Strength Analysis of Hybrid Joint by FEA

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ABSTRACT

Hybrid joint are widely used in automotive and aerospace industries for various structural application. The feasibility and reliability of this system dependent on design of the joints and their type. Adhesive and Bolt joint technology is demanding research area now days. To reduce the weight of structures and enhance the load bearing capacity of joint with respect to the traditional joint composite joints can be used. Traditional joints such as weld, spot, rivet, etc. are used for connecting various Automotive, Aerospace, etc. parts. To enhance strength of already existing joints without changing existing design can be achieved by use of industrial adhesives. So instead of only using adhesively bonded joint it can become advantageous to use hybrid joint. In this thesis, modeling of both joints are done i.e. bolted joint without adhesive and bolted joint with adhesive by using CAD software and analyzing it for induced structural stresses and deformation in CAE software. Furthermore it can also tested experimentally for the tensile load and results were correlated with analysis results. We evaluated the stress analysis of the both joints by using FEA. In post processing step, Reaction force is calculated and compared both the results. We found that reaction force on hybrid joint is more.

Keywords*: Hybrid joint, Adhesive, FEA, Reaction Force*

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1. INTRODUCTION

Joint design in composite materials has been a concern and also, the focus of numerous studies in the past. Mostof the publications in this area have dealt with either adhesive or bolted joints in laminated continuous "fiber composites . Studies on hybrid joints combining adhesive with bolts are very few. The emergence of composite materials in the construction of aircrafts has resulted in the need for improved damage growth predictions and effective/ efficient repair techniques for damaged structures. The damage mechanisms in composites differ significantly than those in metals and hence further testing and analysis are required to achieve optimal structural efficiency. The authors previously investigated the effects of joining thin composite laminates together in a double lap joint configuration. Three fundamental joint structures were looked at – mechanically fastening, bonding and the combination of the two called ‘hybrid’ joints. Results revealed that under static test conditions, there are no significant differences in joint strength between a bonded and hybrid joint; it was during fatigue test cases where hybrid joints showed the greatest durability followed by bonded joints and then fastened joints. This investigation now focuses on the repair of thicker composite structures. In this study it is assumed a flush joint repair is required. Scarf and step lap joints are two common joints used in the repair of thick structures as they are necessary in restoring original stiffness and nearly original strength. Hart-Smith suggested the use of stepped lap joints or scarf joints for thicker composite adherents as they are more efficient joining methods and reduce adhesive peel stresses induced at the ends of the overlap joint.

From the available literature there is limited experimental data on the static and fatigue performance of flush joints made from composite materials. Kim et al. evaluated the fatigue performance of adhesively-bonded composite step lap joints. The number of steps, joint length and edge angle of the adherents were investigated. They concluded that increasing the number of steps and edge angle has the greatest effect in improving bond strength and fatigue performance in a step lap joint. Analyze scarf and step lap joint repairs in composite laminates. They tested one inch wide specimens with a total of eight steps each being two plies thick. However their focus was on comparing experimental strain data to numerical simulations. Look at conducting efficient joints on an F/A-18 wing root using step lap joints. Graphite/Epoxy laminates were bonded to Titanium 6Al-4V and assessed for compressive strength subjected to impact damage. A total of 18 symmetrical steps were used for the repair which surrounded the inner titanium parent structure. This is a key example of a bonded primary structure certified and deployed on air vehicles.

Adhesive bonding requires no holes to be drilled which eliminates the stress concentration and provides uniform stress distribution at the joint. Certain brittle or damage prone adherents are difficult to drill and hence mechanical fasteners cannot be used. However, these joints are very sensitive to the environment and have poor heat resistant properties.

