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Mechanical and Morphological Properties of Kenaf Fiber Reinforced Polyurethane (PU) Biocomposite

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Abstract: ***In recent days, the use of synthetic materials has been increasing rapidly. However the use of synthetic materials have great impact to the environment due to its non-biodegradable nature This draws the interest of researchers to focus on development of natural fiber composites to substitute synthetic fiber composites due to several advantages in the properties of the material. In this study, Kenaf fiber are reinforced with thermosetting polyurethane to develop a polymer matrix based biocomposite material. The aim of this research is to study the effect of Kenaf fiber composition on the mechanical and morphological properties of Kenaf fiber reinforced polyurethane (PU) biocomposite material.The sample preparation was performed by casting method by mixing the Kenaf fiber and the polyurethane to form the biocomposite. Different composition of Kenaf fiber and PU was investigated in this study; namely 2%, 4%,6%,8% and 10% weight percentage. The biocomposite sample with 10% wt. fiber loadings exhibited highest impact strength and hardness value compared to the rest of the biocomposite compostion. Increase in fiber loading, increases the hardness and impact strength of the composite. Morphological properties of the impact fractured showed that there is good fiber and matrix bonding in the Kenaf/PU biocomposite.***

Keywords: Kenaf fiber, polyurethane, biocomposites, mechanical properties

1. Introduction

Fiber reinforced plastics (FRP) are widely used these days due to its excellent mechanical and physical properties. Conventional fiber reinforced composites are composed of carbon fibers, glass fibers, which are incorporated into polymer matrix. These composites show high mechanical and thermal properties and widely used in various industrial applications [1]. However, the use of synthetic filler reincorced composite has several disadvantages due to its non-biodegradable properties. Thus, natural fibers are being used as reinforcement filler to develop environment friendly composites with biodegradable polymer as matrices [2].

Composite materials developed utilizing at least two or more constituent materials with essentially diverse physical or compound properties that, when consolidated, produce a material with attributes not the same as the individual segments. In the course of recent decades, there has been a developing enthusiasm for the utilization of natural fibers in composite applications. These sorts of composites present numerous points of benefits [3]. There has been a developing enthusiasm for the utilization of natural fibers in composite applications. These sorts of composites present many preferences contrasted with synthetic fibers, for example, low tool wear , low density, less expensive cost, accessibility, and biodegradability. One reason for this developing interest is that natural fiber have a higher particular strength than glass fiber and a similar specific modulus. With these attractive properties and less expensive sources, these natural fibers hypothetically offer attractive particular strength and modulus, at a lower cost [4]. However, natural fibers have certain limitations such as hydrophilic in nature, poor fiber/matrix interfacial adhesion and poor thermal stability This limitations can be overcome by chemical treatment or compatibilizer which amended the adhesion between the fiber and polymer matrix [5].

Polymer is a substance that has an atomic structure comprising predominantly or totally of a large number of similar units bonded together. Polyurethane is a synthetic resin in which the polymer units are connected by urethane groups, utilized primarily as constituents of paints, varnishes, adhesives, and froths. Long chains and low crosslinking give a polymer that is extremely stretchy, short chains with heaps of crosslinks to create a hard polymer while long chains and halfway crosslinking give a polymer helpful for making froth. The crosslinking present in polyurethanes suggests that the polymer contains a three-dimensional system and atomic weight is high. Overall, polyurethane can be seen as a monster atom. One after effect of this is regular polyurethanes don't mellow or break up when they are warmed as they are thermosetting polymers [6]. In this study, a novel biocomposite material developed by using Kenaf fiber as reinforcement filler and thermosetting polyurethane (PU) as the polymer matrix.

2. Materials and Method

2.1 Material

Kenaf short fiber was purchased from Innovative Pultrusion Sdn. Bhd. The size of kenaf fiber used were < 212 µm. Its tensile strength, modulus and elongation are 930MPa, 53GPa, and 1.6% respectively. Thermosetting Polyurethane (Mirathane 6414 A/B) were both purchased from Miracon (M) Sdn Bhd. The resin is known as Mirathane 6414-A and it is beige in colour with a viscosity of 2000-4000 CPS at 25^0C. The hardener is known as Mirathane 6414-B and it is brown in colour with a viscosity of 30-80 CPS at 25^0C. The ratio of both this resin and hardener is 100:64.

2.2 Preparation of Kenaf\PU biocomposite

The polymer solution casting method used to prepare the samples. Steps are as shown in Figure 1.

