Pertanika J. Sci. & Technol. 25 (4): 1103 - 1122 (2017)

PERTANIKA JOURNALS

SCIENCE & TECHNOLOGY

Journal homepage: http://www.pertanika.upm.edu.my/

Review Article

Mechanical and Thermal Properties of Natural Fibre Based Hybrid Composites: A Review

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ABSTRACT

Environmental issues have motivated researchers to replace synthetic fibres with natural fibres in the fabrication of polymer composites. However, natural fibres demonstrate weak mechanical or thermal properties which limit their different applications. Researchers have suggested fabrication of hybrid composites in order to improve the mechanical and thermal properties of natural fibre-based composites. Hybrid composites are made up by two or more fibres in one matrix or two polymer blends and with one natural fibre reinforcement. By hybridising one natural fibre with another natural fibre/synthetic fibre in one matrix, the resulting composite is a unique product (hybrid composites) that displays better mechanical and thermal properties in comparison with individual fibre-reinforced polymer composites. The advantages of developing hybrid composites are that they are more reliable for different applications and more environmental friendly. In this review paper, we present some recently published works related to mechanical and thermal properties of natural/natural fibres, and natural/synthetic fibre-based hybrid composites.

ARTICLE INFO

Article history:
Received: 01 March 2017
Accepted: 28 August 2017

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ISSN: 0128-7680

Hybrid composites are one of the emerging fields in material science which has attracted attention for their different engineering applications.

Keywords: Fibres, composites, hybrid composites, mechanical properties, thermal properties

INTRODUCTION

Natural materials are considered as environmental friendly because of their low energy combustion, renewable and biodegradable characteristics. Kenaf, flax, hemp, jute, sisal and banana fibres are introduced as alternative materials for composite reinforcement because of their advantages of being renewable and having marketing appeal in composite manufacturing industries. Recently, manufacturers of different industries are interested in natural fibres and are trying to investigate new composites to replace the glass fibre-based composites or polymers. Applications of natural fibres are found in different industries such as civil constructions industry, aerospace and automotive industries, etc. However, natural fibres have some drawbacks such as low mechanical properties as compared to glass or carbon fibre-based composites. In addition, the water absorbent of natural fibres is considerably higher than that of the synthetic fibres. Therefore, as a solution to these drawbacks and to improve the properties of natural fibre-reinforced polymer composites, hybrid biocomposites are introduced. Hybrid biocomposites are made up of two or more fibres in one matrix.

In a novel review, Faruk et al. (2012), gathered information on most used natural fibres, as well as on the different treatments that could be done on natural fibres. This paper reviewed almost all papers related to natural fibres for the last ten years. Natural lacquer, epoxy, and organic silane compound were used to prepare a bio-based resin. Results indicate that this thermoset resin is capable of being applied in industrial applications for either producing thick resin materials or as a coating (Kanehashi et al., 2014). To avoid environmental issues and keep industrial properties in a desired range, hybrid biocomposites that are made up of a bio fibre, along with a nano-reinforced bio-based polymer, can be used. They presented the optimal designs for a maximum cooperation of the components to establish a benchmark for the enhancement of bio-based hybrid composite applications (Haq et al., 2008). These capabilities of natural fibres increased the attention of researchers to this area. It is understood that using natural fibres in a hybrid composite improves the mechanical properties, as well as thermal properties. In this paper, some of the studies related to the hybrid composites are reviewed to motivate further research on this topic.

Mechanical Properties

Mechanical properties are the most important aspect of an engineering material. The material should be able to bare special amount of loadings in different directions. Therefore, these properties of hybrid biocomposites are well studied. For instance, Narendar et al. (2014) developed coir pith/nylon fabric/epoxy hybrid composites by using hand layup and compression moulding method. The mechanical properties of composites such as tensile strength, flexural strength, impact strength and hardness determine that the coir pith acts as a good reinforcement with the epoxy resin matrix. Moreover, chemical treatment has been proven to enhance the mechanical properties of hybrid composites. It was also found that in hybrid composites, chemical and flame resistance improved after the chemical treatment. In addition, the hybrid composite of coir pith and nylon with chemically treatment were found to have longer durability of the panels in moist conditions. Atiqah et al. (2014) also developed kenaf-glass reinforced unsaturated polyester (UPE) hybrid composite for structural applications. Figure 1 shows the average flexural properties of the developed hybrid composites. The treated kenaf-UPE hybrid materials showed slightly better flexural behaviour in comparison with the untreated kenaf-UPE. This is because of the consolidation of fibre composite which was achieved through a combination of compaction, matrix impregnation and curing resulting in higher flexural properties of the hybrid composites.