Mechanical fastening involves the use of bolts and nuts in the drilled hole at joint interface. Fastener joints could be of interference, push or clearance fits. A rigid pin of diameter $2a \times (1 + \lambda)$ is introduced into a plate with a hole of diameter 2a. If λ is positive the fit is of interference, and if λ is negative the fit is of clearance, and $\lambda = 0$ is the case of a push fit. The fit used here was the interference type because it has the maximum fatigue life. Holes drilled in mechanical fastening cause stress concentration which affects the strength of the adherent and hence the joint. However, bolted joints are proved to be more reliable for assembling variable substrates and have been used in many engineering applications. Strength predictions in the bolted joints are easy and accurate because the mode of failure is progressive, which is a favorable phenomenon. Unlike many adhesives, mechanical fasteners have a very long shelf life. They generally have less environmental concerns and may facilitate repair. In this thesis, modeling hybrid joint in CAD software and analyzing it for induced stresses and deformation in CAE software.

1.1 Problem Statement

Traditional joints such as weld, spot, rivet, etc. are used for connecting various Automotive, Aerospace, etc. parts. To enhance strength of already existing joints without changing existing design can be achieved by use of industrial adhesives. In this thesis, modeling hybrid joint in CAD software and analyzing it for induced structural stresses and deformation in CAE software. It can also tested experimentally for the tensile load and results were correlated with analysis results.

