

Design And Analysis Of Hybrid Composite Lap Joint Using Finite Element Methods

S.Venkateswarlu¹, K.Rajasekhar²

¹ (Assistant Professor Senior, Department of Mechanical Engineering SKIT, Srikalahasthi)

² (P.G Student, Department of Mechanical Engineering SKIT, Srikalahasthi)

Abstract--

Composite materials have made way to several different fields, including aerospace structures, under water vehicles, automobiles and robot systems etc. Due to the high strength they are widely used in the low weight constructions and also used as a suitable alternative to metals. ANSYS FEA tool has been used for stress distribution characteristics of various configurations of double riveted single lap joint with three joining methods namely bonded, riveted and hybrid. In several different applications and also for joining various composite parts together, they are fastened together using adhesives or Mechanical fasteners. Modeling and static analysis of 3D Models of joints such as bonded, riveted and hybrid were carried out and compared for two different composite materials. The results are found in terms of total deformation, vonmises stress, shear stress, and normal stress for stress distribution and strength analysis. The present study deals with the analysis of single lap joint subjected to tensile load and the stress distribution in the joint members under various design conditions are found.

Keywords: FEA–Ansys, joint strength, composite materials, bonded, riveted, hybrid, stresses.

1. Introduction

Nowadays the composite materials like plastics reinforced with carbonfibres (CFRP), glassfibres (GFRP), and aramidfibres (AFRP) are widely used in various industries such as automotive, chemical, electrical industry, aircraft and even in cryogenics. Due to its superior properties, composites have been one of the materials used for repairing the existing structures in various applications and also for joining composite parts together, using adhesives or mechanical fasteners nowadays, a new method called hybrid joint is also being employed where a combination of both adhesive and mechanical fasteners are used. In the present project, an attempt is made to analyze the stress distribution in 3D

models of three configurations of double riveted Single lap joint namely bonded, riveted, hybrid. A major advantage of adhesive bonds with fastener may be designed and made in such a way that they can be stronger than the ultimate strength of many metals and it is broadly used in the fuselage panels in aircrafts structures etc.

2. Objective

In this attempt three joints were modeled using proE and analysis is done by using Ansys workbench. The stresses for two different materials were found such as vonmises, shear and normal stress.

3. Materials and Methods

Material of CFRP (carbon fibrereinforced plastic) composite with modeling and static analysis of 3D models of the joints (bonded, riveted, hybrid) were carried out using PROE (creoparametric) modeling and ANSYS FEA workbench software .The results were interpreted in terms of vonmises stress, normal stress, shear stress. K.N. Anyfantis, et al [2012]., Experimental Parametric Study of Single-Lap Adhesive Joints Between Dissimilar Materials presents an experimental parametric study of adhesively bonded Single Lap Joint (SLJ) geometries between relatively thick dissimilar adherents. The primary objective of this study is to investigate the effect of various parameters, i.e. adherents' thicknesses, adhesive thickness and overlap length, on the failure load and failure mode of joints with dissimilar materials. For this purpose, mild steel and carbon fiber reinforced polymer (CFRP) laminates have been considered as the structural adherent materials. Seven SLJ cases have been considered for fabrication and experimental testing. The SLJ specimens were tested under a uni-axial tensile quasi-static displacement. The force-displacement and force-strains recordings are presented and conclusions regarding the joints stiffness and strength are obtained [1].W.Hufenbach et al [2006]., the rivet joints optimization with the CFRP composite material and aluminium alloy. The analysis of strain, cracking, and failure of riveted joints of plate elements made from the carbon-fibrereinforced plastics (CFRP) and from the 6061 aluminium alloy. The modeled static tensile strength test carried out for the plates from CFRP and from the 6061 aluminium

alloy joined with the steel rivet. Simulations using the mesh with a bigger number of FEM elements do not yield better accuracy of calculations and do not improve convergence with the results of laboratory experiments. Computer simulation has show that the type of contacts employed between elements affects the results significantly

4. Finite Element Analysis of Composite Joints

Width of plate	22.5mm
Length of plate	100mm
Thickness of plate	2.5mm
Plate overlap	20mm
Diameter of the holes in plate	4mm
Diameter of the rivet head	6mm
Height of the rivet head	4mm
Total rivet height	13mm

