

# EXPERIMENTAL ANALYSIS OF RIVETED AND HYBRID JOINTS FOR COMPOSITE STRUCTURES USING FINITE ELEMENT ANALYSIS

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## ABSTRACT

Composites have been used extensively in various engineering applications including automotive, aerospace, and building industries. Hybrid composites made from two or more different reinforcements show enhanced mechanical properties required for advanced engineering applications. Modeling, 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 Mises 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 joints like bonded, riveted and hybrid joints were prepared by glass fibre epoxy composite laminates. And then undergo a tensile test by a universal testing machine with a data acquisition system. The results will then be compared with the joints. The Best Joint is identified by their load Bearing Capacity.

**Keyword :** *static analysis of 3D models, FEA software, Von Mises stress, Glass Fibre - epoxy composite laminates and universal testing machine, load Bearing Capacity etc....*

## 1. INTRODUCTION

Composites are multiple systems obtained by combining two or more different materials that are mixed together to provide specific properties. The individual materials do not mix or merge together completely in the composite. However, they act on individual materials from which it is fabricated or formed. Many composite materials have at least one reinforcing member in the form of fibers, particles, flake, fabric, etc. which provide strength to the composite. The term 'hybrid' is generally used to denote the incorporation of two or more different materials into one single system and the quantity of addition can either be on a small scale (Fibres, Spread tow fabric, etc.) or on a large scale (layers, pultrusions, ribs, etc.). Composites are also classified as particle reinforced, fibre reinforced and sandwich or laminated structure based on the geometry of the reinforcing materials. A prior study conducted by the authors had investigated the behaviour of thin composite double lap joint repairs. This investigation was an extension to the previous study and focused on analysing the behaviour of thick step lap joint repairs which are more complicated in nature. Finite element analysis (FEA) was performed to verify the static and fatigue strength of bolted, bonded and hybrid joint configurations. Thick carbon fibre/epoxy laminates and aerospace grade film adhesive and fasteners were selected. Several configurations were considered in this case. These include varying the number of fasteners in the joint region as well as inclusion of bondline defects. Adhesive non-linear material properties, fastener contacts and frictional forces were all included in the three dimensional (3D) finite element (FE) models. The progressive failure process was simulated and the Multicontinuum Theory (MCT) was used to

determine the stress states in all specimens considered. The strain energy release rate (SERR) as a function of crack length was also utilised to gain further understanding into the fatigue behaviour. Overall the FE models are able to accurately predict the bonded, bolted and hybrid joint strengths. SERR results suggest it is vital to place fasteners closer to the ends of the overlap to suppress the peak peeling stresses and to delay the effects of early crack initiation. This overall improves the longevity of a conventional bonded joint design. Hybrid bonding-fastening is an alternative joining technique that consists of simultaneous adhesive bonding and mechanical fastening of the adherents.

In this paper, pertinent scientific publications are selected and reviewed in an attempt to synthesize the current knowledge on various aspects of this technique. A particular focus is maintained on its application in composite structures. Two major bonding-fastening methods, namely bonding-bolting and bonding-pinning, are identified and contrasted, and the characteristics of each are discussed. Existing gaps in the literature are identified. Finally, perspectives for future research are assessed. The continued requirement of improvements to structural parts of engineering construction to meet better reliability and durability leads to application of new and innovative composite materials with different internal structure. The introduction of the porosity or plastic matrix to the composite modified significantly their properties. In case of adhesive bonded joints of the structural elements one can observe application of the new types of adhesives, which contain nanoparticles or graphene) to modify specific properties (e.g. electric conductivity). This adhesive layer can be treated as a particle reinforced composite. Other possibility is to create a new composite material with gradual changes of physical and mechanical properties, i.e. production of so-called functionally graded material – FGM. In the pure adhesive joints this idea was applied in a form of mixed adhesive, by introduction of plastic and elastic region (with different stiffness) in the adhesive to increase joint strength by minimizing the maximum adhesive stress. The further improvement of the structural elements joining technology is to combine two simple joining techniques. One can distinguish rivet-adhesive and clinch-adhesive joints, spot-welded-adhesive joints etc.

These modern technologies are used not only in aerospace but also in other branches of engineering. The hybrid joints' strength can be 1.5 to 3 times higher than only adhesive bonded joints' strength. They also have higher reliability during the whole lifetime and under cyclic loading. One can distinguish three types of hybrid adhesive bonded and riveted joints: adhesive joints with a small number of rivets, rivet joints where the adhesive fulfills a gasket function and joints, in which both adhesive strength and rivet strength play a part. The objective of the present research is the description of the last type of joints. The main problem to be analyzed in this paper is estimation of an influence of rivet geometrical layout on the hybrid adhesive bonded/riveted joints response to mechanical loading. The state of deformation and local stress concentrations of the adhesive bonded double-lap joints reinforced by three rivets is presented. In order to underline the advantage of the hybrid joints with comparison to the pure adhesive and the pure riveted joints the experimental and numerical analyses were performed. Tensile test method for hybrid joint followed The results data of hybrid joint with similar and dissimilar material Based on the results, for dissimilar material of hybrid joint (GFRP-Al) in Figure-8, the result shows the maximum stress is 19.72 MPa with the strain of 0.82% in test 1 and maximum stress of 22.19 MPa with the strain of 1.04 % in test 2. Continuing with the test, the results obtained from similar hybrid joints (GFRP-GFRP), the maximum stress is 14.13 MPa with the strain of 0.93 % in test 1 and maximum stress of 17.24 MPa with the strain of 1.08% in test 2. Meanwhile, (Al-Al) hybrid joints obtain the results of the maximum stress being 31.10 MPa with the strain of 4.09 % in test 1. While for test 2, the maximum stress is 40.32 MPa with the strain of 3.10 %. Therefore, the average maximum stress for test 1 is 21.65 Mpa and for test 2 is 26.58 Mpa. The location of failure for the (GFRP-Al) hybrid joint damage at the adherent is known as structural failure and this similar phenomenon also occurred at the (GFRP-GFRP) hybrid joint. In contrast, the specimen failed at the adhesive and adherent when the similar joint of metal (AlAl) was attached together and this is known as adhesion and structural failure.

### 1.1 Joining methods in composites

Mechanical fasteners and adhesives or both are used to join composites. The joining technique used on a particular composite depends on the application and material characteristics. For instance, composites used in aircraft are usually joined by a combination of mechanical fasteners and adhesives; on the other hand, composites used in automobiles are often joined only with adhesives. Joints potentially act as weak links in structures, thus it is important to understand their strength and the mode in which they fail. The three common methods of joining composite laminates together is either through mechanical fastening, bonding or the combination of the two, called 'hybrid' joints. Mechanical fasteners such as pins, rivets and bolts have commonly been used in the aerospace industry for decades. Often small machine components are joined together to form a larger machine part. Design

process of joints is as extensive as that of machine components because an unsteady joint may spoil the utility of a carefully designed machine part. Classification of Mechanical joints is mostly into two classes viz., non-permanent joints and permanent joints. Non-permanent joints can be assembled and disassembled without damaging the components. The case of such joints are threaded fasteners (like screw-joints), keys and couplings etc. Permanent joints cannot be disassembled without damaging the components. These can be two kinds of joints depending upon the nature of force that holds the two parts. The forces on specimens can be of mechanical origin, for example, riveted joints, joints formed by press or interference fit etc, where two components are joined by applying mechanical force. The specimen components can also be joined by molecular force, for example, welded joints, brazed joints, joints with adhesives etc. Nowadays riveted joints are very often used to join structural members permanently. However, significant improvement in welding and bolted joints has curtailed the use of these joints. Although these two technologically-advanced composites offer the lighter weight needed in many designs, CFRP and GFRP present joining technologies with even greater challenges than high-strength sheet metals do, since composite materials must be connected to other components in many areas.

Challenges arise in welding, screwing and riveting – the classical joining methods found in automotive production. The matrix of fiber composite materials is a bonded composite. Punching these materials by screwing or riveting damages the laminar structure, which is vital to the material's strength and stability. In addition, the punched hole must be sealed using a complex process to prevent delamination of the material. When joining CFRP to metal, there is also a high risk of corrosion.

An easy and productive method to join composite material to other components is bonding. It is a non-destructive and component-saving joining method, demonstrating both high material flexibility and good resistance to dynamic forces. Bonding allows a high degree of automation with short cycle times for faster production, a top concern in many industrial manufacturing environments.

For stable joints and efficient processes, the laminate should remain intact. Ultrasonic welding can be taken into consideration as an alternative, but has serious disadvantages. It is very power-consuming and suitable for thermoplastic matrix materials only. Therefore, thermal methods are rarely used, while forming techniques cannot be used because of the material's low ductility.

