laminate, made of those laminae can be calculated using those individual properties.

In the highly competitive airline market, using composites is more efficient. Though the material cost may be higher, the reduction in the number of parts in an assembly and the savings in the fuel cost makes more profit. It also lowers the overall mass of the aircraft without reducing the strength and stiffness of its components.

### VI.COMPOSITE JOINTS

Ideally, it is always preferred to make monolithic structures, that is, structures without joints. This ideal can never be realized for many reasons like size limitations imposed by materials or the manufacturing process, need for disassembly of

structure for transportation and access for inspection and repair etc. Basically, there are two types of load-carrying joints available: mechanically fastened joints and adhesively bonded joints. Nowadays, a novel method called hybrid joint is also being used in certain applications.

Reaching a decision about the type of joints to be used requires careful considerations of several parameters together with the knowledge of the service that the joint is expected to provide. Thus a requirement for disassembly and lack of adequate preparation facilities would certainly preclude bonding; a requirement to join thin sheets might rule out the use of mechanical fasteners whereas heavily loaded joints are designed using mechanical attachments.

A short description of the the type of joint used in the present work namely, bonded joint is given below.

### **BONDED JOINT**

Bonded joints can be made by gluing together pre-cured laminates with the suitable adhesives or by forming joints during the manufacturing process, in which case the joint and the laminate are cured at the same time (co-cured). Here, load transfer between the substrates take place through a distribution of shear stresses in the adhesive.

In general, there are numerous advantages of adhesive bonded joints over the traditional mechanical fastened joints. These advantages include large bond area for load transfer, low stress concentration, smooth external surfaces at the joint, less sensitivity to cyclic loading, time and cost saving, high strength to weight ratio, electrical and thermal insulation, conductivity, corrosion and fatigue resistance, crack retardation, damping characteristic and so on. Some of the disadvantages of bonded joints are

1. Disassembly is impossible without component damage.
2. They can be severely weakened by environmental effects.
3. They require surface preparation.
4. Joint integrity is difficult to confirm by inspection. Thus ensuring a quality of bonding has been a challenging task.

### **VII.FEA OF BONDED JOINT**

The commercial FEA software ANSYS has been used to create and analyze the models. The laminates (adherend) were made of Glass Fibre Epoxy composite, with a stacking sequence of (0/45/90/-45)<sub>n</sub> and the adhesive used was Epoxy LY 556. Each lamina was assumed to be 0.15 mm thick.

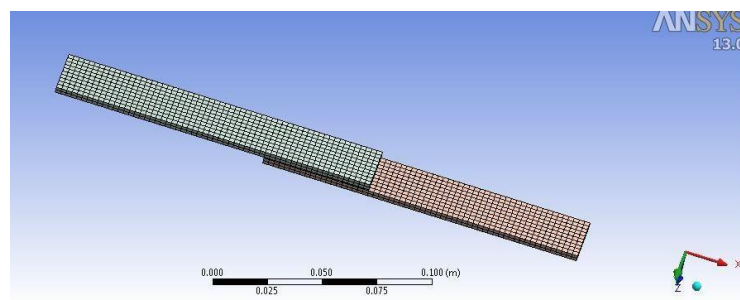


Fig 1: Meshed Model of Bonded Joint

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Materials used for the various components of joints and their properties are given below.

COMPONENT	MATERIAL
Laminates	Glass Fibre /Epoxy Composite
Adhesive	Epoxy LY556
Hardener	HY951

S.No	PROPERTY	VALUE
1	$E_1$	15 GPa
2	Density	2000kg/m <sup>3</sup>
3	Poisson Ratio	0.21

a

b

S. No	PARAMETER	VALUE
1	Thickness of laminate	3 mm
2	Thickness of adhesive	0.2 mm
3	Overlap length	50 mm
4	Width of laminate	25 mm
5	Length of laminate	250 mm

c

Table 1 : List of Values (a) Material specifications (b) Properties of Carbon/Epoxy Composite

(c) Dimensions of Joint

**TENSILE TEST**

The Specimen is subjected to a Load of 1000N at one end and fixed at the other end. No of Elements – 1104

No of Nodes – 7107

Max Stress – 23.423 Mpa

Normal Elastic Strain – 0.0016326 mm/mm Total Deformation – 0.42224 mm

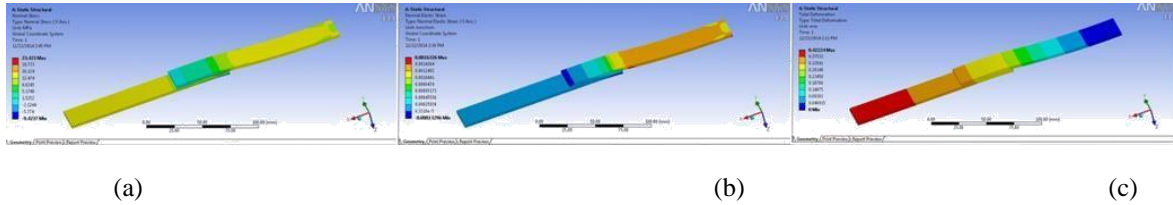


Fig 2 : Tensile Test (a) Normal Stress (b) Normal Strain (c) Total Deformation

**IMPACT TEST**

The Specimen is subjected to a Load of 1000N applied at the centre with a velocity of 100 mm/s. No of Elements – 1104