Proengineering is a feature based parametric solid modeling system with many extended design and manufacturing applications. PROE (creoparametric) was used in the model .The commercial FEA software ANSYS workbench has been used to analyze the models. The adhesive layer between the laminates of thickness 0.4mm an aluminium rivet as

Joints	Number of nodes	Number of elements
Bonded	9979	1320
Riveted	10526	2013
Hybrid	11705	2147

Table: 2

Type of material	Young's modulus in Gpa	Density Kg/mm ³	Poisson ratio
CFRP	150	1.6x10 ⁻⁶	0.26
Aluminium	70	2.71X10 ⁻⁶	0.33
Epoxy	4	1.08X10 ⁻⁶	0.4

Table: 3

5. Figures and Tables

The models of bonded, riveted, hybrid joints is shown in figure 1-3

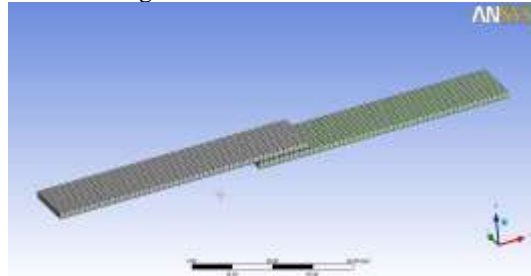


Fig. 1. Bonded joint

used for mechanical fastening .The CFRP material is used for analysis and stress values are found. One end of the adherend was constrained from x, y, z translations. While the other end the load of 5000N was applied to this end towards the positive x-direction. The PROE models of joints such as bonded, riveted, hybrid are shown in figure 1-3 and meshed models of joints such as bonded, riveted, hybrid are shown in figure 4-6. Joints were developed by using hexagonal element. Adherent and adhesive were glued together and finer mesh was used in the design.

Element type: hexagonal

The meshed models of bonded, riveted ,hybrid are shown in fig 4-6



4. Meshed model of bonded joint



Fig .2. Riveted joint



Fig.3.hybrid joint

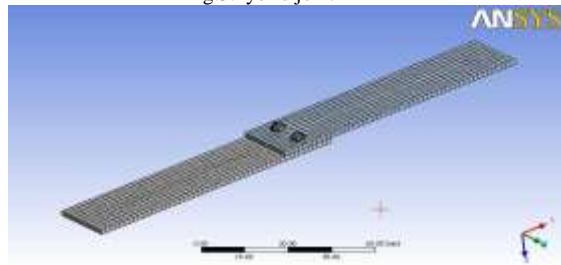


Fig. 5.Riveted joint

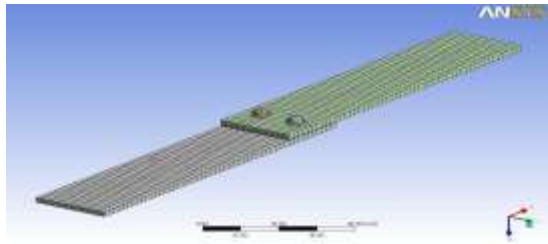


Fig. 6. Hybrid mesh model

Fig

5.1 bonded joints:

The maximum value of vonmises stress is 425.13 N/mm^2 and the minimum value of stress is $0.00073227 \text{ N/mm}^2$. The maximum value of shear stress in bonded joint with CFRP was found to be 63.564 N/mm^2 it was located on the two plates bonded portion. The minimum value of shear stress in CFRP was found to be -165.33 N/mm^2 . The images of analysis result of vonmises, shear stress and normal stress are shown in the Fig 7-11.

