Development of Treated Kapok/Fiberglass Hybrid Composite for Marine Application

M.A.M Mohd Idrus, M. Firdaus. M. Yang, S. B. Ismail, S. E. Abdul Hamid, and S. F. A. Syed Abdullah

***Abstract*—** This study is to investigate the mechanical and physical properties of chemically treated Kapok Reinforced Fibreglass composites (KRFs). The cellulose fibre reinforced fibreglass (KRFs) were fabricated with fibre loadings of 20, 40, 60, 80 gram of Kapok. Results shows that tensile, flextural, and impact strength decreased as the fibre content increased. The ultimate mechanical properties were achieved with a fibre content of 20 gram of Kapok. However, the water absorption and thickness swelling was found to be improve which is lower than fibreglass composites. This indicates, KRF were more water proof than fibreglass. SEM study were carried out to evaluate the microstructure of KRF composites. It shows that, as the resin and fibre content increased it became more brittle and ductility also decreased. Thus, lower the mechanical properties of KRF composites.

***Keywords*—** Kapok Reinforced Fibreglass composites (KRFs), mechanical properties, water absorption.

I. INTRODUCTION

OVER the past few decades, natural fibres have widely used in industry as varied as building & construction, air, ground and sea transportation, industry, and sport & leisure, among others. Natural fibres are renewable resources with mechanical advantages that are ideal for sustainable innovation.

In general, composite materials are formed from fibres and a matrix, which bind the fibres together and transfer the external load to the fibres. The properties of the composites are governed by both the properties of the individual parts (fibres and matrix) and by the ratio and configuration in which these parts enter the composite [1]-[3]. The application of fibre reinforced polymer composites (FRP composites) in maritime was initially driven by a requirement for strong, lightweight, corrosion resistant durable naval boats. These early applications were motivated by the need to overcome corrosion problems experienced with steel or aluminum alloys or environmental degradation suffered by wood. Another reason for using composite was to decrease weight, particularly the hull of ships [17].

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This research based on natural fibre which is Kapok (ceiba petandra) as reinforce fibre [6],[8]-[11],[21]. It is found that, the scientific data on Kapok composite is not available for marine application [16]. Thus, lead to lack of usage in the marine industry.

II. PROCEDURE

A. Materials

Raw kapok fiber (RKF) was obtained from UniKL MIAT, Malaysia. The RKF was cleaned and ground manually into a fine form. Then, the RKF was sun dried. The average particle size of fibre was 16.3 um. Resin Norsodyne 3338 (without wax), Norsodyne 3338 (wax) and Butanox M-50 as catalyst were used.

B. Chemical Treatment of Natural Kapok Fibre

Prior to treatment, the kapok fibre bundle was dried under the sun for about 24 hours until a constant weight was reached in 1-2% moisture content. The dried kapok fibre was then kept in a sealed container. 200 mL of 1% concentration of sodium hydroxide (NaOH) solution was measured into a 500 mL beaker. About 20 g of Kapok fibre was submerged into the solution for about 12 hours at a room temperature. After about 12 hours, the Kapok fibre was taken out of the beaker, washed with distilled water, and finally dried in open air.

C. Preparation of KRFs and Synthetic Fibreglass.

The kapok reinforced fiberglass (KRF) was prepared from raw, treated, synthetic fibreglass and polyester resin. Both KRF and Synthetic fibreglass (20, 40, 60, and 80 g) were mixed thoroughly with polyester resin on a square shape mold. Catalyst was added in the polyester mixtures as a binder. The mixtures were stirred continuously without any external heating until they were uniformly mixed, the mixtures was in a homogeneous state. The mixture was introduced into a mold measuring 300 mm x 300 mm x 5 mm at a room temperature. The molding board was then cut to the test specimen sizes that were appropriate for each test. The molding conditions were as follows: pressure manually with steel roller and cooling at a room temperature.

D. Scanning Electron Microscopy (SEM).

The surface morphology of the manufactured composite was examined using a SEM (JSM-5510) supplied by JEOL Company (Tokyo, Japan). The samples were sputted –coated with platinum and observed under the SEM. The micrographs were taken at a magnification of 300x [18].