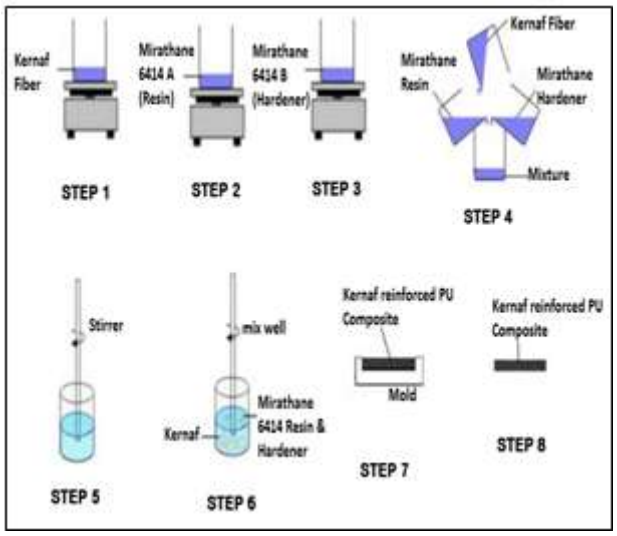

Figure 1: Polymer casting method for Kenaf/PU biocomposite

The weight of the resin, hardener and the Kenaf are measured by using the electronic weighing balance. The weight of this materials are measured based on percentage of fiber loading and also the ratio of the PU. Once all these materials are weighed, all the three materials are then poured into a container and are stirred well for about 5 minutes at room temperature. The mixed substance is then poured into the plastic mould of size 15 cm x 7.3 cm and sample are cured at room temperature for 24 hours. By using the same procedure samples with different fiber loadings were prepared; namely 0, 2, 4, 6, 8, and 10 wt. %.

3. Characterization of biocomposites

3.1 Impact test

The Impact Test was carried out by using the machine model FIT-300EN(ISO 148). The samples used are cut using a band saw machine to form a rectangular shape with dimensions 60 mm x 13 mm x 3 mm. By using a notching cutter, a v-notched impact specimen was prepared according to ASTM D 256. The machine used is a Charpy impact testing machine. There was three specimens for each fiber content and an average value was taken. The impact strength (J/m²) was calculated by dividing the recorded absorbed impact energy by the cross section area of the specimens. The impact energy reading can be obtained when carrying out the test. The dimensions of the sample will be measured by using a digital Vernier caliper for better accuracy. The cross section area will be calculated by multiplying the width and the thickness of the specimen

3.2 Hardness test

The Shore-D hardness test was carried out by using the machine model TRS-150_TRB for this project. The samples were cut to a dimension of 80 mm x 20 mm x 4 mm with the use of a band saw machine. This test was carried out according to ASTM D 2240. A total of five specimens were prepared for this testing. On each specimen a total of 10 points were taken to measure the hardness value.

3.3 Scanning Electron Microscope (SEM)

The surface of the specimen were observed by using JEOL SEM machine model JSM-6010PLUS. The microstructure image were taken on fracture area of the impact test samples. This fractured area is the area after the sample undergoes the impact testing. There were two samples which were studied for morphological analysis which is the 2 wt% and 10 wt% fiber loading sample. Each specimen analyzed by using a magnification of 1000X, 1500Xand 3000X. The specimen is coated with platinum prior to SEM observation. The Auto Fine Coater machine was used with the model JOEL JSC 3000FC

4. Results and Discussion

4.1 Impact strength

The impact energy and impact strength of the Kenaf\PU biocomposite are shown in Figure 2. Impact energy found to be increasing as the Kenaf fiber loading increased. The highest impact energy observed for biocomposite with 10% fiber loading with a value of 2.13 J. Impact strength showed a positive increasing trend by increase in fiber fraction. The lowest impact strength is for pure PU sample and the highest impact strength is the 10% fiber loading with 25199.17 J/m². There is a gradual increase in the impact strength as there is an increase in the fiber loading of the Kenaf fiber and this can be seen in Figure 3. Nearly 30.29% of increase in impact strength was observed when fiber loading was varied from 0% to 10%.

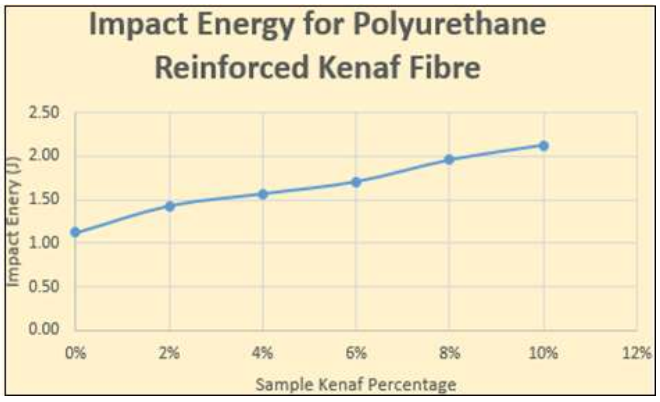

Figure 2: Impact energy for Kenaf\PU biocomposite with different fiber loading.

