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Damage Analysis of Carbon / Glass Fiber Reinforced Composite Materials Connected with Bolt

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Abstract

In this study, carbon fiber and glass fiber composite materials with 0 ° tilt angle with holes in circular, square, and hexagonal profiles were assembled using resolvable connection methods. It was aimed to determine which profile structure was suitable for stress accumulation and load capacities in carbon fiber composite and glass fiber composite materials. Numerical and experimental studies have been carried out for this purpose. In experimental studies, samples of different profiles were subjected to tensile testing on the tensile tester after the connections were made. Numerical studies have used the ANSYS 14 finite element package program for the design of specimens of different profiles and for the application of tensile tests. By comparing the results of experimental and numerical studies, it was determined that the optimal profile structure is circular profile.

Key Words: Bolt Connection, Carbon Fiber Composite, Glass Fiber Composite, Finite Element Method, Tensile Test.

1. Introduction

Significant progress has been made in the methods used to produce composite materials with recent studies. These advances in particular have led to increased use of low weight and high strength fiber reinforced composite materials in vehicles where weight such as air and sea vehicles is important. Composite materials are used with different joining elements in construction and machinery manufacturing. Composite material connections are formed by unresolvable and resolvable connection methods. While bolts, pins, rivets are used as resolvable connection elements, adhesives are used as unresolvable connection elements. Depending on the type of coupling element used, the connection design has different mechanical properties.

They used the ABAQUS software to perform stress analysis to determine which of the circular and racetrack-like hole designs were more efficient when composite materials were combined. As a result, they found that the tension in the circular design was more advantageous than the design in the shape of a race track [1].

In this study, it was aimed to determine which profile structure was suitable for the accumulation of stresses in carbon fiber composite materials and glass fiber composite materials and for load capacities.

2. Material and Method

Under this title, experimental and numerical studies applied to carbon fiber composite materials and glass fiber composite materials are explained.

2.1. Experimental Studies

The carbon fiber composite materials and glass fiber composite materials used in this study has been commercially supplied as cut and drilled using CNC ROUTER bench according to figure 1.

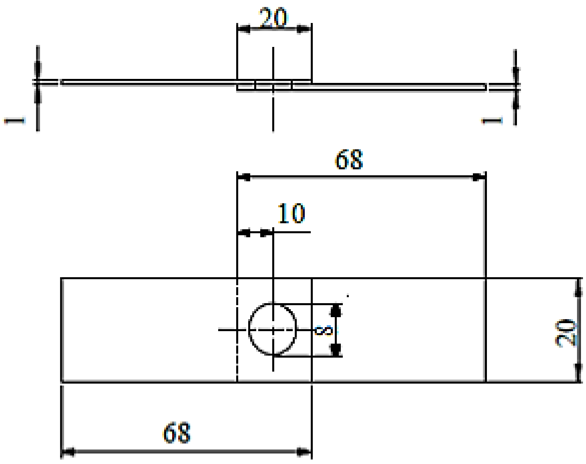


Figure1. Technical drawing used in connection design

The carbon fiber composite materials and glass fiber composite materials obtained in the desired dimensions has been given in figure 2.

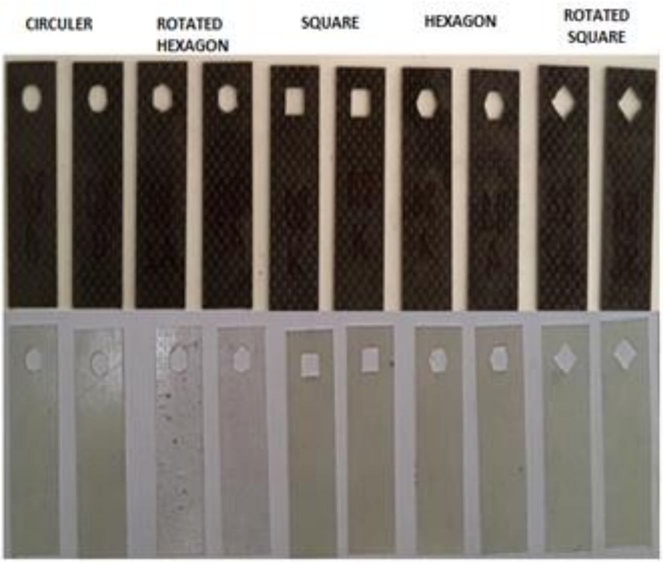


Figure 2. Combined carbon fiber composite materials and glass fiber composite materials

Fiber composite materials combined using bolts, nuts, washers has been given in figure 3.

