

TENSILE BEHAVIOR OF SINGLE ELBOW ASSEMBLY WITH RIVETS ORIENTATION ON JUTE/EPOXY COMPOSITE

I.G.L Aditya Pradnyana¹, I.G.K Dwijana¹, I.K Adi Atmika¹, I.D.G Ary Subagia^{1*}

¹P.S Teknik Mesin, Fakultas Teknik, Universitas Udayana, Bukit Jimbaran-Badung (80361) Bali

*E-mail: arsubmt@unud.ac.id

Accepted: 24-05-2021

Revised: 27-09-2021

Approved: 01-12-2021

ABSTRACT

This experiment's purpose is to investigate the tension strength of the elbow joint with the variation of rivets position. The Joining was made based on jute woven fabric reinforced composite epoxy. The vacuum-assisted resin transfer molding process was employed to manufacture composites. In this joint two rivets were used in three orientations of positions such as diagonal (D), Vertical (V), and horizontal (H). In order to investigate the properties of a sample, the tensile loading was carried out. Then, the failure of samples based on the photographic method has analyzed. The test result shows that the tensile strength of joints with D orientation has the highest value compared with rivets on orientation V and H are 3.329 MPa, 2.946 MPa, dan 2.737 MPa, respectively. Additionally, the shear stress value of each rivets orientation on tangential states have D = 59.49 N/mm², V = 47.46 N/mm², and H = 45.35 N/mm², respectively. It can be concluded that the rivet state orientation becomes an important factor for the tension strength of the tangential joint of the composites.

Keywords: composite; elbow joint; jute fiber; rivet; tangential load; tensile test.

1. INTRODUCTION

Fiber reinforcement polymer (FRP) composites have been widely applied to engineering products such as structural elements of vehicles, aircraft, railways, and other engineering products [1, 2] in recent years. The advantages of composite materials are excellent in mechanical properties, also physically superior such as lightweight, corrosion resistant and biodegradable [3]. These advances promote composite materials that can replace metals in engineering products [4]. Another advantage of composite is a man-made material that can be produced intact according to design purposes, so its joint can be ignored. However, product engineering needs connecting continue to be employed in structures. Meanwhile, many damages occurred in the machining process of

the composites due to its material is brittleness, consequently, it will dangerous because of can fracture without warning.

Technically, the joining of material is very important conducted to add dimension, length, and size of materials. In splicing of material can be divided into three types such as adhesive, mechanics like rivet and bolt method, and combination splicing [2, 5]. Technically, all splicing techniques are very possible to do on the material assembly. However, connection using adhesive to be weak due to stress concentration on edges of joint occurred. Also, it cannot be easily disassembled [6]. In addition, the welding technique splicing has wide employed and it became a good technique in the assembly of material, however, welding splicing is relatively expensive due to in application the process needed electricity to support that process. Also,

the welding just only can be done by an expert operator [7]. Meanwhile, mechanic splicing is consists of rivets and bolt joints that have widely employed in the assembly of materials. A riveted joint is commonly used for connecting thin material because it has advantages in dimension and is easy to disassemble. But, the rivet joint is not strong splicing, because in the area of rivet hole there are often crack and also between the rivet body and whole area be source the shear stress which is become disadvantages [8]. In this regard, it is necessary to understand some parameters on the rivet connection such as pitch (p) shows a distance between the two centers of the rivet, back pitch (pb) is indicates the shortest distance between two consecutive rows in the connection. Then, the diagonal pitch (pd) is shown the distance between the centers of rivets in adjacent zigzag rows in a single row. While margin (m) exhibits the distance between the centers of the nail hole to the edge of the nearest plate.

In the last decades, several studies for rivet joint have been conducted. Several researchers have experimented on the mechanical properties of rivets. As a result of their studies is obtaining that the orientation of rivet position has reduced residual stress on the area splicing of metal materials [9]. Then, splicing the stacking using rivets shows that the bond becomes very strong. This is due to a balanced distribution of strength so that the life of the connection becomes long-lived [10]. Then, splicing with rivets for FRP-type composite materials is highly dependent on the quality of rivet holes, and construction of the composite, as well as the composite forming base material [11]. Based on the above research, the splicing of jute fiber-based composites with variations in the orientation of rivet positions on single-lap elbow joints is very interesting to research, because not much research has been done with models and composite materials.