III. Mechanical Properties.

In order to examine the mechanical properties of the samples, specific test for tensile, flexural, and Impact were conducted. For each test, five specimens were utilized and the average values were reported

A. *Tensile Test*

The tensile tests were carried out in accordance with ASTM D638-01 using a Shimadzu Universal Testing Machine with a loading capacity of 300 kN. Each test was performed at a crosshead speed of 10 mm/min. The dimension of the specimen was 148 mm x 10 mm x 4 mm.

B. *Flexural Test*

Flexural test were conducted in accordance with ASTM D 790-00 using the same aforementioned testing machine at the same crosshead speed. The dimension of the specimen was 79 mm x 10 mm x 4.1 mm. The deflection reading and flexural strength were gain from the raw data resulted from the testing.

C. *Impact Test (Charpy)*

Charpy specimens are notched to prevent deformation of the specimen during impact. The standard specimen for ASTM is 55 mm x 10 mm x 10 mm.The specimens were clamped into the pendulum impact test fixture with the notched side facing the striking edge of the pendulum. The pendulum is released and allowed to strike through the specimen. If breakage does not occur, a heavier hammer is used until failure occurs.

D. *Water Absorption and Thickness Swelling Test*

KRF samples with the dimensions of 40 mm x 10 mm x 4.1 mm were prepared for the water absorption test. Prior to immersion in a static de-ionized water bath, the samples were air-dried at 80°C until a constant weight was reached. The specimens were periodically taken out the water, wiped with tissue paper to remove water on the surface, reweighted, re-measured, and immediately put back into the water. Water absorption was calculated according to the following equation:

$$\text{Water absorption } \% = (W_2 - W_1 / W_1) \times 100\% \quad \text{......... (1)}$$

Where W_2 is the specimen weight after soaking and W_1 is the specimen weight before soaking (Mun'aim, 2012).

Thickness Swelling. Thickness swelling is directly affected by several factors. Durability depends on low swelling and high resin content is the best way to control thickness swelling.

Thickness swelling (TS) were calculated using the following equation:

$$TS = [(T_2 - T_1)/ (T_1)] \times 100\% \quad \text{............... (2)}$$

Where T_1 and T_2 is the thickness of the specimen before and after the test respectively (Fauzar, 2014).

IV. Result and Discussion

A. *Scanning Electron Microscopy (SEM).*

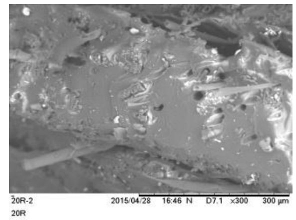

Fig.1(a) 20 g raw kapok

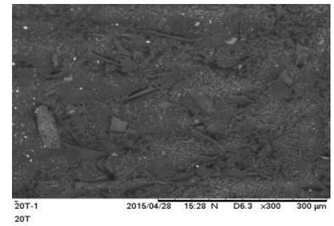

Fig.1(b) 20 g treated kapok

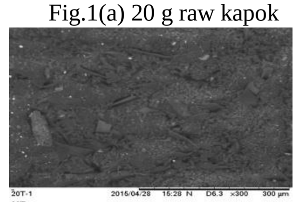

Fig.1(c) 20 g treated KRF

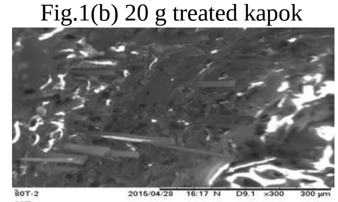

Fig.1(d) 80 g treated KRF

Fig. 1(a) and 1(b) shows the crack propagation in Raw and KRF composites with 20 g Kapok fibre loading. Extensive fibre fracture, fibre bridging and matrix fracture can be clearly observed. Such fracture mechanisms lead to enhance the mechanical properties in the composites.

Fig. 1(c) and 1(d) shows the high magnification images of the fracture surface of KRF composites loaded with 20 and 80 g treated Kapok fibres loading. It can be observed that composites loaded with higher fibre content show better fibre matrix interfacial bonding than those loaded with lower fibre content. Fibred bonding and gaps between fibres and matrix are more prevalent in composites with lower fibre content.

