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Factors that affect the mechanical properties of kenaf fiber reinforced polymer: A review

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ABSTRACT

Kenaf fibre has emerged as an important plant cultivated in Malaysia and has been regarded as an industrial crop. The utilization of natural fibres, such as kenaf fibre, in the polymer matrix composites has, in fact, received much attention due to certain attributes, such as low in cost and density, as well as its biodegradability feature. Moreover, numerous potential applications using the kenaf fibre can be explored due to its vast physical and mechanical properties. For instance, chemical treatment, fibre content and form, interfacial adhesion, and water absorption are some of the factors that affect the mechanical properties of kenaf fibre reinforced polymer. Besides, the study on the mechanical properties of kenaf fibre composites is indeed important as it plays an important role in determining a suitable application for various industrial products. In this review work, the factors that affect the mechanical properties of kenaf fibre reinforced polymer composite are highlighted to provide a source of literature for further researches concerning the use of kenaf fibre polymer composites on various applications.

Keywords: Kenaf fibre; polymer matrix composite; mechanical properties

INTRODUCTION

Natural fibre polymer composites have become a great alternative solution to replace the use of man-made fibres [1-4]. Natural fibres can be divided into animal-based and plant-based. Examples of animal-based fibres are silk, wool, and chitosan [5], whereas some instances of plant-based fibres are pineapple, sisal, bamboo, flax, hemp, jute, kenaf, and ramie [6]. Past these recent years, natural fibre from kenaf has been widely used across the world due to the raising environmental concern, as well as its lower cost compared to synthetic fibre [6-8]. Moreover, according to Nishino et al., [9], producing 1 kg of kenaf needs 15 MJ of energy, while the production of 1 kg of glass fibre needs 54 MJ of energy. Thus, the usage of natural fibre can substantially reduce energy consumption in the future. In fact, numerous studies have looked into the use of kenaf fibre polymer composites [10-12], including the various factors that affect the mechanical properties of the kenaf fibre reinforced polymer. Besides, the usage of kenaf fibre in various structural and non-structural applications, such as automotive, furniture, and textiles [9, 13-17], has led to this review. The review on factors that affect the mechanical properties of kenaf fibre reinforced polymer is significant to reduce the problems encountered by many researchers who intend to use kenaf fibre with the desired properties. The publication of this review article should be of significant value to researchers who utilise kenaf fibre reinforced polymer [14, 18-21]. As such, the sole objective of this paper is to list the factors that affect the mechanical properties of the kenaf fibre reinforced polymer matrix. Furthermore, previous studies on the mechanical properties of the kenaf fibre reinforced thermosetting and thermoplastic polymers are also highlighted in this study. Then, the factors that affect the mechanical properties of composite materials are also presented in this paper. Lastly, the paper ends with a conclusion of the review.

KENAF FIBER

Kenaf (*Hibiscus cannabinus, L. family Malvaceae*) is suitable to be grown in a tropical country like Malaysia and Indonesia due to its weather condition [22]. Besides, kenaf can grow to more than 3 m and its yield can be harvested three months later [6, 22]. In the Asean Free Trade Agreement (AFTA), tobacco was excluded from the list and thus, the import of tobacco has decreased drastically. Hence, kenaf has substituted tobacco in Malaysia [23]. Additionally, the Malaysian government has spent a lot of money in research and further development of kenaf. For example, RM 35 million was allocated for the research in the 9th Malaysian plan and RM 65 million was spent in the 10th Malaysian plan [24]. Furthermore, the Malaysian government proposed to plant 5000 ha of land with kenaf in 2015, as reported by the National Kenaf and Tobacco Board [25]. Therefore, kenaf would emerge as the third commodity plant in Malaysia, just behind rubber and oil palm. The states that are involved with kenaf planting are the Peninsular Malaysia, Sabah, and Sarawak with a total area of approximately 328600 km^2 [23], divided into 131600 km^2, 73700 km^2, and 123300 km^2 respectively [23]. With that, 5000 tobacco farmers have been considered for planting kenaf to replace tobacco on their lands. Besides, kenaf is high in minerals for animal feed and it is also a substitute to softwood and hardwood [26]. In addition, according to Faruk et al., [27] and Saba et al., [5], kenaf bast fibre can be used to replace glass in polymer composites.

The kenaf fibre can be produced by the retting process. Kenaf fibre can be extracted from its bast and core. Different parts of kenaf have various percentages of components, as shown in Table 1. Cellulose provides the strength and stiffness of the kenaf fibre, whereas hemicellulose controls biodegradation, thermal degradation, and moisture absorption of kenaf fibre [6]. Thus, selecting the correct fraction of kenaf fibre can help researchers or manufacturers obtain their desired properties for utilization in various applications. Rouison et al., [28] too agree that the percentage of components in kenaf fibre affects its overall properties.

Table 1. Percentage of components in different parts of kenaf fibre [29].

