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MANUFACTURING DEFECTS, INTERFACIAL ADHESION, IMPACT AND WATER ABSORPTION PROPERTIES OF HYBRID POLYESTER COMPOSITE IN BOAT CONSTRUCTION

Fibre composite boat construction industry is one of the largest industries that greatly contributes to most of the countries' economies. Synthetic fibre composite like fibreglass is widely used in making the composite boat hull. The use of fibreglass is costly and it gives a huge effect on the environmental pollution. Nowadays, the green fibres have growth as a demand in hull construction and another industry, because of their light mass, great relative mechanical properties, and more advantages to the fibreglass. The demand for boat from green hybrid materials has gone in striking. Green hybrid materials, like any other composite components used in industries, went through the process of incorporating the reinforcement which is the natural fibre into composite or matrix. All imperfections such as voids, area where resin has unevenly wetted the fibre and misaligned fibres have been determined using non-destructive technique (NDT) namely Infrared Thermal (IR) imaging technique. Then composite specimens were observed via the Scanning Electron Microscopy (SEM). SEM micrograph had been validated the results of IR thermal imaging, impact test and water absorption by following ASTM D6110 and ASTM D570 standard respectively. 45% of the woven kenaf/glass fibre to polyester determines the highest impact properties of 542.22 kJ/m^2 and shows the least percentage of moisture absorption at the same time showing the greatest water resistance for the composite material. The defects and interfacial adhesion were observed on the specimen by IR thermal imaging and SEM technique. It was revealed that 45% of the woven kenaf/glass fibre to polyester demonstrated less manufacturing defects and possessed a good interfacial adhesion, while 60% of the woven kenaf/glass fibre to polyester showed the highest manufacturing defects. The consequence of fibre contents had crucial effect towards manufacturing defects and interfacial adhesion of composite testing coupon. As conclusion, the specimens with less manufacturing defects, high impact properties and water absorption had been proposed as hybrid green composite materials for boat hull construction.

Keyword: Infrared Thermal Imaging; Manufacturing defects; Natural fibre composite; Non-destructive Technique; Scanning Electron Microscopy (SEM)

1. Introduction

Nowadays, composite are well known substance as they can change metal with more benefits alternatives [1] Advanced composites material technology are being used for automotive and high-performance industry business [2]. Though, it is the smallest amount in the boat hull structure.

Environmentally friendly materials such as natural fibre composites have grown consideration in the industrial parts of automobile and building construction in the previous period. As a consequence, more scientists' and fabricating industries' efforts have moved to green applies in order to decrease substantial budgets while also conserving the surroundings [3]. The development of future generation materials resulting from green resources is a growing field of study when nonrenewable not available to meet our needs in the future [4].

Plant fibres normally surpass synthetic and mineral fibres due to their low mass, biodegradable, bio standardization, high specific strength and ease of processing. Natural fibres have a few weaknesses, despite their abundant benefits, including

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low strength, high water absorption, and is effortlessly flammable. To overcome this issue, a hybridization method is being recommended, which combining both synthetic-natural fibres polymer matrix.

Hybridization technique permits the alteration of composite's characteristic to fix the demand. Through all phenomena, hybridization is used to create a new type of substance that preserves the advantages of their component materials while to prevent some of limitations [5]. Hybridization of composites is concerned worldwide and is now greatly suggested in many industries to improve performance properties [6]. Previously, Senthilkumar et al. [7] reviewed mechanical properties evaluation of sisal fibre reinforced polymer composites and reported that Sisal fibre reinforced polymer composites offered comparable tensile strength besides superior flexural strength as observed by many researchers and furthermore, these fibres could be used in various structural applications due to their eco-friendly nature, low density, non-abrasive and it can be utilized in variety of structural application such as auto-industrial, light weight constructional applications and ropes

Nurrazi et al. [8] reported that the mechanical performance of hybrid natural fiber-reinforced polymer composites has seen a lot of research and development in recent decades. Fiber selection, extraction, handling, and interfacial engineering, as well as composite manufacturing, have all advanced. In terms of stiffness and cost, natural fiber polymer composites are now competitive with other syntheticpolymer composites; tensile and impact strength values are approaching synthetic values.

