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STRENGTH OF COMPOSITES HYBRID JOINT

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ABSTRACT

The strength of composites hybrid adhesive joint consisting of mechanical fastening with similar and dissimilar materials (aluminium/composites) of adherends was investigated. This paper is concerned with a static study to identify the mechanical property of GFRP composites and determine the optimum overlap length. The adhesive used was high performance Araldite Epoxy type. The results are presented in the form of volume fraction test and also in the form of stress versus strain to predict the strength performance. It is found that the aluminium hybrid joint shows the greatest in failure load when compared to others.

Keywords: hybrid joint, mechanical fastening, aluminium and composites, shear stress, shear strain

INTRODUCTION

Over years and years of testing and researching, there are many types of material that have been used by the automotive and aeronautical industries previously which are metal alloys, titanium, aluminium, plastic steel, stainless steel, rubber and etc. [1,2]. Besides that, with the improvement of technology nowadays, a material with a lower price, high in properties and light in weight is used in automotive and aerospace industry. Fibre reinforced polymers (FRPs) is increasingly being widely used in the manufacturing industry along with the current needs and modernity since it is a lightweight material with high strength to mass ratio [3]. Hybrid joining is a method that involves a combination of adhesive and mechanical fastener (i.e. riveted, screwed etc.) which is the better way of structure joining and it enhances the individual effects of each kind of joint [4-6]. In mechanical fastening, the fasteners themselves are an important source of weight increase.

One example of hybrid adhesive joint as shown in Figure-1 is single-lap joint using Huck bolt. Through the research, in this paper, the effect of Huck bolt attachment on the joint with the adhesive of epoxy is studied by testing the hybrid joint of both combination.

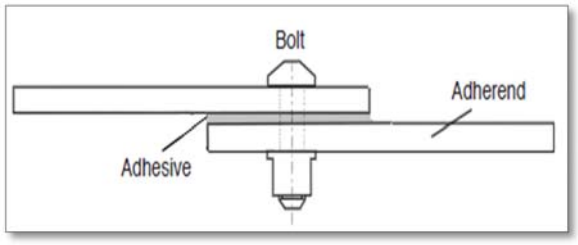


Figure-1. Single-lap of hybrid joint.

LITERATURE REVIEW

Hybrid joint is formed by adhesive and mechanical fastener. With the help of the mechanical fasteners together with adhesive, the strength of the hybrid joint will become higher if compared to an adhesive joint [7]. There are some parameters need to be concerned in the hybrid joint which are the overlap length of adhesive, adhesive bond thickness, and used of mechanical fastener which is Huck bolt chosen as design parameters [8]. Overlap length is one of the important parameters in single lap adhesive joint which will influence the failure at adhesive layer or adherent. The increasing of the overlap length will cause the average shear stress and the displacement of the adherents' decrease [9]. Hence, it will cause failure on adherents but not adhesive. In other research parameters, dissimilar adherend material of Dual Phase (DP800) and Micro-Alloy (HSLA 320) steel had been conducted by Bartosz application in car body structures as a bonding part. In this study, the influence parameters of overlap length (i.e. c=15mm, 25mm, 35mm and 45mm) were analyzed by tensile, destructive and finite element analysis and found that as the length of overlap is increased, the value of stress is lower. Hence, it is stated that different sheet thickness in a single-lap joint leads to greater stress concentration in the vicinity of the layer edge with smaller rigidity [10].

Study of hybrid joint method has been done by several experts. A lot of methodology approaches and analytical method were proposed by those experts to test the hybrid joints [9]. The methodology approaches that the experts study included shear stress force. From the methodology approaches, some of the experts tested the strength of hybrid joint by combination of dissimilar materials, while some tested in different kind of combination of adhesive and mechanical fastener. Glass fiber reinforced polymer composites (GFRP) is the most common reinforced plastic material that used in not only

construction industry but also automotive and aeronautical industrial. The tensile strength of the GFRP composites will be affected by the types of glass fibre, thickness of sheets and resin content. Method that uses to produce the GFRP composites will also affect the result of the tensile strength upon the GFRP composites [11]. There are some common fiber glass types which are chopped strands and roving, woven roving, continuous roving and so on. The methods used for the production of GFRP composites are commonly known as spray lay-up, hand lay-up, continuous lamination, and pultrusion [12]. Table-1 shows the relation between the different orientations and tensile strength of GFRP composites. Huck bolt is one of the mechanical fasteners that is used to combine the hybrid joint in aerospace industries. It has high tensile and shear strength compare to other mechanical fastener. The advantages of using a Huck bolt are high vibration resistant and it will not loosen easily when strong vibration occurs. It is also quick and easy to install [13].

