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Design, Static Analysis and Fabrication of Composite Joints

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Abstract--- *The Bonded joints will be having one of the important issues in the composite technology is the repairing of aging in aircraft applications. In these applications and also for joining various composite material parts together, the composite materials fastened together either using adhesives or mechanical fasteners. In this paper, we have carried out design, static analysis of 3-D models and fabrication of the composite joints (bonded, riveted and hybrid). The 3-D model of the composite structure will be fabricated by using the materials such as epoxy resin, glass fibre material and aluminium rivet for preparing the joints. The static analysis was carried out with different joint by using ANSYS software. After fabrication, parametric study was also conducted to compare the performance of the hybrid joint with varying adherent width, adhesive thickness and overlap length. Different joint and its materials tensile test result have compared.*

Keywords--- *Mechanical Fasteners, Composite Joints, Tensile Test.*

I. INTRODUCTION

Over the past three decades, application of composite materials are continuously increasing from traditional application areas such as vehicles body frame, ship body, aircraft body 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. Composite materials have been widely used as structural elements in vehicles structures due to their superior properties. 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. 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. Ever increasing aerospace performance requirements make the high strength-to-weight ratios and cost efficiency associated with bonded joints attractive. However, bonding cannot be fully utilized without validated analytical methods to increase confidence in bonded designs and to reduce the expensive testing often necessary to certify bonded joints in critical locations. Current standard analysis methods are not capable of predicting all of the complex failure mechanisms associated with composite bonded joints. Most existing bonded joint analyses do not include shear deformation of the adherents and cannot account for peel failures at the end of the overlap which are often a primary cause of joint failure. In addition, they often truncate the adhesive stress-strain.

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II. COMPOSITE JOINTS

Short description of the three types of joints used in the present paper namely, bonded, riveted and hybrid joints was given below.

A. 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.

B. Riveted Joint

Riveted joints can be used quite successfully on laminates up to about 3mm thick and also where a tight fit, called interference fit, is necessary. The choice lies between solid & hollow types and whichever is chosen, care must be taken to minimize damage to the laminate during hole-drilling and closing of rivet. In addition to material and configurationally parameters, the behaviour of riveted joints is also influenced by rivet parameters such as rivet size, clamping force, hole size and tolerance.

C. Hybrid Joint

Hybrid joints have a combination of adhesive bonding and mechanical fasteners. In the present case, rivet has been used as the mechanical fastener. The advantages of using a combined bonded-riveted design apply mainly in a repair situation. It is generally accepted that a bonded joint is stronger than a mechanically fastened joint and a well-designed bonded joint is stronger than a hybrid joint.

III. LITERATURE REVIEW

Hart-Smith (1986) conducted theoretical investigation of combined bonded/bolted stepped lap joints between titanium and Carbon Fiber Reinforced Plastic (CFRP). While no significant strength benefits were found in comparison to perfectly bonded joints, the combined bolted-bonded joint was found to be beneficial for repairing damaged bonded joints and limiting damage propagation. Under room temperature and ambient humidity conditions, 98% of the applied load was predicted to be transferred by the adhesive. Chan and Vedhagiri (2001) investigated that the use of bolted, bonded and combined bonded-bolted joints used in repair. The structural response of various configurations of single lap joint, namely, bonded, bolted and bonded-bolted joints, was analyzed by three-dimensional finite element method. For the case of hybrid joints, it was found that the bolts do not take an active role in load transfer before the initiation of the failure. However, the bolts in the hybrid joint actually reduce the in-plane axial stress near the edge of overlap. Gordon Kelly (2005) investigated that the load distribution in hybrid joints numerically through the use of finite element analysis. A three dimensional finite element model was developed including the effects of bolt-hole and nonlinear material behaviour and large deformation. From the study, it was found that load transferred by the bolt increases with increasing adherent thickness and adhesive thickness and decreases with increasing overlap length, pitch distance and adhesive modulus. Fu and Mallick (2001) investigated that the static and fatigue strength of hybrid joints in a Structural Reaction Injection Molded (SRIM)