Organic composition of fibres				Inorganic (ash content) (%)	Fibre length (Avera) (mm)	Composition of whole stem (%)
Fractions	Cellulose (%)	Hemicellulose (%)	Pentosan (%)			
Bast	56.4	26.2	13.4	2.2	2.48	34.3
Stem	48.7	28.1	19	1.8		
Core	46.1	29.7	20.7	1.6	0.72	65.7

Cellulose is a non-branched macromolecule and contains various lengths of 1-4 linked β-d-anhydroglucopyranose units [30]. The cellulose is composed of C, H, and O_2. Figure 1(a) shows the chemical structure of cellulose. The general chemical formulae for cellulose is $C_6H_{10}O_5$. The strength of kenaf fibre depends on the cellulose and the modulus of kenaf fibre is higher due to the high cellulose content [6]. The hemicellulose is located at the primary cell wall and it is hydrophilic. It is used to strengthen the cell wall. In its structure, it is composed of 6- and 5-carbon ring sugars and it is in a branched structure. Figure 1(b) illustrates the chemical structure of hemicellulose in kenaf fibre. Meanwhile, Figure 1(c) shows the chemical structure of a lignin. The function of lignin is to support the plant mechanically and also to strengthen the plant. The location of the lignin is between the cellulose and the hemicellulose to bind them together. Lignin also controls the UV degradation in kenaf fibre [6].Pectin is one of the components of the cell wall, which is responsible for flexibility of the plant and solubility in water. Pectin holds cellulose and hemicellulose together on to the stem and surrounds them. Therefore, pectin is removed in order to separate cellulose and hemicellulose from the stem [31].

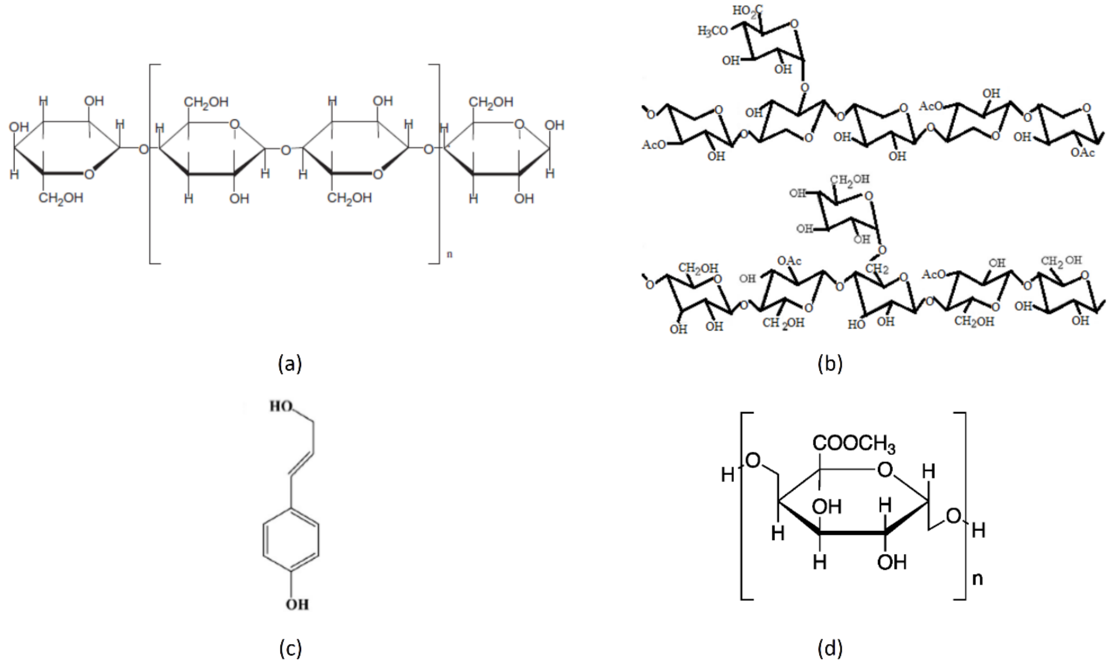


Figure 1. Chemical structure of (a) cellulose; (b) hemicellulose; (c) lignin; (d) pectin [6, 31].

Polymer matrices are divided into two types; thermoset and thermoplastic polymers [14, 22, 32]. Thermoset polymer cannot be recycled due to the cross-linked bonding and it does not change its phase after a solid phase. However, the thermoplastic can be recycled and remoulded. The thermoset polymer only needs low heat and pressure for production, which differs from thermoplastic polymer. Besides, low tooling system is applied to the production of thermoset composites. On the other hand, the production of thermoplastic composites needs a heavy and strong tooling. The mechanical properties of the kenaf fibre reinforced thermoplastic and thermoset composites are shown in Tables 2 and 3, respectively. Table 2 shows numerous factors that eventually affect the mechanical properties of the kenaf fibre reinforced polymers.

Table 2. Mechanical properties of thermoplastic composites.