Nowadays, the increase in worldwide user concern in eco-friendly substance that shift the whole or a part of synthetic fibre with plant fibre composites. Based on previous study, the cost can be reduced by partially using manmade in the composites and hybrid technique can resist greater loads compare to single-fibre reinforcements [9]. Therefore, most of the research is concentrated on the hybridization of green material with fibreglass to increase their mechanical characteristics. Asyraf et. al., [10] explored the development of hybrid natural fibre composite ballistic helmets can be used as a consideration in the future as a revolution to create a sustainable design. Balasubramanian et. al., [11] purposed the study to understand the behavior of hybrid bio-composites under varied applications. His study reported that the tensile properties like tensile strength and tensile modulus of flax/hemp/sisal/Coir/Palmyra fiber-reinforced composites are majorly dependent on the chemical treatment and catalyst usage with fiber. The flexural properties of flax/hemp/sisal/coir/Palmyra are greatly dependent on fiber orientation and fiber length. Impact properties of flax/hemp/sisal/coir/Palmyra are dependent on the fiber content, composition, and orientation of various fibers [10].

Thus, the use of woven kenaf/fibreglass to polyester as the matrix was studied. The outcome of dissimilar weight content percentages (wt.%) fibre content of hybrid composite was studied. The 0, 15, 45, and 60 wt.% of woven kenaf /fibreglass to polyester were fabricated. The defects, interfacial adhesion, impact, and water absorption properties were analyzed. This experiment basically shows the greatest of weight percentage of woven kenaf/fibreglass to polyester, show the relationship of manufacturing defects and interfacial adhesion that can influence the impact and water absorption properties. This important research was to develop the innovative hybrid green composite in boat hull structure due to eco-friendly substance and it is limited in used.

2. Methodology

Hybrid green composite was manufactured by using woven kenaf/fibreglass as reinforcement. The polyester is used as a resin. Woven kenaf was prepared by Bio-composite Lab, INTROP, Universiti Putra Serdang, Selangor. Polyester resin and fibreglass were prepared by Miracon (M) Sdn. Bhd., Selangor, Malaysia. TABLE 1 shows the density of the materials used in this research.

TABLE 1

The Density of Materials Used in This Research

Material	Properties	
	Density (g/cm^3)	Reference
Kenaf fibre	1.2 g/cm^3	[23] [29]
Polyester	1.28 g/cm^3	[30]
Fibreglass	2.55 g/cm^3	[31]

The preparation of composite testing samples based on the different fibre volume in weight percentage (wt.%) woven kenaf of 0%, 15%, 45% and 60%. The woven kenaf fibre was prepared by using traditional method. The thickness of testing sample is 5 mm. TABLE 2 presented the specimen designation of weight percentage of materials.

TABLE 2

The Specimen Designation of Each Weight Percentage Materials

Percentage of materials (wt.%)	Designation of each weight percentage materials			
	0 wt.% (Control sample)	15 wt.% of content	45 wt.% of content	60 wt.% of content
Polyester + catalyst	90	75	45	30
Natural fibres (woven kenaf)	0	15	45	60
Fibreglass	10	10	10	10

SEM is used to examine the surface morphological by taking the pictures on topmost side of the surface after manufacturing are done. The SEM observed the manufacturing defects that happened on the samples. SEM was started with crucial step by coating the specimen with pure gold by using a sputter coating machine.

Impact test have undergone to define the energy absorbed by a specimen throughout breakage. The manufacture sample of standard Charpy impact were cut according to ASTM D6110.

Five replicates' composites were tested in every weight percentage and the average values were recorded. The experiments were completed by using an INSTRON instrumented pendulum.

The water absorption test performed by following ASTM D570 standard.