## **2. PROBLEM STATEMENT:**

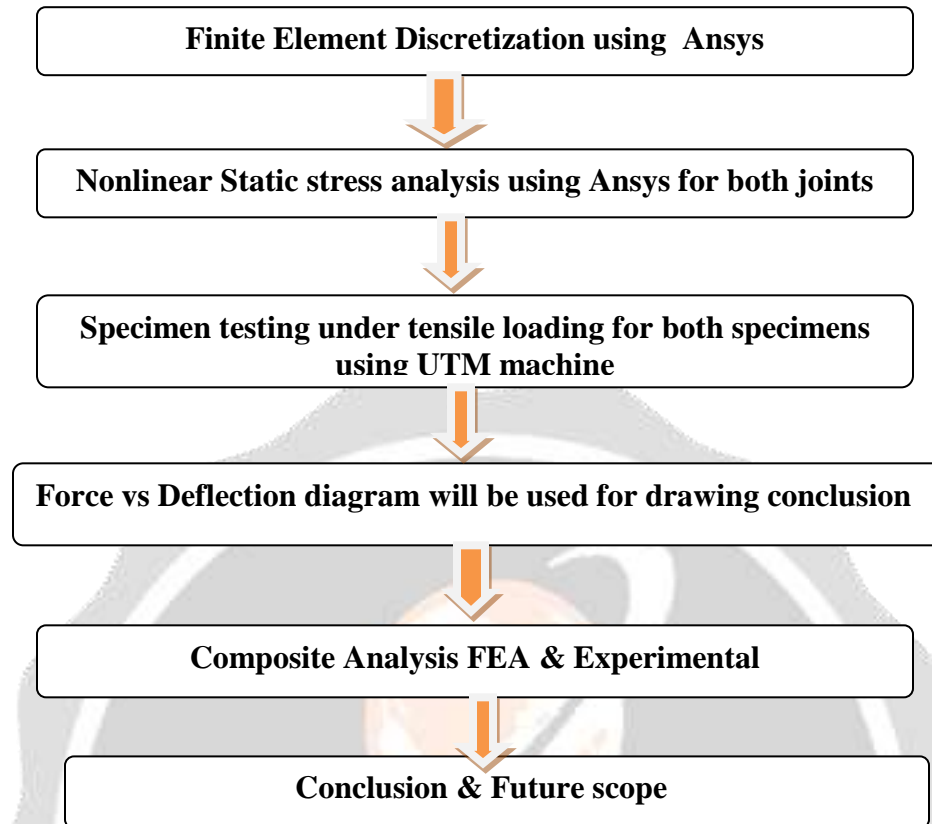
Traditional joints such as weld, spot, rivet, etc. are used for connecting various Automotive, Aerospace, etc. parts. To enhance the strength of already existing joints without changing, existing design can be achieved by use of industrial adhesives.

## **3. OBJECTIVES:**

- Modeling & static analysis of 3D models using Various Softwares.
- Analyzing for stresses and deformation in joints using FEA software.
- Manufacturing of the composite joints (bonded, riveted and hybrid) were carried out using FEA software.
- The behaviors of composite joint were investigated by using UTM.
- Experimental testing and correlating results.

## **4. METHODOLOGY:**

We have set up a design procedure based on reference design data books and past literature research papers.



## 5. DESIGN:

### 5.1.CAD:-

Computer-aided design (CAD) is the use of computer systems (or workstations) to aid in the creation, modification, analysis, or optimization of a design. CAD software is used to increase the productivity of the designer, improve the quality of design, improve communications through documentation, and to create a database for manufacturing. CAD output is often in the form of electronic files for print, machining, or other manufacturing operations.

Its use in designing electronic systems is known as electronic design automation (EDA). In mechanical design it is known as mechanical design automation (MDA) or computer-aided drafting (CAD), which includes the process of creating a technical drawing with the use of computer software. CAD software for mechanical design uses either vector-based graphics to depict the objects of traditional drafting, or may also produce raster graphics showing the overall appearance of designed objects. However, it involves more than just shapes. As in the manual drafting of technical and engineering drawings, the output of CAD must convey information, such as materials, processes, dimensions, and tolerances, according to application-specific conventions. CAD may be used to design curves and figures in two-dimensional (2D) space; or curves, surfaces, and solids in three-dimensional (3D) space. CAD is also used for the accurate creation of photo simulations that are often required in the preparation of Environmental Impact Reports, in which computer-aided designs of intended buildings are superimposed into photographs of existing environments to represent what that locale will be like, where the proposed facilities are allowed to be built. Potential blockage of view corridors and shadow studies are also frequently analyzed.

CAD is an important industrial art extensively used in many applications, including automotive, shipbuilding, and aerospace industries, industrial and architectural design, prosthetics, and many more. CAD is also widely used to produce computer animation for special effects in movies, advertising and technical manuals, often called DCC digital content creation. The modern ubiquity and power of computers means that even perfume bottles and shampoo dispensers are designed using techniques unheard of by engineers of the 1960s. Because of its enormous economic importance, CAD has been a major driving force for research in computational geometry, computer

graphics (both hardware and software), and discrete differential geometry. The design of geometric models for object shapes, in particular, is occasionally called computer-aided geometric design (CAGD)

### 5.2.USES:

Computer-aided design is one of the many tools used by engineers and designers and is used in many ways depending on the profession of the user and the type of software in question. CAD is one part of the whole Digital Product Development (DPD) activity within the Product Lifecycle Management (PLM) processes, and as such is used together with other tools, which are either integrated modules or stand-alone products, such as:

- Computer-aided engineering (CAE) and Finite element analysis (FEA)
- Computer-aided manufacturing (CAM) including instructions to Computer Numerical Control (CNC) machines
- Photorealistic rendering and Motion Simulation.
- Document management and revision control using Product Data Management (PDM).

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CAD has been proven to be useful to engineers as well. Using four properties which are history, features, parameterization, and high-level constraints. The construction history can be used to look back into the model's personal features and work on the single area rather than the whole model. Parameters and constraints can be used to determine the size, shape, and other properties of the different modelling elements. The features in the CAD system can be used for the variety of tools for measurement such as tensile strength, yield strength, electrical or electromagnetic properties. Also its stress, strain, timing or how the element gets affected in certain temperatures, etc.

### 5.3.TYPES:

There are several different types of CAD, each requiring the operator to think differently about how to use them and design their virtual components in a different manner for each. There are many producers of the lower-end 2D systems, including a number of free and open-source programs. These provide an approach to the drawing process without all the fuss over scale and placement on the drawing sheet that accompanied hand drafting since these can be adjusted as required during the creation of the final draft. 3D wireframe is basically an extension of 2D drafting (not often used today). Each line has to be manually inserted into the drawing. The final product has no mass properties associated with it and cannot have features directly added to it, such as holes. The operator approaches these in a similar fashion to the 2D systems, although many 3D systems allow using the wireframe model to make the final engineering drawing views.

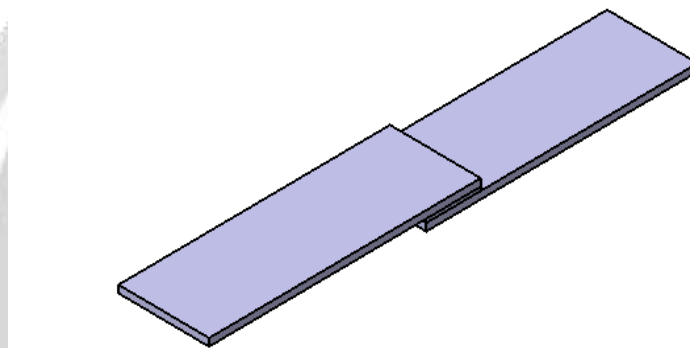
3D "dumb" solids are created in a way analogous to manipulations of real-world objects (not often used today). Basic three-dimensional geometric forms (prisms, cylinders, spheres, and so on) have solid volumes added or subtracted from them as if assembling or cutting real-world objects. Two-dimensional projected views can easily be generated from the models. Basic 3D solids don't usually include tools to easily allow motion of components, set limits to their motion, or identify interference between components.

There are two types of 3D Solid Modelling

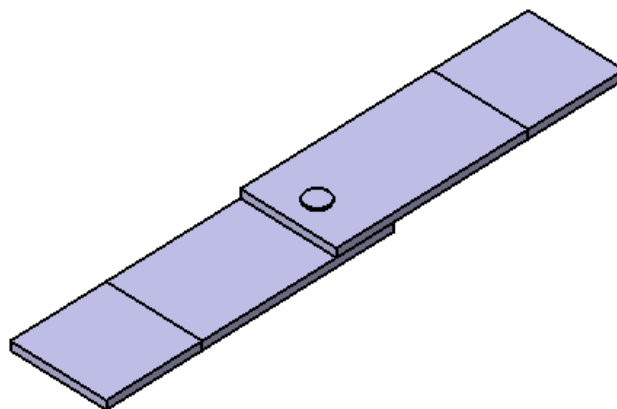
Parametric modelling allows the operator to use what is referred to as "design intent". The objects and features created are modifiable. Any future modifications can be made by changing how the original part was created. If a feature was intended to be located from the centre of the part, the operator should locate it from the centre of the model. The feature could be located using any geometric object already available in the part, but this random placement would defeat the design intent. If the operator designs the part as it functions the parametric modeler is able to make changes to the part while maintaining geometric and functional relationships. Direct or Explicit modelling provides the ability to edit geometry without a history tree. With direct modelling, once a sketch is used to create geometry the sketch is incorporated into the new geometry and the designer just modifies the geometry without needing the original sketch. As with parametric modelling, direct modelling has the ability to include relationships between selected geometry (e.g., tangency, concentricity).

Top end systems offer the capabilities to incorporate more organic, aesthetics and ergonomic features into designs. Freeform surface modelling is often combined with solids to allow the designer to create products that fit the human form and visual requirements as well as they interface with the machine.