Composite/ Fibre	Purpose/Treatment	Method	Result	Ref.
Kenaf fibre reinforced polypropylene	Two types of treatments were carried out: i) Kenaf mixed with polypropylene. ii) Chemical/enzyme treatment	Compression moulding	The tensile strength and the modulus of treated kenaf reinforced polypropylene were higher by 36% and 63% respectively compared to that untreated.	[33]
Kenaf fibre reinforced polypropylene	Six different temperatures (190°C, 200°C, 210°C, 220°C, 230°C, and 240°C) and four types of barrel speed	Compression moulding	The optimum processing of temperature and barrel speed were 230°C and 16 Hz.	[34]
Kenaf fibre reinforced polyurethane	Two tests were performed: i) The optimum of processing parameters ii) Various fibre sizes (smaller 125 µm, 125-300 µm, and 300-425 µm.	Compression moulding	The optimum processing parameters were 190°C, 11min, and 40 rpm. The optimum fibre size was 125-300 µm.	[35]
Soil buried kenaf fibre reinforced polyurethane	Determine the effect of water absorption for 30% of fibre volume, as well as 20, 40, 60, and 80 days of soil buried test.	Compression moulding	The flexural strength of composite was not affect significantly. The tensile strength was significantly influenced and dropped to 16.14 MPa after 80 days.	[36]
Kenaf fibre reinforced polypropylene	To determine the relationship between flexural modulus, kenaf weight fraction, and heating time.	Hot press forming	Kenaf and polypropylene displayed better wetting when the heating time increased. The thickness of composite was 2 mm for 18 layers with higher flexural modulus.	[37]
Kenaf fibre reinforced high-density polyethylene	To find out tensile, rheological, and mechanical properties of the composite at high (HPT) and low processing (LPT) temperatures.	Extrusion and compression	At LPT and HPT, the tensile modulus increased when both the temperatures increased. However, when the fibre content increased in the composite, the HPT had better tensile strength than LPT. HPT provided better rheological and mechanical properties for the composite compared to LPT.	[38]
Kenaf fibre reinforced polypropylene	The effect of the temperature on tensile and flexural properties	Extrusion	The suitable processing temperature for 40% fibre content was 185/200°C.	[39]

Table 2. Continued.

Composite/ Fibre	Purpose/Treatment	Method	Result	Ref.
Kenaf bast fibre reinforced thermoplastic elastomer composites	Fibre content was 20%. 70:30 was the ratio between thermoplastic and elastomer. The purpose is to compare the mechanical properties of kenaf fibre reinforced natural rubber (TPNR) and kenaf fibre reinforced polypropylene/ethylene-propylene-diene-monomer (PP/EPDM).	Compression moulding	Maleic anhydride polypropylene (MAPP) increased the mechanical properties of both composites. With the presence of kenaf, tensile strength of TPNR-kenaf-MAPP and PP/EPDM – kenaf-MAPP increased 55% and 81%, respectively.	[13]
Kenaf fibre reinforced polypropylene	Fibre content was 30% and 40%. A comparison was made for the mechanical properties between the different types of natural fibre reinforced polypropylene.	Compression moulding	The 3% Epolene G3015 improved the adhesion between fibre and matrix. Kenaf reinforced polypropylene had similar tensile and flexural strength compared to 40% of flax and hemp.	[40]
Kenaf fibre reinforced polypropylene	To study the use of zein as a coupling agent. Kenaf was processed to non-woven. 2% of zein was mixed with ethanol and water (80/20). Later, kenaf was immersed in it for 2 hours and dried at 110°C.	Compression moulding	Zein increased the mechanical properties of kenaf fibre reinforced polypropylene.	[41]

The processing temperature affects the mechanical properties of the kenaf fibre reinforced polypropylene. The fabrication process of the thermoset polymer only needs low pressure and temperature. However, the compression moulding is preferable to produce thermoplastic composite due to the high temperature and pressure. One possible explanation is that a compression moulding could produce great mechanical properties for kenaf fibre reinforced thermoplastic composite. Moreover, high temperature and pressure could increase the interfacial bonding between the thermoplastic polymer and the kenaf fibre. Meanwhile, Table 3 depicts that most of the methods used in the preparation of kenaf fibre composite had been via hand lay-up. The hand lay-up technique is a traditional and the simplest method to prepare thermoset composite. Besides, the mechanical properties of kenaf fibre reinforced thermoset decreased after an optimum fibre content. This is because; the bonding between the thermoset polymer and the kenaf fibre becomes poor. Monteiro et al., [42] agree that the lower bonding between polymer and fibre decreases the strength of polymer matrix composite.

FACTORS THAT AFFECT MECHANICAL PROPERTIES OF KENAF FIBER REINFORCED POLYMER

The composite materials consist of two parts: matrix and reinforcement. Apparently, both are the main components for the optimum mechanical properties. This section explains in detail the factors that affect the mechanical properties of kenaf fibre reinforced polymer.

Table 3. Mechanical properties of thermoset composites.