For hybrid joining method, the overlap length will influence the strength of the adhesive. Therefore, the overlap length must be determined in advance to prevent yielding beyond the metal properties during test.

Table-1 . Different orientations and tensile strength of GFRP composites.

Orientation	**Tensile strength** (Psi)	**Tensile strength** (MPa)
Orientation A	15007.5641	103.4719
Orientation B	5101.1753	35.1708
Orientation C	10977.9295	75.6889

The allowable overlap length can be determined as Eqn. (1) below [14]:

$$L = \sigma_y t/\tau \quad (1)$$

where

L = overlap length, mm

t = metal thickness, mm

σ_y = metal yield point (or stress at proportional limit), MPa

τ = 50 per cent of the estimated average shear strength in adhesive bond,MPa.

Adhesive bond thickness is one of mainly considered parameters in destructive test of a hybrid joint. Based on some researchers findings, increasing of adhesive bond thickness will increasing the strength of the joint [15], while some have reported that no affect observed with increasing of adhesive thickness [16, 17] or even a decrease in strength was reported [18, 19]. In some research, strength of the composite hybrid joint will be tested by using different method. The usually methods that conducted by the experts are Finite Element analysis (FEA) and Experiment analysis. FEA is used by using ANSYS software [20]. For experiment analysis, there are a lot tests that have been conducted by the researchers to evaluate the strength of the hybrid adhesive joint. A tensile application is one of the tests which include a general formula to test the strength of the hybrid joint which is commonly shear stress. Burn-off test is commonly a test that uses to determine the fiber volume fraction of the fabricated panels. This test is able to ensure the consistent percentage of fiber laminate and epoxy in an adherent [21]. The volume fraction of fabricated panels can be determined by using Equation (2):

$$Vf = Mf/Mi \times 100 \times \rho c/\rho f \quad (2)$$

where

Mi = initial mass of the specimen

Mf = final mass of the left over specimen after combustion

ρc = density of the specimen

ρf = density of in the fiber reinforcement

METHODOLOGY

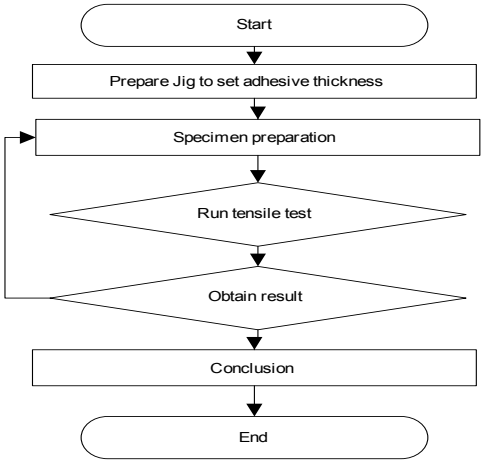


Figure-2. Research methodology flow chart.

From Figure-2, it illustrates the research flow chart that was carried out through the experiment. The aluminium A-7075 and GFRP composites material were chosen to be the adherent for the hybrid joint. The dimensions of both adherents are 160 mm of length, 40

mm of width and 3 mm of thickness according to ASTM standard. The mechanical properties of both adherents are tabulated in Table-2. The jig was used to confirm that the adhesive was equally dispersed along the overlap length of the specimens. The adhesive thickness was set to be 0.2 mm and black thermos was chosen as the jig with the dimension is set to be 320 mm lengths, 296 mm width and 20mm thickness. The completed jig is shown in Figure-3.

Table-2. Mechanical properties of stainless steel and aluminium.

Material	**Ultimate tensile strength** (MPa)	**Yield strength** (MPa)
Aluminium (A7075)	276	145
Fibre Glass composites, GFRP	52	52

Figure-3. Completed jig for 0.2 mm adhesive thickness.