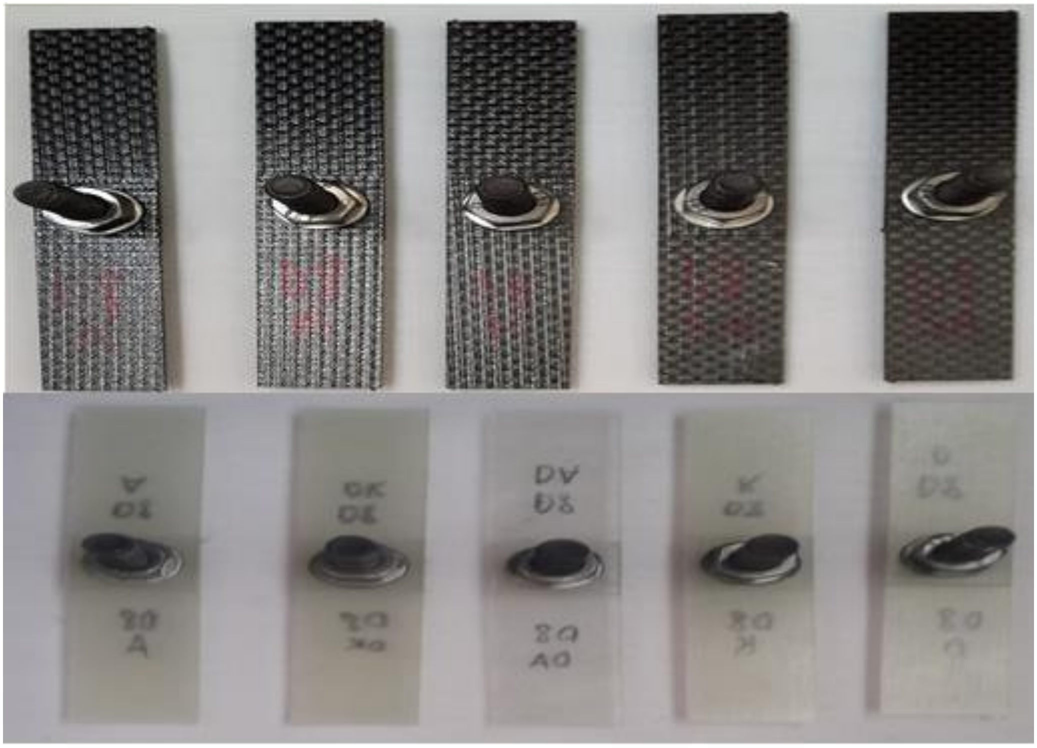


Figure 3. Carbon fiber composite materials and glass fiber composite materials joined together using bolts

At experimental studies were repeated three times for each sample using the Geratech SJV-30K Electric Motor Tester and SH-10K Dynamometer has given in figure 4,and the average value was considered to be the tensile strength. After the samples were fixed by connecting to the tensile testing device, the load applications has been done by setting the pull speed to be 60 mm / min.

Figure 4. The experimental setup and tensile testing device

Tensile tests were applied to the single-piece carbon fiber and glass fiber composite materials that 116 mm x 20 mm x 1 mm dimensions having 0^o and 90^o stacking angles given in figure 5.

Figure 5. Carbon fiber composite material and glass fiber composite material prepared for the determination of mechanical properties

The mechanical properties of the fibers obtained as a result of the tensile tests has given in table 1.

Table 1. Mechanical properties of composite materials

Material Type	E_1 (MPa)	E_2 (MPa)	E_3 (MPa)	v_{12}	v_{23}	v_{13}	G_{12} (MPa)	G_{23} (MPa)	G_{13} (MPa)
Carbon Fiber Composite	210035	19347	19347	0.2	0.2	0.2	6645.7	6645.7	6645.7
Glass Fiber Composite	47902	20395	20395	0.10	0.10	0.10	7812.9	7812.9	7812.9

2.2 Numerical Studies

In this section, designs were made using ANSYS 14 finite element program and force-elongation curves were obtained by applying the tensile forces obtained from experimental studies to these designs. Then, the tensile distributions in the direction of elongation were determined for the breaking force values. Using the results of stress analysis, it was tried to determine that will occur damage in which parts of the the connection. In stress analysis, square, circular, hexagonal, 45^o rotated square and 90^o rotated hexagonal profile samples were used that finite element models was given in figure 6. The separation sensitivity to elements has been increased in the lap region. The solid 186 element type was selected for bonded carbon fiber materials and glass fiber materials.