Composite/ Fibre	Purpose/ Treatment	Method	Result	Ref.
Kenaf fibre reinforced polyester	To determine the tensile strength of the composite	Hand lay up	It was found that 40% of the fibre volume fraction can be used to replace human tissue.	[43]
Kenaf fibre reinforced polyester	Kenaf fibre was treated with different concentrations of NaOH (3%, 6%, and 9%) and various soaking times (12 hours and 24 hours)	Vacuum infusion	The results showed that increasing the immersion time spoilt the structure of the fibre. Alkali treatment can improve the mechanical properties of kenaf fibre reinforced polymer.	[44]
Kenaf fibre reinforced urea formaldehyde, phenol formaldehyde, and melamine urea	To determine the mechanical properties and the moisture content of various resin systems	Hot pressing	The melamine urea formaldehyde can tolerate higher load and have an intermediate moisture content.	[45]
Kenaf fibre reinforced epoxy	To compare the flexural strength of untreated and treated kenaf fibres	Hand lay-up	The flexural strength of the treated kenaf was higher by 36% than the untreated.	[46]
Kenaf and glass fibre reinforced epoxy	To study the mechanical properties of kenaf and glass fibre reinforced epoxy as car bumper and was compared with glass mat thermoplastic (GMT) to determine the mechanical properties	Sheet moulding compound	It was found that the tensile and flexural of the hybrid were around 150 MPa and 220 MPa respectively, which was better than GMT. However, for the impact test, GMT was better than the hybrid.	[47]
Kenaf bast fibre bundle (KBFB) and kenaf bast fibre reinforced epoxy	To study the tensile properties of KBFB and kenaf bast fibre reinforced epoxy	For the KBFB, it is produced by using bacteria retting and compression moulding	Two failure mechanisms were identified, where the fibre was pulled out and broken. The tensile modulus did not have any reaction to the high processing temperature.	[48]
Kenaf fibre reinforced epoxy	To study the defect of the composite by using infrared camera	Hand lay-up and compression moulding	The defect of infrared camera was 95% compared with SEM	[49]
Kenaf fibre reinforced concrete	Fibre content was 1.2% and 2.4%. To determine the mechanical properties of kenaf bast fibre concrete	Hand lay-up	With lower fibre content, the strength of kenaf fibre reinforced concrete was almost similar to that of non-air entrained plain concrete. However, for higher fibre content, the strength was lower.	[50]
Cellulose-fibre reinforced epoxy laminates	To study the mechanical and fracture properties of the composite	Hand lay-up	Flexural strength and modulus increased with the strain at break.	[51]

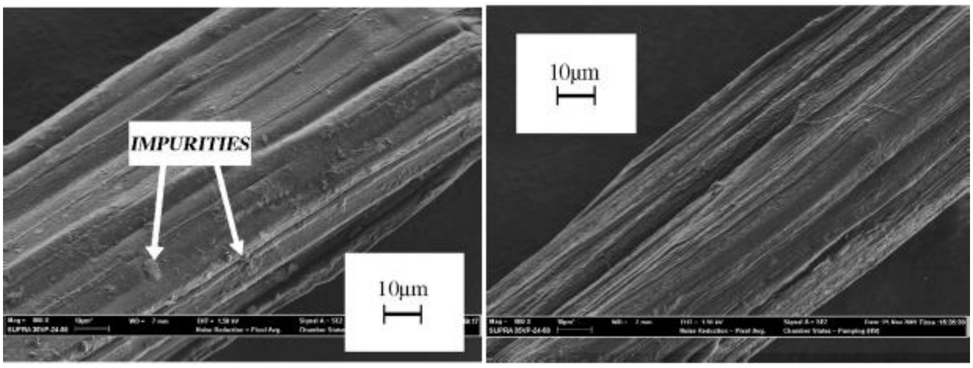
The factors include chemical treatment, fibre content, part of kenaf fibre, a form of fibre, bonding between matrix and fibre, as well as water absorption.

Chemical Treatment

Chemical treatment is one of the factors that affect the mechanical properties of kenaf fibre due to surface modification. Kenaf fibre is hydrophilic in nature and it tends to react with the hydroxyl group of the polymer. The hydrogen bond is formed and it is connected between the fibre and the polymer. During chemical treatment, the fibre was washed with warm tap water. Then, it was soaked in sodium hydroxide (NaOH) for a certain hour. According to Zhang and Kandlikar [52], kenaf fibre was immersed in 3%, 6%, and 9% of NaOH and the soaking time was 12 hours and 24 hours. After it was dried at room temperature for 24 hours, the fibre was left to dry in an aging oven at a temperature between 40°C and 70°C [46, 53]. The reaction between kenaf fibre and sodium hydroxide is shown in Eq. (1).

$$\text{Fibre-OH} + \text{NaOH} \rightarrow \text{Fiber-ONa} + H_2O \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

From the chemical equation depicted in Eq. (1), water is produced from the chemical reaction. Any impurities on the surface of the fibre were removed by water. On the other hand, Figure 2 shows that impurities were reduced after the chemical reaction from the chemical treatment. Figure 2 (a) shows the scanning electron microscope (SEM) images of the fibre before chemical treatment, while Figure 2 (b) shows the SEM image of kenaf fibre after chemical treatment.