In order to obtain the research target, three orientations of rivets were employed on the composite joints such as horizontal (H), Vertical (V), and diagonal (D) position. The research aim is to investigate the effect of rivet position orientation on composite material structures against tension loads. An ultimate tension machine (UTM) was used to test joints tension properties according to the ASTM 3039 standard. Afterward, a photomicrography was done to analyze their damages after the testing.

2. METHODS

In this work, an experimental method was carried out to examine the properties of composites in elbow joint mode using orientation rivets position bonded. The composite was produced based on the reinforcement fiber epoxy matrix. In addition, three orientation positions of rivets were employed on joining mode such as horizontal, vertical, and diagonal directions. The structure has applied two rivets for each splicing mode. In this experiment, the result is exhibited on tensile strength, Young's Modulus, displacement, and shear stress of tensile.

Natural fiber such as jute woven fabric has been employed as the main reinforcement of composites. Jute fiber was sourced from the tree skin of *Corchorus capillaries* and *Corchorus olitorius* as shown in Figure 1. Where, jute fiber is consists of cellulose 71%, lignin 13%, hemicellulose 13%, pectin 0,2%, as well 2,3% for substances that are soluble in water, also wax 0,5%..

In addition, thermosetting polymer class that is epoxy *Bisphenol A-Epichlorohydrin* (EPR-174) and hardener Cycloaliphatic Amine (EPH-555), distributed by PT. Justus Kimiaraya-Indonesia has been employed for matrix the composites. The main materials properties of the composite are exhibited in Table 1.

Table 1. Performance of Jute fabric [4, 12, 13] and epoxy resin

item (units)	Jute fibers	Epoxy
Fiber diameter (µm)	26	
Density (g/cm ³)	1,5-1,6	1,1-1,4
Elongation at brake (%)	1,7	1-6
Tension stress (MPa)	1.316	35-100
Modulus Young's (GPa)	91,9	3-6

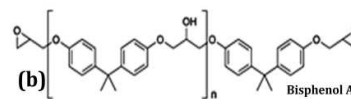


Figure 1. a). Sources of jute woven fabric, b). diglycidyl ether of bisphenol-A

Figure 2 shows the vacuum-assisted resin transfer molding schematic that is used to fabricate composites. The VaRTM is the improvement of the Resin transfer Mold (RTM) system.

In general, the VRTM processes are divided into five steps. Firstly, the step is preparing laminate reinforcement and mold. Secondly, step covering the mold by plastic bag using sealant tape, and check for vacuum leaks occurred. Thirdly, this step is preparing a matrix mixture of epoxy and hardener with ratios of 2:1. Additionally, the mixture is degassed on a dry vacuum machine to make perfect mixtures and remove some bubbles. The next steps, fourthly, are the mixtures injected into the mold by using a vacuum pump at pressures of -0.8 atm. This process is running for at least 45 minutes depending on mold size. In the last step, fifthly is the curing process, where is panel cured on a dry vacuum at temperature 65°C constant. After that, the composite panel was removed from the mold and cutter for produced the tensile specimen according to ASTM D 3039 standard.

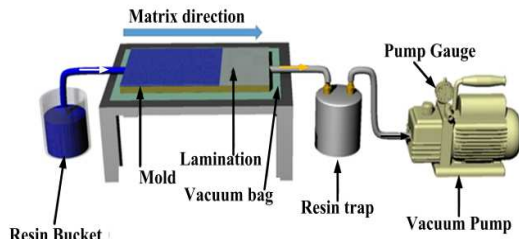


Figure 2. Schematic of Vacuum Injection molding process

The tensile test is conducted based on the ASTM D 3039 standard for investigates tension strength, elongation, Young's modulus, and shear stress of rivet joint. Universal tension machine (UTM) Tensilon RTG-1250 type was used with load cell 5 kN and crosshead speeds 3 mm/min. In this test five repeating for every orientation of rivets, positions were conducted. Meanwhile, the sample was shown in Figures 3a and b.

