Failure analysis on hybrid fiber reinforced plastics for bolted joint under geometric parameters effect

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ABSTRACT – In this study, glass fiber and kenaf reinforced thermoplastic hybrid composite were fabricated using compression method. The composite is layout in sandwich structure. Woven glass fiber is sandwiched in between woven kenaf fiber with polypropylene matrix. The nominal thickness of the composite is 3mm. Bolted joint test was conducted according to ASTM D5961 using Universal testing machine. The results confirm geometric parameters affect the failure mode.

1. INTRODUCTION

Composite materials are frequently used in advanced engineering fields such as in aerospace, leisure, automotive, construction and sporting industries. Composite materials have wide application because of their high specific strength and modulus [1,2]. The objective of a composite is to make a component strong and stiff with low density. Thermoplastics are more preferable than thermosetting since they are moldable after initial process whereas thermosetting polymers are permanent and irreversible after solidify. Recently, natural fibers have become a hot topic in composite materials. The advantages of natural fibers are low cost, low density, comparable specific tensile properties, recyclability and bio-degradable, etc. [3]. The application of lightweight, low-cost natural fibers provides the potential to replace a large segment of the glass and mineral fillers in automotive industries [4].

Mechanically fastened joints are frequent and critical elements in composite structure such as aircraft structures. It is important to design the joint properly because if an improper design is used, it may lead to overweight or defective structures. A bolted joint is engaged to hold two or more parts together to form an assembly in a mechanical structure. Since most composite materials display a brittle failure, with little or no margin of safety through ductility, the mechanism of the brittle failure propagation in bolted joint must be fully known [5].

The stress distribution around the hole in the bolted joints is a perplexing phenomenon. The stress distribution is strongly affected by the geometric parameters, clamping force, stacking sequences, and clearance between the hole and the pin. A large part of the research that has been carried out on bearing strengths had showed that the failure mode is dependent on the width-to-diameter (W/D) and edge distance-to-diameter (E/D) ratios [6]. There are 4 types of common failure modes in bolted composite plates which are cleavage, net-tension, shear-out and bearing.

The present study will investigate the failure analysis of the bolted joint under geometric parameters with a ratio of 3 and 6 on W/D and E/D parameter on glass fiber-kenaf hybrid composite.

2. METHODOLOGY

A custom stainless steel jig is fabricated in order to conduct the bolted joint test. The function of jig is to hold the specimen through the bolt connected to the jig. Figure 1 shows the jig.

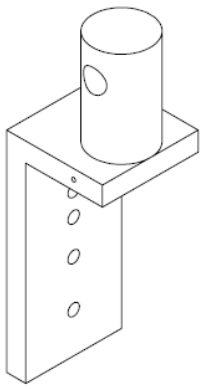

Figure 1 Jig for bolted joint test.

Kenaf and glass fibers are used as reinforcement fibers while PP for the polymer matrix. The layout of the composite structure is sandwich structure, where glass fiber is the central component of the sandwich structure, in between of two woven kenaf layer. A 3mm thick picture frame was used when fabricating the composite in order to get a final nominal composite thickness of 3 mm. The temperature for the compression molding process is 180˚C with a pressure of 30 psi.

The composites were cut into appropriate specimen dimension based on ASTM D5961 as shown in Figure 2. The length of the specimen, L = 135 mm. Table 1 shows the specimen dimension ratio used for the test.

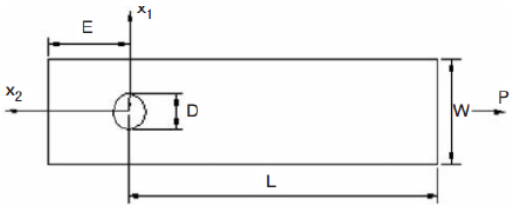

Figure 2 Specimen geometry.

Table 1 Dimension ratio.

D(mm)	E/D	W/D
6.0	3,4,5,6	3,4,5,6

Universal testing machine INSTRON 5969 is used to perform bolted joint test according to ASTM D5961. Three test were conducted for each ratio to obtain the average. The specimen is loaded until a maximum force is reached and force dropped off about 30% from the maximum force. The test is then terminated after the force reached the 30% of the maximum force so the failure mode can be observed.

3. RESULTS AND DISCUSSION

Bolted joint tests were conducted and average maximum load values were computed. According to the test result, some specimens break away suddenly. This failure mode is called net-tension. For a number of specimens, the load then increases with rising damage and reaches the ultimate point. Then, the load decreases with rising damage. However, the specimen continues to hold up loading. This failure mode is called bearing. Net-tension failure occurs to specimen with W/D ratio below than 5 whereas specimen with W/D ratio higher than 4 will experience bearing failure. Figure 3 shows the two extreme results from the test.

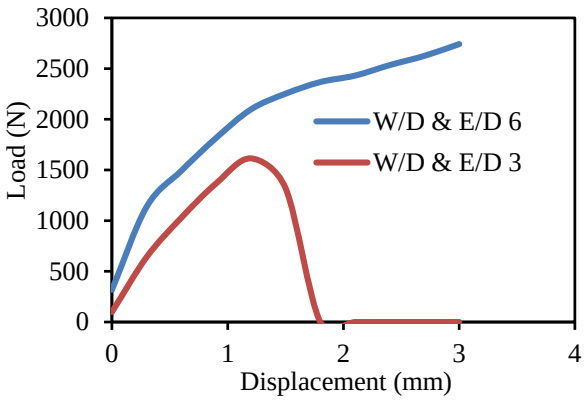

Figure 3 Loads versus displacement graph.

4. CONCLUSION

According to the experimental results, the failure modes of the bolted joint have been investigated experimentally. The effects of changing the geometric parameters were observed. According to the experimental study results, it can be concluded that when W/D ratio is equal and below 4, net-tension failure will occur whereas bearing failure will occur when W/D ratio is equal or more than 5.

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