## 6.ANALYSIS:



*Fig 1. Adhesive joint cad model*



*Fig 2. rivet joint cad model*

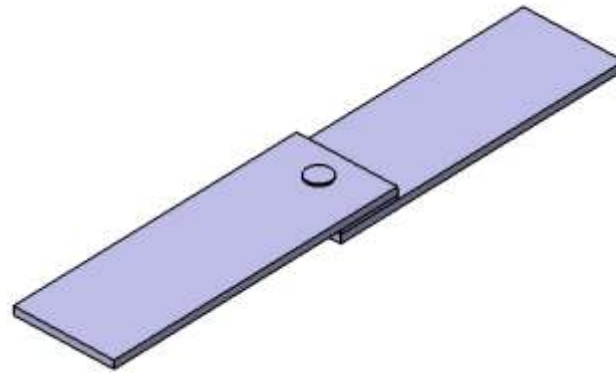


Fig 3. hybrid joint cad model

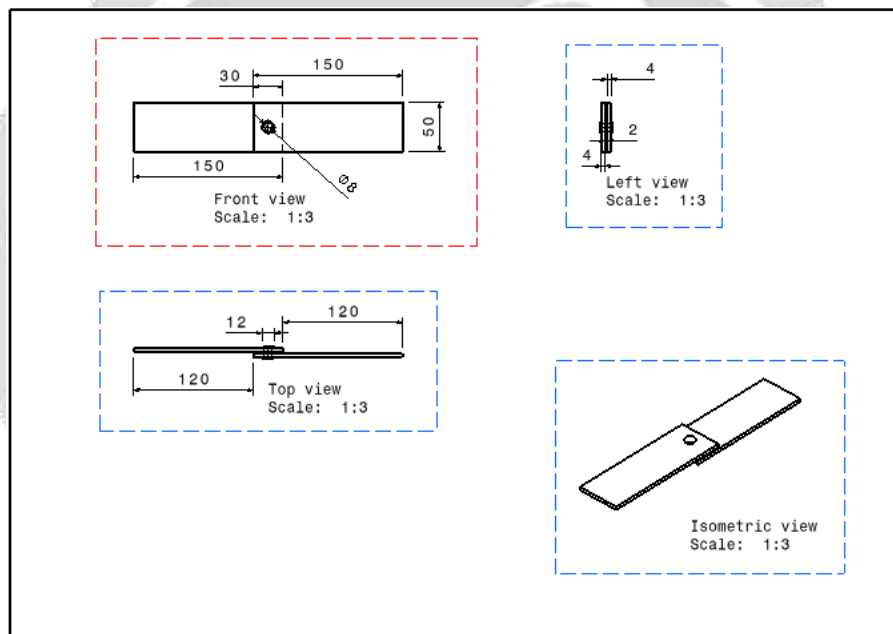


Fig 4. Engineering Drawing

### 6.1.Introduction of Finite Element Analysis:

The finite element method (FEM), is a numerical method for solving problems of engineering and mathematical physics. Typical problem areas of interest include structural analysis, heat transfer, fluid flow, mass transport, and electromagnetic potential. The analytical solution of these problems generally require the solution to boundary value problems for partial differential equations. The finite element method formulation of the problem results in a system of algebraic equations. The method yields approximate values of the unknowns at a discrete number of points over the domain. To solve the problem, it subdivides a large problem into smaller, simpler parts that are called finite elements.

In the first step, the element equations are simple equations that locally approximate the original complex equations to be studied, where the original equations are often partial differential equations (PDE). The process, in

mathematical language, is to construct an integral of the inner product of the residual and the weight functions and set the integral to zero. In simple terms, it is a procedure that minimizes the error of approximation by fitting trial functions into the PDE. The residual is the error caused by the trial functions, and the weight functions are polynomial approximation functions that project the residual. The process eliminates all the spatial derivatives from the PDE, thus approximating the PDE locally with

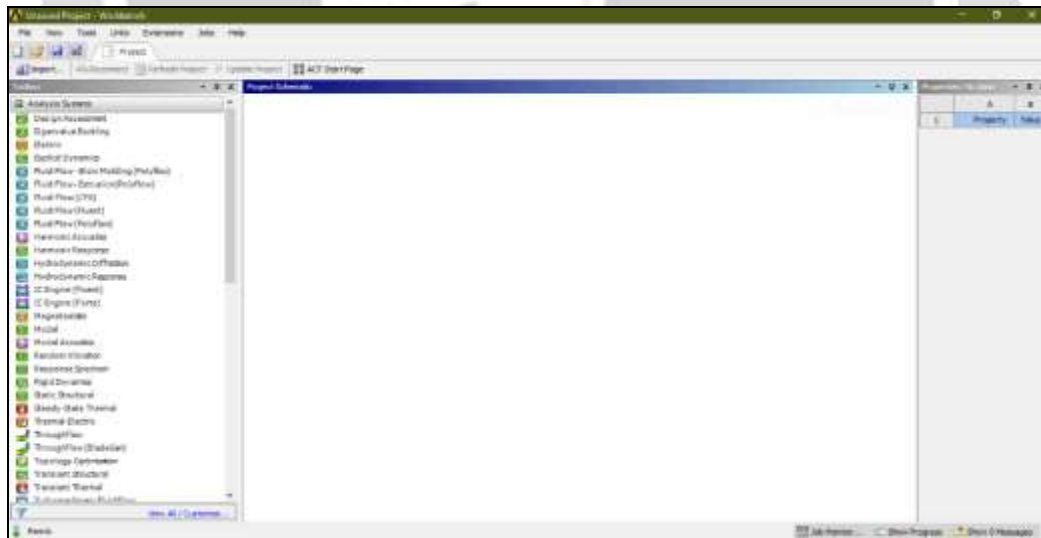
- A set of algebraic equations for steady state problems,
- A set of ordinary differential equations for transient problems.

These equation sets are the element equations. They are linear if the underlying PDE is linear, and vice versa. Algebraic equation sets that arise in the steady state problems are solved using numerical linear algebra methods, while ordinary differential equation sets that arise in the transient problems are solved by numerical integration using standard techniques such as Euler's method or the Runge-Kutta method.

FEM is best understood from its practical application, known as finite element analysis (FEA). FEA as applied in engineering is a computational tool for performing engineering analysis. It includes the use of mesh generation techniques for dividing a complex problem into small elements, as well as the use of software programs coded with FEM algorithms. In applying FEA, the complex problem is usually a physical system with the underlying physics such as the Euler-Bernoulli beam equation, the heat equation, or the Navier-Stokes equations expressed in either PDE or integral equations, while the divided small elements of the complex problem represent different areas in the physical system.

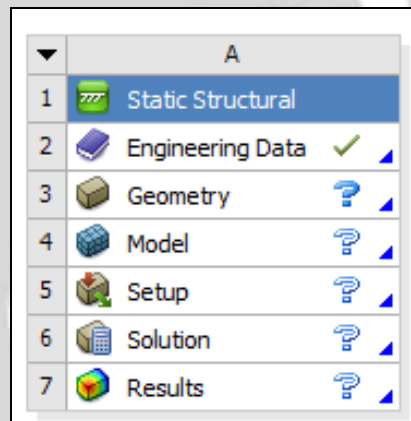
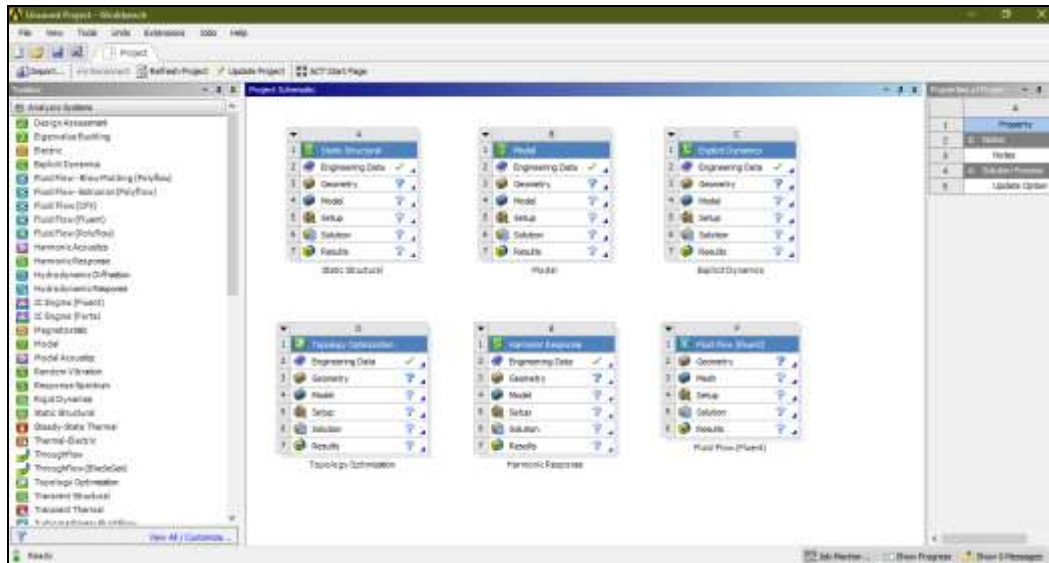
In present research for analysis ANSYS (Analysis System) software is used. Basically, it's the present FEM method to solve any problem. Following are steps in detail

1. Geometry
2. Discretization (Meshing)
3. Boundary condition
4. Solve (Solution)
5. Interpretation of results



Workbench contains analysis of different types namely static, modal, harmonic, explicit dynamics, CFD, ACP tool post, CFX, topology optimization etc. as per problem defined.





Step 1: Details of material namely copper, steel, grey cast iron, composite material, fluid domain material is defined in engineering data. i.e. ANSYS default material is structural steel.

Step 2: Import of geometry created in any CAD software namely CATIA, PRO E, SOLIDWORK, INVENTOR etc. in the geometry section. If any correction is to be made it can be created in the geometry section in Design modeler or space claim.

Step 3: In model section after import of component

- Material is assigned to component as per existing material
- Connection is checked in the contact region, bonded, frictionless, frictional, no separation etc. for multi body components.
- Meshing or discretization is performed to break components in small pieces (elements) as per size, preferably tetra mesh and hexahedral mesh for 3D geometry and for 2 D quad or tria are generally preferred.

Step 4: Boundary conditions are applied as per analysis namely in fixed support, pressure, force, displacement, velocity as per condition.

Step 5: Now the problem is well defined and the solve option is selected to obtain the solution in the form of equivalent stress, strain, energy, reaction force etc.

