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International Journal Of Modern Engineering Research (IJMER)

Design and Analysis of Bolted Joint in Composite Laminated

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Abstract: *In this work plate was designed for single and four bolted joint with two different materials such as mild steel and E-glass fiber. The aim of this work is to examine the distribution of tensile and crushing stress among the different bolts by changing material of plates and bolt. The bolted joints for mild steel plate and composite laminate were analyzed by using FEA. The result shows that tensile stress and crushing stress is less for composite laminate compare to mild steel .It is concluded that Weight reduction of structure is also achieved for e-glass fiber structure. The stress concentration was reduced in composite laminate bolted joints compare to mild steel so this will improve strength of structure.*

I. Introduction

Until early 1990s, the use of fiber-reinforced polymer (FRP) composites was almost limited to only aerospace and military applications. By the mid-1990s, civil engineers started to realize the advantages of such materials especially in the structural repair and rehabilitation of existing reinforced concrete bridges and buildings. In structural applications such as in aircraft, spacecraft and civil engineering structures, composite components are often fastened to other structural members by bolted joints. Since bolted joints require holes to be drilled in the structure, large stress concentration tends to develop round the hole, which can severely reduce the overall strength of the structure [4,14]. The introduction of composite materials in the automotive industry, places new demands on the materials and manufacturing processes in terms of cost, cycle time and automation. Manufacture and assembly of composite structures require knowledge of reliable joining techniques. Mechanical fastening is a common method used to join composite materials. Mechanically fastened joints commonly adopted in aerospace structures are characterized by tight tolerances on both the fasteners and on the machined holes. Joints are the potential weakest point in the structure in order to make useful structure. Consideration is given to the ways of joining the various components of the structure [10]. In structural application such as in aircraft, space craft and in civil engineering structures the components are often fasten to the structural members by bolted joints. Since bolted joint is to be required to drill hole in the structures, large stress concentration developed around the hole, which can reduce the overall strength of the structure. The usage of composite is increasing in aerospace and other engineering industries and the study of joining methods for composite materials became an important research area. The composite materials are widely used because they have high strength to weight ratio, good fatigue resistance and high damping properties. The main objective of the bolted joint is to transfer the applied load from one part of the joint structure to the other through the fastener element. However, the presence of bolt holes induces high stress concentration which has thus recognized to be a source of damage developed during fatigue loading.

The objective of this work is to determine the various types of stress induced in bolted joints by using ANSYS 14.5 and finally comparison is made between the metal plate and FRP plate with bolted joint.

II. Description of the Problem

Load sharing in mechanically fastened joint depends upon number, size and material of the bolt and stiffness of joining members. The problem associated with bolted joint is stress concentration. High stress concentration in mechanical joint reduces strength of the structure. Strength of the structure depends on strength of joint. So present work deals with analyzing various stresses induced in bolted joint made up of two different materials.

Aim and Scope of the Work

The aim of this work is to examine the distribution of tensile and crushing stress among the different bolts by changing material of plates and bolt and to increase the strength of joint by reducing the stress concentration.

2.1 What is Composite Material

A material composed of two or more constituents is called composite material. Composites consist of two or more materials or material phases that are combined to produce a material that has superior properties to those of its individual constituents. The constituents are combined at a macroscopic level and or not soluble in each other. The main difference between composite and an alloy are constituent materials which are insoluble in each other and the individual constituents retain those properties in the case of composites, whereas in alloys, constituent materials are soluble in each other and forms a new material which has different properties from their constituents.

Classification of Composites

- Polymer matrix composites.
- Metal matrix composites.
- Ceramic Matrix.

Material Properties

Table 5.1 : Properties of the E-Glass fiber and mild steel.

Properties	*Unit*	*E-glass fiber*	*Mild steel*
σ_t	Mpa	2050	350
σ_c	Mpa	5000	207
ρ	(kg/m^3)	2000.0	7845
υ	_	0.3	0.27
E	Gpa	72	190

- **Design of rectangular plate**
- **Design For Single Bolted Joint for E-Glassfiber material.**

