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# Tensile Strength Characteristics of C-Glass Composite with Epoxy Matrix

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**Abstract**
Metal is a material that is widely used in industry. However, it has various weaknesses such as easy to form, high density and not resistant to corrosion, so composite material technology has begun to develop as an alternative material to replace metal. This study aims to determine the tensile strength of the C-Glass/epoxy composite structure which refers to the ASTM (American Society for Testing Material) D3039/D3039M standard. The composite specimen manufacturing method used is hand lay-up with variations in the direction of unidirectional fibre 0°, bidirectional WR 0/90°, and WR ±45 ° and the analytical method used from the test results is the Weibull distribution to determine the reliability of the composite material. The results of the analysis show that the tensile strength of the largest to the smallest sequentially is in the C-Glass composite specimen with unidirectional direction of 0°, bidirectional WR of 220 MPa. For fibre direction WR 0/90° is 57.8 MPa and for fibre direction WR 0°/90° and WR ±45°

**Keywords:** C-Glass Composite, tensile strength, Weibull distribution, hand layup,

## 1. Introduction

Composite materials have several advantages when compared to metal alloy materials previously used as aircraft materials. Some of the advantages of composites include; Lighter, has optimum strength and stiffness, has a longer fatigue life, corrosion resistance, easy to design, cheaper for some parts and fast in production (Cambell, 2010). A composite is a combination of 2 or more different materials in an arrangement or shape. The principal elements or elements that make up a composite retain their respective identities. In other words, each element does not disappear or merge with each other. Each can be physically identified, and shows the boundaries between each other (Sanderson, 2003). In general, fiber has a function as the main composite material that withstands the most load, determining the tensile strength, compressive strength and bending strength, toughness and rigidity of composite materials. While the matrix serves to bind fiber together, maintaining the matrix in a certain direction so that the load received can be optimally held by the fiber and channeling or transferring loads between fibers and is a load transfer medium that determines the ability of composite fibers to receive loads, especially for short fibers (Kuswoyo, 2015). Fiber that is often used is a type of glass reinforced plastic (GRP) fiber. Glass fibers are often used because they are cheap, high tensile strength, high impact resistance, and resistant to chemical reactions (Campbell, 2010). Table 1 shows the various classifications and physical properties of glass fibers.

**Table 1.** Classification and physical properties of glass fibers (Sathishkumar, 2014)

| Fiber | Density (g/cm$^3$) | Tensile strength (GPa) | Young's modulus (GPa) | Elongation (%) | Coefficient of thermal expansion ($^{10-7}$/o C) | Poison's ratio |
|---|---|---|---|---|---|---|
| E-Glass | 2.58 | 3.445 | 72.3 | 4.8 | 54 | 0.2 |
| C-Glass | 2.52 | 3.310 | 68.9 | 4.8 | 63 | - |
| S-Glass | 2.46 | 4.890 | 86.9 | 5.7 | 16 | 0.22 |
| A-Glass | 2.44 | 3.310 | 68.9 | 4.8 | 73 | - |
| D-Glass | 2.11-2.14 | 2.415 | 51.7 | 4.6 | 25 | - |
| R-Glass | 2.54 | 4.135 | 85.5 | 4.8 | 33 | - |
| EGR-Glass | 2.72 | 3.445 | 80.3 | 4.8 | 59 | - |

The fiber used in this study is Type C-glass because it has good physical properties as shown in Table 1 and has the advantage of withstanding chemical impacts well (Yadav, 2015). Calculation of tensile strength using the equation below (ASTM D 3039/D3039M, 2002):

$$F^{tu} = P^{max} / A \quad (1)$$

$$\sigma_i = P_i / A \quad (2)$$

Description:
$F^{tu}$ = maximum tensile strength, MPa
$P^{max}$ = maximum load, N
$\sigma_i$ = tensile strength, MPa
$A$ = surface area, $mm^2$

Weibull distribution statistical method is used to determine the value of material strength to its reliability in receiving a load, reliability function is used in analyzing test results data using the following equation (Dirikolu, 2002):

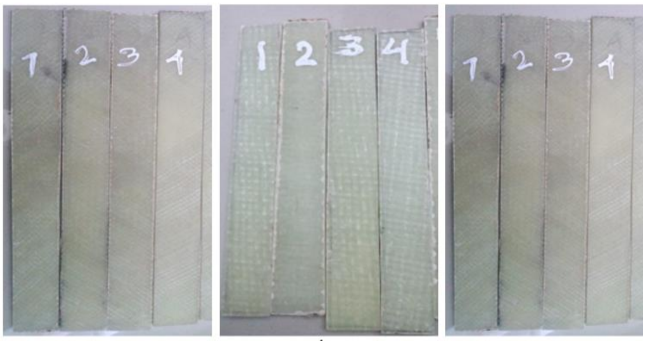
$$R(x; b, c) = \exp\left\{-\left(\frac{x}{b}\right)^c\right\} \quad (3)$$