**6.2.MATERIAL PROPERTIES USED FOR RIVET, SPECIMEN AND ADHESIVE**

Properties of Outline Row 5: Structural Steel			
	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	7850	kg m <sup>-3</sup>
4	Isotropic Secant Coefficient of Thermal Expansion		
5	Coefficient of Thermal Expansion	1.2E-05	C <sup>-1</sup>
6	Isotropic Elasticity		
7	Derive from	Young's Modulus an...	
8	Young's Modulus	2E+11	Pa

*Table 1 : Material properties for rivet*

Properties of Outline Row 4: Epoxy E-Glass UD			
	A	B	C
1	Property	Value	Unit
2	Density	2E-09	mm <sup>-3</sup> t
3	Orthotropic Elasticity		
4	Young's Modulus X direction	45000	MPa
5	Young's Modulus Y direction	10000	MPa
6	Young's Modulus Z direction	10000	MPa
7	Poisson's Ratio XY	0.3	
8	Poisson's Ratio YZ	0.4	
9	Poisson's Ratio XZ	0.3	
10	Shear Modulus XY	5000	MPa
11	Shear Modulus YZ	3846.2	MPa
12	Shear Modulus XZ	5000	MPa

*Table 2 : Material properties for Specimen*

Properties of Outline Row 3: ARALDITE			
	A	B	C
1	Property	Value	Unit
2	Material Field Variables	Table	
3	Density	1.16E-09	tonne mm <sup>-3</sup>
4	Isotropic Elasticity		
5	Derive from	Young's Modulus and...	
6	Young's Modulus	1600	MPa
7	Poisson's Ratio	0.42	
8	Bulk Modulus	3.3333E+09	Pa
9	Shear Modulus	5.6338E+08	Pa

Table 3 : Material properties for Adhesive

6.3 ANALYSIS FOR RIVET JOINT

**Model**

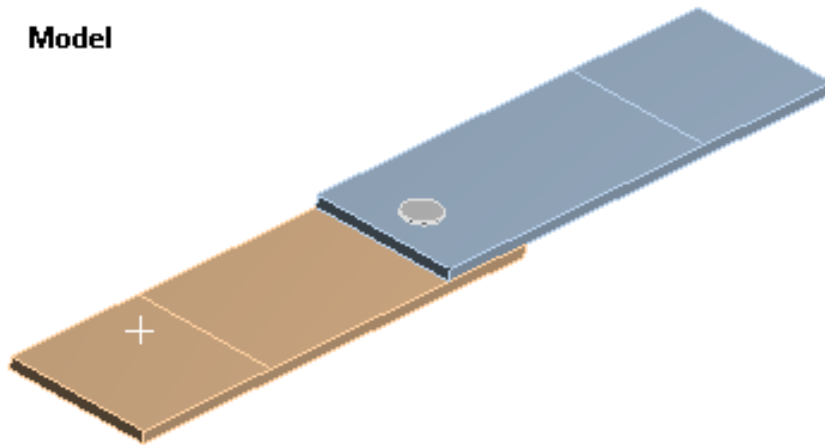


Fig 5. Rivet joint Geometry

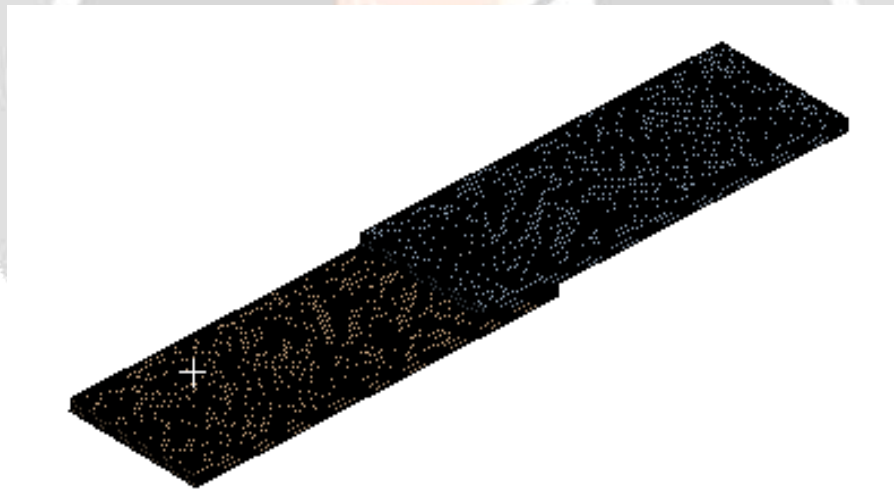
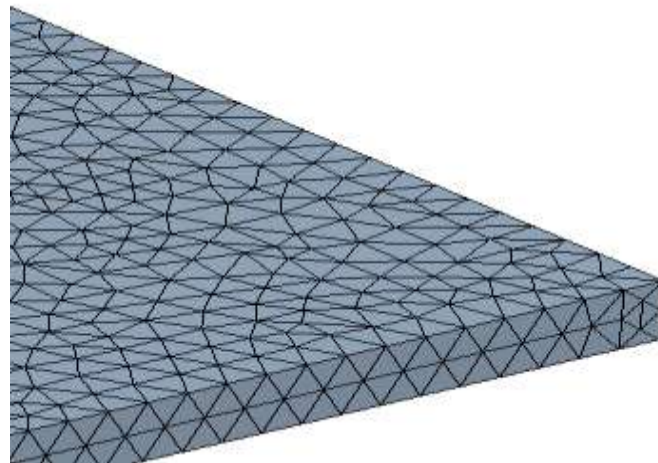


Fig 6 : Rivet Joint Specimen Mesh



Details of "Body Sizing 2" - Sizing	
<b>Scope</b>	
Scoping Method	Geometry Selection
Geometry	3 Bodies
<b>Definition</b>	
Suppressed	No
Type	Element Size
<input type="checkbox"/> Element Size	2.0 mm
<b>Advanced</b>	
<input type="checkbox"/> Defeature Size	Default
Behavior	Soft
<b>Statistics</b>	
<input type="checkbox"/> Nodes	110467
<input type="checkbox"/> Elements	69174