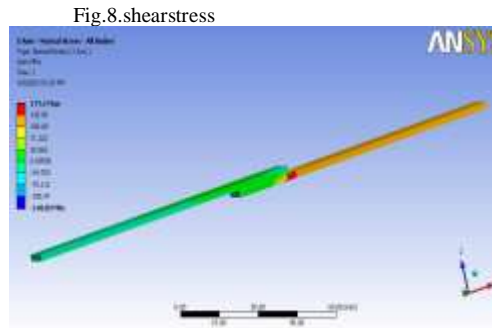


Fig.8.shearstress

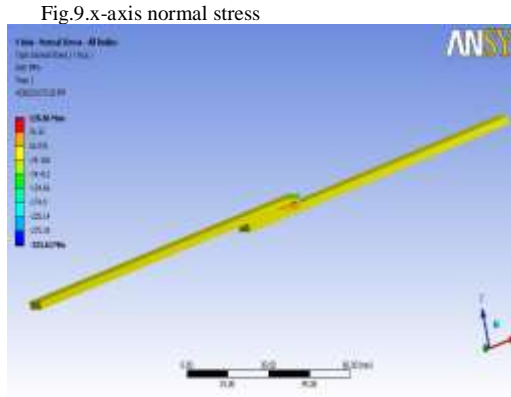


Fig.9.x-axis normal stress

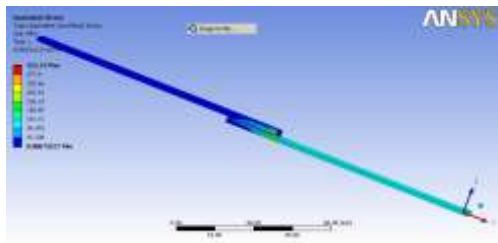


Fig. 7. Vonmises stress of bonded joint

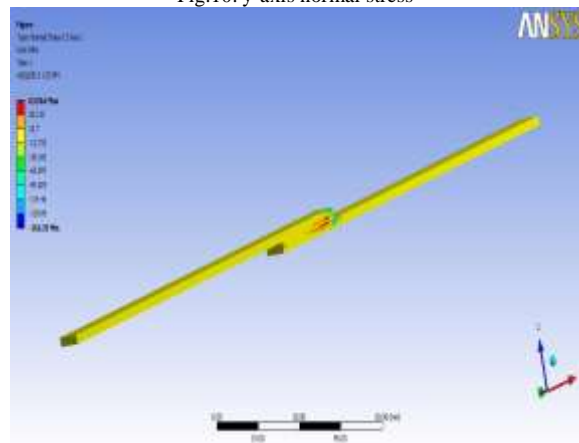


Fig.10. y-axis normal stress

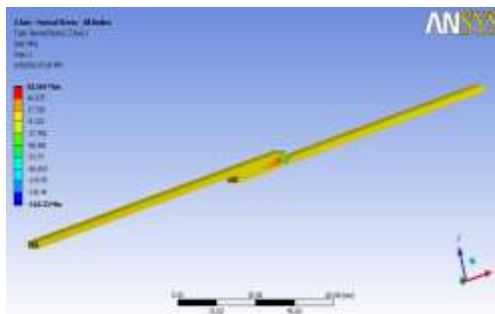


Fig.11. Z-axis normal stress

5.2 Riveted joints: The maximum value of vonmises stress for riveted joint is 446.32 N/mm^2 and the minimum value of stress is $0.00073253 \text{ N/mm}^2$. The rivet was meshed by using solid 45, an 8node brick element and the composite laminates were designed and meshed using hexagonal element. The minimum value of shear stress in CFRP was found to be -159.7 N/mm^2 and the maximum value of shear stress in CFRP was found to be 61.226 N/mm^2 it was located around the head of the rivet portion. The images of analysis result

of vonmises stress, shear stress and normal stress of riveted joints are shown in the figure 12-16.

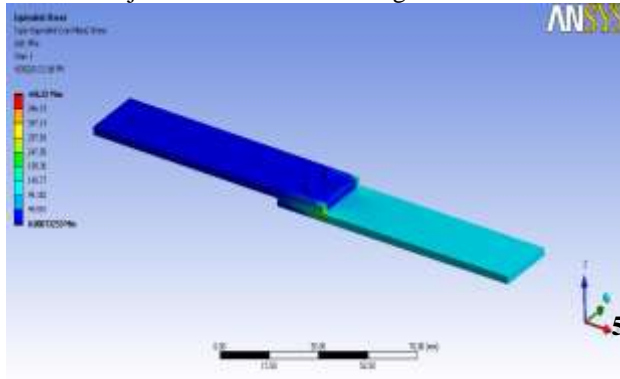


Fig .12.Vonmises stress of riveted joint

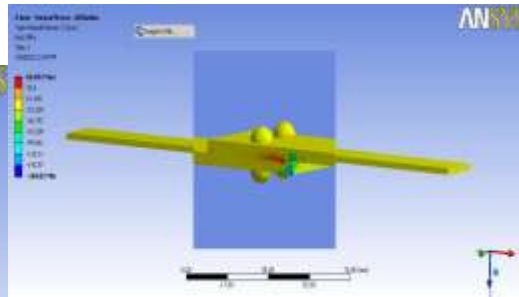


Fig.15.y-axis normal stress

5.3 hybrid joints:

This model is similar to the riveted joint except that it has a thin layer of adhesive between the laminates the minimum value of shear stress in CFRP was found to be -160.13 N/mm^2 and the maximum value of shear stress was found to be 63.449 N/mm^2 around the rivet region. The images of analysis result of vonmises, shear stress, and normal stress of the hybrid joint are shown in the figure 17-21.