B. *Tensile Test.*

Fig. 2 and 3 shows the tensile strength (stress) and strain of KRF and fibreglass composites, with the KRF composite at different fibre loadings. The results shows that the synthetic fibreglass has the highest tensile strength with 239.04 MPa followed by 20 g of Kapok fibre content with 79.01 MPa and the lowest was 80 g Kapok fibre content with 34.36 MPa. However in Fig. 2, KRF composite shows a fluctuation in term of strain. Refer Fig. 2 for tensile strain, the highest was showed by KRF with 4.14% followed by synthetic fibreglass with 3.21%. The lowest tensile strain was 80 g Kapok fibre loading with 2.85%. From the results obtained, it shows that at all specimen KRF fibre loading, the tensile strength of the fibreglass composite is greater than the KRF. The decreasing value of KRF tensile strength is due to the improper fibre orientation and fibre/matrix interphase [2], [12]-[15], [21].

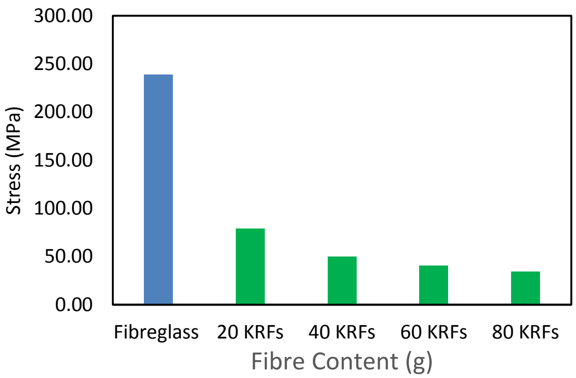

Fig. 2 Tensile strength of the composites

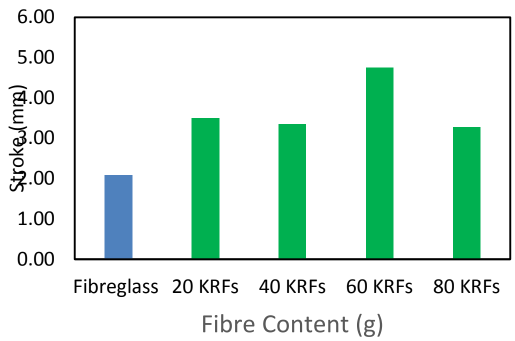

Fig. 3 Tensile strain of the composites

C. Flexural test

Five replicates of each composites formulation were test and the average values were reported. From Fig. 4, the results showed that synthetic fibreglass has the highest flexural deflection with 33.77 mm followed by 20 g of Kapok fibre content with 19.41 mm and the lowest was 80 g Kapok fibre content with 6.17 mm. While the deflection reading decreases, the flextural strength increases as Kapok fibre content increases. From Fig. 5, 80 g KRF stated the highest flextural strength with 8.45 kN, the lowest is Fibreglass composite with 7.65 kN [17]-[18].

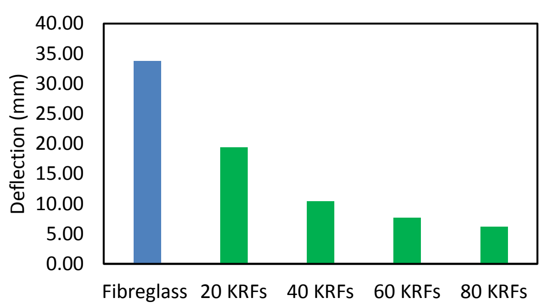

Fig. 4 Fibreglass and treated Kapok reinforced fibreglass composites allowable deformation.

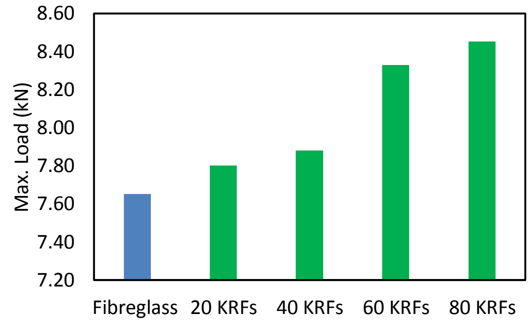

Fig. 5 Fibreglass and Kapok reinforced fibreglass composites maximum load before failure.

D. Impact Test

The effect of fibre weight fraction for KRF and fibreglass composites is illustrated in Fig.6. It can be observed that impact strength significantly decrease as fibre content increase. It is because; the interfacial bonding between Kapok and the matrix are poor. From Fig. 6, it shows that the highest impact strenght/energy stated by 20 g Kapok fibre loading with 297.27 J followed closedly by fibreglass composite with 294.13 J. The lowest impact strenght is at 80 g Kapok fibre loading with 287.79 J.