The boundary conditions used in the stress analysis were given in figure 7 [2].

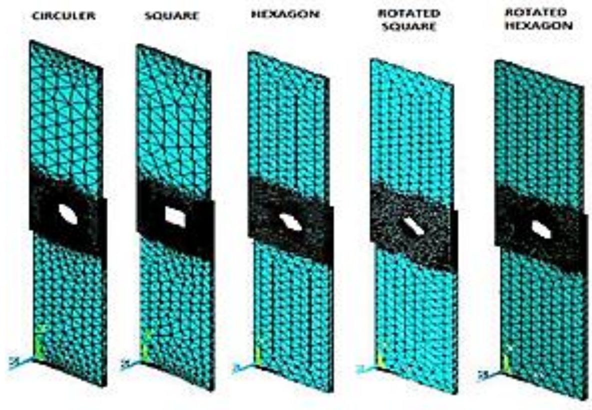


Figure 6. Finite element models of links

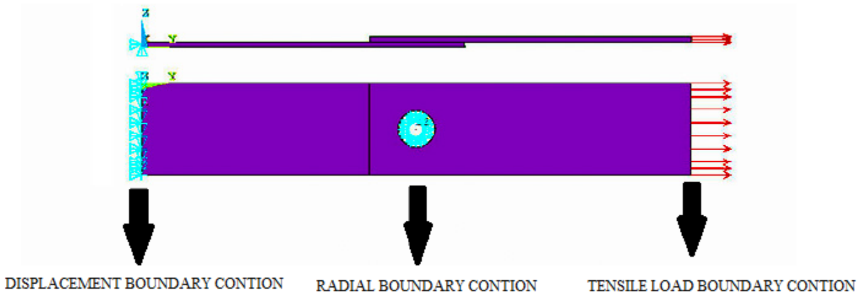
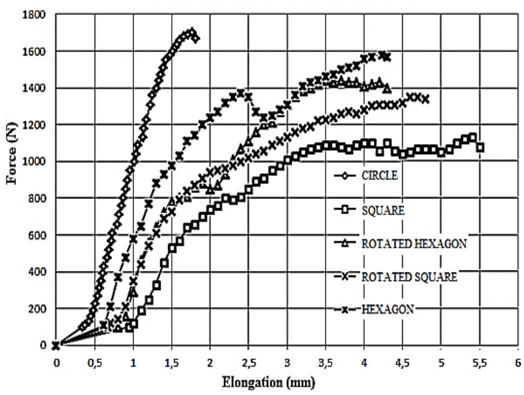


Figure 7. Boundary conditions used

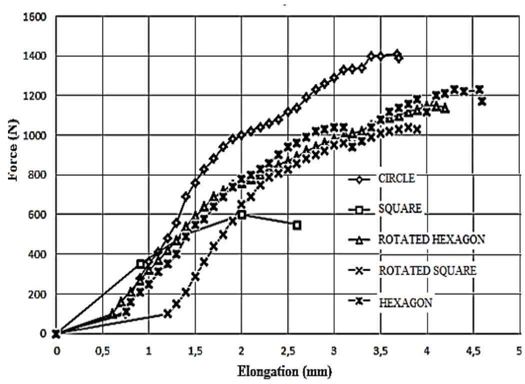
At the tensile load boundary condition, the breaking forces obtained in the experimental works were used and the tensile analyzes in the direction of the tensile force were obtained. It was accepted that there were no displacement in each case with the displacement boundary condition. Models were created by using radial boundary conditions in bolt designs while stress analyzes were performed, and assuming no displacements in the holes on the connections. It was assumed that damage occurs at the point where the stress intensity was maximum.