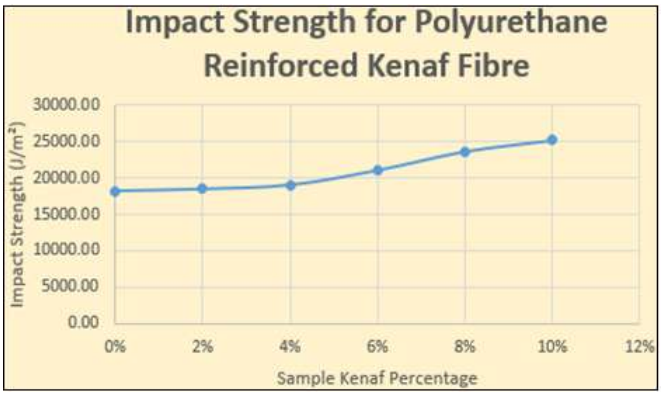

Figure 3: Impact energy for Kenaf\PU biocomposite with different fiber loading.

From the results, it can be observed that different fiber loading of the Kenaf fiber has significant effect on the impact strength of the Kenaf fiber reinforced polyurethane (PU) composite. Due to the presence of Kenaf, the biocomposite undergo ductile deformation before fracture when load is applied on it. Due to this increase ductility property they can absorb more energy, as a result impact strength is increasing. A similar trend has been observed when woven flax fiber were reinforced with polyurethane by Bledzki et al.[6]. Polyurethane is a generally a brittle material. Usually for brittle materials it will deform faster when load is applied to it. As can be seen the impact energy of the pure polyurethane is very low compared to the composite material of the Kenaf fiber reinforced polyurethane. Thus, it can be said that the material is able to absorb more load due to this properties and therefore the impact strength will increase as a consequence of this. Similar trend is observed when emu feather is reinforced with epoxy composite by V. Chandra sekhar et al. [8]

3.2 Hardness of Kenaf\PU Biocomposite

Hardness strength of the Kenaf fiber reinforced polyurethane biocomposite are shown in the graph in Figure 4. Hardness value for the biocomposite increased as the fiber loading increased. However pure PU has higher hardness then the composite. The pure polyurethane has a hardness strength of 40.512 HB. The 2% fiber loading composite has the lowest hardness amongst the composites with a results of 20.428HB. 10% fiber loading had the best hardness it has the highest reading for hardness with 27.74HB. An increased of additional fiber loading will result with higher hardness and previous study reported the same trend by Zainudin et al. [9]. In comparison for both the impact test and the hardness test, it can be said that the mechanical properties of the composite changes with addition of the Kenaf content. As seen from the results, a low fiber loading composite has low hardness strength and also low impact energy and strength. As the fiber loading increases the value of the hardness strength, impact energy and strength increases as well.

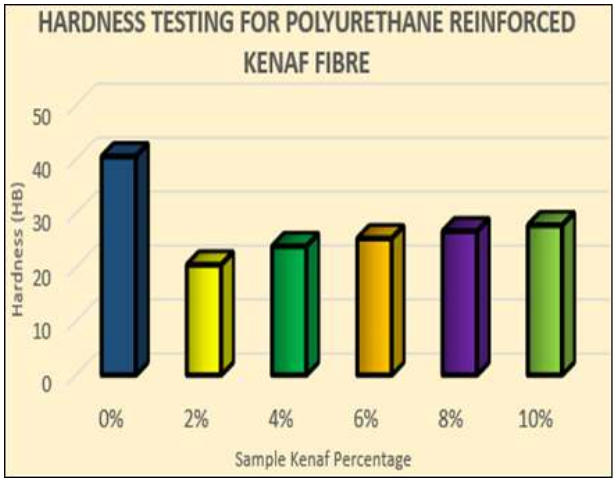

Figure 4: Hardness of Kenaf\PU biocomposite with different fiber loading.

The mechanical properties greatly affected with the fiber loading. This shows that the hardness strength and the impact strength has a linear relationship with the percentage of the fiber loading. For the pure polyurethane, it shows that it has the highest hardness but lowest impact energy and impact strength. As said earlier, pure polyurethane is a brittle material and therefore it will possess the highest hardness but low impact energy.