Fig 7 : Rivet Joint Model Mesh body sizing

**6.3.1.BOUNDARY CONDITION**

**A: WITH RIVET**

Static Structural  
Time: 1. s

**A** Fixed Support

**B** Force: 4000. N

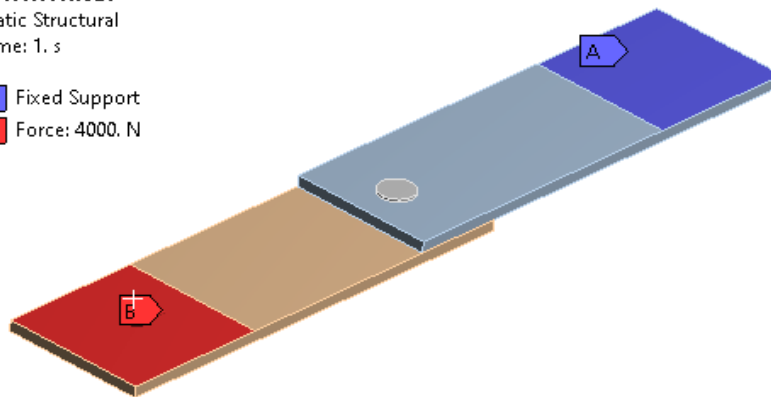


Fig 8 : Rivet Joint Static Structure Analysis

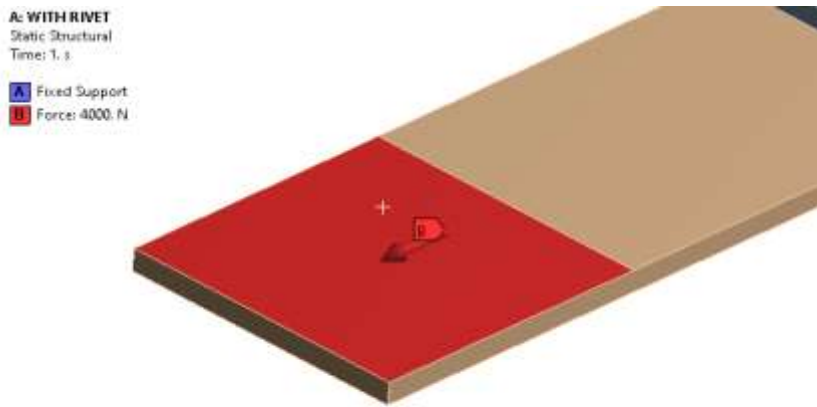


Fig 9 Rivet Joint Static Structure Analysis

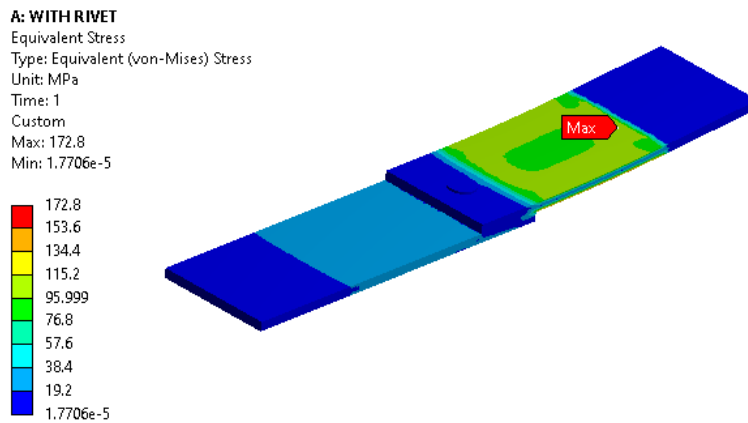


Fig 10 : Rivet Joint Equivalent stress

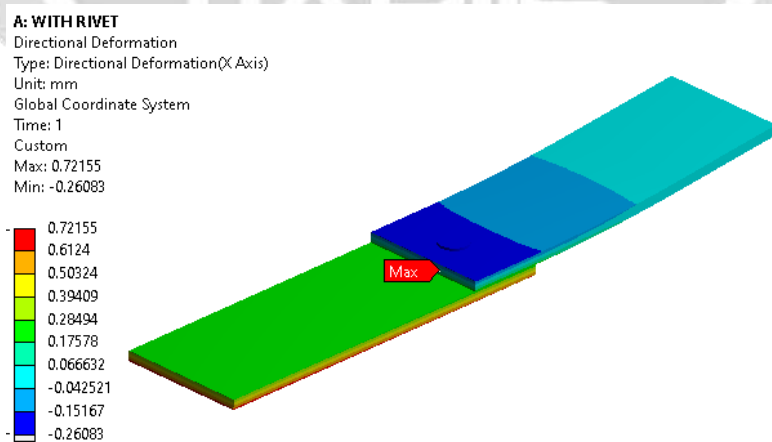


Fig 11 : Rivet Joint Directional deformation

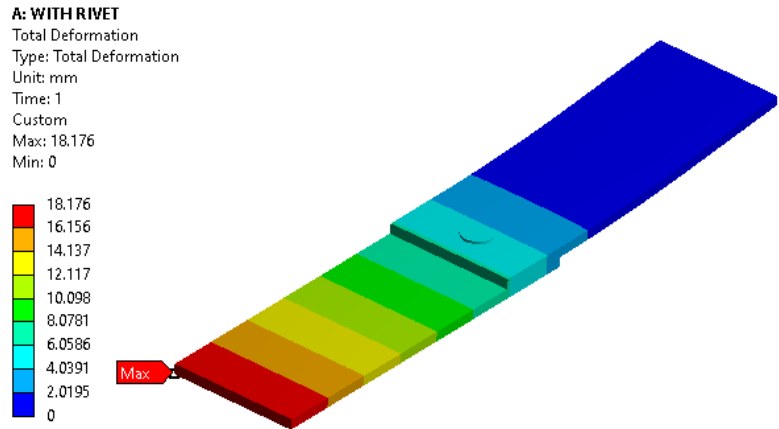
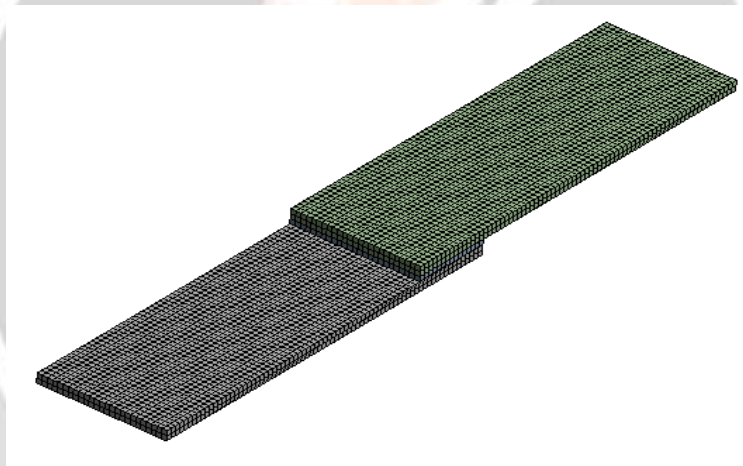


Fig 12 : Rivet joint Total deformation

**6.4 ANALYSIS FOR ADHESIVE JOINT**



Details of "Body Sizing" - Sizing

<b>Scope</b>	
Scoping Method	Geometry Selection
Geometry	3 Bodies
<b>Definition</b>	
Suppressed	No
Type	Element Size
<input type="checkbox"/> Element Size	2.0 mm
<b>Advanced</b>	
<input type="checkbox"/> Defeature Size	Default
Behavior	Soft

**Statistics**

<input type="checkbox"/> Nodes	45688
<input type="checkbox"/> Elements	7875

Fig 13 : Adhesive Joint.Mesh

6.4.1 BOUNDARY CONDITION

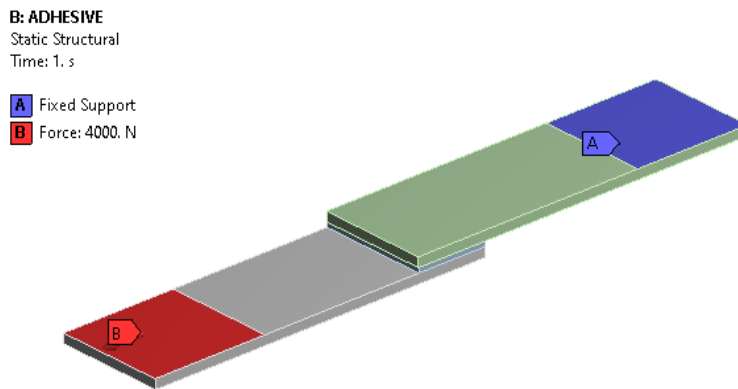


Fig. 14 Adhesive Joint Static Structure

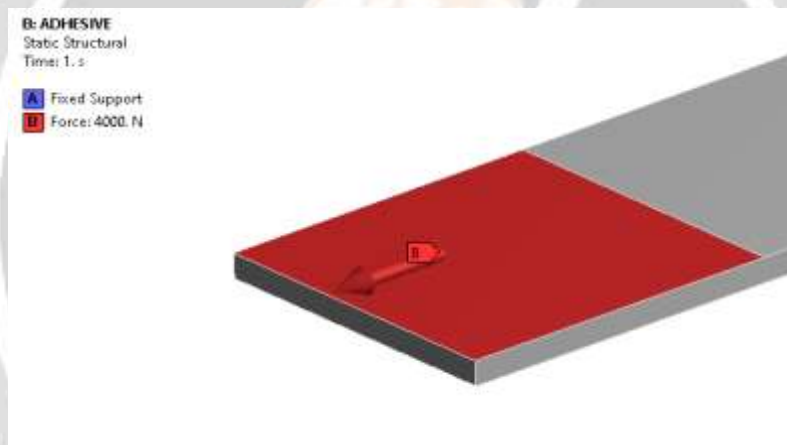


Fig. 15: Adhesive joint static structure

6.4.2 RESULT

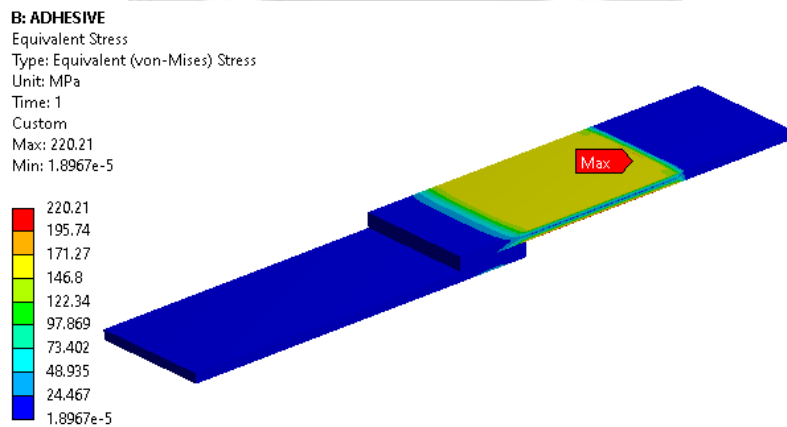


Fig 16: Adhesive joint Equivalent stress

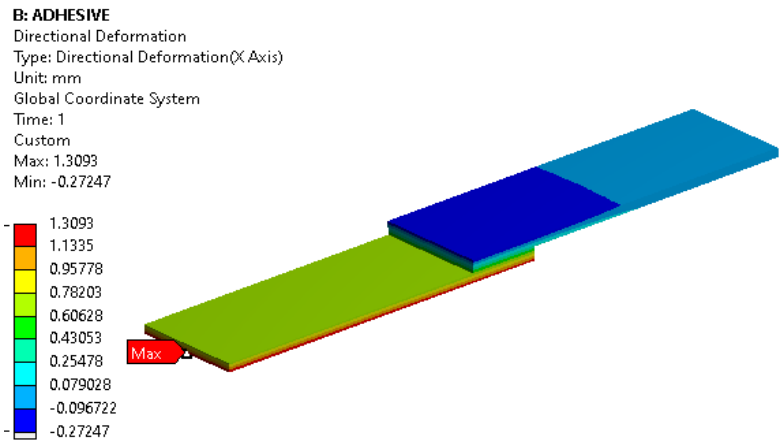


Fig. 17 : Adhesive joint Directional deformation

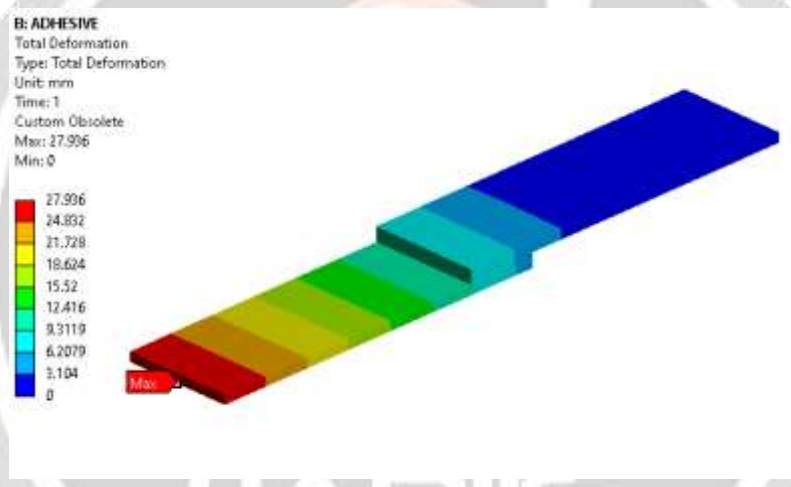
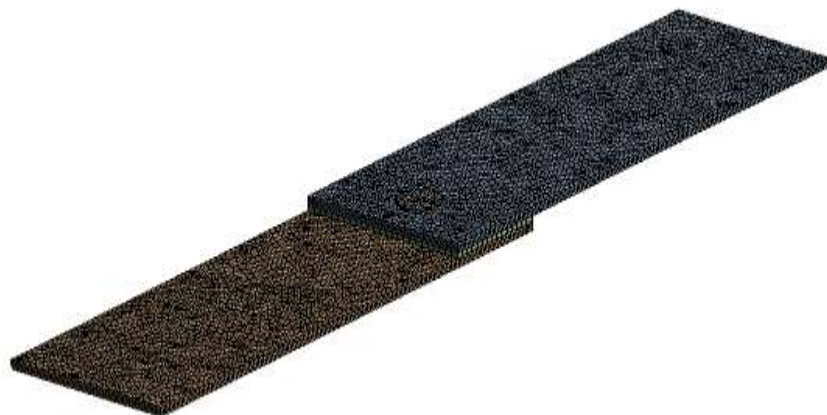