2. FE Analysis

2.1 CAD Model of both joints

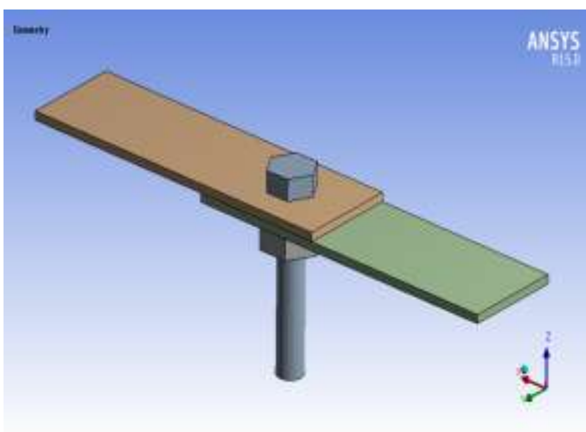

Fig.1 CAD Model of bolted joint

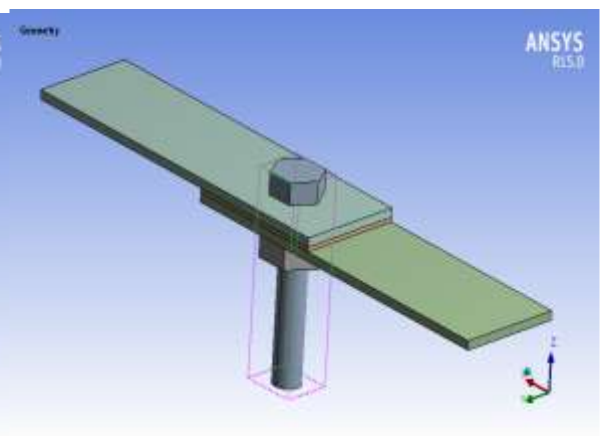

Fig.2 CAD Model of Hybrid joint

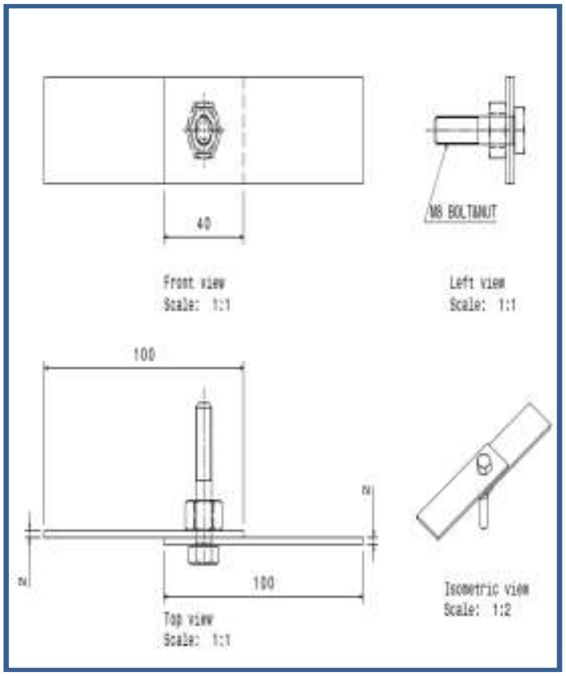

Fig.3 Drafting of bolted joint

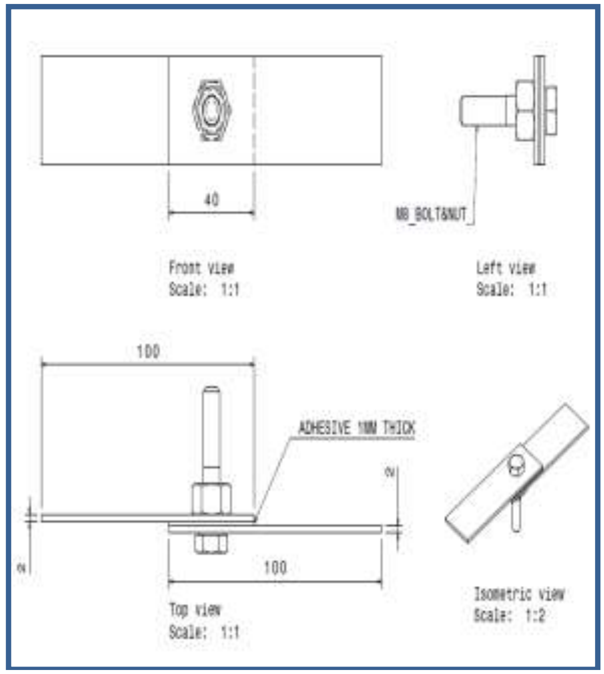

Fig.4 Drafting of Hybrid joint

Dimensions of plates:
Length=100mm
Width=40mm
Thickness=2mm
Overlapping length=40mm
Adhesive Thickness=1mm