Consider,

- Tensile Force for mild steel, σ_t = 175 MPa; (Text Book of R.S.Khurmi, Design of Bolted Joint)
- Tensile Force for E-Glass Fiber, σ_t = 1025 MPa;
- Crushing Force for Mild steel, σ_c = 207MPa
- Crushing Force for E-Glass fiber, σ_c =5000MP
- t = 4.16 mm; l =100mm
- Ultimate Tensile stress = 2050; Factor of safety = 2
- $(\sigma_t)_{theoretical} = \frac{Ultimate\ \ tensile\ \ stress}{Factor\ \ of\ \ safety}$
- Stress $(\sigma_t) = \frac{Force}{Area}$
- $F_t = (b \times t) \times (\sigma_t)_{theoretical}$
- $155 \times 10^3 = (37 \times 4.16) \times (\sigma_t)_{Cal.}$
- $(\sigma_t)_{Cal.}$ = 1007.016 Mpa
- $(\sigma_t)_{Cal.} < (\sigma_t)_{theoretical}$

"The obtained Dimensions are safe for the Design, so the Design is safe."

Consider the Crushing Stresses induced in Single Bolted Joint made of E-Glass Fiber,

- **Design calculations for four bolts:**
- Consider Tensile Force on Plate, for four bolted joint is
- $F_t = 620 \times 10^3$ kN
- $F_t = n \times (b \times t) \times (\sigma_t)_{theoretical}$
- $620 \times 10^3 = n \times 37 \times 4.16 \times 1025$
- n = 3.92
- i.e. n = 4
- Therefore, Four Bolts are required for this force.

For Four Bolts (n = 4)

- $620 \times 10^3 = 4 \times 37 \times 4.16 \times (\sigma_t)_{cal.}$
- $(\sigma_t)_{cal.}$ = 1007.01 MPa
- "Which is less than $(\sigma_t)_{theoretical}$. therefore, the Design is safe."

- Consider the Crushing Stresses induced in Single Bolted Joint made of Mild Steel, F_c = 27 kN
- $F_c = (d \times t) \times (\sigma_c)_{theoretical}$
- $27 \times 10^3 = (d \times 4.16) \times 207$
- d = 6.96 mm

let d = 8 mm

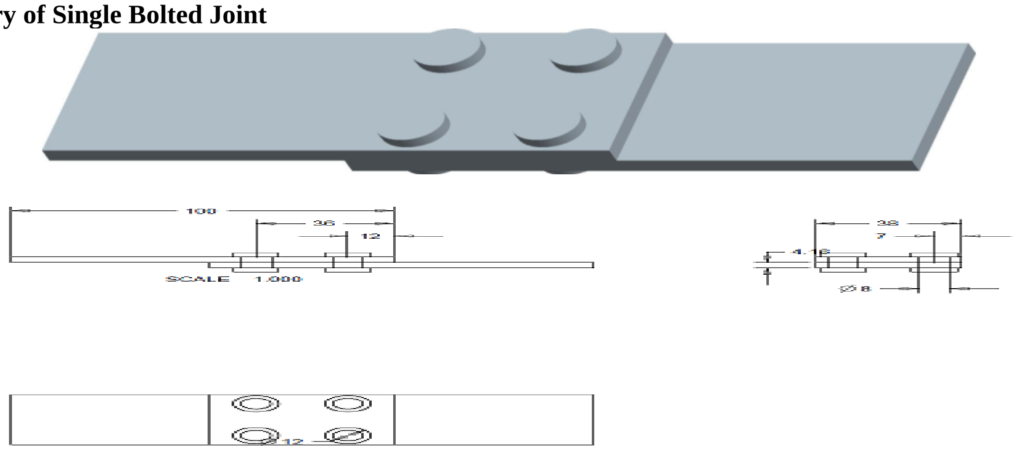
- Then,
- $27 \times 10^3 = (8 \times 4.16) \times (\sigma_c)_{Ca}$
- $(\sigma_c)_{Cal.}$ = 180.28 MPa
- $(\sigma_c)_{Cal.} < (\sigma_c)_{theoretical}$
- "The obtained Dimensions are safe for the Design, so the Design is safe."