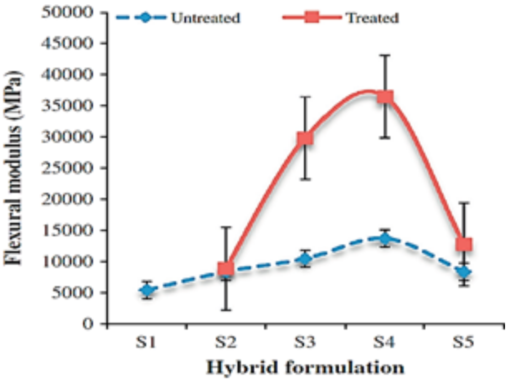


Figure 1. The flexural modulus of hybrid composite (Atiqah et al., 2014)

In another study, Özturk (2010) did a novel work that researched on the mechanical properties with different fibre loadings in natural composites of kenaf and flax fibers with phenol-formaldehyde resin. Stress-strain analysis of the above composite is demonstrated in Figure 2. The variation of fibre loading is between 19-62 vol %. That increment in fibre content up to 43 vol% increased the ultimate stress and elongation at break, while further increment in fibre content reduced these values of the composites. Akil et al. (2010) studied the flexural behaviour of pultruded jute/glass and kenaf/glass hybrid composites. According to this research, pultrusion is a proper method for fabricating kenaf and jute fibre composites, as well as their hybrid with glass fibres. Although optimisation may be needed due to the insufficient fibre impregnation and problem associated with control of fibre orientation to improve flexural and indentation performances of the laminate, especially for kenaf fibre laminates.

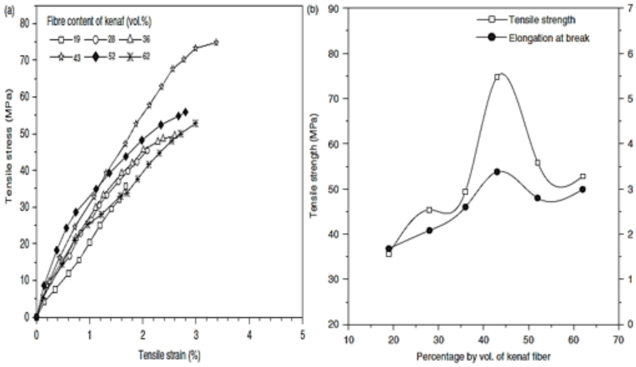


Figure 2. The effect of fibre loading on: (a) stress-strain behaviour of kenaf/PF composites, and (b) tensile strength and elongation at the break of kenaf/PF composite (Özturk, 2010)

Similarly, the mechanical properties of sisal-glass fibre epoxy hybrid composites were studied as a function of fibre length (Ashok et al., 2010). Fibre length of 2 cm showed a better performance in hardness and impact strength in comparison with those having 1 cm and 3 cm length, as shown in Figure 3. In addition, they also determined that fibre alkaline treatment improved the mechanical properties compared to the untreated fibres due to the improvement of interfacial bonding of fibre/ matrix.

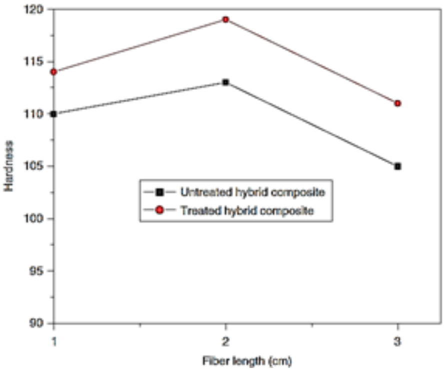


Figure 3. Hardness of the untreated and treated epoxy-based sisal-glass hybrid composites with different fibre lengths (Ashok et al., 20102)

In another study, Venkateshwaran et al. (2011) investigated the mechanical properties and water absorption behaviour of banana/sisal reinforced epoxy hybrid composites. The results indicated that an addition of sisal up to 50% by weight in banana/epoxy composites increased the mechanical properties, but decreased the water absorption of hybrid composites. In another interesting work, researchers studied the mechanical properties of coir/silk unsaturated polyester-based hybrid composites as a function of fibre length. Results of their studied are illustrated in Table 1 and based on the findings, it is concluded that the mechanical properties tested in this experiment showed a better result for the hybrid composites having 2 cm fibre length (Noorunnisa et al., 2010).

Table 1
The mechanical properties of treated sisal fibre-reinforced polyester composites (Noorunnisa et al., 2010)

Composites	Tensile strength (MPa)	Young's modulus (MPa)	Flexural strength (MPa)	Flexural modulus (MPa)	Temp (°C)	Diffusion coefficient $\times 10^5$ (cm^2/min)	Sorption coefficient (g/g)	Permeability coefficient $\times 10^6$ (cm^2/min)
R40	67±2.3	2196±54	84±1.7	3495±36	30	21.5	0.106	23.0
					60	26.9	0.121	33.6
					90	32.5	0.145	47.2
RN40	79±1.8	3002±45	102±1.9	4737±25	30	8.8	0.059	4.92
					60	11.1	0.055	6.11
					90	11.3	0.077	8.75
RH40	74±2.1	2559±19	101±2.9	4552±56	30	8.8	0.041	8.16
					60	15.0	0.103	15.6
					90	20.1	0.092	19.0
RB40	70±1.8	2431±28	93±2.1	4362±38	30	5.11	0.123	2.14
					60	9.64	0.025	2.41
					90	10.60	0.026	2.75
RP40	72±1.5	2697±14	106±3.3	4590±49	30	8.91	0.062	5.54
					60	13.1	0.055	7.26
					90	16.9	0.065	11.0
RS40	76±2.2	2444±45	102±2.6	4849±56	30	8.35	0.092	6.51
					60	14.3	0.098	14.0
					90	18.1	0.083	15.1