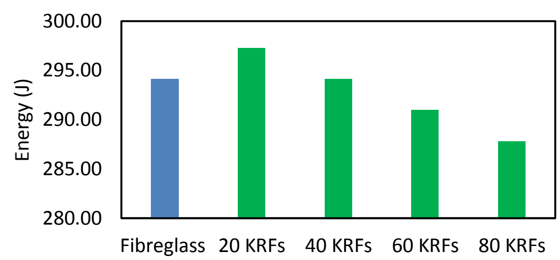

Fig.6 Comparison of Fibreglass and treated Kapok reinforced fibreglass composites in term of impact strength

E. Water absorption test

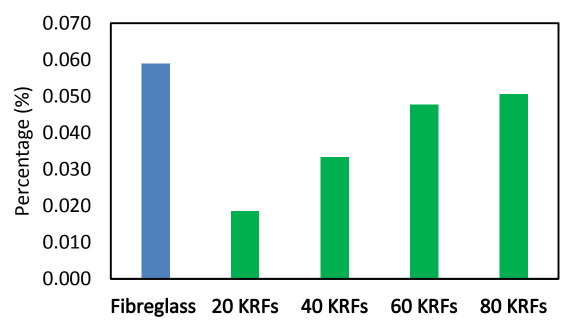

Fig. 7 Treated Kapok reinforced fibreglass shows an improvement compared to Fibreglass composites.

Fig.7 presents the effect of the storage time checked after 16 days with 20, 40, 60, and 80 g of KRF fibre content, respectively. It was found that the KRF composites showed the increasing trend of water absorption with the increasing storage time [17]. Nevertheless, water absorption of different composites clearly decreased as the fibre content increased. The Kapok fibre could decrease the water absorption of the KRF matrix because the raw Kapok fibre were treated with Sodium Hydroxide (NaOH) that change the physical structure; therefore, reduced the the hollow internal wall of the kapok fibre. Moreover, the strong adhesion between the matrix and cellulosic fibres also decreased the free volume of the starch molecular chains and leaded to the difficulty of water penetration (Pracayawarakorn et al, 2013). Because of the chemical treatment property KRF shows an improvement in waterproof characteristic than synthetic fibreglass composite. It was expected that the water absorption of the KRF should be less than those of the fibreglass composite due to the treatment effect.

F. *Thickness Swelling Test*

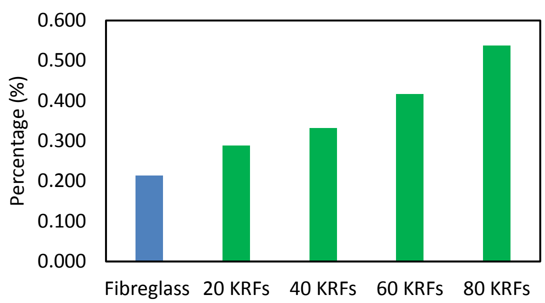

Fig.8 Graph of comparison thickness swelling between Fibreglass and Kapok reinforced fibreglass composite.

From Fig.8, it shows the thickness swelling of the composite coefficient for the composites which is varying depending upon the fibre loading. From the observations, it shows that the thickness swellings are increased for all KRF composites [1],[18]. The highest thickness is recorded by 80 g Kapok fibre loading with 0.538 % increment while the lowest was stated by fibreglass composite with 0.213 % increment It also shows that the thickness for Raw kapok are higher than the chemically treated kapok [22].

From the result obtained, the increase number of porosity lead to highest water absorption as the water filled the void space in the composites structure. It is also indicated that thickness swelling values increase with water absorption time [18], [22].

V. CONCLUSION

The effect of fiber content, orientation, and form (mate) on the mechanical and physical properties of treated KRF has been investigated. The impact and water absorption were found increased, however tensile and flexural strength were slightly decrease but at acceptable level for marine application. Besides, due to the increasing of resin usage, the physical properties of KRF also change. At this stage, KRF was not build up to its full potential. There are many factors need to be considered and improved in the future such as chemical treatment. Base on this, Kapok have potential in boat construction and towards green environment.

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