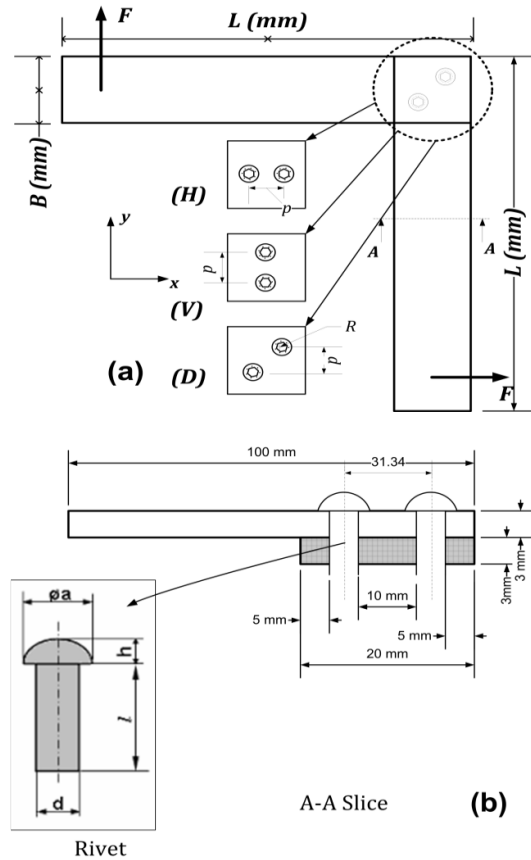


Figure 3. a) Composite joining, b) rivet geometry and schematics

Figure 4 shows the tensile testing for each sample. As can be seen in figure 4 the sample damage during the tensile loading can be classified into three types of failures under rivet position on splicing. On the diagonal position of rivets, the failures of the joint were occurred on at rivet whole area as shown on the inset of Figure 4. While on rivet horizontal position on splicing of composites is shown that failures occurred on the rivet bodies. Then, for the vertical position of the rivet on splicing of composites were occurred on both materials (rivet and composites).

In the form of an elbow joint with the position of the rivet, theoretically, the joint will receives a tangential load. This load is not passing in the centerline of structures, where the load received by rivets becomes is not equilibrium.

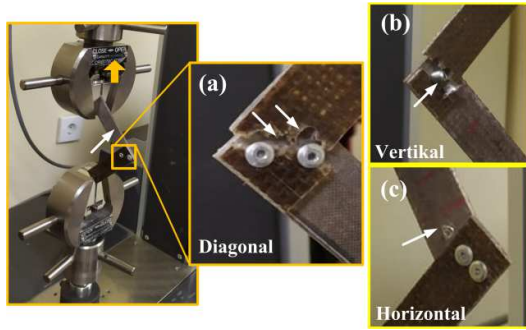


Figure 4 Tensile testing of joint process

The properties of splicing composite material with rivets caused by tensile loads can be determined following the equation below.

The tension strength and elongation of the joint under the tensile load are calculated by the equation below;

$$\sigma_t = \frac{F}{A} \text{ (MPa)} \quad (1)$$

$$\varepsilon = \frac{\Delta L}{L_0} \left(\frac{\text{mm}}{\text{mm}} \right) \quad (2)$$

The shear strength of the joint that occurred on the rivet during the tensile loading can be analyzed by the equation below;

$$\tau = \frac{F}{A} \quad (3)$$

The tangential load on an elbow joint the distances between the centerline with load position can improve the moment in the rivets. The moment is caused by the distances of rivets to the X, Y-axis. This work can be determined by the equation as below;

$$\bar{x} = \frac{\sum Ax_i}{\sum A}, \bar{y} = \frac{\sum Ay_i}{\sum A} \quad (4)$$