Anuar et al. (2008) analysed the mechanical properties of thermoplastic natural rubber reinforced with short carbon/kenaf fibre in the hybrid composites. In the experiment, hybrid composites were fabricated with different fibre contents and flexural testing was carried out for the composites with fibre contents below 20 vol%, while impact testing was done for the samples having up to 30% fibre content. The results indicated that flexural strength and modulus increased up to 15 % vol of the fibre content and after that it displayed a decreasing trend, whereas impact strength had increment for both the untreated and treated composites at higher fibre contents. This research determines that fibre loading causes increment in flexural properties although the flexural properties of a single type of reinforcement show better results than those of the hybrid composites. In the case of impact strength, fibre loading increases the absorbed energy whereas the results demonstrate a higher strength for the untreated hybrid composite than the treated one. Similarly, the mechanical properties of hybrid kenaf/glass reinforced epoxy composite for passenger car bumper beam fabricated by modified sheet moulding compound (SMC) method were investigated (Davoodi et al., 2010). The results indicated that tensile strength, Young's modulus, flexural strength and flexural modulus of hybrid composites are similar to glass mat thermoplastic (GMT), but impact strength is still low, which makes it suitable for utilisation in car bumper beam. It can be observed from Figures 4 to 6 of this study that tensile and flexural properties (strength and modulus) of the hybrid composite have better mechanical properties in comparison with the common bumper beam material. However, impact property is not sufficient for this application. The hybrid composite introduced in this paper could be used as the bumper bean by improving the impact properties to optimise the structural design parameters, or by improving the material properties.

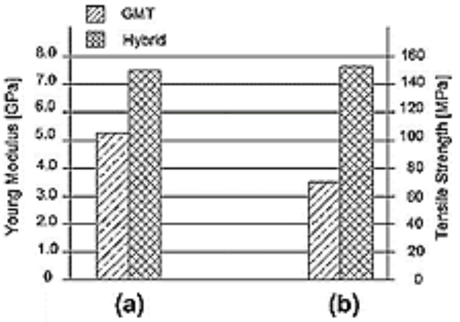


Figure 4. (a) Tensile modulus, and (b) tensile strength (Davoodi et al., 2010)

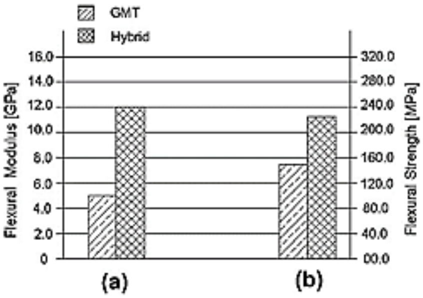


Figure 5. (a) Flexural modulus, and (b) flexural strength (Davoodi et al., 2010)

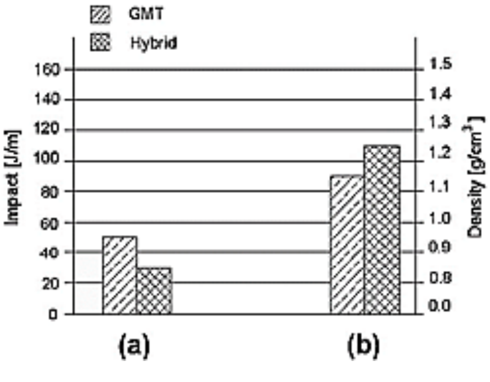


Figure 6. (a) Impact property, and (b) density (Davoodi et al., 2010)

In another study, Sathishkumar et al. (2013) determined the mechanical properties of randomly oriented snake grass (SG) fibre with banana (B) and coir (C) fibre-reinforced hybrid composites. The mechanical properties were evaluated based on the ASTM standards. The results showed that the SG/B composites displayed the maximum tensile properties at 20% volume fraction, while the SG/C composites showed the maximum flexural strength. This finding implies that by adding more than one fibre into the composites and fabricating a hybrid composite, it is possible to achieve the maximum strength of the materials.

Ghani et al. (2012) studied the mechanical properties of kenaf/fibre glass fibre-reinforced polyester hybrid composite in respect to water absorption level. They prepared the specimens in three different liquid environments (sea water, distilled water and acidic solution) at ambient temperature. The results indicated that longer immersion time decreased the tensile modulus of composites due to the formation of hydrogen bonding between the water molecules and cellulose fibre (Figure 7). It is also mentioned that humidity aging has severe effects on the mechanical properties and declines the tensile modulus of the composites. The strain to failure showed an in improvement due to the inclusion of kenaf fibre reinforcement, together with the fibre glass in the hybrid composites.