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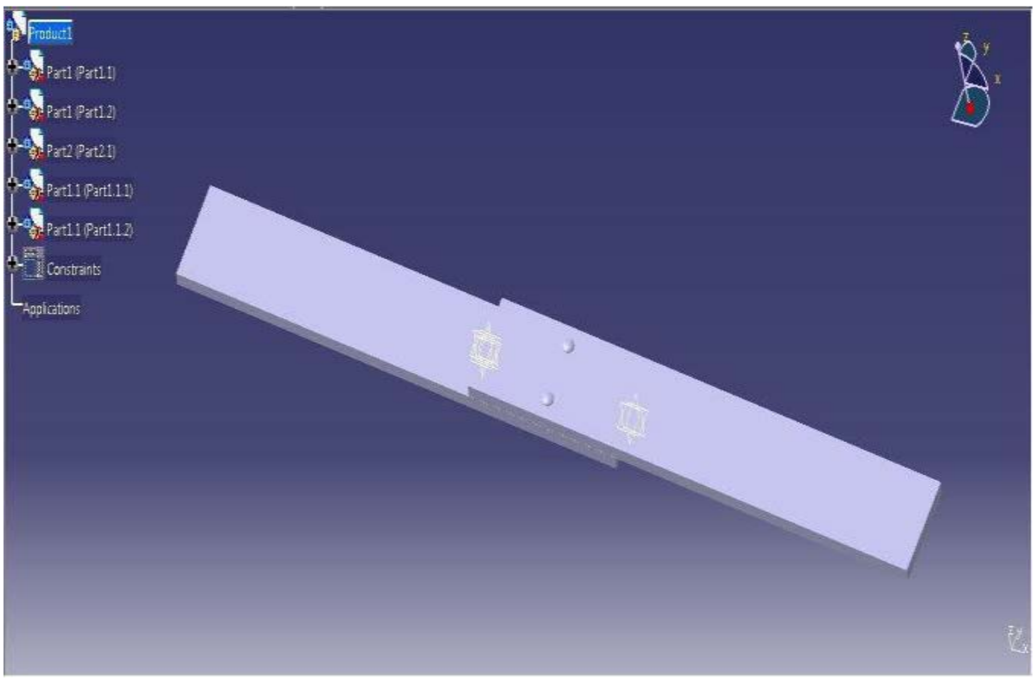
composite materials. The authors performed an experimental investigation on a single lap joint considering the effect of different washer designs.

It was concluded that the performance of the hybrid joints was dependent upon the washer design which affected the distribution of the bolt clamping force. The hybrid joints were shown in higher static strength and longer fatigue life than adhesive bonded joints for the studied material system. Jin-Hwe Kweon et al., (2006) conducted tests to evaluate the strength of carbon composite to aluminium double lap joints with two different adhesive materials, film and paste types.

IV. DESIGN OF COMPOSITE JOINT



In this laminate, REINFORCEMENT - Glass reinforced plastic fiber (bi-directional type) MATRIX Epoxy. Correct ratio of resin and hardener is 10:1 Resin: LY556 Hardener: HY951. For Hybrid Composite Joint Design is as shown in figure. Similarly we done bonded and riveted design through ANSYS.

V. FABRICATION OF COMPOSITE JOINTS

Even though the method has been replaced with automated techniques, the lay-up of pre-impregnated material by hand is the oldest and most common fabrication method for advanced composite structures. Furthermore, the basic features of the method remain unchanged. Each step must follow in successive fashion in order to obtain a high-quality composite laminate after final processing. A description of these steps follows.

STEP 1

Make the surface of the glass fiber material clean, if the dust or unwanted particles on the material will affect lamination preparation.

STEP 2

Cut the glass fiber material according to the required dimension for lamination preparation, into six layers for getting 3mm thickness.

STEP 3

Prepare the epoxy resin by mixing the adhesive (LY556) and hardener (medium HY951) in the ratio 10:1 and mixing it continuously for lamination.

STEP 4

Placing the plastic layer of cover on the cover glass fiber layer of material is pasted one by one by using the epoxy resin, repeating the pasting process for six layers, make sure that there should be no vacuum created in between the laminations. Press each layer after applying the adhesive for better lamination.

STEP 5

Cover the laminated surface by using plastic layer of cover and keep the glass plane on the lamination for distribution of even application of load and apply load about 4 to 5kg on the plane. Keep in observation about 48 hours.

STEP 6

Take the lamination and cut the outer surface of the lamination because size and surface of the boundary layer will differ from the centre part. Make the marking on the lamination for cutting the exact dimension for getting the specimen (150mm*25mm).