2.2 Mesh Generation

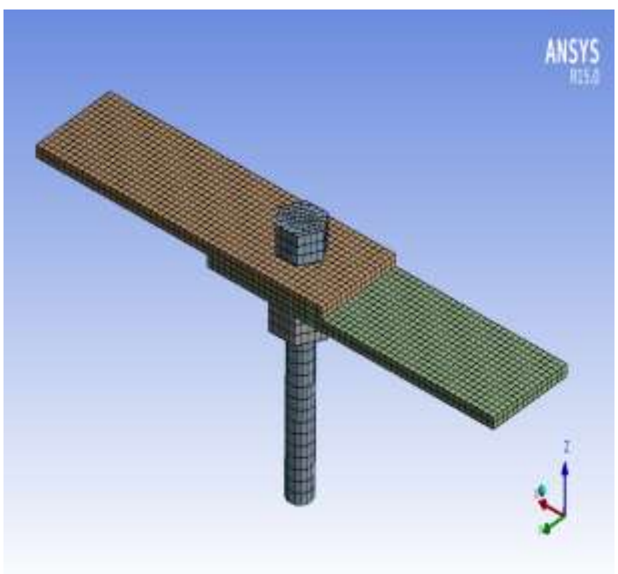

Fig.5 Mesh Generation in bolted joint

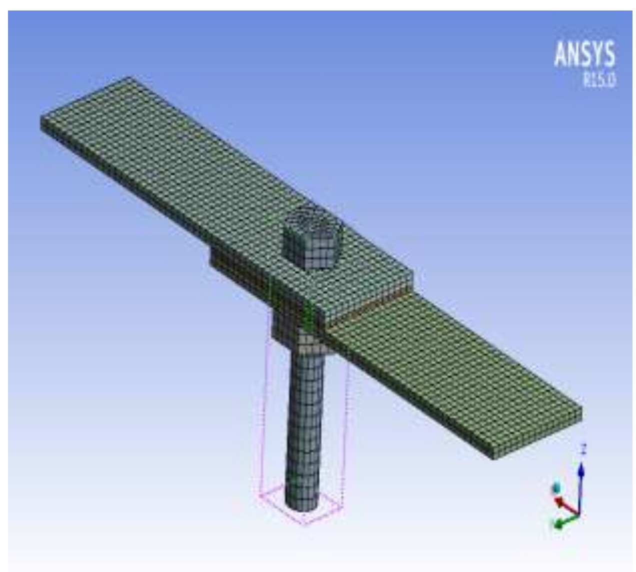

Fig.6 Mesh Generation in Hybrid joint

Parameters	Without Adhesive Joint	With Adhesive Joint
Element type	Hexahedron	Hexahedron
No. of Elements	4648	4648
No. of Nodes	7074	7074

Table1. Details of Meshing

2.3 Static Structural Analysis

The Finite Element Method is a numerical approximation method, in which the complex structure is divided into number of small parts that is pieces and these small parts are called as finite elements. These small elements are connected to each other by means of small points called as nodes. As the finite element method uses matrix algebra to solve the simultaneous equations, so it is also known as structural analysis and it's becoming primary analysis tool for designers and analysts.

The three basic FEA process are

a) Pre processing phase

b) Processing or solution phase

c) Post processing phase

A static structural analysis is the analysis displacements, stresses, strains and forces on structure or a component due to load application. The structures response and loads are assumed to vary slowly with respect to time. There are various types of loading that can be applied in this analysis which are externally applied forces and pressures, and temperatures.

The pre-processing of the hybrid joint is down for the purpose of the dividing the problem into nodes and elements, developing equation for an element, applying boundary conditions, initial conditions and for applying loads. The information required for the pre-processing stage of the hybrid joint is as follows:

• **Material properties**: The values of young's modulus, poisons ratio, density, and yield strength for both joints are taken from material library of the FEA PACKAGE.

Steel	Araldite Epoxy Resin (Adhesive)
Modulus of Elasticity : 200GPa	Modulus of Elasticity : 3100 MPa
Poisson's ratio : 0.30	Poisson's ratio : 0.42
Density :7.85 kg/mm^3	Density : 1.15 gm/cc3
Yield Strength : 520 Mpa	Yield Strength : 83 MPa

Table 2. Material properties

Constraints: Fully constrained at one end of the plate. Displacement in along X- direction applied on other side.

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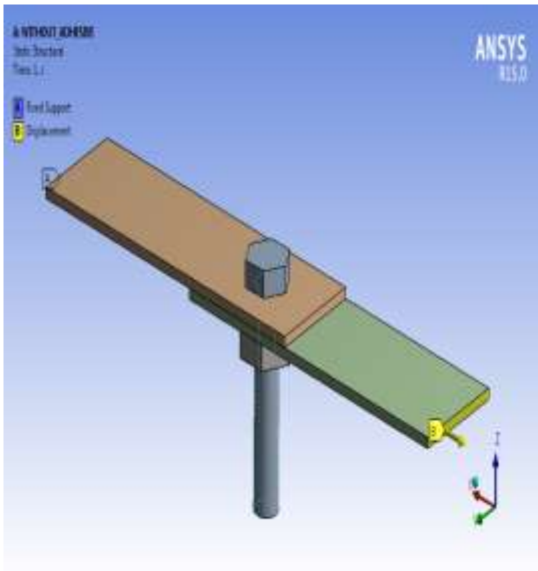


