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Effect of angle orientation lay-up on uniaxial tensile test specimen of Fiber carbon composite manufactured by using resin transfer moulding with vacuum bagging

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Abstract. The main objective of performing uniaxial tensile test is to determine the maximum uniaxial load that a laminate specimen could withstand. The tensile test was carried out to obtain the maximum load and to study effect of the angle-ply laminated composite plates. Specimen is fabricated by using resin transfer moulding with vacuum bagging. Carbon/Epoxy composite with [+45/-45], [0/90] and [0/90 45/-45 combination] lamination schemes were built. The test set was done by using ASTM Standard D3039 with 12 layers of composite laminate. Geometry specimen is 250 mm x 25 mm x 2.75 mm. Fiber carbon composite plates under uniaxial tensile loading for several lamination schemes were modelled by using ACP tool. The tensile strength obtained in ANSYS and compared with experimental value. Based on the result, it can be seen that highest tensile strength on specimen with 0/90 orientation angle lay-up.

1. Introduction

High demand of materials with specific properties in engineering design makes the development of new material grow fast. Lightweight material with high strength becomes high priority in the development of new material. Composite materials have high possibility to meet that demand continues to evolve rapidly [1, 2]. Fiber reinforced composite materials have been increasingly used as structural members in many structures. The advantages of these materials are derived from their high strength, stiffness and damping together with low specific weight. On the other hand, composite materials have the potential of reducing costs in construction, operation and development while improving structural reliability and enhancing safety. Because of these unique specifications, they are widely used in high technology structural applications, such as aeronautic and aerospace [3]. Composite is a mixture of two or more materials with different physical/chemical properties at the macroscopic or microscopic scale [1].
In general composites have two or more constituents, fiber and matrix. The basic idea of the composite is to optimize material properties of the composite, i.e., the properties of the matrix are to be improved by incorporating the reinforcement phase. Fibers are the principal load-carrying constituents while the surrounding matrix helps to keep them in desired location and orientation and also act as a load transfer medium between them [4].
Composite materials as anisotropic materials have specific structure with different properties from isotropic materials such as metal. Composite materials consist matrix and fiber in their structure. It implies that their interface is built from many layers of fibers. Normally, the strength of composite

materials depends on the direction of the fiber itself as anisotropic materials, but the strength also varies depending on the fiber bridging. Therefore, the fiber orientation and number of the fiber layers in the thickness direction influence the strength of composite materials. This studies suggests the importance to investigate variation of angle orientation lay-up on uniaxial tensile test specimen was manufactured by using resin transfer moulding with vacuum bagging.

2. Method

Carbon Fiber composite laminate of dimensions 250 × 25 x 2.75 mm are fabricated using resin transfer molding with vacuum bagging (Figure 1). Twelve layers of Kyoto 3K 220GSM carbon fiber with Resin Epoxy Bekelite EPR 174 are manufactured to provide the tensile test specimens accordance to ASTM D 3039 standards [5]. Figure 2 shows the dimension of tensile test specimen.

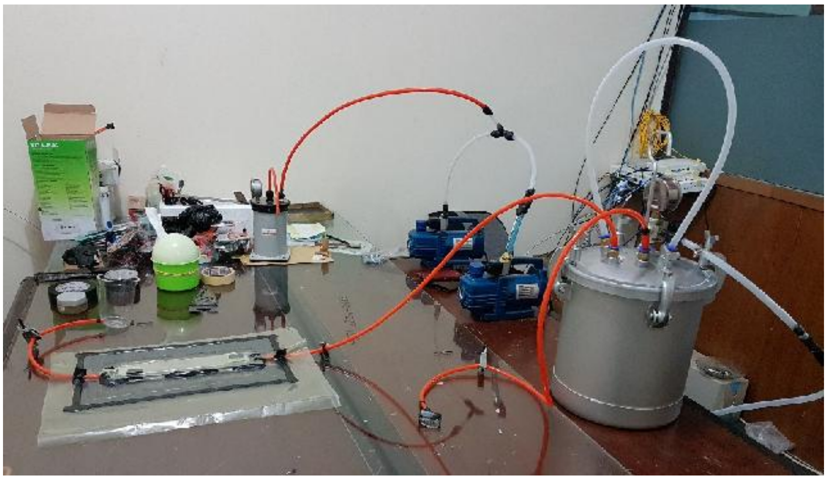

Figure 1. Schematic of experimental of resin transfer molding with vacuum bagging