STEP 7

Filing the edges of the cutter specimen because while cutting the specimen by using hand saw some improper dimension will occur in the specimen. Filing the surface of specimen from one side about 50mm for joining the specimen in bonded and hybrid types of joint.

STEP 8

Joining the specimen only by using epoxy resin on the 50mm filed surface of the specimen .Place any material under the specimen for the balancing support and apply load on the specimen for getting the composite structure. Keep it in observation about 48 hours and file the specimen to remove excess adhesive particles.

STEP 9

For the riveted joint, drill the hole about 3mm diameter according to the respective dimension in the model of the specimen. Joining the specimen by using aluminium rivet by hammering the rivet in to the respective holes of the specimen.

STEP 10

For making hybrid joints, bond the specimen by using epoxy resin and make the hole by drilling according to the respective dimension at 3mm diameter and make the second joint by using aluminium rivet by hammering.

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STEP 11

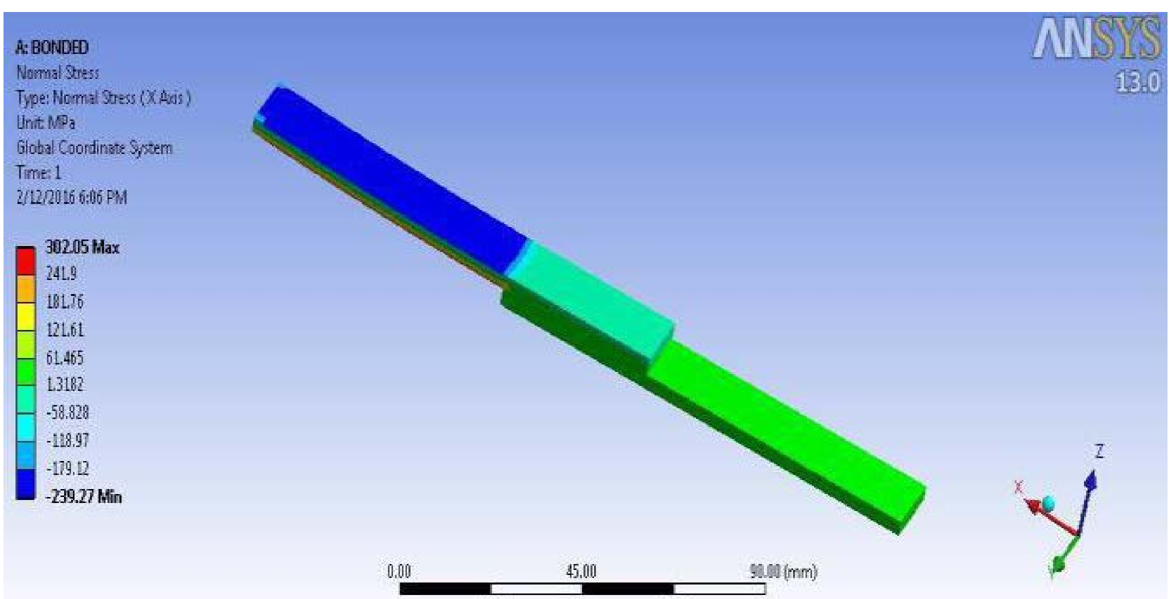
The cure of epoxies is the conversion of the liquid resin and hardener components to a solid high-performance plastic material. Cure is only initiated once the components are metered in the correct ratio to one another and are physically mixed together. The cure of all epoxies is an exothermic process where heat is liberated as a natural consequence of the chemical reaction. Success in using epoxies most efficiently is dependent upon handling the product in the correct way in order to avoid wastage and premature cure, and this can be achieved by some understanding of the basic chemistry and the various stages of the chemical transformation.

VI. MECHANICAL TESTING

After the fabrication of specimen, the specimen should undergo through a mechanical testing to take the experimental evaluation. The testing were made namely, tensile test. This type of tensile machine has two crossheads; one is for adjust the length of the specimen and other is for driven to apply tension .There are four main parameters: force capacity, Speed, precision and accuracy. Force capacity refers to the machine must able to generate enough force to fracture the specimen. The machine must be accurately and precisely measure the gauge length and force applied. A standard specimen is prepared in a round or a square section along the gauge length, depending on the standard used. Both ends of the specimens should have sufficient length and surface condition so they are firmly gripped during testing. The testing process involves placing the test specimen in the testing machine and slowly extending it until it factures. During this process, the elongation of the gauge section is recorded against the applied force.