Then, the cross-section value of the rivet is calculated by equation;

$$A = n \frac{\pi d^2}{4} \quad (5)$$

Then, by inserting equation (5) into equation (3), so the shear stress of rivet is got from the calculation by using an equation below;

$$\tau = \frac{F}{A} = \frac{F}{n \frac{\pi d^2}{4}} = \frac{4F}{n \cdot \pi \cdot d^2} \quad (6)$$

Where the pressure on the cross-section that arises between the rivets and the composite plate is determined by an equation;

$$\sigma_0 = \frac{F}{n \times d \times t} \left(\frac{N}{\text{mm}^2} \right) \quad (7)$$

In the splicing of material using the rivet that is influenced by tangential loads, then moment on rivet is determined by using an equation below;

$$M = F \times e \quad (8)$$

Where, the comparison factor of the rivet "k" is determined by the following name:

$$k = \frac{F \cdot e}{\sum n_i \cdot r_i^2 \dots n_n \cdot r_n^2} \quad (9)$$

Where; the load on structures is "F" (N), the cross-section area of the specimen is "A" (mm²). Additionally, τ = shear stress, n = the rivet number, d = rivet diameter, t = stacking thickness of the material, and e = 70 mm the distance values to center-line.

3. RESULTS AND DISCUSSION

Figure 5 shows load versus displacement curves during tensile loading on composite material splicing by orientation of rivet position with diagonal, horizontal, and vertical direction. Table 2 exhibits average values tensile properties of composites splicing on variation rivet position.

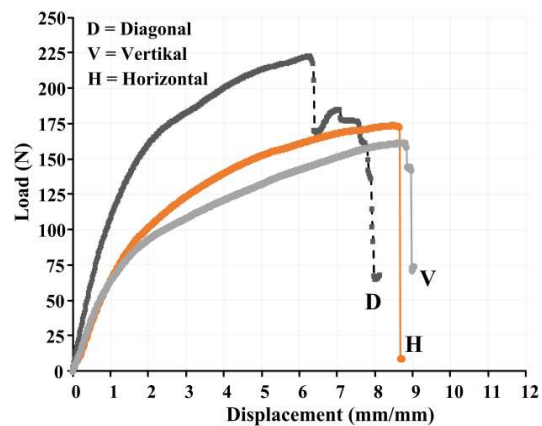


Figure 5. Load versus displacement curve for rivet orientation (H=Horizontal, V = Vertical, D = Diagonal)

According to figure 5 can be seen the best curve of sample from five repeats of each sample variation. The best result from the curve in Figure 5 is shown that the diagonal rivet position on the composite joint has the highest values compared to other rivet positions.

Table 2. Average of Tension properties values the splicing of composite using rivet orientation

Rivets position	σ (MPa)	ϵ (%)	E (GPa)	τ (N/mm ²)
Diagonal	3.329	0.189	12.750	59.49
Vertical	2.946	0.232	11.871	47.46
Horizontal	2.737	0.281	9.433	45.35

The average values of each rivet orientation are shown in Table 2. However, the largest average displacement values of the sample have occurred in the horizontal rivet position. The different result of each rivet position on splicing of composites with tangential load is caused by the load received by structure do not equilibrium, so the strength concentration is different for each rivet, as explained also by [9]. Then, on diagonal rivet orientation during the tension loads, the failure of joint has not occurred at the same time. It is shown in Figure 5 after the first fractures, and load still worked, the graph increasing for the next rivet and continues to break. The shear stress is the main rivet property joint when it's receiving tension loads. Based on tensile activity on joining composites using rivet orientation has been resulted in shear stress values for every rivet orientation as shown in Table 2. The result shows that the rivet with diagonal orientation in joining composite has the highest average values than average values vertical and horizontal orientation. The differences in shear stress between the vertical and horizontal rivets orientation are 0.06% and 0.26%, respectively. While the average values general for shear stress of rivets position on joining composite materials is 0.13%. However, the rivet with horizontal orientation on splicing of composites has the longest value of displacement compared to diagonal and vertical oriented.