(a) (b)

Figure 2. Kenaf fibre (a) before; (b) after chemical treatment [54]

Therefore, the bonding between the polymer and the treated kenaf fibre is stronger compared to the untreated kenaf fibre composites. Yousif et al., [46] also agree that the results of flexural strength for treated kenaf fibre outperformed the pure epoxy and the untreated kenaf fibre composites. Furthermore, Figures 3 and 4 portray that the flexural strength and the modulus of treated kenaf fibre are superior compared to the pure epoxy and the untreated kenaf fibre composites. In fact, the flexural strength and modulus improved by 60% and 62% respectively [46]. This is because; the surface roughness of the fibre increased and thus, caused better mechanical interlocking [55]. In short, the adhesion between kenaf fibre and polymer matrix was improved. Table 4 shows the results of mechanical properties of previous works after chemical treatments were performed on kenaf fibre. Besides, Table 4 presents that the optimum concentration of

NaOH for kenaf fibre was 6%. The alkali treatment is not only related to the concentration of the alkali, but also immersion and drying time. However, if the concentration is too high, which is beyond 6% or the immersion time is too long, the structure of kenaf fibre can be damaged, thus affecting the mechanical properties of the kenaf fibre indirectly.

Table 4. The findings of chemical treatment for kenaf fibre

Composite/ Fibre	Treatment	Result	Ref.
Kenaf fibre	Comparison of a few categories for i) untreated ii) immersed with 10% NaOH for 2 h iii) immersed with 15% NaOH for 1 iv) immersed with 15% NaOH for 2 h v) immersed with 15% NaOH for 4 h vi) immersed with 15% NaOH for 6 h	It showed that untreated had the highest tensile strength, which was 320 MPa, followed by kenaf fibre immersed in 15% of NaOH for 1 hour, which was 263MPa. As for kenaf immersed in 15 % NaOH for 4 to 6 hours, the fibres lost their substance.	[56]
Kenaf fibre-reinforced polylactic acid (PLA)	i) Alkali treatment with 5% NaOH and immersed for 2 h. ii) Silane treatment with 5 % of APS and immersed for 3 h	Fibre treated with NaOH or APS had higher mechanical properties compared to untreated fibre.	[57]
Kenaf fibre reinforced MAPP/MAPE	The kenaf fibre was treated with 0%, 3%, 6%, and 9% of NaOH. They were immersed in NaOH for a day and dried for 24 hours.	6% of NaOH was the optimum concentration to treat kenaf fibre.	[58]
Kenaf fibre reinforced epoxy	Kenaf fibre was treated with 6% NaOH for 48 and 144 hours at room temperature. Then, the fibres were washed with distilled water and dried for 6 hours.	Chemical treatment of 48 hours cleaned the impurities. However, the 144 hours of alkali treatment spoiled the structure of kenaf fibre.	[11]
Kenaf fibre	There are 5 categories: i)Untreated fibre ii)Treated with 5% NaOH for 3 h iii)Treated with 7% NaOH for 3 h iv)Treated with 10% NaOH for 3 h v)Treated with 15% NaOH for 3 h	5% NaOH was the optimum concentration for kenaf fibre compared to 10% and 15%	[30]

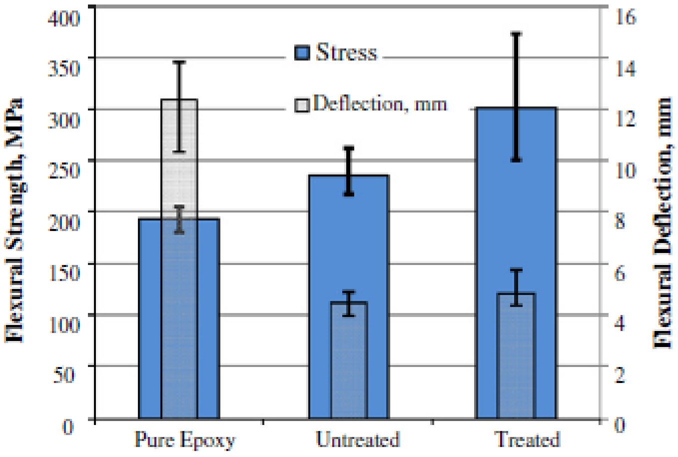


Figure 3. Flexural strength and deflection of pure epoxy, untreated, and treated kenaf fibre [46].

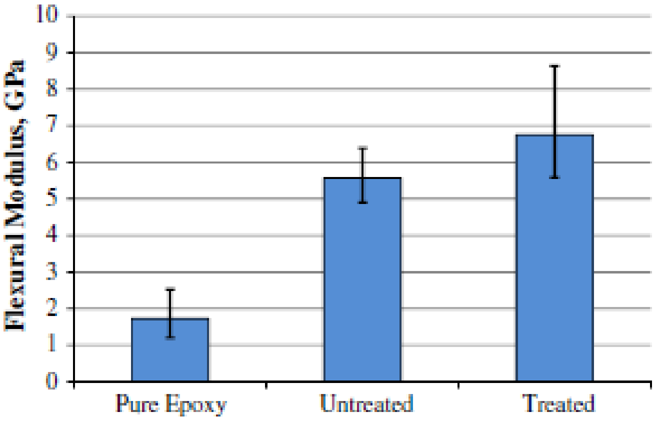


Figure 4. The flexural modulus of pure epoxy, untreated kenaf, and treated kenaf [46].

Fibre Content

Different fibre contents also affect the mechanical properties of the kenaf fibre reinforced polymer. The amount of fibre in the composite can be calculated by using Eq. (2).

$$V_f = \frac{V_f}{V_c} \qquad (2)$$

Where V_c is the total volume of the composite and V_f is the volume of fibre.