Fig.18 : Adhesive joint Total deformation

### 6.5.1 ANALYSIS FOR HYBRID JOINT

#### MESHING





Scope	
Scoping Method	Geometry Selection
Geometry	4 Bodies
Definition	
Suppressed	No
Type	Element Size
<input type="checkbox"/> Element Size	2.0 mm
Advanced	
<input type="checkbox"/> Defeature Size	Default
Behavior	Soft

Statistics	
<input type="checkbox"/> Nodes	112020
<input type="checkbox"/> Elements	68418

Fig 19 : Hybrid Joint mesh

6.5.2 BOUNDARY CONDITION

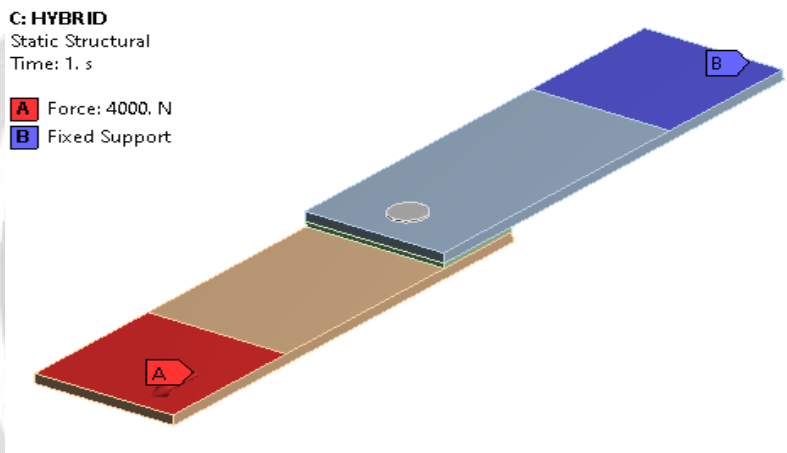


Fig.20 : Hybrid Joint Static Structure condition

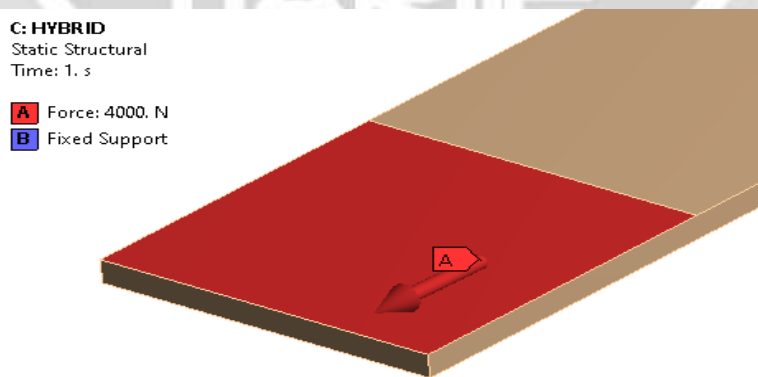


Fig. 21 : Hybrid Joint Static Structure

6.5.3 RESULT

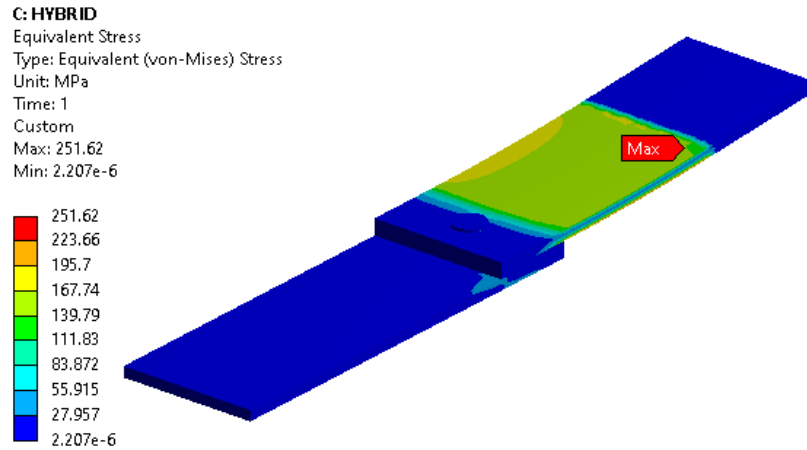


Fig.22 : Hybrid Joint Equivalent stress

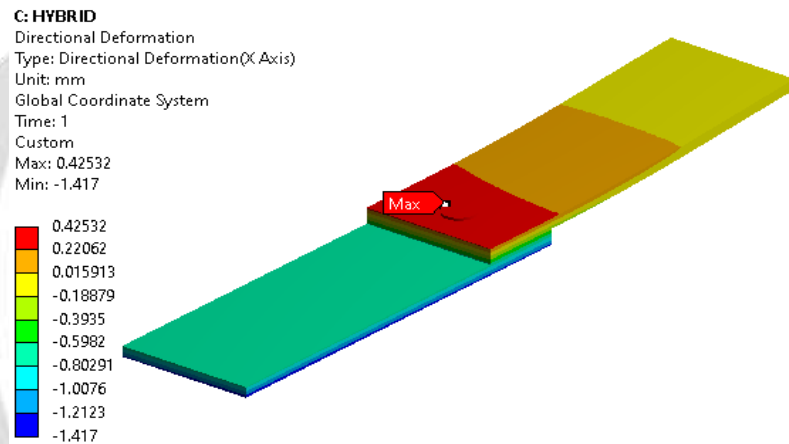


Fig.23 : Hybrid Joint Directional deformation

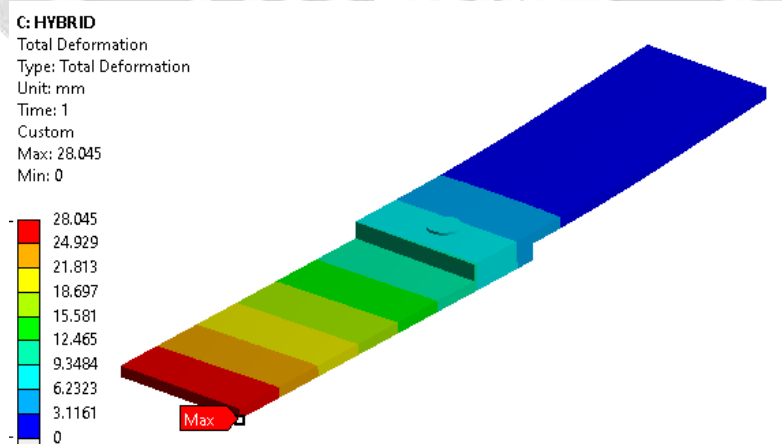
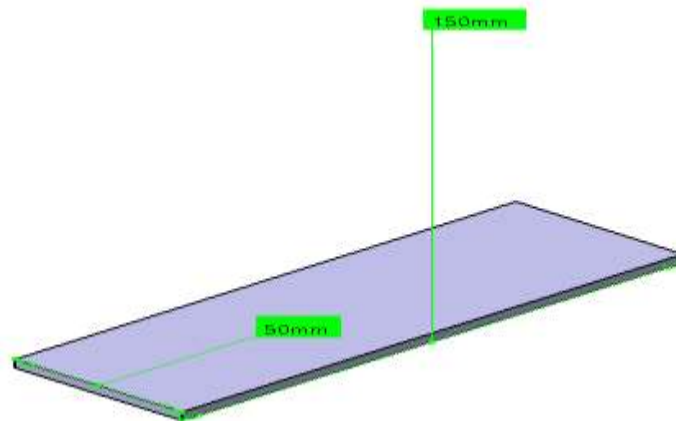


Fig.24 : Hybrid Joint Total deformation

**7. GLASS FIBER USED FOR MANUFACTURING SPECIMEN**



*Fig. Dimension of specimen using catia model*



*Fig. Glass fiber*

*specimen*



*Fig. Total 6 specimen manufactured*

### 7.1 ADHESIVE USED FOR JOINING



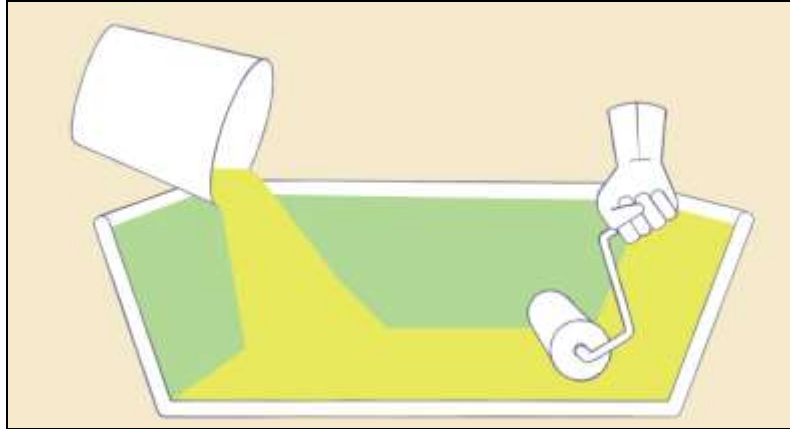
## 8. SPECIMEN MANUFACTURING PROCESS

### 1] Open Molding

Composite materials (resin and fibers) are placed in an open mold, where they cure or harden while exposed to the air. Tooling cost for open molds is often inexpensive, making it possible to use this technique for prototype and short production runs.