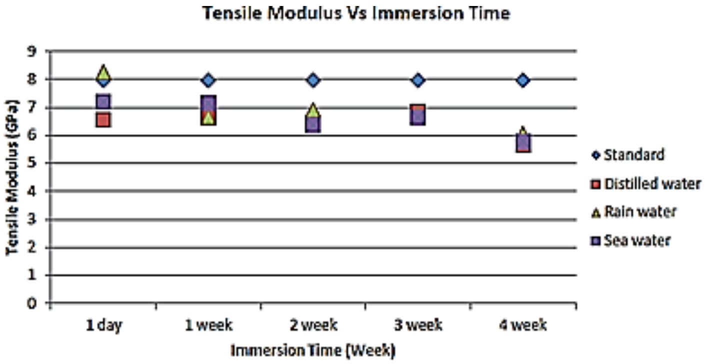


Figure 7. Tensile Modulus (GPa) at different environmental conditions (Ghani et al., 2012)

Several researchers reported on the effects of hybrid composition including different factors such as the hybrid effects on the mechanical properties of curaua/glass fibres (Almeida et al., 2013), effects of silica on the properties of marble sludge filled hybrid natural rubber composites (Ahmed et al., 2013), effects of glass fibre hybridisation on the properties of sisal fibre–polypropylene composites (Jarukumjorn & Suppakarn, 2009), environmental effects on the mechanical behaviour of pultruded jute/glass fibre-reinforced polyester hybrid composites (Akil et al., 2014) and prediction of the mechanical properties of natural hybrid composites (Venkateshwaran et al., 2012). In addition, the mechanical and other properties of hybrid natural composites are well studied such as the glass/natural fibre hybrid composites in curved pipes (Cicala et al., 2009), oil palm empty fruit brunches/jute fibres and epoxy hybrid composites (Jawaid et al., 2010) or for flax/glass fibre hybrid composite (Zhang et al., 2013) and talc/calcium carbonate filled polypropylene (Leong et al., 2004). Anbusagar et al. (2014) experimentally studied hybrid sandwich laminates to determine the effects of nano-modified polyester resin. They concluded that factors such as the flexural strength and modulus, charpy impact strength, hardness of the composite and adhesion of fibres to the matrix showed significant increase or improvement by using the nanoparticle reinforcement in the sandwich composites.

Bagheri et al. (2013) developed a new type of hybrid composite of carbon/flax/epoxy for bone plate applications. They studied the mechanical properties and determined that the aforementioned hybrid composite is suitable for long bone fracture plates. Many researchers have reported on jute fibre-reinforced hybrid composites such as oil palm/jute, sisal–jute–glass, abaca–jute–glass, and concluded that the hybrid composites displayed better mechanical properties than their single fibre counterparts (Jawaid et al., 2011; Jawaid et al., 2011; Ramesh et al., 2013; Ramesh et al., 2013; Ramnath et al., 2014). In addition, researchers also studied the interface shear strength of jute/polypropylene hybrid non-woven geotextiles (Rawal & Sayeed, 2013) and determined that the hybridisation of alkali-treated palmyra palm leaf stalk/ jute fibres is effective enough to be used as a useful method for producing low weight material for automotive component at the optimum ratios of 40% wt of jute for the best results in the tensile test (Shanmugam & Thiruchitrambalam, 2013). In another work, jute cloth/wood felt hybrid composite was investigated for its mechanical properties (Santulli et al., 2013). The results indicated that the hybridisation of jute cloth/ wood improved the adhesion of fibre/ matrix with reasonably high mechanical properties. Kenaf fibre was also studied to investigate the different mechanical properties of the hybrid composites and the results demonstrated that the hybrid composites displayed better results in comparison with the single fibre composites (Ghani et al., 2012; Sayeed et al., 2014; Salleh et al., 2013).

Researchers investigated thermal, mechanical and thermo-mechanical properties of flax hybrid preform reinforced epoxy composites and the results indicated that the hybrid composites improve the performance and are beneficial in term of economic issues (Muralidhar, 2013). Some other researchers studied the hybrid composite laminates based on basalt fibres in combination with flax, hemp and glass fibres and among the hybrids; it was found that the best properties are offered by glass/flax to basalt fibre reinforced laminates (Petrucci et al., 2013). Another study on the mechanical and thermal properties of banana/flax composites (Srinivasan et al., 2014) determined that the hybrid composites have much better impacts and flexural properties in comparison with single fibre composites. In another interesting work carried out by hybridisation of sisal fibres with silica micro-particles, the results indicated that the flexural strength of hybrid composites was not influenced by the presence of silica in the composites (da Silva et al., 2012). The treatment of sisal fibre demonstrated better tensile and flexural properties in the case of cork/sisal hybrid composites (Fernandes et al., 2013). Surface microfibrillation of sisal fibres was performed to investigate its effect on mechanical properties of sisal/aramid fibre hybrid composites. It was demonstrated that the surface microfibrillation improved the tensile, compression and internal bonding stress of the hybrid composites (Zhong et al., 2011). The tensile properties of hybrid composites were prepared using banana/sisal fibres of 40:0, 30:10, 20:20, 10:30, and 0:40 ratios and predicted by using the Rule of Hybrid Mixtures (RoHMs) equation [see Figures 8(a-d)] (Venkateshwaran et al., 2011).