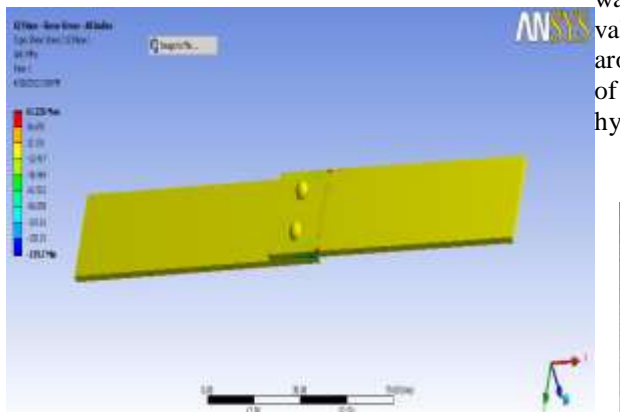


Fig.13.shear stress

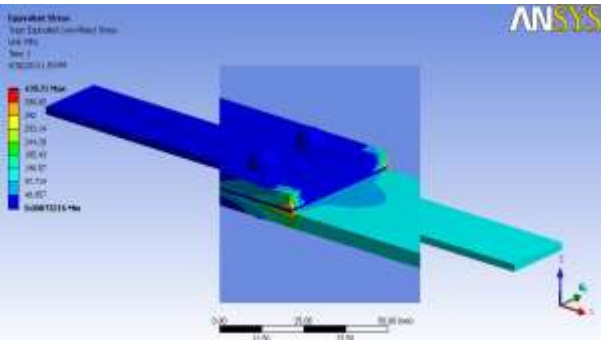


Fig .17.vonmises stress of hybrid joint

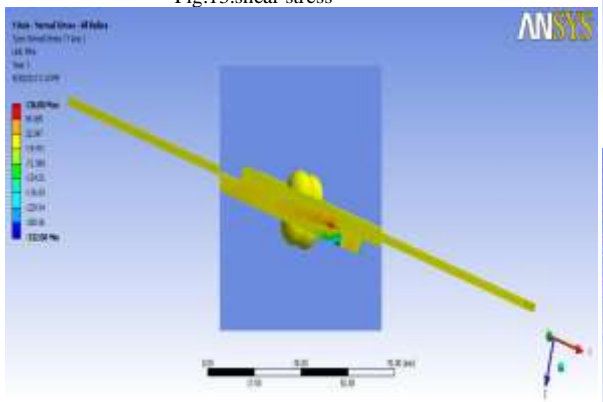


Fig.14.x -axis normal stress

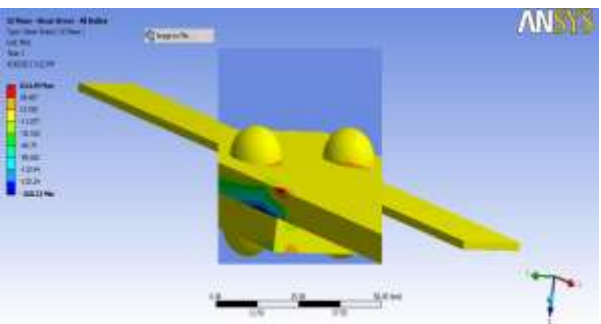


Fig .18. Shear stress

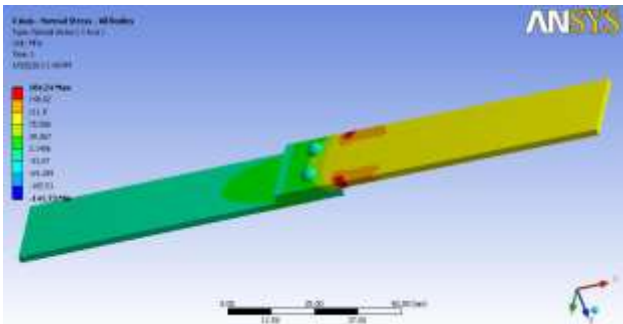


Fig.19.x-axis normal stress

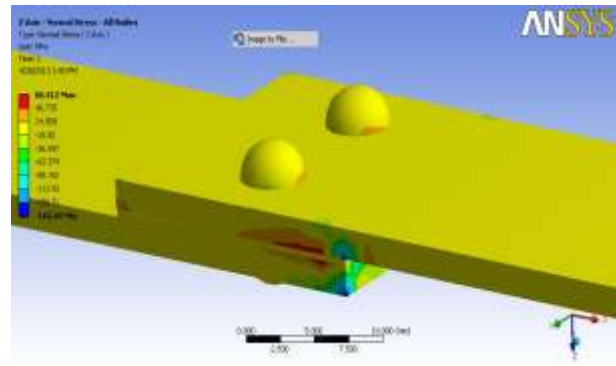


Fig.21.z-axis normal stress

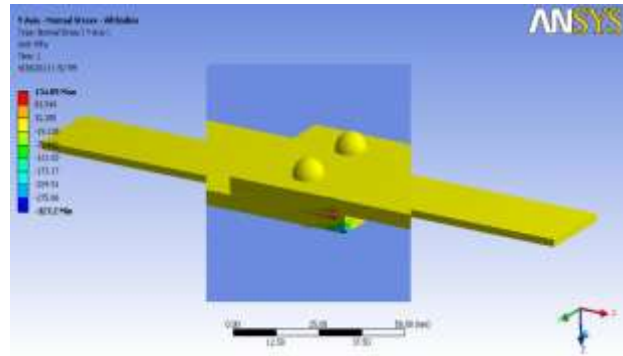
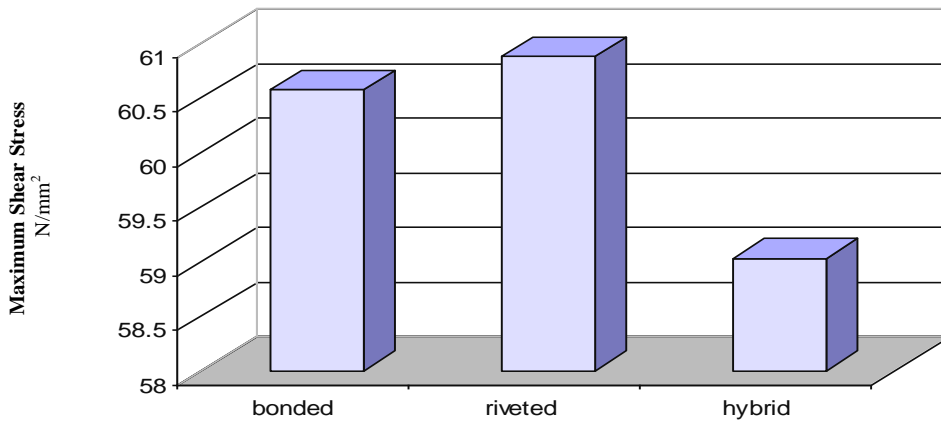


Fig .20.y-axis normal stress

The above diagrams shows the Comparison between bonded, riveted, hybrid joints, the stress was distributed throughout the laminate and the adhesive took up much of the load. Since applying load acts on the joint, whereas in riveted joint, the rivet head and the laminate surface take up stress compared to the interior of the laminate and the rivet shank. The case of hybrid joint is found to have a situation that is the stress values, total deformation are less when compared to bonded, riveted joints. So the hybrid joint is more efficient and also the hybrid joint with CFRP material the cost is less. The values of vonmises stress, shear stress, and normal stress are referred in the table (3) and graph (1) is shown below