Fig.7 Constraint for bolted joint

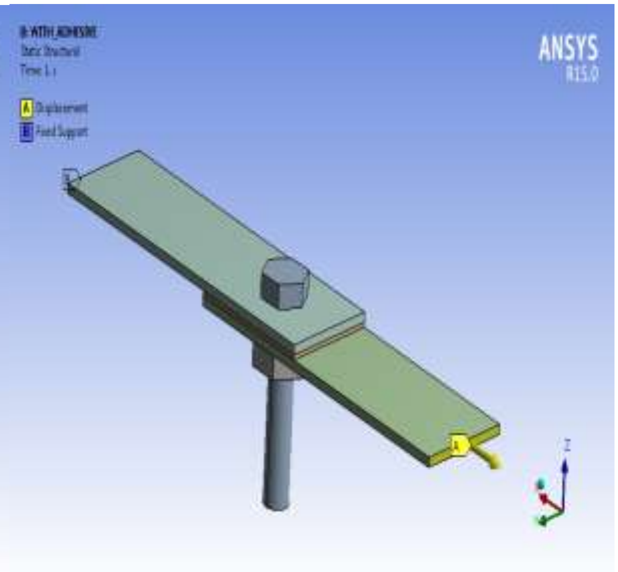
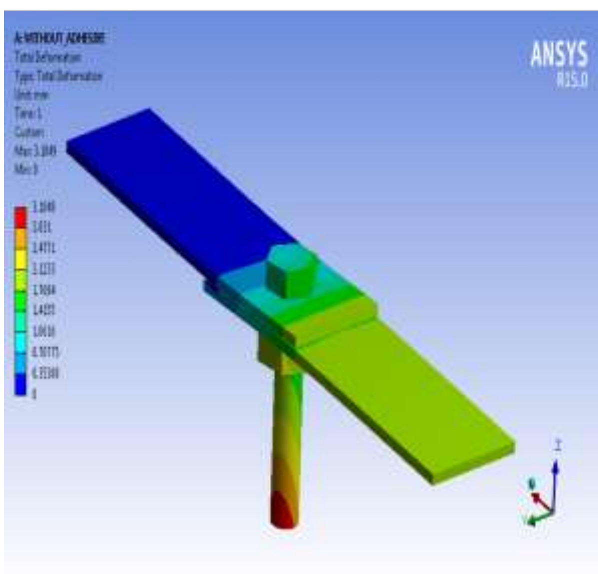
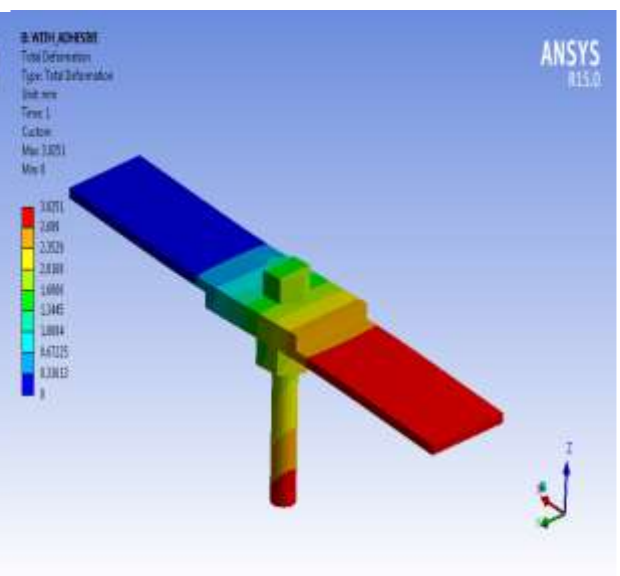


Fig. 8 Constraint for Hybrid joint

- **Post Processing**

a) Deformation:





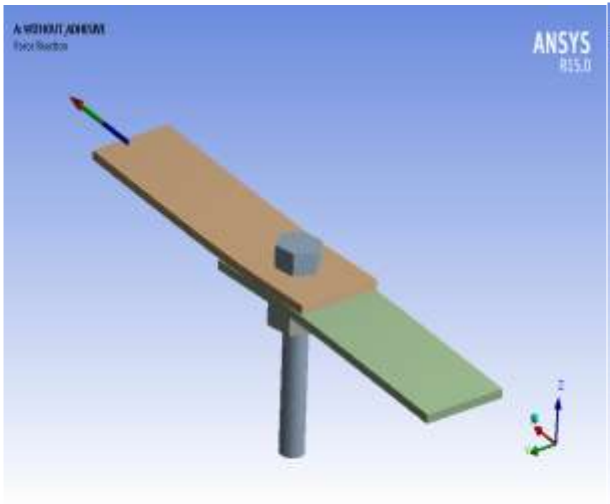
Maximum Deformation is 3.185mm.