#### Hand Lay-Up

Hand lay-up is an open molding method suitable for making a wide variety of composites products from very small to very large. Production volume per mold is low; however, it is feasible to produce substantial production quantities using multiple molds. Hand lay-up is the simplest composites molding method, offering low cost tooling, simple processing, and a wide range of part sizes. Design changes are readily made. There is a minimum investment in equipment. With skilled operators, good production rates and consistent quality are obtainable.



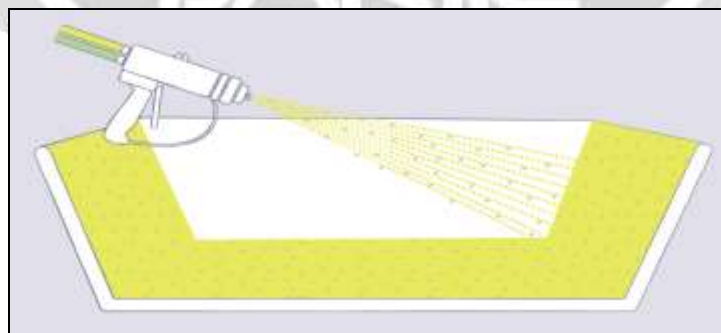
### Process

Gel coat is first applied to the mold using a spray gun for a high quality surface. When the gel coat has cured sufficiently, roll stock fiberglass reinforcement is manually placed on the mold. The laminating resin is applied by pouring, brushing, spraying, or using a paint roller. FRP rollers, paint rollers, or squeegees are used to consolidate the laminate, thoroughly wetting the reinforcement and removing entrapped air. Subsequent layers of fiberglass reinforcement are added to build laminate thickness. Low density core materials such as end-grain balsa, foam, and honeycomb, are commonly used to stiffen the laminate. This is known as sandwich construction.

### Spray-up

Spray-up, or chopping, is an open mold method similar to hand lay-up in its suitability for making boats, tanks, transportation components, and tub/shower units in a large variety of shapes and sizes. A chopped laminate has good conformability and is sometimes faster to produce than a part made with hand lay-ups when molding complex shapes.

In the spray-up process, the operator controls thickness and consistency, therefore the process is more operator dependent than hand lay-up. Although production volume per mold is low, it is feasible to produce substantial production quantities using multiple molds. This process uses simple, low cost tooling and simple processing. Portable equipment permits on-site fabrication with virtually no part size limitations. The process may be automated.



### Process

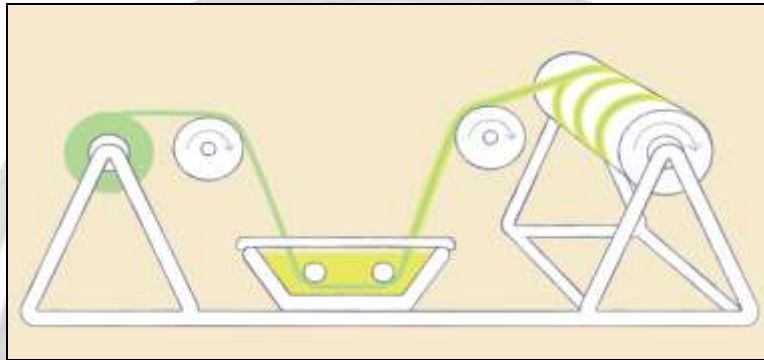
As with hand lay-up, gel coat is first applied to the mold and allowed to cure. Continuous strand glass roving and initiated resin are then fed through a chopper gun, which deposits the resin-saturated “chop” on the mold. The laminate is then rolled to thoroughly saturate the glass strands and compact the chop. Additional layers of chop laminate are added as required for thickness. Roll stock reinforcements, such as woven roving or knitted fabrics, can

be used in conjunction with the chopped laminates. Core materials of the same variety as used in hand lay-ups are easily incorporated.

### Filament winding

Filament winding is an automated open molding process that uses a rotating mandrel as the mold. The male mold configuration produces a finished inner surface and a laminate surface on the outside diameter of the product.

Filament winding results in a high degree of fiber loading, which provides high tensile strength in the manufacture of hollow, generally cylindrical products such as chemical and fuel storage tanks, pipes, stacks, pressure vessels, and rocket motor cases. The process makes high strength-to-weight ratio laminates and provides a high degree of control over uniformity and fiber orientation. The filament winding process can be used to make structures that are highly engineered and meet strict tolerances. Because filament winding is computer-controlled and automated, the labor factor for filament winding is lower than other open molding processes.



### Process

Continuous strand roving is fed through a resin bath and wound onto a rotating mandrel. The roving feed runs on a trolley that travels the length of the mandrel. The filament is laid down in a predetermined geometric pattern to provide maximum strength in the directions required. When sufficient layers have been applied, the laminate is cured on the mandrel. The molded part is then stripped from the mandrel. Equipment is available for filament winding on a continuous basis with axis winding for pressure cylinders. Filament winding can be combined with the chopping process and is known as the hoop chop process.

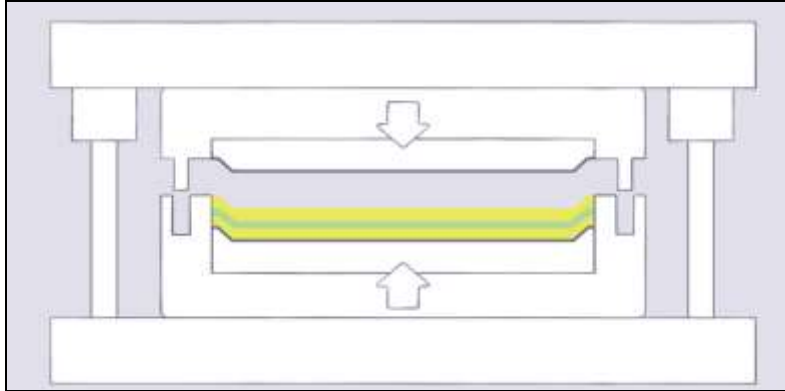
### 2] Closed Molding

Composite materials are processed and cured inside a vacuum bag or a two-sided mold, close to the atmosphere. Closed molding may be considered for two cases: first, if a two-sided finish is needed; and second, if high production volumes are required.

### Compression molding

Compression molding is a high-volume, high-pressure method suitable for molding complex, fiberglass-reinforced polymer parts on a rapid cycle time.

There are several types of compression molding that are defined by the type of material molded: sheet molding compound (SMC), bulk molding compound (BMC), thick molding compound (TMC), and wet lay-up compression molding. Compression molding tooling consists of heated metal molds mounted in large hydraulic presses. The process can be automated. Compression molding enables part design flexibility and features such as inserts, ribs, bosses and attachments. Good surface finishes are obtainable, contributing to lower part finishing cost. Subsequent trimming and machining operations are minimized in compression molding and labor costs are low.

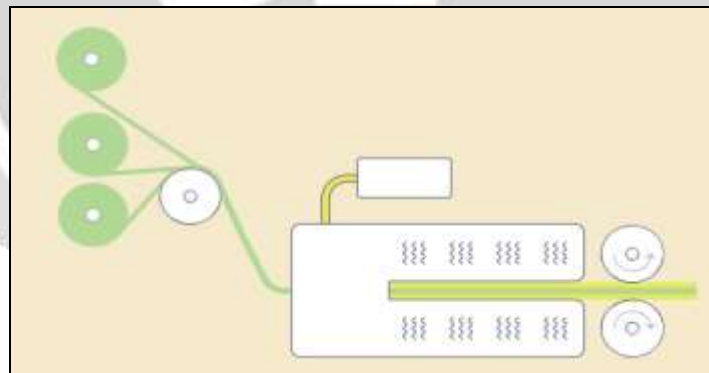


### Process

The mold set is mounted in a hydraulic or mechanical molding press and the molds are heated from 250° to 400° F. A weighted charge of molding material is placed in the open mold. The two halves of the mold are closed and pressure is applied. Depending on thickness, size, and shape of the part, curing cycles range from less than a minute to about five minutes. After the cure, the mold is opened and the finished part is removed. Typical parts include automobile components, appliance housings and structural components, furniture, electrical components, and business machine housings and parts.