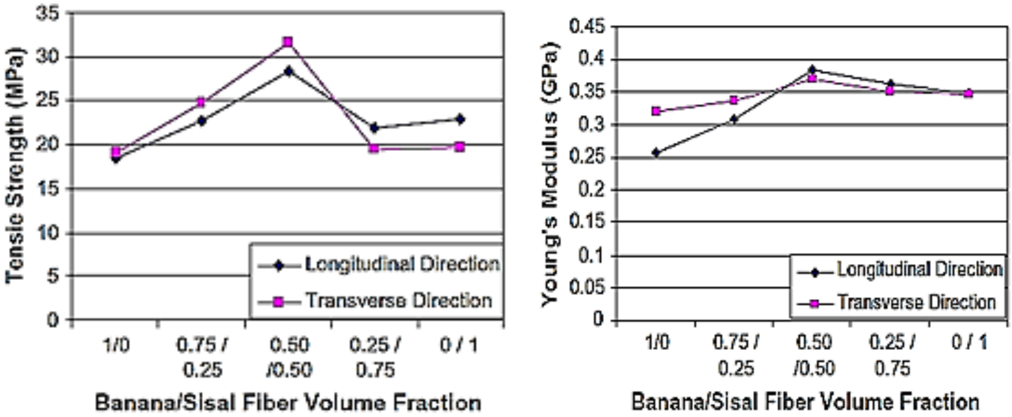


Figure 8a. The experimental tensile strength of hybrid composite

Figure 8b. The experimental tensile modulus of hybrid composite

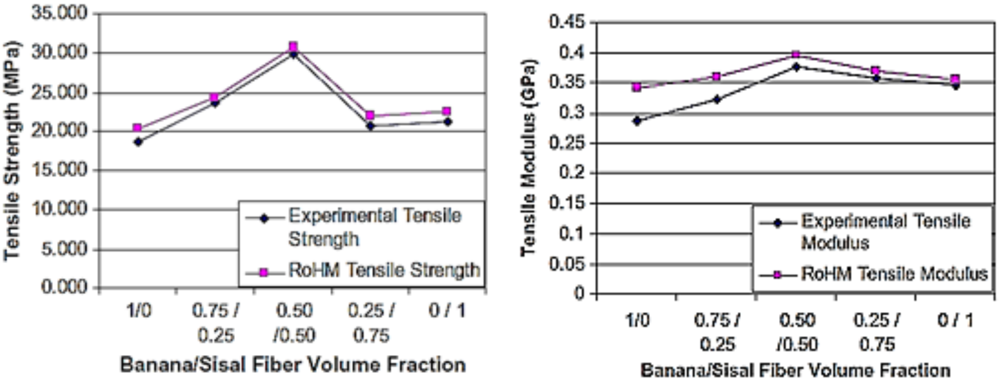


Figure 8c. A comparison of the experimental and RoHM tensile strengths of composite

Figure 8d. A comparison of experimental and RoHM tensile modulus of composite

Figure 8. Prediction of the tensile strength and tensile modulus of hybrid composites (Venkateshwaran et al., 2011)

The hybrid composites consisted of short, randomly oriented natural fibre and were subjected to this prediction. Results of the prediction determined that the experimental tensile properties were a little lower than the predicted tensile properties. This could be due to the presence of micro voids which are formed during the preparation of the composites. In the case of prediction, Mirbagheri et al. (2007) applied the RoHM equation to predict the elastic modulus of random short discontinuous natural fibre reinforced hybrid composites. The results indicated that the elastic modulus, as well as tensile modulus in prediction, was higher than the experimental values. A comparison of the two values from the prediction and experimental tests determined a good linear relationship between them. Therefore, it can be concluded from the published literature that the RoHM equation can properly be used for the prediction of the elastic modulus of short natural fibre hybrid composites.

Aji et al. (2013) investigated the mechanical properties of the hybrid kenaf/pineapple leaf fibres (PALF) reinforced high density polyethylene (HDPE) and evaluated the effects of fibre size and fibre loading on the properties of the composites. The results determined that there was a good adhesion of fibre/matrix, which resulted in an increment of the mechanical properties proportionately to the different fibre sizes and fibre loading. In order to study the effects of hybridisation on natural-fibre-based hybrid composites, the mechanical properties of the kenaf/pineapple leaf fibre (PALF) reinforced polyethylene were also determined (Aji et al., 2011). In this study, Figure 9 describes the tensile properties exhibited by the hybrid materials.

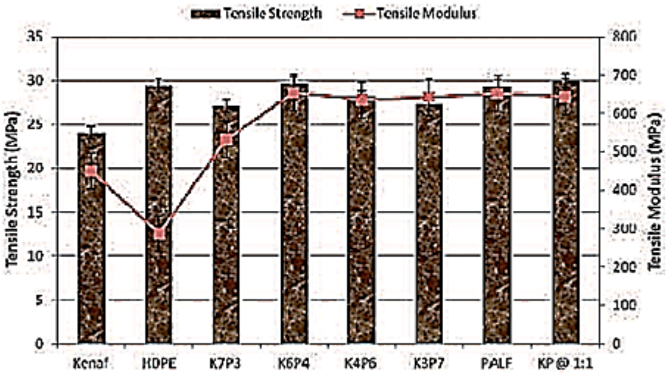


Figure 9. The tensile properties of hybridised kenaf/pineapple leaf fibre (PALF) at varying fibre proportions (Aji et al., 2013)

Due to the lack of proper synergistic loading to encourage interaction, the tensile properties were at their lowest value at the points where kenaf and PALF were at the most advantage loadings. However, increment in the percentage of PLAF in the composite increased the strength and modulus values. In another study, Kwon et al. (2014, pp. 232-237) determined the role of the aspect ratio of natural fibres by studying the tensile properties of kenaf fibre and corn flour reinforced poly (lactic acid) hybrid composites. Meanwhile, the effects of aspect ratio of kenaf fibers on the mechanical properties and the values of the Halpin-Tsia equation were studied by measuring the aspect ratio before and after passing through the extrusion process. The cross-sectional micrographs of the extruded PLA pellets with different reinforcement loadings are shown in Figure 10.