The tensile properties were obtained using an electro- mechanical Instron Universal Testing machine where three sets of hybrid joints were tested as shown in Figure-4, 5 and 6. After that, Huck C6L lock bolt and collar with the material of steel with zinc were attached at the center of the joint through a hole drill of 6.4mm.

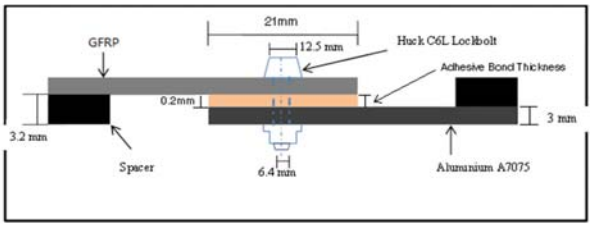


Figure-4. Set 1 of hybrid joint setup for tensile test.

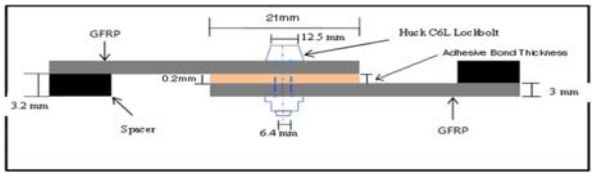


Figure-5. Set 2 of hybrid joint setup for tensile test.

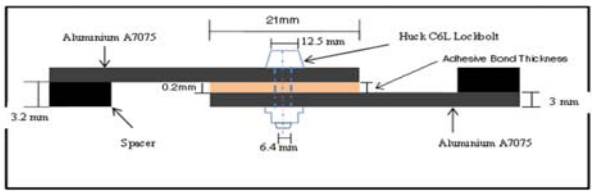


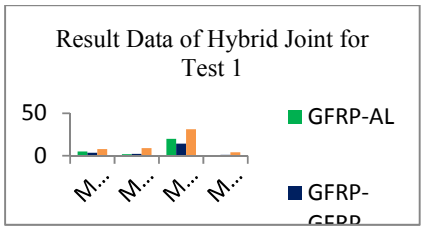
Figure-6. Set 3 of hybrid joint setup for tensile test.

RESULTS AND DISCUSSIONS

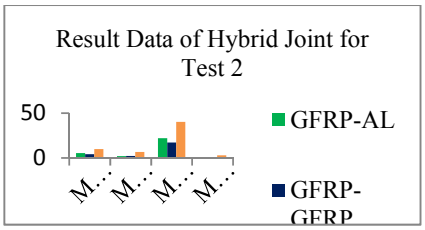
All the specimens prepared undergoes tensile test to predict the strength performance of each hybrid joint with similar and dissimilar material. In addition, optimum overlap length is calculated using Equation (1) with the value of tensile strength obtained from tensile test and the result is equals to 21mm. GFRP composites also undergoes the volume fraction test with the thickness of 3mm was calculated using Equation (2) and the result obtained, *Vf* equals to 43.41%.

Tensile test result for hybrid joint

The results data of hybrid joint with similar and dissimilar material is shown in Figure-7. Based on the results, for dissimilar material of hybrid joint (GFRP-Al) in Figure-8, the result shows the maximum stress is 19.72 MPa with the strain of 0.82% in test 1 and maximum stress of 22.19 MPa with the strain of 1.04 % in test 2. Continued with the test, the results obtained from similar hybrid joint (GFRP-GFRP) in Figure-9, the maximum stress is 14.13 MPa with the strain of 0.93 % in test 1 and maximum stress of 17.24 MPa with the strain of 1.08% in test 2. Meanwhile, (Al-Al) hybrid joint shown in Figure-10 obtain the results of the maximum stress is 31.10 MPa with the strain of 4.09 % in test 1. While for test 2, the maximum stress is 40.32 MPa with the strain of 3.10 %. Therefore, the average maximum stress for test 1 is 21.65 Mpa and for the test 2 is 26.58 Mpa. The location of failure for the (GFRP-Al) hybrid joint damage at the adherent and it is known as structural failure and this similar phenomenon also occurred at the (GFRP-GFRP) hybrid joint. In contrast, the specimen failed at the adhesive and adherent when the similar joint of metal (Al-Al) was attached together and this is known as adhesion and structural failure.