3.3 Scanning Electron Miscroscope (SEM) analysis

The Scanning Electron Microscope (SEM) test was done for the 2, 3, and 3 wt% Kenaf fiber loading samples.. The SEM test was done for magnifications of ×1000 and ×1500. From the 2% fiber loading SEM test as shown in Figure 5 and Figure 6, it can be seen there is more voids between the polyurethane and the Kenaf fiber. This is the reason why a low amount of impact energy is need to break the composite.

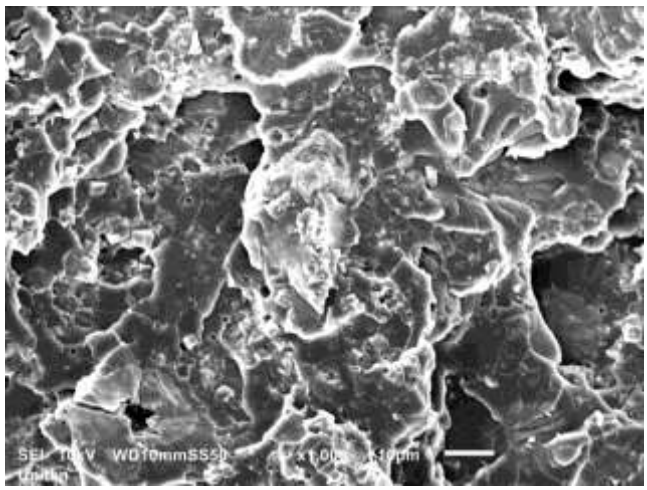

Figure 5: SEM image of 2 wt. % kenaf fiber reinforced PU biocomposite at ×1000 magnification

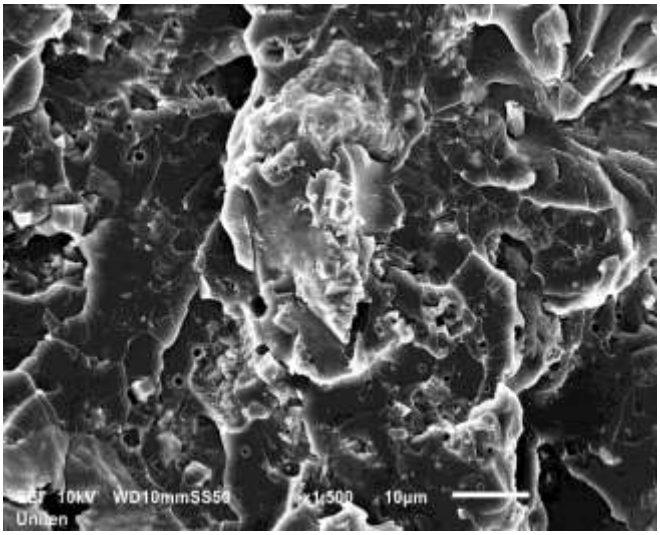

Figure 6: SEM image of 2 wt. % kenaf fiber reinforced PU biocomposite at ×1500 magnification

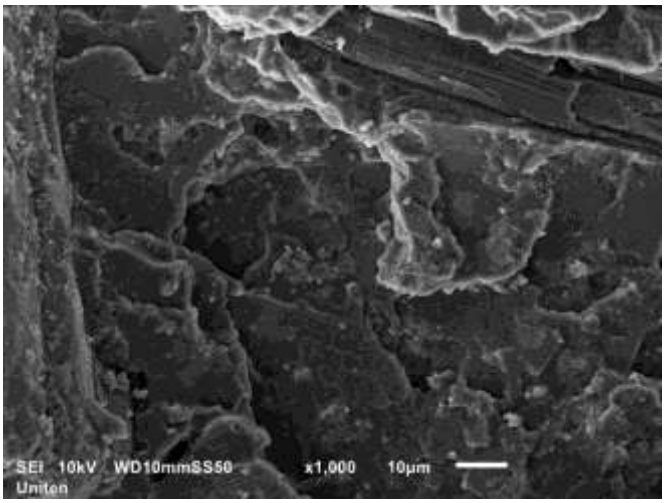

Figure 7: SEM image of 8 wt. % kenaf fiber reinforced PU biocomposite at ×1000 magnification