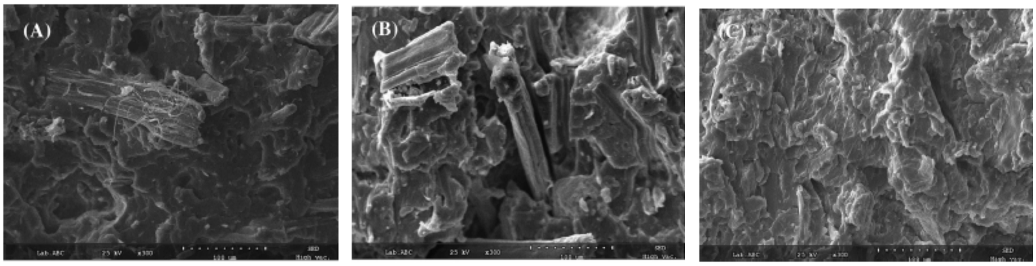


Figure 10. The cross-sectional micrographs of the extruded PLA pellets with different reinforcement loadings: (A) kenaf 30 wt%, (B) kenaf 15 wt% and corn husk 15 wt%, and (C) corn husk 30 wt% (Kwon et al., 2014)

The results indicated that the aspect ratio generated after the extrusion process did not significantly influence the difference between the experimental values and the theoretical values of the tensile modulus (Figure 11). As a result, the initial values of aspect ratio were obtained before the extrusion which could be used directly. The optimisation of the mechanical properties of a hybrid bio-composite can be controlled via a scale ratio between the reinforcement with different aspect ratios.

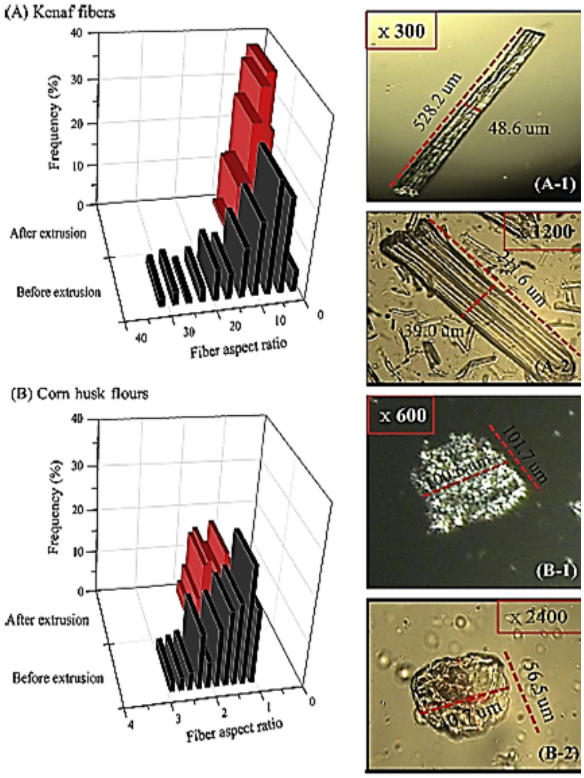


Figure 11. The variations of the aspect ratio of (A) kenaf fibers and (B) corn husk flours before and after the extrusion process: A-1 and B-1 before the extrusion, A-2 and B-2 after the extrusion (Kwon et al., 2014)

In a novel study, an industrial waste was used for hybridisation in composites (Ahmed, 2013). The mechanical properties were investigated to indicate the capability of marble waste powder as a composite filler. In addition, silica was used as a reinforcement with natural rubber hybrid composites (Ahmed et al., 2014; Ahmed et al., 2013). Results demonstrated that the minimum and maximum torque, tensile modulus and strength, together with the crosslink density volume fraction and hardness, had increased. However, elongation at break, swelling ratio and shear modulus decreased with the increment of silica loading. Moreover, Salleh et al. (2012) investigated the fracture toughness of long kenaf/woven glass hybrid composite in relation with water absorption effect. The investigation was done for three different water conditions as distilled water, rain water, and sea water. The maximum moisture content, maximum fracture load and critical stress intensity factor of the hybrid composite are shown in Table 2 of this study. Apparently, soaking time plays an important role in moisture content and the increment in soaking time results in increment in moisture absorbed although the flexural behaviour is not predictable with respect to the soaking duration. This is due to the effect of water penetrability.