VII. RESULTS AND DISCUSSIONS

Figure shows the normal stress induced in specimen under the action of 1500N load. The maximum stress is induced at the fixed end of the laminate its maximum value is 302.05 MPa. Red zone indicates the area of maximum stress and blue zone indicates the area of minimum stress.



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Stress intensity, total deformation analysis were done for bonded joint. Similarly Normal stress, stress intensity, total deformation analysis were done for riveted joint and hybrid joints. The test has taken at macro lab which is ISO associated (IS/ISO/IEC 17025).It is located at SP-101,2nd Main Road, Ambattur Industrial Estate, Chennai

Result 1

For bonded joint, the figure 6 shows the maximum load of 6.1KN is obtained as maximum extent at this point bonded joint breaks. The bonded joint attains the maximum stress level of about 65Mpa at full tensile load.

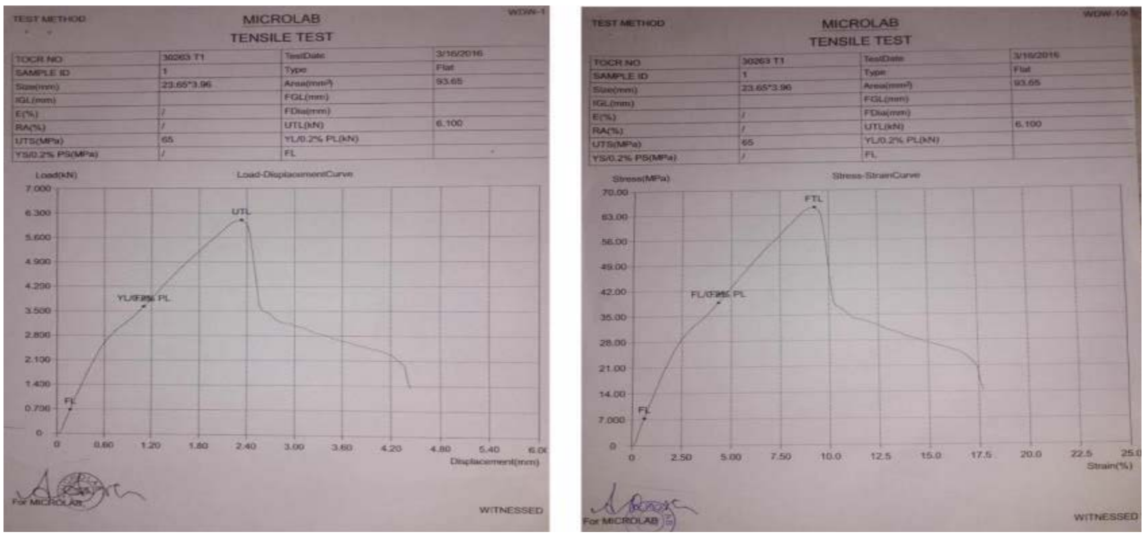

Fig: Test report of bonded joint

Result 2

For riveted joint, the figure shows the maximum load of 1.67KN is obtained as maximum extent at this point riveted joint breaks. The riveted joint attains the maximum stress level of about 19Mpa at full tensile load. The rived joint has very lower tensile strength when compare to both bonded and hybrid joint.