No of Nodes – 7107

Max Stress – 1012.4 Mpa

Normal Elastic Strain – 0.065153mm/mm Total Deformation – 2.5936 mm Analysis Type – Explicit Dynamics Solver – Autodyn Solver

Velocity – 100mm/s

Impact Mt/l – Structural Steel

Youngs Modulus – 210 GPa

Density – 7800 Kg/m<sup>3</sup>

Poisson Ratio – 0.28

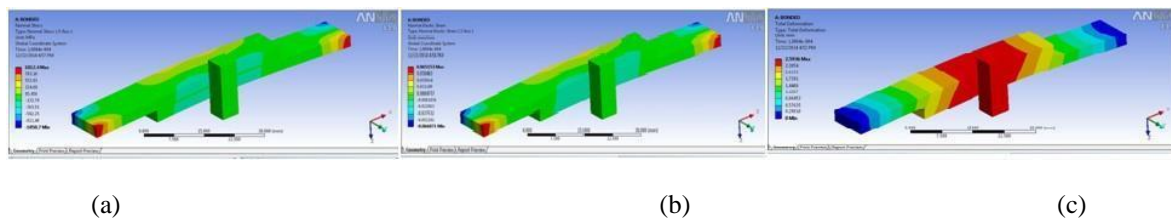


Fig 3: Impact Test (a) Normal Stress (b) Normal Strain (c) Total Deformation

**3- POINT BENDING TEST**

The Specimen is subjected to a Load of 1000N applied at the centre with fixed support at both ends.

No of Elements – 1104

No of Nodes – 7107

Max Stress – 913.38 Mpa

Normal Elastic Strain – 0.027347mm/mm Total Deformation – 15.038 mm Analysis Type – Static Structural

Solver – Mechanical APDL

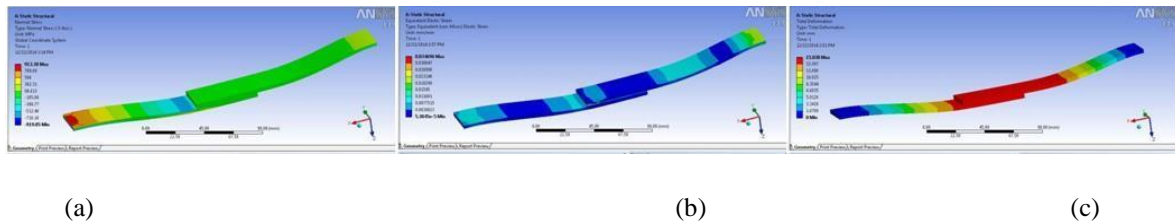


Fig 3 : 3 - Point Bending Test(a) Normal Stress (b) Normal Strain (c) Total Deformation

**VIII. RESULTS**

**TENSILE TEST RESULTS**

Table 4: Tensile Test Results

PROPERTY	MAX VALUES	MIN VALUES
Normal Stress	23.423MPa	-9.4237MPa
Normal Strain	0.0016326mm/mm	-0.00013296mm/mm
Total Deformation	0.42224mm	0mm

**IMPACT TEST RESULT**

Table 5: Impact Test Results

PROPERTY	MAX VALUES	MIN VALUES
Normal Stress	1012.4MPa	-1050.7MPa
Normal Strain	0.065153mm/mm	-0.066871mm/mm
Total Deformation	2.5936mm	0mm

**3-POINT BENDING TEST RESULT**

Table 6: 3-Point Bending Test Results

PROPERTY	MAX VALUES	MIN VALUES
Normal Stress	913.38MPa	-919.85MPa
Normal Strain	0.027347mm/mm	-0.027981mm/mm
Total Deformation	15.038mm	0mm

**IX. CONCLUSION**

The results from the analysis of the models were interpreted in terms of Von Mises stress.

Von Mises Stress actually refers to a theory called the “Von Mises - Hencky criterion”. In an elastic body that is subject to a system of loads in 3 dimensions, a complex 3 dimensional system of stresses is developed. That is, at any point within the body there are stresses acting in different directions, and the direction and magnitude of stresses changes from point to point. The Von Mises criterion is a formula for calculating whether the stress combination at a given point will cause failure. There are three "Principal Stresses" that can be calculated at any point, acting in the x, y, and z directions. The Von Mises criteria is a formula for combining these 3 stresses into an equivalent stress, often called the "Von Mises Stress", which is then compared to the yield stress of the material. The yield stress is a known property of the material, and is usually considered to be the failure stress. A short interpretation of the results of the analysis is given below.

Thus the Tensile test , 3 Point Bending Test and Impact Test are carried out using Ansys 13 Software and the Stress, Strain and Total Deformation values are tabulated.

In bonded joints, the stress was distributed throughout the laminate and the adhesive took up much of the load. The maximum stress is also low since the applied load alone acts on the joint.

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### X. FUTURE SCOPE

The study is extended to Rivet and Hybrid Joints and the results are compared. The riveted and hybrid joint will be prepared and then this will undergo for testing. Then compare the mechanical characterization with data acquisition system.

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