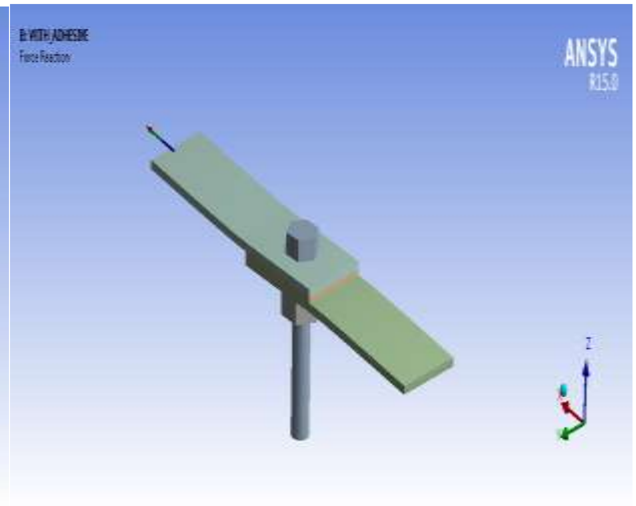
Maximum Deformation is 3.025mm.

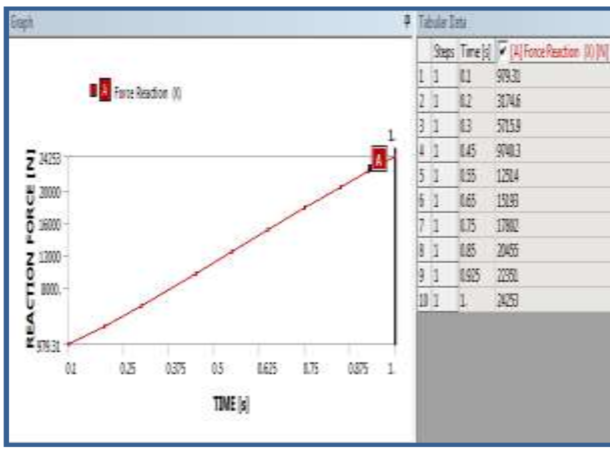
Fig.9 Total deformation in bolted joint

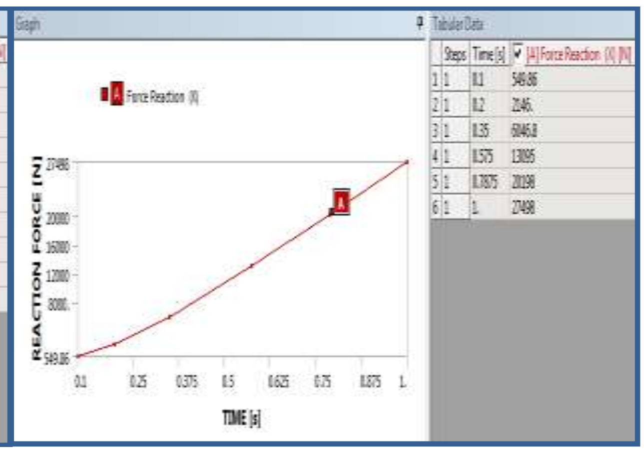
Fig 10 Total deformation in Hybrid joint

b)Reaction Force:









Reaction force = 24253 N Reaction force = 27498 N

Fig.11 Reaction force on bolted joint **Fig.12 Reaction force on Hybrid joint**

3. CONCLUSION

Hybrid joints give better static as well as fatigue performance than only mechanically bolted joints. The finite element analysis shows the maximum deformation and reactions force on each joint. In case of bolted joint it was 3.185mm & 24253 N respectively other side in case of Hybrid joint it was 3.025mm & 27498N respectively. This results proves that for improving the strength performance of joint Adhesive plays an vital role. Although, qualitative this results is in conformance with analysis.

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