Table 2
Tensile strength, flexural strength, and compressive strength of the untreated and treated polysted-based coir/silk hybrid composites with different fibre lengths (Salleh et al., 2012)

S.no.	Fibre length (cm)	Tensile strength (MPa)		Flexural strength (MPa)		Compressive strength (MPa)	
		Untreated composites	Treated composites	Untreated composites	Treated composites	Untreated composites	Treated composites
1	1	11.419	15.014	37.419	39.533	134.895	154.034
2	2	15.624	17.24	43.744	45.067	142.087	152.975
3	3	12.924	16.144	39.692	42.018	138.401	159.822

The capillary action becomes active as water penetrates into the interface through the voids induced by swelling of the kenaf fibres. However, it is shown that Intensity Factor (K_C) decreases with the increment of immersion time until the third week and slightly decreases in the fourth week. The load vs. extension of the fracture test (Single Edge Notch Bend, SENB) is shown in Figures 12 (a-c) of this study. In this case, all the specimens have similar dimensions and pre-crack length. Some ductility was observed before the final fracture. For most cases, the hybrid composite of two weeks' immersion showed the lowest load.

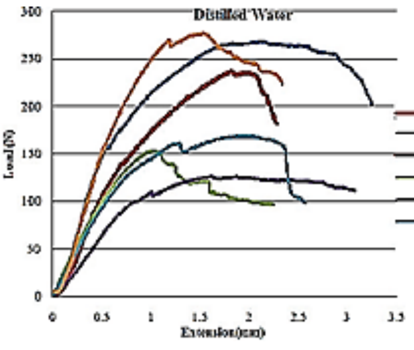


Figure 12a. Distilled water

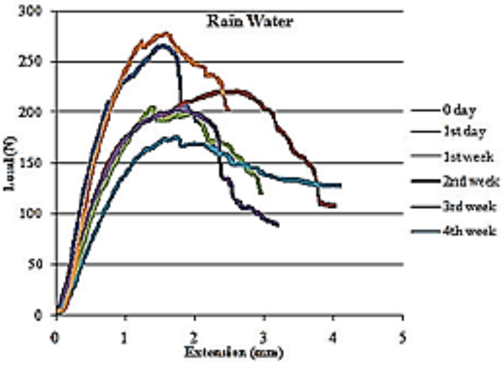


Figure 12b. Rain water

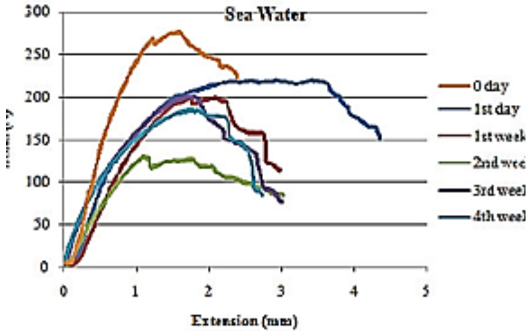


Figure 12c. Sea water

Figure 12. Load vs. extension for the SENB test (Salleh et al., 2012)

In addition, the mechanical properties of curaua/glass fiber hybrid composite were studied under water aging situation (Silva et al., 2009). This study indicated that hybridisation reduced water absorption of the composite and the mechanical properties were affected by the different water absorption conditions. Furthermore, the effect of water absorption on the mechanical properties of natural fibres/polyester hybrid composites was studied and the results indicated that the tensile and flexural strength decreased in the presence of moisture (Athijayamani et al., 2009). Finally, to review the mechanical properties in hybrid composites, Nunna et al. (2012) summarized the major factors affecting the mechanical behaviour of natural fibre-based hybrid composites. The first factor that affects the mechanical properties is the volume fraction of high strength fibres up to a certain maximum value. Because of the formation of agglomerates, a negative hybrid effect was observed. Secondly, the properties of the extreme fibre layers influenced the properties of hybrid composites. It was understood that by using the high strength fibres, the skin layers led to optimum mechanical properties. Another factor that is important in improving the interfacial bonding between the fibres and the matrix is the use NaOH as the chemical treatment of natural fibres. Finally, the time of exposure and temperature related to various environmental conditions played an important role in the degradation of the mechanical properties.

Thermal Properties

Panthapulakkal and Sain (2007) studied the mechanical, water absorption and thermal properties of short hemp fibre/glass fibre-reinforced polypropylene hybrid composites. The results demonstrated that the performance properties were increase by hybridisation of the reinforcement with glass fibres. The results of the thermo-gravimetric analysis showed a two-step degradation for both hemp and hybrid fibre composites, as shown in Figure 13 of this study. However, hybridisation with glass fibre mats improved the thermal properties and water absorption resistance behaviour of the hemp fibre reinforcement composites.

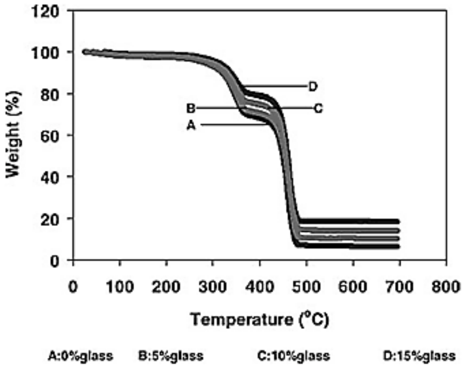


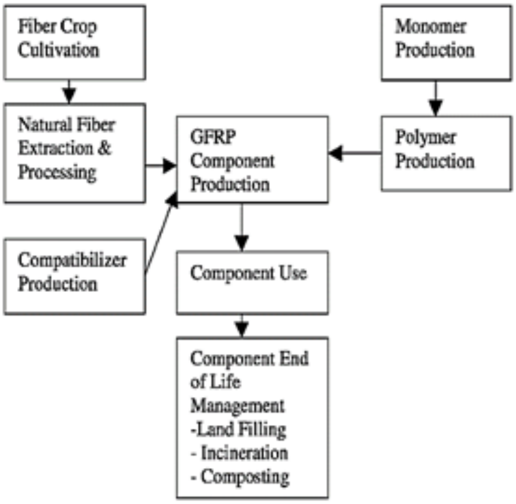
Figure 13. Thermograms of hemp/PP and hemp/glass/PP composites (Panthapulakkal & Sain, 2007)