Result for test 1



Result for test 2

Figure-7. Result data of hybrid joint with similar and dissimilar material.

Figure-8. Location of failure for test 1 of GFRP-Al hybrid joint.

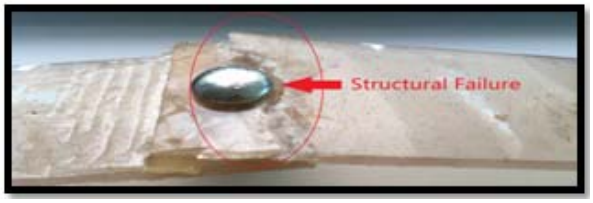


Figure-9. Location of failure for test 1 of GFRP-GFRP hybrid joint.

Figure-10. Location of failure for test 1 of Al-Al hybrid joint.

A. Comparison of tensile test results between similar and dissimilar material of hybrid joint

In Figure-11, it shows the comparison of similar and dissimilar material of hybrid joint which explained as the strain increase, the percentage of strain increase as well. This graph clearly shows that the strain for (Al-Al) hybrid joint is in between 3 % to 5 %, greater than (GFRP-GFRP) hybrid joint and (GFRRP-Al) hybrid joint once it fails. The value for average maximum stress against average maximum strain is plotted as shown in Figure-12.

The results shows that the average maximum stress of Al-Al hybrid joint is greater than GFRP-GFRP hybrid joint as well as GFRP-Al hybrid joint. While, the average maximum stress of GFRP-Al hybrid joint is greater than GFRP-GFRP hybrid joint. The average maximum stress for Al-Al hybrid joint, GFRP-GFRP hybrid joint and GFRP-Al hybrid joint are 35.7107 MPa, 15.68 MPa and 20.96 MPa respectively. Overall, the strength of aluminium hybrid joint is higher than the GFRP composite hybrid and aluminium-GFRP composite hybrid joint as may referred in Figure-13.

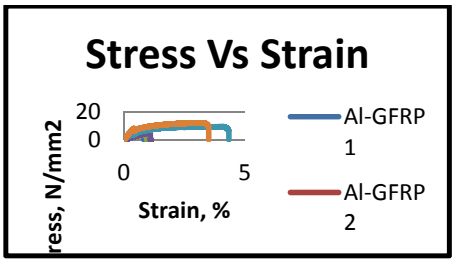


Figure-11. Comparison of similar and dissimilar material of hybrid joint.

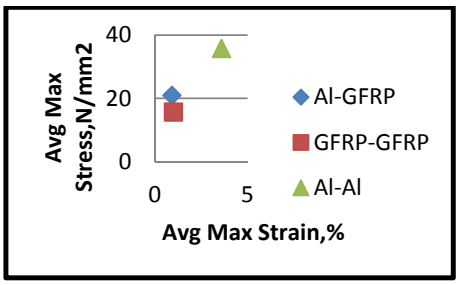


Figure-12. Graph for average maximum stress against average maximum strain.

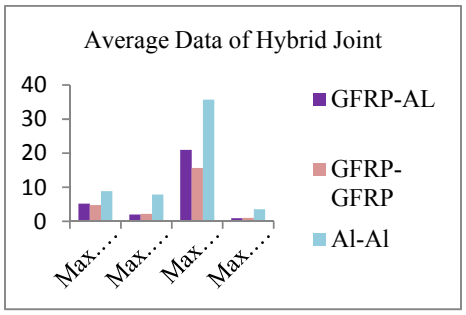


Figure-13. Average data of similar and dissimilar material hybrid joint.

CONCLUSIONS

The tensile test result from both similar and dissimilar materials of hybrid joint were successfully conducted. The tensile testing procedures for hybrid joint follow the standard of ASTM D1002, while the tensile testing procedures for GFRP composites adherent follow the standard of ASTM D3039. The mechanical properties of GFRP composites adherent is obtained with the tensile test. The ultimate strength for the composites is 52 MPa. The optimum overlap length for the hybrid joint was determined, as 21 mm. The results of tensile test for the hybrid joint shows that the hybrid joint with the material of aluminium A7075 has the greatest strength if compared to the other. With the results shown, the GFRP composites hybrid joint relatively low in strength compared to aluminium A7075 hybrid joint.

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