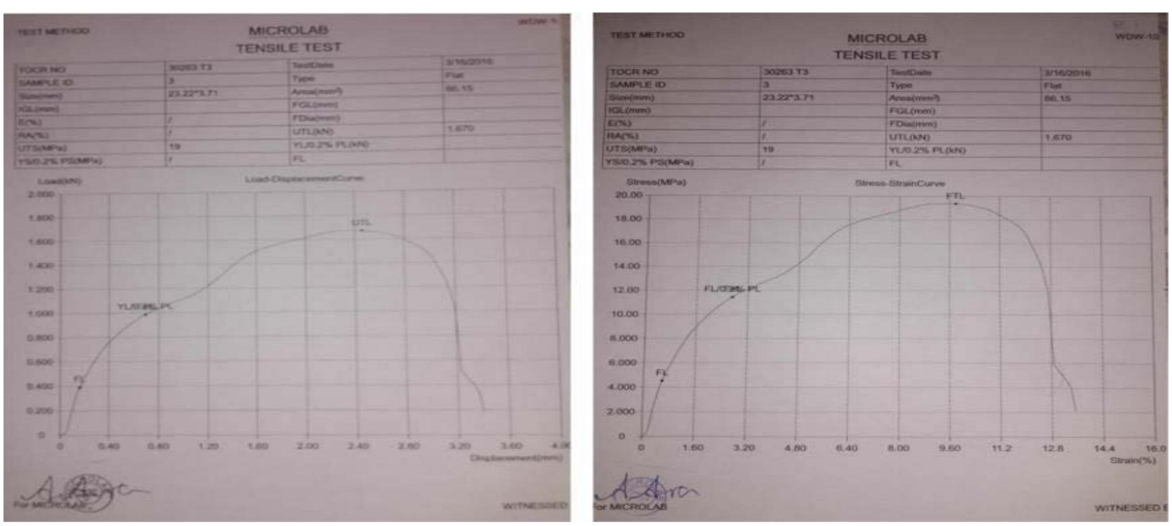

Fig: Test report of riveted joint

Result 3

For hybrid joint, the figure 8 shows the maximum load of 7.125KN is obtained as maximum extent at this point hybrid joint breaks. The hybrid joint attains the maximum stress level of about 82Mpa at full tensile load. When compare to bonded and riveted joint the hybrid joint withstand more tensile stress and has higher tensile strength.

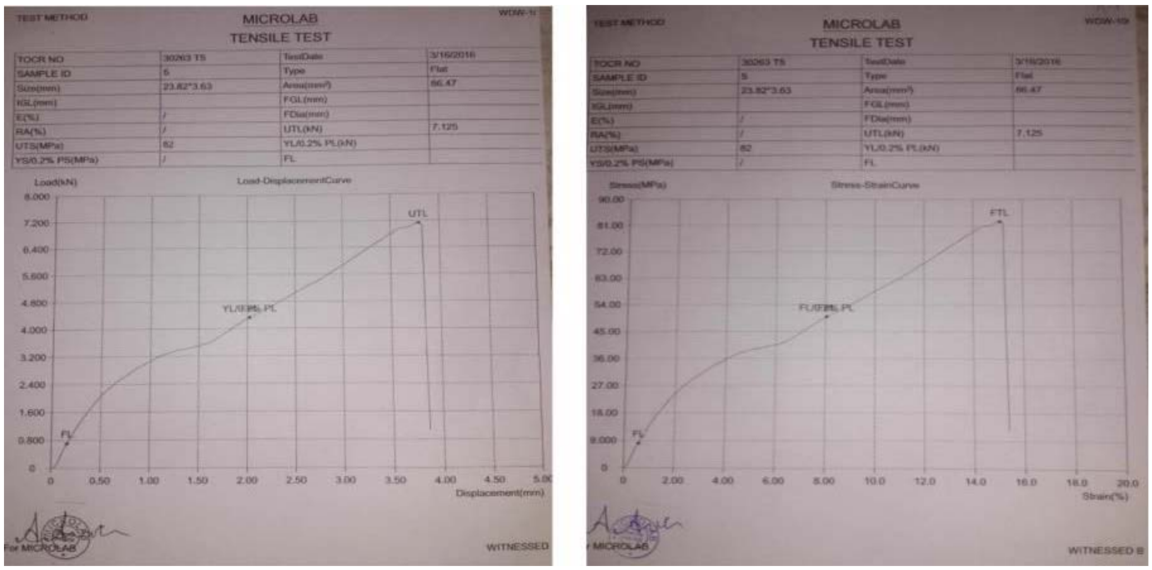

Fig: Test report of hybrid joint

VIII. CONCLUSION

From the results, it is observed that the hybrid joint gives better result in tensile strength on joints under static load condition. In the present work, Numerical and experimental for the prediction of stress distribution in bonded, riveted and hybrid joints has been carried out. 3-D models were created and analyzed using ANSYS FEA software. Von Misses stress was used to compare the results. Parametric study has been performed to reveal the effect of various geometric parameters on the stress distribution of hybrid joint. Thus from the present study, it was found that a well-designed hybrid joint is very efficient when compared to bonded or riveted joints in the case of repair situation in aircraft structures.

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