Linear regression method converts two-parameter weibull distribution equation into equation linear form y=mx+r by performing logarithm operations:

$$ln\left(ln\left(\frac{1}{1-F(x;b,c)}\right)\right) = c\, lnx - c\ln b \quad (4)$$

Several types of glass fiber composites have been tested for tensile, namely S-Glass / epoxy composites LY-5138 with a strength of 412.97 + 6.71 MPa in the direction of fiber 0 °/ 90 ° and 147.52 + 6.71 MPa in the direction of fiber ±45 ° (Hero D. S., 2013). Then E-Glass / polyester composite with a strength of 104.72±12.28 MPa in the direction of fiber ±45° (Lathifa Rusita Isna et all, 2018).
Based on the literature study, this study conducted mechanical characteristics of C-Glass / epoxy composite bakellite EPR 174 which can then be applied to structures that have excellent resistance to chemical impacts.

**2. Materials and Research Methods**
In this sub-chapter is to manufacture composite specimen C -glass / epoxy bakellite EPR 174 with unidirectional fiber direction 0°, woven roving (WR) 0°/90° and ±45° with fiber volume fraction ( $V_f$ ) of 50% while the matrix used is epoxy bakelite EPR 174. The first step is to laminate each specimen with fiber direction of 0°, 0°/90° and ±45° using the hand lay up method with curing time for 7 hours. Tensile testing refers to ASTM D 3039/D3039M. Figure 1 each shows a C-glass/Epoxy eplite EPR 174 composite tensile test specimen with Unidirectional fiber directions of 0°, WR 0°/90° and ±45°.

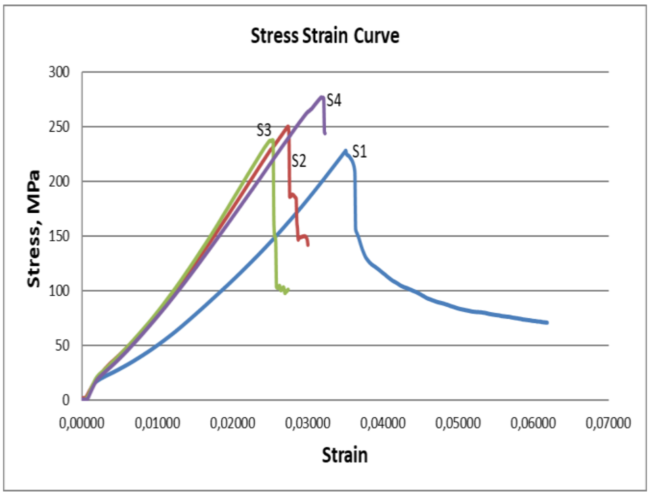


a. b. c.

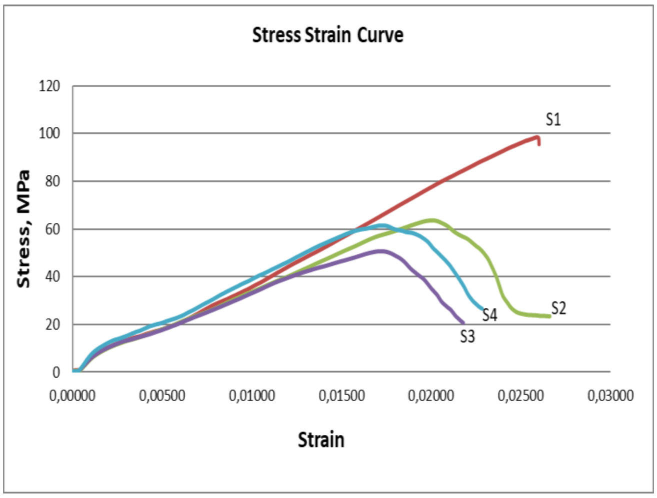
**Figure 1.** Composite specimen C-glass/Epoxy bakellite EPR 174 with fiber direction: a. unidirectional 0°, b. WR 0°/90° and c. WR ±45°.