Table Table 3: Stress Values

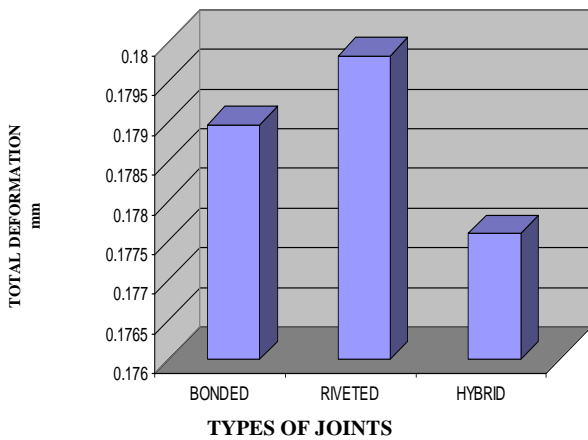
Types of joints	Vonmises stress	Shear stress	Normal stress in x-axis N/mm ²	Normal stress in y-axis N/mm ²	Normal stress in z-axis N/mm ²	Joint Deflection mm
Bonded	416	60.594	174.62	103	47.504	0.907
Riveted	443.66	60.872	176.66	117.99	62.167	0.92414
Hybrid	417.16	59.029	178.18	109.16	59.024	0.88748



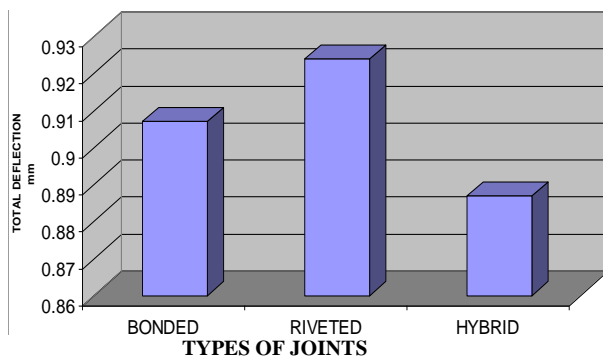
Graph.1.GFRP Composite

Table 4: stress values

types of joints	Vonmises stress N/mm ²	Shear stress N/mm ²	Normal stress in x-axis N/mm ²	Normal stress in y-axis N/mm ²	Normal stress in z-axis N/mm ²	Joint Deflection mm
Bonded	425.13	63.564	177.4	126.56	63.564	0.17896
Riveted	446.32	61.226	181.8	136.08	69.053	0.17983
hybrid	439.71	63.449	184.24	134.89	66.512	0.17759



Graph 2. GFRP composite total deflection



Graph 3. CFRP composite total deflection

6. Conclusion

In this analysis, FEA for the prediction of stress distribute on in bonded, riveted and hybrid joints have been carried out 3D models were created by using PROE (creoparametric) and analyzed using ANSYS workbench FEA software .shear stress was used to compared the results with three joining methods .The shear stress with hybrid joint has less value of stress and also the carbon fibre reinforced plastic is more strength than any other composite material. The stress induced by using ANSYS is less than the material ultimate stress and ultimate limit. The total deformation for both the materials in hybrid joint is less. It was found that a well designed hybrid joint is very efficient when compared to bonded, riveted joints in case of repair situation in aircraft fuselage panels ,structures etc.

Scope of future work

1. Increasing the efficiency of composite single-shear lap joints using bonded inserts.

2. CFRP with aluminium alloy plates can be tested in experimental.
3. CFRP with aluminium alloy plates can be tested in experimental and can find the strength and stress distribution with different composite materials.
4. The joint design can be made and optimization of riveted joint can be performed.
5. Stress and Failure Analysis Of Laminated Composite Pinned Joints can be performed.

References

- [4].
- [1] K.N. Anyfantis, N.G. Tsouvalis . Experimental Parametric Study of Single-Lap Adhesive Joints between Dissimilar Materials. ECCM15 - 15TH EUROPEAN CONFERENCE ON COMPOSITE MATERIALS, Venice, Italy, 24-28 June 2012.
- [2]. W.Hufenbach a, L.A.Dobrzański b, M.Gude a, J.Konieczny b, A.Czulak a, “Optimisation of the rivet joints of the CFRP composite material and aluminium alloy” Achievements in Materials and Manufacturing Engineering Volume 20 (2007).
- [3]. Hart-Smith, L.J. ‘Adhesive –bonded single lap joints’Nasa Report Cr-112236, Langely research Center, VA (1973).
- [4]. Paroissien Eric, Sartor Marc, Huet Jacques, “hybrid (bolted/bonded) joints applied to aeronautic parts: analytical one-dimensional models of a single lap Joint”, composite single-lap joints”, Composite Structures, Volume 69, Issue 1, 2005, pp.35-43.
- [5] k.mohammad bak, k .prasannavenkatesan, k.kalaichelvan,” parametric study of bonded, riveted, hybrid, journal of applied sciences 12(10):1058-1062,2012,issn 1812-5654.