According to Sapuan et al., [36], the kenaf reinforced poly-L-lactic acid (PLLA) was used as the specimen and the tensile strength was tested. Figure 5 shows the Young's modulus and tensile strength of kenaf fibre composites. It can be seen that the tensile strength and Young's modulus increased when the fibre content increased. However, after 70% of fibre content, the tensile strength and Young's modulus decreased. This had been due to the poor bonding between resin and kenaf fibre [9].

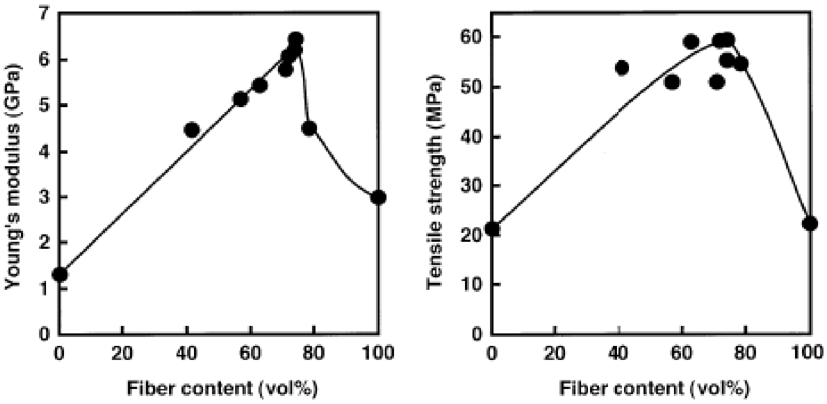


Figure 5. Young's modulus and tensile strength versus kenaf fibre content [9].

Figure 6 illustrates the results of tensile strength with a variation of kenaf and jute fibre weight fraction. The fibre weight fraction was varied from 0% to 70%. The results show that the tensile strength increased as the fibre weight fraction increased. Moreover, Ku et al., [59] agree that the fibre weight fraction affected the tensile properties of natural fibre reinforced polymer. However, the tensile strength of the natural fibre reinforced polymer was reduced by 40% [60], as the natural fibre composites achieved its optimum fibre weight fraction.

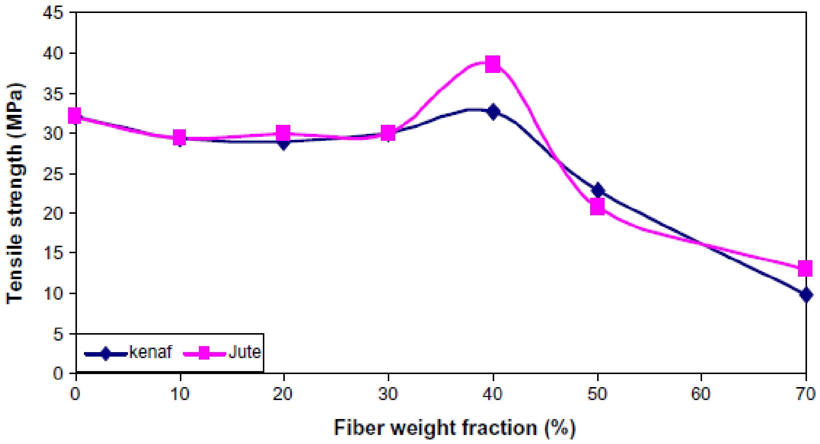
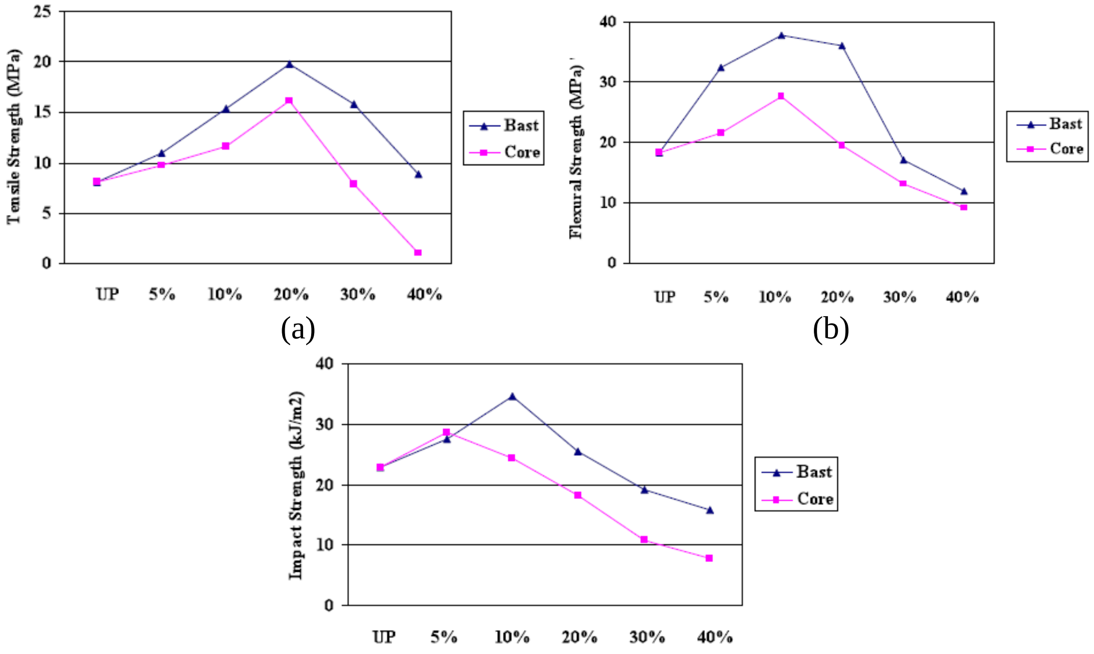


Figure 6. Tensile strength versus fibre fraction in kenaf and jute reinforced polypropylene [59].