Weight Calculation

- **I) For Composite laminate Plate:**
- Mass = Density x Volume
- = 2000 x l x b x t
- = 2000 x 0.100 x 0.037 x 0.00416
- = 0.03078 kg
- **II) For mild steel Plate:**
- Weight = M × g
- Mass = Density× Volume
- = 7845 x l x b x t
- = 7845 x 0.100 x 0.038 x 0.00416
- = 0.12401 kg

- **Weight Reduction %** $= \left(\frac{0.12401 - 0.03078}{0.12401}\right) \times 100$
- =75.17%

Geometry of Single Bolted Joint



FEA analysis of Bolted joint mild steel and E-glass Fiber:

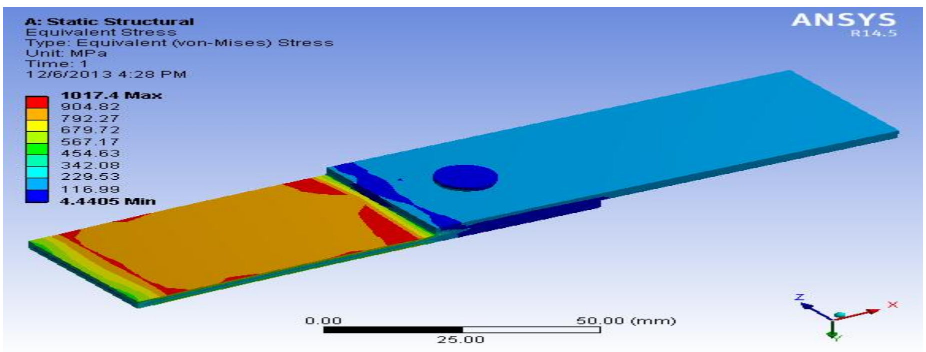


Fig : FEA analysis of single bolted joint in E-glass fiber

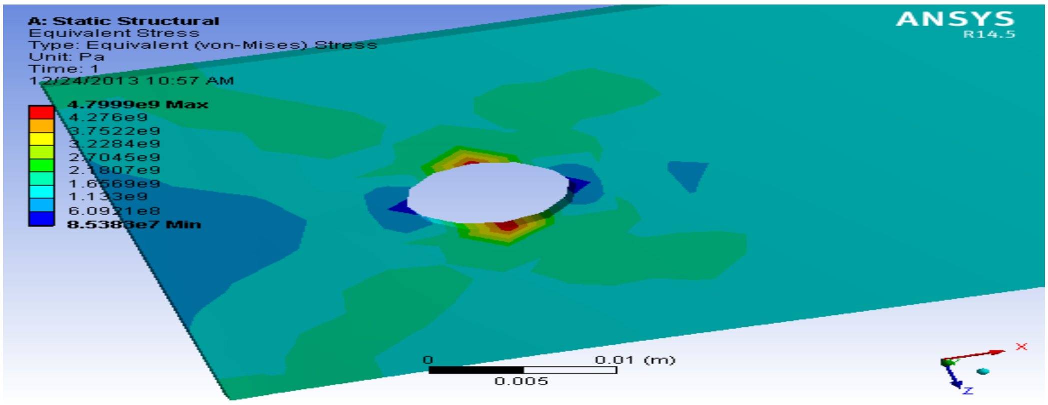


Fig. : FEA analysis of single bolted joint in E-glass fiber

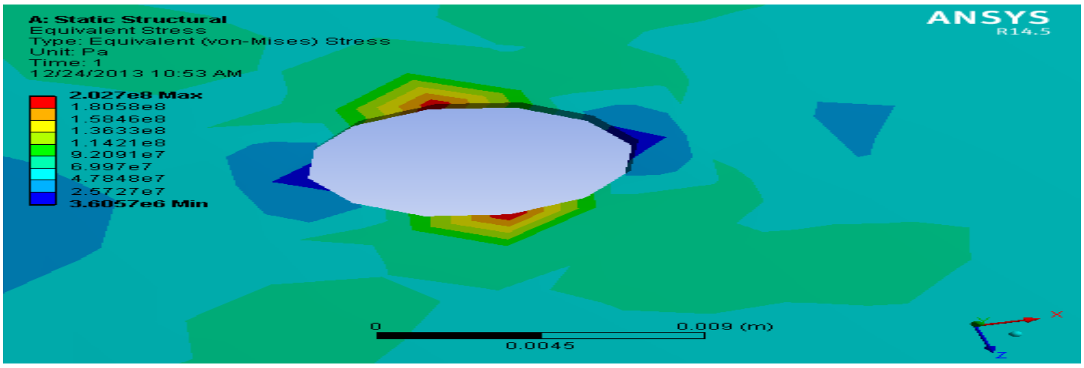


Fig. : FEA analysis of single bolted joint in mild steel

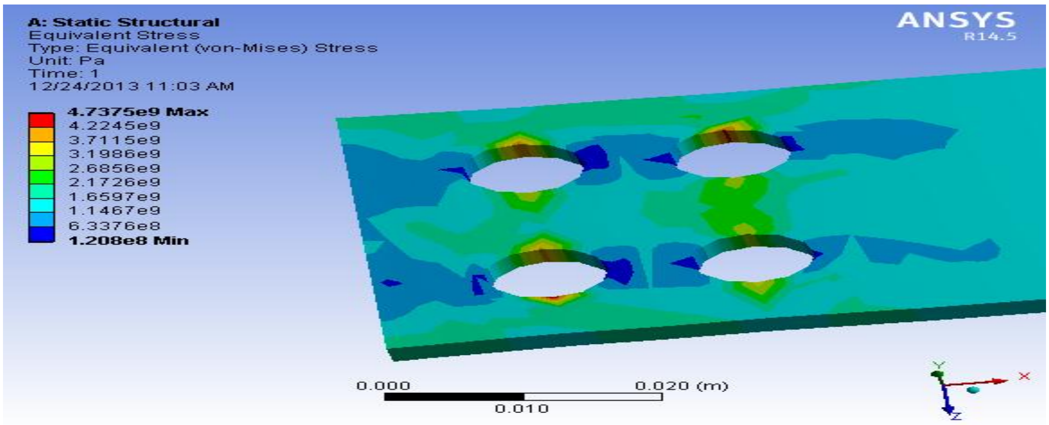


Fig. : FEA analysis of Four bolted joint in E-Glass Fiber steel

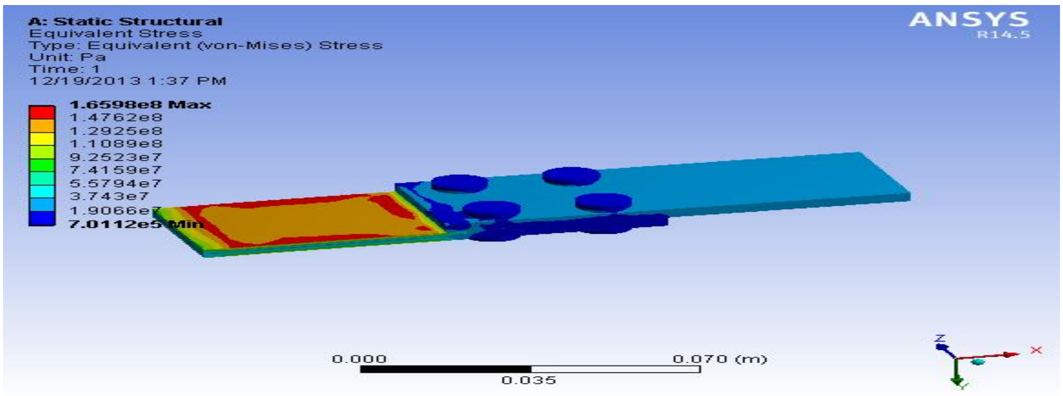


Fig. : FEA analysis of Four bolted joint in mild steel fiber

Comparison of Results

Table 8.1: Comparison of Results

NO. OF BOLTS	MATERIAL	ANALYTICAL RESULTS		FEA RESULTS		% DIFFERENCE	
		σ_t (tensile stress) MPa	σ_c (crushing Stress) MPa	σ_t (tensile stress) MPa	σ_c (crushing Stress) MPa	σ_t (tensile stress)	σ_c (crushing Stress)
Single bolted joint	E-glass fiber	1025	5000	1017.4	4799	0.741	3.28
	Mild steel	175	207	160.57	202.7	8.24	1.88
Four bolted joint	E-glass fiber	1025	5000	1069.2	4736	4.133	5.28
	Mild steel	175	207	165.20	198.3	5.6	4.202

III. Conclusion

- From the results obtained theoretically and by FEA, the difference in Tensile stress is not more than 8.24%.and for crushing stress is not more than 5.28%.
- The replacement of composite materials has resulted in considerable amount of weight reduction about 75% when compared to conventional mild steel plates.
- By using composite material there is substantial weight saving is about 75% than that of conventional mild steel plate.

Finally it is concluded that with the same geometry, plates with E-Glass Fiber have better strength. The life the joint is increased because of high resistance to corrosion, resistance to chemical attack, high stiffness to weight ratio and high strength to weight ratio of E-Glass fiber.

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