Flexural behaviour of jute, glass, and Carbon fibre reinforced Polyester hybrid composites

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Abstract. This study is a part of a project in developing natural fibre reinforced composite for wind turbine blade. The objective of this study is to evaluate the effect of fibre stacking sequence on flexural behaviour of the natural fibre reinforced composite hybridized with synthetic fibre. The flexural behaviour of the composite becomes an important consideration in deciding stacking sequence of the fibres. Material used in this study is polyester resin as the matrix. Jute, glass, and carbon fibres are used as the reinforcement. The composites were fabricated using vacuum bagging method cured at room temperature. The combinations of fibre as the reinforcement are configured by arrange two and three types of fibre. As a natural fibre, jute exists in all kind of combination. Flexural behaviour was observed using 3-point-bending test. The specimens were tested in accordance to the fibre stacking sequence. The result shows that stacking sequence of the fibres give significant different flexural behaviour regardless the effect of the fibre strength.

Keywords: natural fibre composites, wind turbine, blade, green materials, renewable energy

1. Introduction
Low speed wind turbines need the appropriate blade properties, such as strength, stiffness, and lightweight [1-4]. The materials used for the blade are composites consisting of resin and reinforcing fibres [5]. The reinforcing fibre used is generally glass fibre.

The problem arose when a huge amount of blade waste will occur in the next 30 years [5]. This blade material waste will not easily degrade naturally and has a long-term impact on the environment. Therefore, this research is looking for solutions to reduce non-degradable waste. The wind turbine blade will be made of partially natural material, i.e., natural fibre as reinforcing composite.

To meet the properties required by low-speed wind turbine blade, natural fibre is hybridized by synthetic fibres, i.e., glass and carbon fibre, as reinforcement of the composite [6-10]. Characterization of composite is carried out in order to obtain the best configuration to meet the demand of low-speed wind turbine blades characteristic.

2. Materials and Method
The material used in this research consists of matrix and fibres. The matrix material is polyester with the product name Yucalac 157 BTQN-EX, licensed by Showa Highpolymer Co., Ltd (Japan) and Polyt
SpA (Italy). At normal temperature, this type of polyester is resistant to water and weak acids. This polyester is widely used in shipbuilding, tanks, sanitary ware, and FRP Pipe.

As the reinforcement, good quality of jute (*Corchorus capsularis*) fibre cloth obtained from local supplier is used. The jute fibre is in the form of plain weave type. The jute fibre cloth obtained from the supplier is dried prior to composite fabrication. Drying is carried out using an electric heater with a temperature of 150°C until the weight of the jute fibre cloth is no longer reduced. The final weight of the dried jute fibre cloth is 25 g/m². For hybridizing, S-glass type fibres cloth with areal weight 220 g/m² in plain weave woven and 2x2 plain weave carbon fibre cloth with areal weight 220 g/m² are used.

Figure 1 shows the experiment design in this research. The hybrid composite, in the combination of jute, glass, and carbon fibres, arranged according to their pair with the notation of jute fibre (J), glass fibre (G), and carbon fibre (C). The hybrid combination considers the aspects of mechanical properties, thickness, and economical cost. As a natural fibre, jute exists in all kind of combination. The configurations of the specimens are GJJ, GJG, CJJ, and CJG. It can be seen that the role of glass and carbon fibres as the outermost layer or skin. Specimens were made using vacuum bagging technique.

Three-point flexural tests were carried out according to ASTM D7264. Each specimen configuration is tested in two stacking sequence. For example, GJJ specimen is tested in GJJ and JJG sequences. The first letter is the surface that contacted to the loading nose, i.e., the compression surface. The last letter is the tension surface.

### 3. Results and Discussions

The test results are presented in Figures 2 - 5. Figure 2 shows the test result of GJJ specimens. JJG specimen show higher flexural strength and larger deflection than GJJ specimen does. In the case of JJG specimen, glass fibre cloth is in the tension surface of the specimen. Therefore, glass fibre, which has higher strength than jute fibre, contributes to the flexural strength of the specimen [11-12]. Also, since glass fibre has good elongation, the total deflection of the JJG specimen shows larger than GJJ specimen. The flexural strength of JJG specimen (140 N/mm²) is more than two times of GJJ specimen (65 N/mm²).

Figure 3 shows the test result of GJG specimen. Since the both side of the specimen is the same fibre cloth layer, the test result shows a single curve. GJG specimen shows a similar flexural behaviour to that of JJG specimen in Figure 2. Although in the case of GJG specimen consists of two layers of glass fibre cloth, the first layer, the compression surface, has no obvious effect on the flexural strength [13].
Figure 2. Specimen with stacking sequence GJJ and JJJ.

Figure 3. Specimen with stacking sequence GJJ.

In Figure 4 and 5, carbon fibre cloth gives significant effect on the flexural strength in JJC specimen of 158 N/mm² compared to CJJ specimen of 93 N/mm² (Figure 4) and GJC specimen of 209 N/mm² compared to CJG specimen of 162 N/mm² (Figure 5). In these cases, carbon fibre cloth is in tension surface. Therefore, the flexural strength of the specimen is mainly affected by carbon fibre cloth. In addition, it can be seen in Figure 4, specimen with jute fibre cloth in the tension surface shows a smaller total deflection than that of with other fibre cloth. In the case of GJC and CGJ specimens, both specimens have the highest flexural strength among other specimens with corresponding tension surface of carbon fibre (JJC) and glass fibre (JJG, GJG).

Jute fibre cloth exists in all cases of specimens. In the configuration of jute and glass fibre, there are two options of combination, i.e., JJG and GJG. According to Figure 2 and 3, the flexural strength of
both configurations is almost the same. Therefore, based on the goal to reduce the use of the synthetic fibre, JJG specimen is the best choice for building wind turbine skin.

![Graph](image1)

**Figure 4.** Specimen with stacking sequence CJJ and JJC.

![Graph](image2)

**Figure 5.** Specimen with stacking sequence CJG and GJC.

Figure 6 - 9 are the examples of fractured specimen of configuration of CJG and GJC. Figure 6 and 8 show the fractured surface of CJG specimen in which the tension surface is glass fibre. It can be seen in figure 8, tension surface shows less damage since the matrix remain tightly bonded to glass fibre [14]. On the other hand, in Figure 7 and 9, in tension surface, part of matrix is broken in the brittle manner since the carbon fibre cloth shows the high stress and large elongation. The total elongation of the specimen GJC is longer than that of CJG specimen.
4. Conclusion
Hybrid polymer composite reinforced with jute and glass fibre has properties: good strength and stiffness, where the glass fibre is the skin (outer surface) of wind turbine blades. This configuration is also considered economical cost for common application. The result also shows that stacking sequence of the fibres give significant different flexural behaviour regardless the effect of the fibre strength.

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