3. RESULTS

As a result of the experimental studies, the force-elongation curves in figure 8 were obtained.



a)



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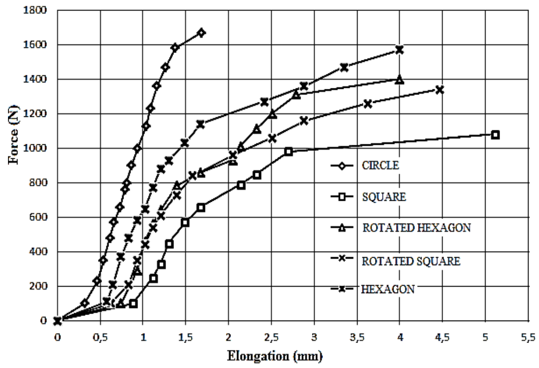

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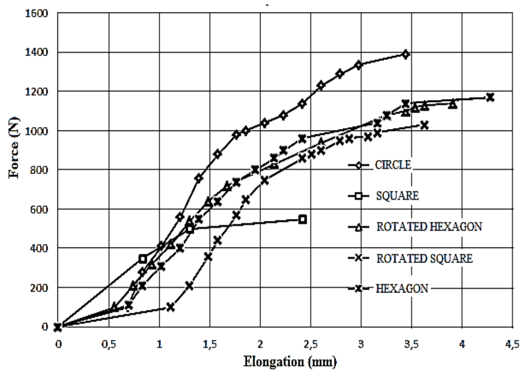


d)

Figure 8. Force- Elongations curves; a) Experimental study results of carbon fiber composite materials, b) Experimental study results of glass fiber composite materials, c) Numerical study results of carbon fiber composite materials, d) Numerical study results of glass fiber composite materials

According to the force-elongation graphs shown in figure 8 while the highest strength connection was a circular carbon fiber composite damaged at 1670 N, the lowest strength connection is determined as a square glass fiber composite damaged at 550 N. In figure 9 was given incurred damages as a result the experimental studies for circular carbon fiber composite and glass fiber composite connections that was the highest strength.

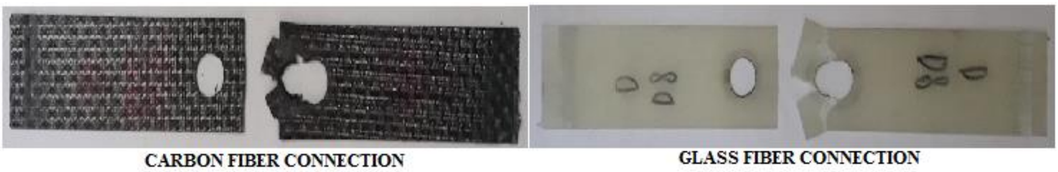
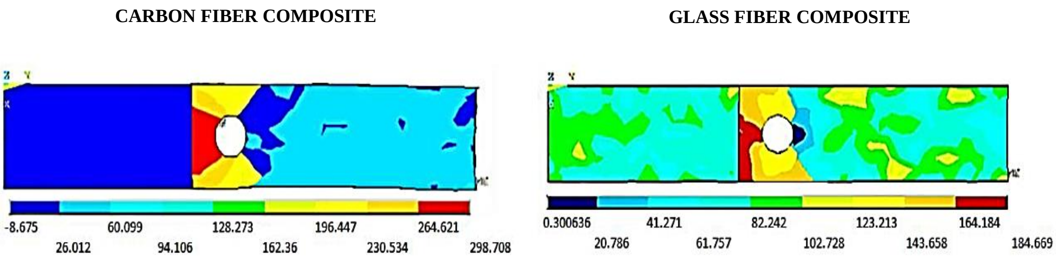


Figure 9. Damage detected during experimental operation

While the circular carbon fiber composite connection shown in figure 9 damaged from the composite material at 1670 N, the circular glass fiber composite connection was damaged from the composite material at 1390 N. In figure 10 were given determined stress distributions, which circular carbon fiber composite and glass fiber composite connections that is the highest strength as a result at numerical studies.



While the maximum tension in the circular carbon fiber composite connection shown in figure 10 was determined to be 298.708 MPa, the maximum tension in the circular glass fiber composite connection it was determined to be 184.669 MPa. It has been determined that maximum stresses were formed in the composite materials.

4. CONCLUSIONS

As a result of experimental and numerical studies, the highest strength connection was determined as a circular carbon fiber composite, while the lowest strength connection was determined as a square glass fiber composite.

5. ACKNOWLEDGMENT

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6. RESOURCES

[1] Yadong Zhou, Qingguo Fei, Jiayue Tao. , *Profile design of loaded pins in composite single lap joints: From circular to non-circular*, 2016, **6**, 471- 480.

[2] Aktaş, A. *Bearing strength of carbon epoxy laminates under static and dynamic loading, Composite Structures*, 2005, **67**, ,485-489.