This study illustrates that where thermal resistance and high stiffness are needed, natural base hybrid composites such as the short hemp/glass fibre reinforced polypropylene can be of great use. In addition, sisal glass fibre reinforced (SGFR) polypropylene (PP) hybrid composites were studied and their performance characteristics were also analysed (Nayak & Mohanty, 2010). The researchers found that after the chemical treatment of the fibres with the maleic anhydride grafted PP, the optimal mechanical performance was obtained, and in order to increase the mechanical properties and water absorption resistance, the replacement of the hydrophilic sisal fibre with stiffer and stronger fibre was also required. The hybrid composites of flax/carbon were also studied to determine their enhanced properties (Dhakal et al., 2013) and the results showed improvement in the thermal and mechanical properties.

Researchers have investigated ways to overcome the problem of low impact properties of plasticised polylactic acid (PLA) filled with kenaf fibre (KF) and montmorrilonite (MMT); with this aim in mind, polyethylene glycol (PEG) was added as a plasticiser during the hybridisation process of the PLA composites (Anuar et al., 2012). The impact strength of the hybrid composite showed a significant increment by using this plasticising agent. Meanwhile, the effects of partial replacement of palm ash by silica powder on the curing characteristics, mechanical properties and morphology of hybrid palm ash/silica/natural rubber composites (Ismail & Haw, 2010), as well as the comparison of recycled newspaper (RNP)/carbon black (CB) and recycled newspaper (RNP)/silica hybrid filled polypropylene (PP)/natural rubber (NR) composites were investigated (Osman et al., 2010).

Applications

After the above discussion, there is a question of whether or not natural fibre composites are preferable over glass fibre-reinforced composites when taking environmental issues into consideration (please revise the end of this question). Joshi et al. (2004) did answer the above question in their research paper. Figures 14(a-b) show simplified, generic life cycle stages of a component made from glass fibre-reinforced composite material and a natural fibre composite material, respectively.



b.

Figure 14(a). Lifecycle of a glass fibre-reinforced composite component. (b) Lifecycle of a natural fibre-reinforced composite component (Joshi et al., 2004)

Based on the specific application, different material and manufacturing process are required. The authors found that for some applications, bio-fibre composites are environmentally preferable for some important reasons such as lower environmental impacts in comparison with glass fibres, or having higher fibre content for equivalent performance, which results in less amount of polluting base polymers. Besides, natural fibre composites have lower weight which results in better fuel efficiency and less emissions when in use, such as in automotive applications. Finally, the last part of the lifecycle of the natural fibre results in energy and carbon credits. In another research, Mansor et al. (2013) defined an application for the hybrid natural and glass fibre-reinforced polymer composites in automotive brake lever design. To choose the most proper natural fibre for the hybridisation process, the analytical hierarchy process (AHP) method was used. By using this method, kenaf fibre was chosen to have all the performance requirements for this specific application. In addition, sensitivity analysis determines that kenaf fibre is the best candidate. One of the important aspects of the natural fibre is its energy efficiency. The automotive industries are interested to utilise natural fibres for manufacturing different components because of economic, environmental and technical reasons. The natural based hybrid composites have very wide applications in almost all sections of the car industry, such as in passenger car bumper beam (Davoodi et al., 2012). In addition, for the automotive industry, a hybrid kenaf/glass reinforced composite was developed for bumper beam in a passenger car. The mechanical properties indicated that this particular hybrid composite could be utilised in the automotive industry (Jeyanthi et al., 2012).

CONCLUSION

In this review paper, we concluded that several studies reported on the mechanical and thermal properties of natural fibres/natural fibres and natural fibre/synthetic fibre-based hybrid composites. It was concluded that a combination of two natural or natural/synthetic fibres enhanced the mechanical and thermal properties of the composites with values higher than those obtained for the individual fibre reinforced polymer composites. It was also observed that the treatment and modification of the fibres, orientation of fibres and physical properties of fibres affect the mechanical properties of the hybrid composites. A few researchers have reported investigations on the thermal analysis of hybrid composites, therefore further studies are required in order to understand the effects of hybridisation on the thermal properties of hybrid composites. It was attributed that advanced hybrid composites have a better prospective in the fabrication of automotive parts and in the construction and building industries as compared to single fibre-reinforced polymer composites. It is understood that the hybrid composites developed by a combination of natural/natural and natural/synthetic fibres are environmentally friendly, cost effective and have comparable mechanical properties to glass fibre-reinforced and virgin polymer composites.

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