(a) (b)

(c)

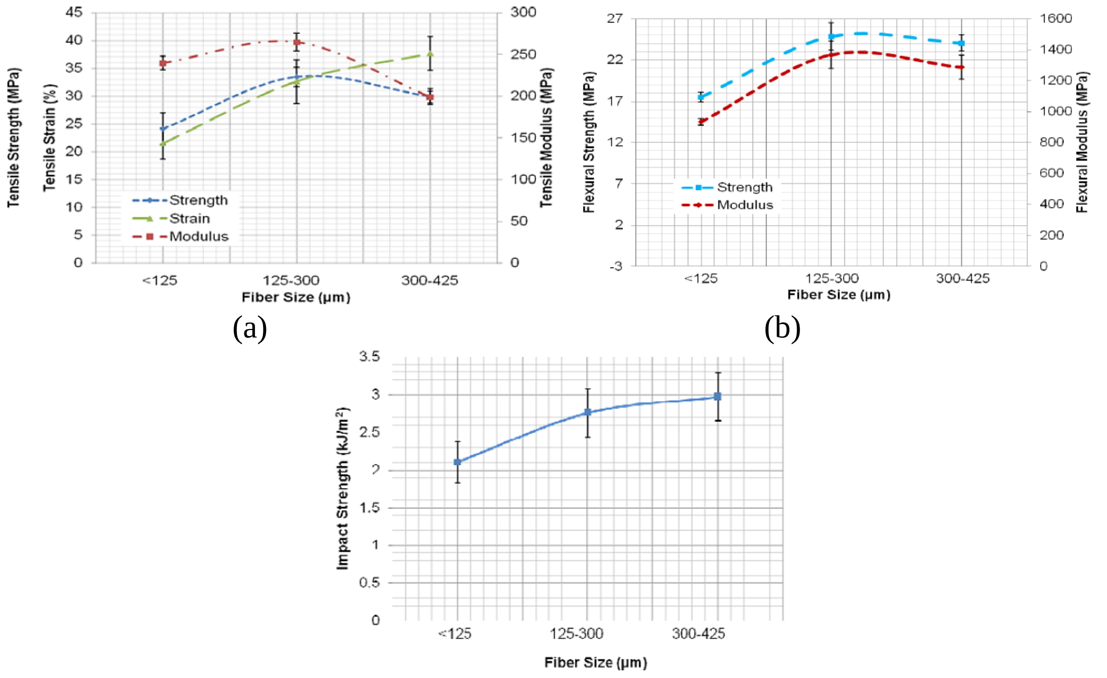
Figure 7. (a) Tensile strength; (b) Flexural strength; and (c) Impact strength with variation of bast and core kenaf fibre content [60].

Part of Kenaf Fibre

Bast, stem, and core are parts of kenaf fibre highlighted in several studies [29]. Figures 7 (a) to (c) illustrate the results of tensile strength, flexural strength, and impact strength of bast and core kenaf fibre reinforced unsaturated polyester (UP), respectively. The kenaf fibre content varied from 5% to 40% with UP as the datum. It clearly shows that bast kenaf fibre exhibits better mechanical properties as compared to the core kenaf fibre. The mechanical properties of fibres are affected strongly by cellulose, hemicellulose. and lignin contents and it is mainly influenced by cellulose [61, 62]. Thus, the higher mechanical properties displayed in Figure 7 is probably due to the higher cellulose content in the bast kenaf fibre.

Fibre Form

There are many types of form for reinforcement, such as fibre, powder, and bulk. Compared to the other types of fibre form, the powder form has the smallest volume. According to El-Shekeil et al., [35], the mechanical properties of kenaf fibre reinforced polyurethane composites was influenced by the size of kenaf fibre. Figures 8 (a) to (c) respectively illustrate tensile strength, flexural strength, and impact strength of kenaf fibre composite. In fact, the three different sizes of kenaf fibre studied had been smaller than 125 µm, 125-300 µm, and 300-425 µm. From the results, it can be seen that the optimum fibre size for kenaf fibre reinforced unsaturated polyester is 125-300 µm. This is because; larger-sized kenaf fibre can absorb more energy [35].



(a) (b)

(c)

Figure 8. (a) Tensile strength; (b) Flexural strength; and (c) Impact strength versus fibre size [35].