## 3. Results and Discussions

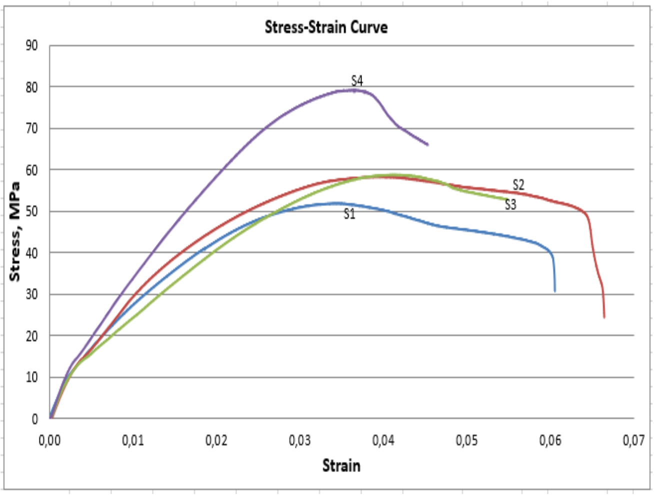
In Figures 2, 3 and 4. each shows a graph of the tensile strength and elongation of the C-Glass/epoxy bakelite EPR 174 unidirectional 0°, woven roving (WR) 0°/90° and ±45°.




a.




b.




c.

**Figure 2.** Graph of C-Glass/Epoxy eplite EPR 174 composite tensile test results with fiber direction: a. Unidirectional 0°, b. WR 0°/90° and c. WR ±45°.

Figures 3 and 4 show one example of linear regression graphs and Weibull distributions of C-Glass/epoksi bakelite EPR 174 composite specimen tensile test results 0º.

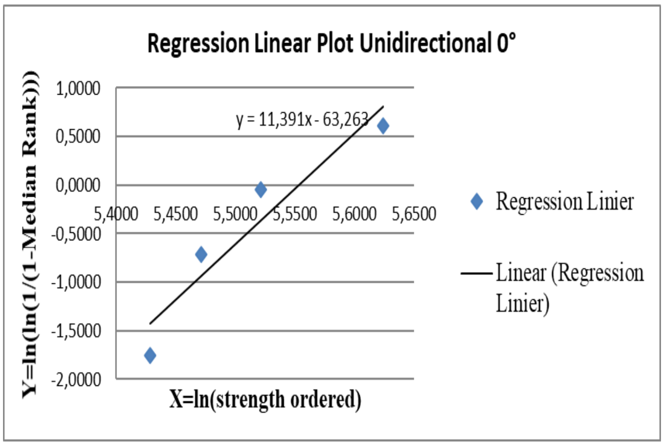



**Figure 3.** Linear regression graph of C-Glass composite specimen/epoksi bakelite EPR 174 unidirectional orientation 0º

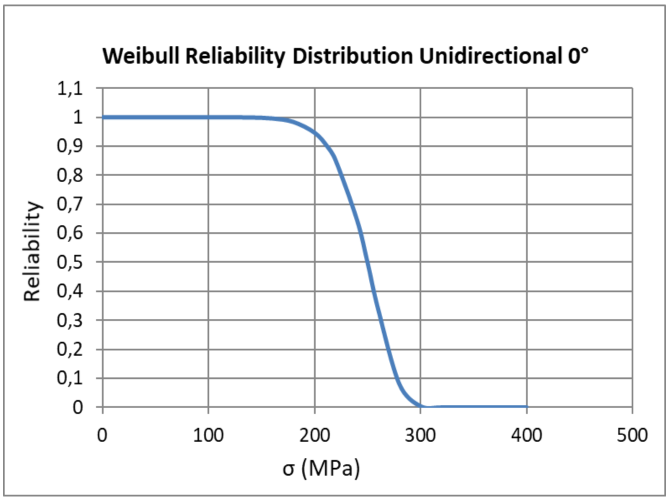



**Figure 4.** C-Glass composite weibull distribution graph/epoksi bakelite EPR 174 unidirectional direction 0º

In Table 2. shows graphs of tensile strength and strain composite C-Glass/epoxy bakelite EPR 174 unidirectional 0°, woven roving (WR) 0°/90° and ±45°. The strength of the resulting tensile test results is analyzed based on Weibull distribution statistical calculations to determine the reliability value of composite specimens using 90% reliability as shown in one of the examples in the Weibull distribution graph in Figure 4.