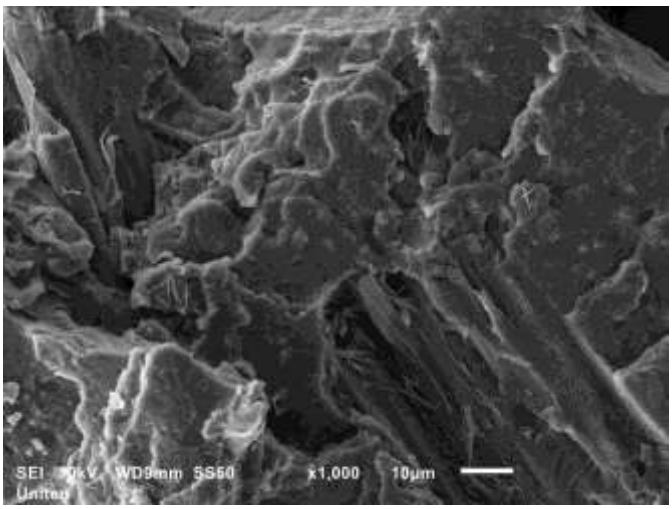

Figure 8: SEM image of 10 wt. % kenaf fiber reinforced PU biocomposite at ×1000 magnification

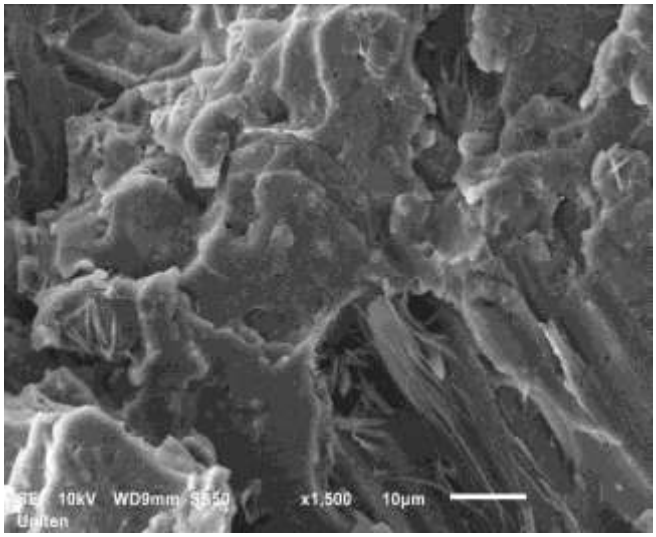

Figure 9: SEM image of 10 wt. % kenaf fiber reinforced PU biocomposite at ×1500 magnification

For the 10% fiber loading SEM test is as shown in Figure 9 and Figure 10. From the test it can be seen that the bonding between the Kenaf and the polyurethane shows a closely packed particles. There is very less gaps between the polyurethane and the Kenaf fiber bonding. This the reason why a very high impact energy is need to break the bonds between the polyurethane and the Kenaf fiber. It can be said that the 10% fiber loading SEM test showed the best result compared to the 2% fiber loading. The 10% fiber loading showed a very good interaction or bond between the polyurethane and Kenaf. The void content of the composite decreases when the fiber loading increase as we can see from the Figure 5 to Figure 10. From all the magnification of the 10% fiber loading, it can be seen that there are lesser voids between the Kenaf and polyurethane bonding.

Basically, there were no any fiber pullouts from the analysis. This shows that the Kenaf and the polyurethane has good bonding. From the 10 wt.% fiber loading which is in Figure 9 to 10, it can be said that the bonding strength between the fiber and the polymer matrix is very strong. The bonding between this Kenaf and polyurethane is due to a physical bonding process. Kenaf fiber has a rough surface which actually is an advantage as it can provide better interlocking between the composite materials. Previous studies reported the same trend by El-Shekeil et al. [11]. From the mechanical properties tested, it can be seen that the hardness strength and impact strength for the 10% fiber loading was the highest. From the morphology study, the 10% fiber loading showed lesser void and stronger interfacial bonding between the fiber and polymer matrix. Therefore, it can be said that Kenaf reinforced polyurethane with stronger bonding will have higher hardness. For the 2% fiber loading the morphological study showed that it had more void contents. This is the reason why the hardness was very low and the impact energy needed to fracture the composite only needed a smaller amount compared to the 10% fiber loading.

5. Conclusion

Based on the results, following conclusions drawn for this study.

1) Impact strength increases with increase in fiber loading. It can be concluded that 10% fiber loading PU biocomposite exhibits the highest impact strength.
2) Kenaf fiber reinforced PU has lower hardness than pure PU. However, increase in fiber loading increases the hardness of the composite. Hardness was the best for the 10% fiber loading as it was the highest for the composite.
3) The morphology observation showed the bonding between the composites. It can be seen that 10% fiber loading showed the best fiber and filler bonding as there is less voids in the biocomposite.

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