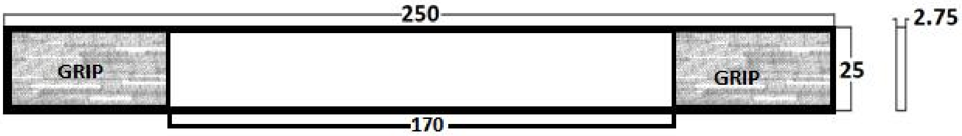

Figure 2. Geometry and dimension of tensile test specimen

Table 1 and 2 show the Technical Data Sheet Kyoto 3K 220GSM and Resin Epoxy Bekelite EPR 174.

Table 1. Technical Data Sheet Kyoto 3K 220GSM

Tensile Strength	3310 MPa
Tensile Modulus	240 GPa
Elongation	1.6%
Density	1.78 g/cm^3
Yield Strength	220 g/1000m

Table 2. Technical Data Sheet Resin Epoxy Bekelite EPR 174

Tensile Strength	55.1 MPa
Elongation	6%

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Flexural Strength	81.4 MPa
Compressive Strength	80 MPa

In ANSYS software the parameters for analysis purpose chosen were based on the matrix material and the reinforcement. The material model was considered to be isotropic in nature and the boundary condition and load conditions applied were similar to the experimental condition. The half model of tensile test geometry is chosen with shell element type. The Figure 3 shows the boundary condition and meshing details of the FEA models.

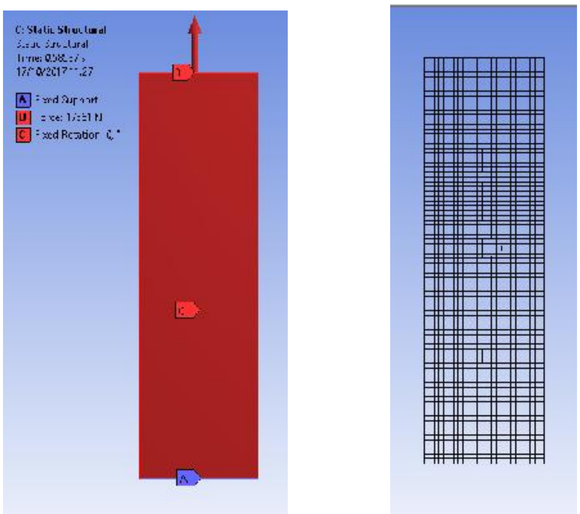

Figure 3. The boundary condition and meshing applied in the half model of tensile test geometry

3. Results and Discussion

The uniaxial tensile test specimen was manufactured by using resin transfer molding with vacuum bagging as shown in the Figure 4. Three variation of angle orientation lay-up were set with [0/90], [45/-45] and ([1-1] 0/90 45/-45) combination. Based on tensile test, it can be drawn the stress-Strain Relationship on all specimen variation (Figure 5). In the production process, it should be considered that to acquire high strength and high modulus of carbon based composite as desired, the strength and modulus of carbon fiber should have at least twice value from expected strength and modulus of the carbon composite final product.

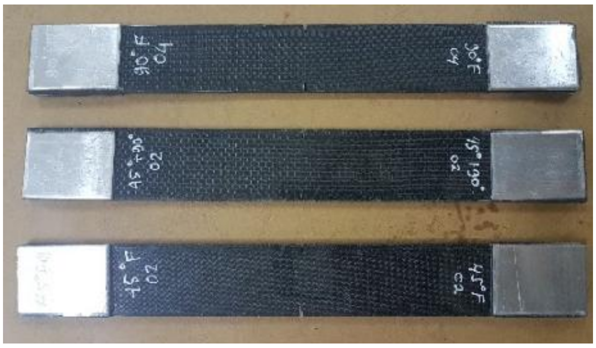

Figure 4. Uniaxial tensile test specimen (ASTM D 3039 standards)

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Table 3. Tensile test results

Angle Orientation Lay-up	Experimental Maximum Stress (MPa)	ANSYS Maximum Stress (MPa)
0/90	494	467.39
([1-1] 0/90 45/-45) Combination	420.8	622.11
45/-45	234.2	696.98