**Table 2.** Comparison of tensile strength, strain and density composite C-Glass/epoxy bakelite EPR 174 unidirectional 0°, woven roving (WR) 0°/90° and ±45°

| Komposit C-Glass/epoksi bakelite EPR 174 | Tensile strength, σ (MPa) | Strain | Densitas, ρ (g/cm3) |
|---|---|---|---|
| Unidirectional 0° | 250 | 0,03 | 1,48 |
| WR 0°/90° | 87,5 | 0,02 | 1,52 |
| WR ±45° | 62,5 | 0,038 | 1,50 |

In Table 1. It shows that based on the results of the Weibull distribution analysis, it can determine the reliability value of material strength to analyze the strength of the structure, in the sense that if the structure is analyzed using 50% reliability, it is safe especially when using the reliability of 90% of the structure will be safer. The composite tensile strength of unidirectional fiber direction of 0° has the highest tensile strength with a value of 250 MPa when compared to the direction of wr bidirectional fiber 0°/90°, because the load during the tensile test received by the resin is then distributed entirely in the direction of the fiber 0° in accordance with the direction of the tensile test. As for the direction of bidirectional fiber WR 0°/90° the load received by the resin is distributed partly for the direction of the fiber 0° according to the direction of the tensile test and partly in the direction of the tensile test and partly in the direction of the tensile test so that the tensile strength and strain decrease. Similarly, for the direction of fiber ±45° the load is distributed in the direction of ±45° so that the strength is lower because the direction of the fiber is not in the direction of the tensile test. Meanwhile, the value of the composite strain of wr bidirectional fiber direction ±45° has a greater value of 0.038 when compared to the direction of fiber 0° of 0.03 and the direction of 0°/90° of 0.02. This suggests that the direction of the ±45° fiber causes a shift first before breaking during the tensile test. As for the density produced from each direction of composite specimen fibers there is little difference because it uses hand lay-up manufacturing methods on composite specimens so that the thickness of the resulting specimen laminate is uneven.

In Figure 5. indicates C-Glass/epoksi bakelite EPR 174 composite specimen failure mode with unidirectional fiber direction of 0° and bidirectional WR 0°/90° and ±45°

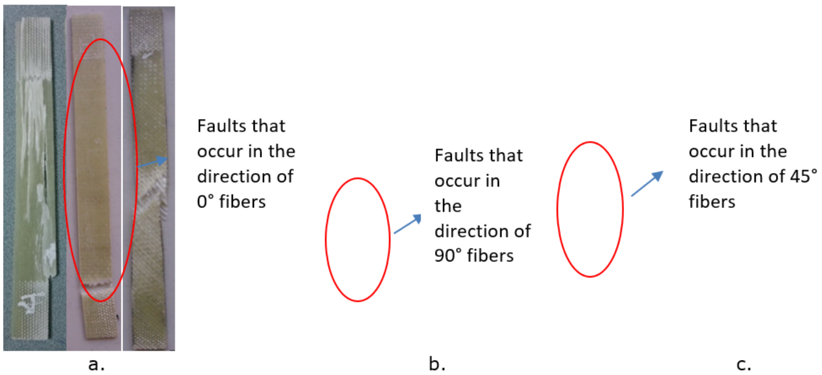



**Figure 5.** Modus kegagalan specimen komposit C-Glass/epoksi bakelite EPR 174: a. unidirectional 0° b. bidirectional WR 0°/90°, c. bidirectional WR ±45°

In Table 3. shows the ratio of tensile strength and density of C-Glass/epoxy bakelite EPR 174 composite with other conventional material types.

**Table 3.** Comparison of tensile strength of C-Glass composite/epoksi bakelite EPR 174 with conventional materials

| Material | Tensile strength, $\sigma$ (MPa) | $\rho$ (g/cm3) |
|---|---|---|
| Komposit C-Glass/epoksi bakelite EPR 174 unidirectional 0° | 250 | 1,48 |
| Komposit C-Glass/epoksi bakelite EPR 174 bidirectional WR 0°/90° | 87,5 | 1,52 |
| Komposit C-Glass/epoksi bakelite EPR 174 bidirectional WR ±45° | 62,5 | 1,50 |
| Aluminium 6063- T4 (www.aalco.co.uk) | 90 | 2,68 |
| Aluminium 4145- H16 (www.aalco.co.uk) | 185-225 | 2,68 |

In Table 3. It shows that the C-Glass/epoxy bakelite EPR 174 composite has greater tensile strength and lower density when compared to al-6063-T4 and Al 4145-H16 composites, so they can be used as alternative materials to replace conventional aluminum materials.

## 4. Conclusions and Suggestions

Based on the results of the study concluded that the composite C-Glass / epoxy bakelite EPR 174 direction unidirectional fiber 0° has a greater tensile strength than the bidirectional direction WR 0°/90° and ±45°. Besides that, it has better mechanical properties when compared to other types of conventional aluminum materials although by using a simple composite hand lay-up manufacturing method but produces a fairly good tensile strength, so it has a good potential to be further developed to be applied to the automotive industry and unmanned aerial aircraft / UAV (Unmanned Aerial Vechicle) which has excellent resistance to chemical impacts.

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