Figure 6 shows the combination of tensile strength and Young's Modulus the splicing of composite with rivets orientation. This graph illustrated the performance of the joint, and also it illustrates the effect of rivet orientation in the assembly of materials. It is detected from the graph that there is a decrease in the tensile properties of the rivet orientation linearly in both stress and Young's modulus. The value of Young's modulus for the highest tensile load is in the orientation of the diagonal position of the rivet with an angle of 45o. Several studies to analyzing of joining quality and mechanical properties are dependent to rivet orientation,

rivet geometry, and looseness, as well as design parameters, also tightness [8, 14-16].

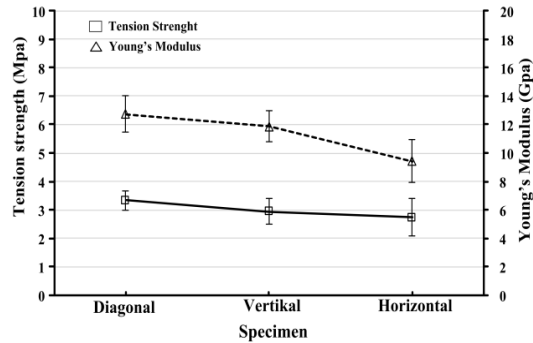


Figure 6. Graphic of Tensile strength vs Young's Modulus of rivet orientation

Figure 7 shows the damage form of composite materials connected with the rivet orientation position against the tensile loads. In general, the damage that occurs is tearing in the composite material as illustrated in Figure 4. In Figure 7a it is observed that the fracture of the composite occurs in the pitch region with relatively flat fracture, which indicates that the epoxy composite with jute fiber reinforcement is brittle. In addition, the fracture occurred until the edge side of the composite is shown in Figure 7b. Then, the shear defects that are accompanied by failure propagation occur in the tensile loading of the entire connection as shown in Figure 7c. In this case, the shear defects are caused by the presence of concentrated stresses on the rivets when tensile loads are applied to the elbow joints.

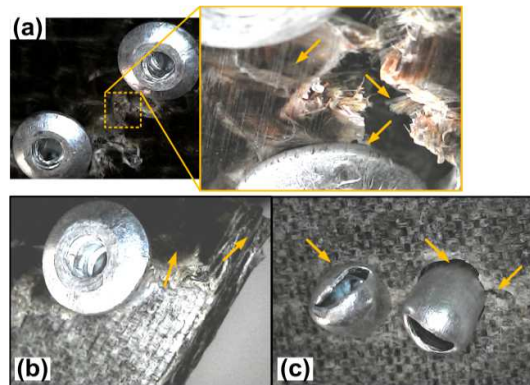


Figure 7. The failure of the composite elbow joint with rivet orientation after the tension loads

4. CONCLUSIONS

The Research on mechanical properties of elbow joints using rivet position orientation of Jute fabric reinforced epoxy composite due to tensile loading has been carried out. The jute fabric epoxy composites have been produced through vacuum-assisted resin transfer molding. Then, the composites are joined in three types of orientations single elbow joints such as horizontal, vertical, and diagonal against to line axis. In this work, we have been tested the sample using the tensile load in five repetitions of each variation, according to the ASTM D 3093 standard.

The result of tensile loads has shown such tension strength, tensile strain, and Young's Modulus, as well as shear stress. Then, the failures of each sample according to photographic analysis have resulted in a brittle manner.

From these results, it can be concluded that the orientation position of the rivets on the connection has a strong effect on the strength of the connection due to tensile loading. The orientation of the diagonal position of the rivets on the single joint of the composite material elbow was the best among all the orientations tested. This is because the stress concentration does not occur simultaneously on the rivets so that the tensile strength is given by each rivet.

ACKNOWLEDGMENTS

The author would like to thanks the Metallurgical Lab team and all parties who have supported and funded the realization of this paper.

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