Bonding between Matrix and Fibre

The main problem during the reinforcement of the kenaf fibre, which is hydrophilic in nature and a polymer that is hydrophobic in nature, is the incompatible reaction between them. Figure 9 shows the image of voids in a specimen due to the incompatible reaction between the kenaf fibre and the matrix. Thus, poor results were produced when there was lack of bonding between matrix and its reinforcements [6, 54]. The agglomeration of kenaf fibre caused insufficient bonding between matrix and kenaf fibre. This reduced the mechanical properties of kenaf fibre composite. Moreover, the presence of voids in the specimens also reduced the performance of kenaf fibre composites. One possible explanation is that the load transfer to the composite was blocked [63]. Besides, it is widely known that natural fibre is hydrophilic in nature. When the kenaf fibre is mixed with polymer, hydrogen bond is formed. The disruption of hydrogen bond in the structure of kenaf fibre increases the surface roughness. Therefore, the interfacial adhesion between matrix and kenaf fibre could be increased.

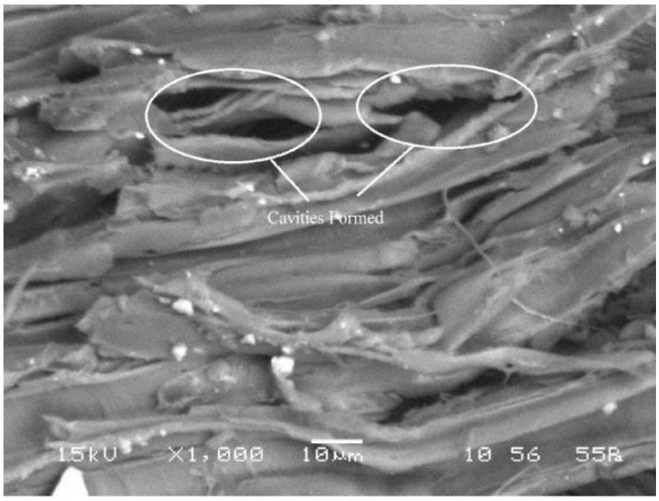


Figure 9. Voids in specimen [64]

Water Absorption

The natural fibre is hydrophilic in nature and tends to absorb moisture. The weight percentage obtained from the moisture absorption can be calculated by using Eq. (3).

$$W\% = \frac{W_t - W_o}{W_o} \ldots\ldots\ldots\ldots(3)$$

Where *W%* is the moisture content, W_t is the weight after immersion, W_o is the original weight of the specimen.

Figure 10 shows an image of crack on a specimen due to water absorption. According to Taib et al., [65], water absorption causes de-bonding and crack between matrix and fibre. The bonding between fibre and matrix swells due to moisture absorption.

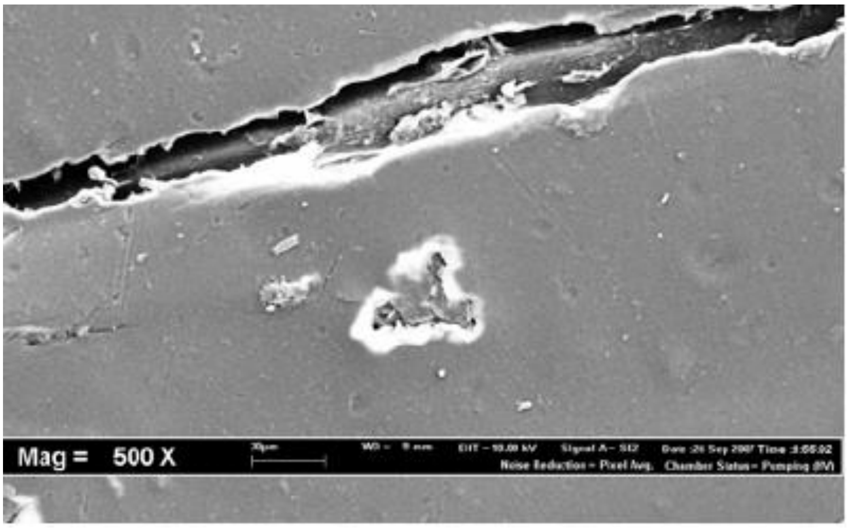


Figure. 10. Crack due to water absorption [65].

CONCLUSIONS

Kenaf fibre has been focused by the Malaysian government in these recent years due to AFTA. Therefore, a lot of money has been spent in the research and development of kenaf. Nonetheless, some factors have been identified to affect the mechanical properties of kenaf fibre reinforced polymer. First, those fibres that go through chemical treatment are clean from containments as compared to those untreated. Besides, fibre content also influences mechanical properties. Part of the kenaf fibre contributes to the results of mechanical properties due to the percentage of cellulose. Next, the fibre form, which is used in the fabrication process, affects the mechanical properties and it is related to the length and the diameter of the fibre. Last but not least, water absorption induces micro cracks in fibre. Kenaf fibre has a great potential for replacing synthetic fibres, such as glass fibre. However, further studies need to be conducted to replace other synthetic fibres, such as carbon fibre. In addition, the study of hybrid kenaf fibre for both structural and non-structural applications could increase the manufacturing of products using green technology. Lastly, this review paper could hopefully provide a literature source for the development of kenaf fibre composite.

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