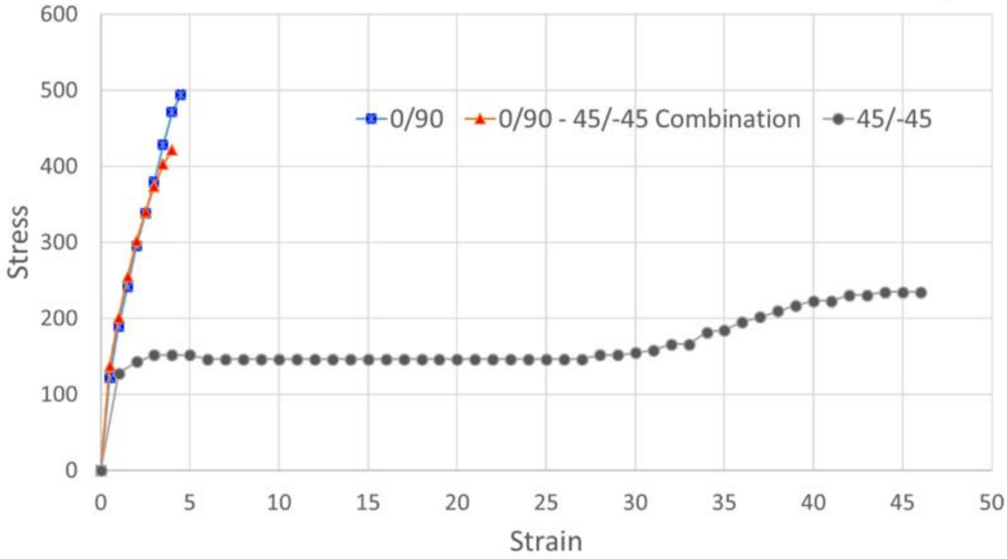

Figure 5. Stress-Strain Relationship on all specimen variation

The half model is built due to limitations of the ANSYS academic version license which gives a maximum limit of 32 thousand nodes. ACP tool is used due to the advantage which are modeling process follows manufacturing, simple and fast modification of composite layup and composite designs possible. Figure 6 shows project schematic of ACP integrated in ANSYS Workbench. Figure 7 shows stress distribution in the [0/90] lay-up.

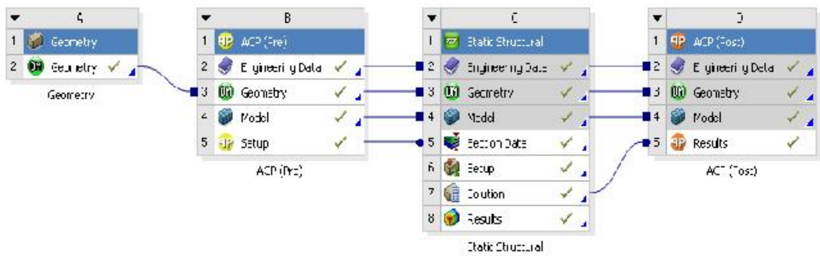

Figure 6. Project Schematic of ACP-ANSYS Workbench

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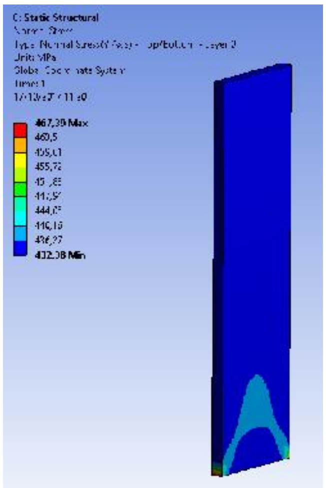

Figure 7. Plot of stress distribution in the [0/90] lay-up

Based on Table 3, resin/matrix strength is increased as 8.9, 7.6, and 4.2 multiply in the angle orientation lay-up of [0/90], [45/-45] and ([1-1] 0/90 - 45/-45) combination. It can be state that resin/matrix strength as baseline increase after reinforced with fiber carbon [6].

4. Conclusion

The aim of this study is carbon fiber composite lay-up design to provide the improvement of mechanical strength. Modeling of carbon fiber composites has been developed by utilizing application software based on finite element method. The process of manufacturing carbon fiber composites is done by using vacuum bagging method. Tensile test was performed on three variations of Fiber Carbon Composite specimen (0/90, 45/-45, and 0/90 45/-45 combination) with highest tensile strength on specimen with 0/90 orientation angle lay-up.

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