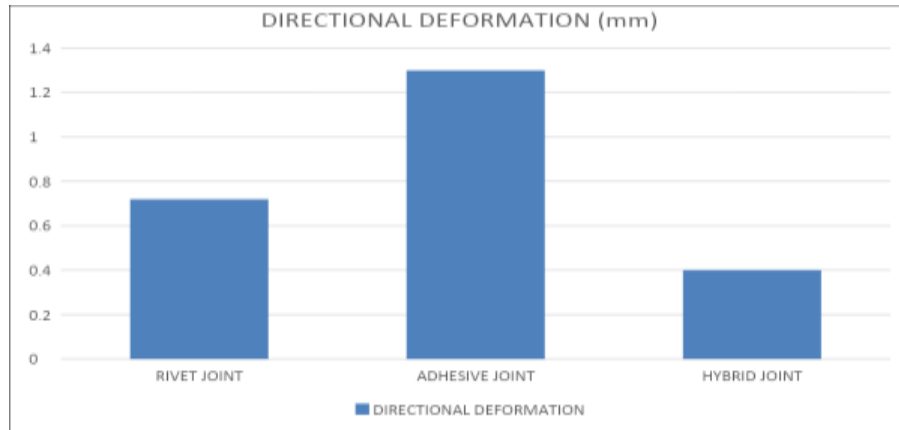
### Pultrusion

Pultrusion is a continuous process for the manufacture of products having a constant cross section, such as rod stock, structural shapes, beams, channels, pipe, tubing, fishing rods, and golf club shafts. Pultrusion produces profiles with extremely high fiber loading; thus, pultruded products have high structural properties. The process can be readily automated and is adaptable to both simple and complex cross-sectional shapes. Very high strengths are possible and labor costs are low.

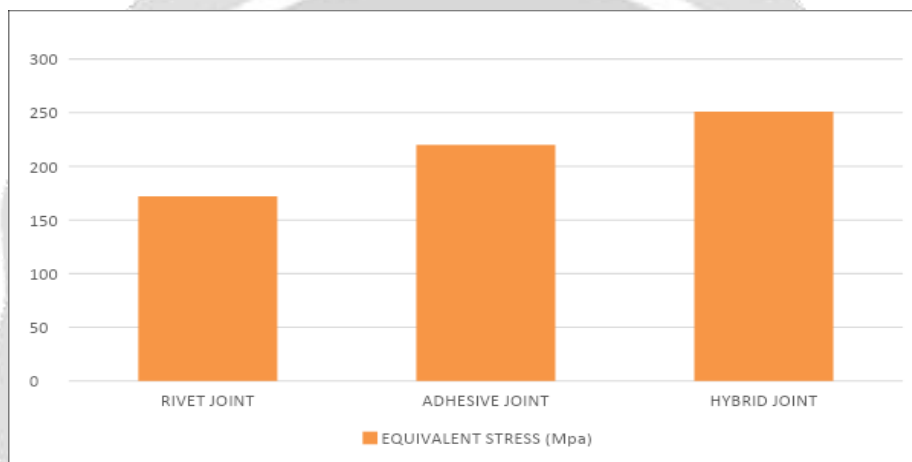


### Process

Continuous strand glass fiber, carbon fiber or basalt fiber roving, mat, cloth, or surfacing veil is impregnated in a resin bath and then pulled (therefore the term *pul*-trusion) through a steel die by a powerful tractor mechanism. The steel die consolidates the saturated reinforcement, sets the shape of the stock, and controls the fiber/resin ratio. The die is heated to rapidly cure the resin. Many creels (balls) of roving are positioned on a rack, and a complex series of tensioning devices and roving guides direct the roving into the die.



Graph. Directional deformation comparison



Graph. Equivalent stress comparison

### 9.EXPERIMENTAL TEST

A Universal Testing Machine (UTM) is used to test both the tensile and compressive strength of materials. Universal Testing Machines are named as such because they can perform many different varieties of tests on an equally diverse range of materials, components, and structures.

Universal Testing Machines can accommodate many kinds of materials, ranging from hard samples, such as metals and concrete, to flexible samples, such as rubber and textiles. This diversity makes the Universal Testing Machine equally applicable to virtually any manufacturing industry.

The UTM is a versatile and valuable piece of testing equipment that can evaluate materials properties such as tensile strength, elasticity, compression, yield strength, elastic and plastic deformation, bend compression, and strain hardening. Different models of Universal Testing Machines have different load capacities, some as low as 5kN and others as high as 2,000kN.

#### 9.1 SPECIFICATION OF UTM

<b>1</b>	<b>Max Capacity</b>	<b>400KN</b>
<b>2</b>	<b>Measuring range</b>	<b>0-400KN</b>



3	Least Count	0.04KN
4	Clearance for Tensile Test	50-700 mm
5	Clearance for Compression Test	0- 700 mm
6	Clearance Between column	500 mm
7	Ram stroke	200 mm
8	Power supply	3 Phase , 440 Volts , 50 cycle. A.C
9	Overall dimension of machine (L*W*H )	2100*800*2060
10	Weight	2300Kg

Table 4 : Specification of UTM Machine

*Fig. Tensile test of adhesive joint**Fig. Testing for rivet joint*



Fig. result for rivet joint

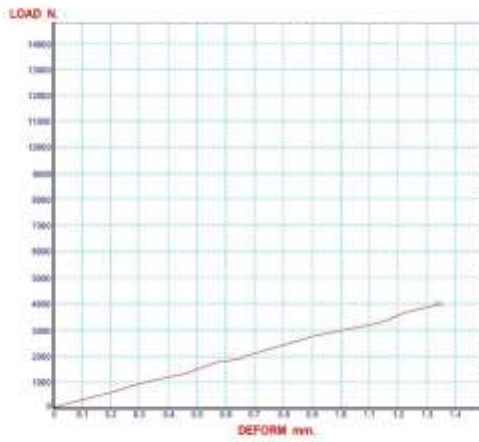


Fig. UTM result for adhesive joint



Fig. UTM result for hybrid joint

SR NO	TYPES OF JOINTS	EQUIVALENT STRESS (MPa)	TOTAL DEFORMATION (mm)	DIRECTIONAL DEFORMATION (mm)
1	RIVET JOINT	172	18.17	0.72
2	ADHESIVE JOINT	220	27.93	1.3
3	HYBRID JOINT	251	28.04	0.4

Table 5 : 3 Specimen Test Result comparison

## 10. CONCLUSION

- In the types of joints, this project is for 3 types of joints which are rivet joint, adhesive joints and hybrid joints.
- Perform Static analysis on the specimen using different types of joints with the help of ANSYS software.
- Perform static structure to find out direction deformation at the pulling direction of force and equivalent stress. Take 4000 N force constant at all 3 analyses for comparison between them and find optimized results as shown in table.

## 11. REFERENCES

- 1) Adhesive selection for hybrid spot-welded/bonded single-lap joints: Experimentation and numerical analysis G.P. Marques, R.D.S.G. Campilho, F.J.G. da Silva, R.D.F. Moreira
- 2) An investigation into the stresses in double-lap adhesive joints with laminated composite adherends M.Y. Tsai, J. Morton
- 3) Optimization Study Of Hybrid spot-welded/bonded single-lap joints R.D.S.G. Campilho, A.M.G.Pinto, M.D.Banea, L.F.M.daSilva
- 4) Fatigue resistance curves for single and double shear riveted joints from old portuguese metallic bridges Bruno Pedrosaa, José A.F.O. Correio, Carlos Rebeloa, Grzegorz Lesiukc, Abílio M.P. De Jesusb, António A. Fernandesb, M. Dudac, Rui Calçadab
- 5) Galvanic Corrosion Protection and Durability of Polyaniline-reinforced Epoxy Adhesive for Bond-riveted Joints in AA5083/Cf/Epoxy Laminates Lei Pana, WenyeDinga, Wenliang Maa, Jingling Hua, XiaofeiPanga, Fei Wanga, Jie Tao
- 6) Stress distributions and crack growth in riveted lap joints fastening thick steel plates Jackeline Kafie-Martinez, Peter B. Keatinga, Pranav Chakra-Varthyb, José Correiac, Abílio de Jesus

- 7) Design improvement of hybrid composite joints by axiomatic design, The Seventh International Conference on Axiomatic Design Worcester – June 27-28, 2013, Marc Ouellet, Aurelian Vadean
- 8) Finite analysis and experimental evaluation of bonded riveted and hybrid joints in glass fiber epoxy composite laminates, International Journal of Innovative Research in Science, Engineering and Technology, Lokesh K, Ragul Venkatesh S, Dr. Prakash M
- 9) Numerical & Experimental Comparison of Bonded, Riveted and Hybrid Joints, International Engineering Research Journal (IERJ) Volume 2 Issue, Ahire Bhupendra Prof. Kachave Sharad D.
- 10) Review on techniques to improve the strength of adhesive joints with composite adherend, International Journal of Composites, X. Shang a E.A.S. Marques b J.J.M. Machado b R.J.C. Carbas b,c D. Jiang a,\* L.F.M. da Silva
- 11) Experimental and Finite Element Studies of Thin Bonded and Hybrid Carbon Fibre Double Lap Joints Used in Aircraft Structure International Journal of Composites John Wangb ,Wing Kong Chiua and Paul Changb
- 12) An Experimental and Numerical Study of Repairs on Composite Substrates with Composite and Aluminum Doublers Using Riveted, Bonded, and Hybrid Joints, Licensee MDPI, Basel, Switzerland. Francesc Roure, Daniel Crespo and Jose I. Rojas
- 13) Design, Static Analysis And Fabrication Of Composite Joints, IOP Conference Series: Materials Science and Engineering, G.Mathiselvan, R.Gobinath, S.Yuvaraja, T.Raja
- 14) W.D. Bascom, R.L. Cottington, R.L. Jones, P. Peyser. 1975. "The fracture of epoxy and elastomer-modified epoxy polymers in bulk and as adhesives," J Appl Polym Sci, vol.19, pp. 2545–62.
- 15) D.W. Schmueser, N.L. Johnson. 1990. "Effect of bondline thickness on mixed-mode debonding of adhesive joints to electro primed steel surfaces," J Adhes, vol. 32.