3. Results and discussion

3.1. Manufacturing Defects and Interfacial Adhesion

Fig. 1 depicted manufacturing defects and interfacial adhesion observed by naked eyes.

Fig. 1. Manufacturing defects and interfacial adhesion observed by naked eyes

Then, manufacturing defects and interfacial observation observed by IR thermal imaging and SEM were observed to understand the connection of defects and impact properties of woven kenaf/fibreglass composite materials as shown in Figs. 2, 3 and 4 respectively.

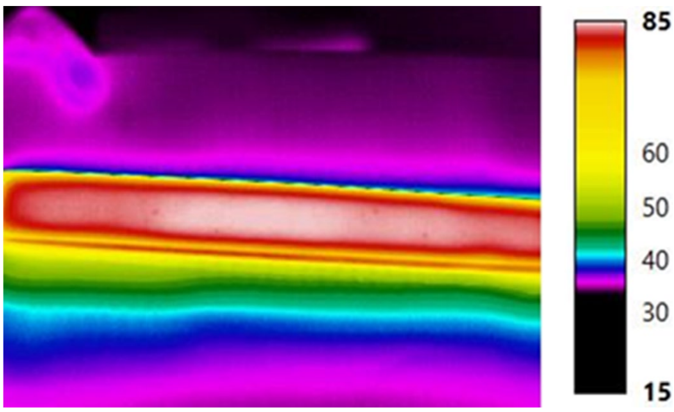

Fig. 2. Manufacturing defects and interfacial adhesion observed in specimen 60% of woven kenaf/fibreglass by IR thermal imaging

The defects in the specimen apparently seen such as voids, misaligned fibres, and fibre pull-out. One of the most common manufacturing defects today is voids [11]. Other researcher claimed, voids usually happened due to air bubbles stuck in the matrix throughout manufacture, however voids also initiated by multiple of reasons Thus, the weaknesses that happened in the composite specimen can influence the presentation of mechanical properties of composite [12]. Voids are formed at three different scales: macro, meso, and micro. Voids in between the fibres in a bundle or a tow are referred to as micro-voids, in between the tows as meso-voids, and in larger zone of the preform (visible to the naked eye) as macro-voids [13]. Voids have been called differently in the literature. For instance, a macro-void is known "dry spot"; a meso-void as "interbundle", "intertow", or "channel" void; and a micro-void as "intrabundle", "intratow", or "tow" void [14].

Usually, voids always occur in the matrix, caused by some reasons [15] such as surrounding condition. It also develops a usual flaw that can simply presented into the material during the manufacturing progress [16]. In the manufacturing procedure, porosity which is also known as void is one of the destructive imperfections that will appear and in structural composites, it plays a huge part in its mechanical performance [16]. Fig. 3 portrays voids and misaligned fibre observed in specimen 60% of woven kenaf/fiberglass.

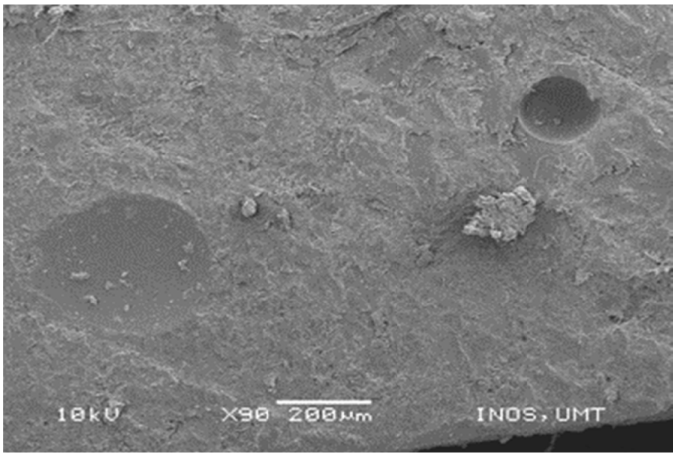

Fig. 3. Voids and misaligned fibres observed in specimen 60% of woven kenaf/fiberglass through SEM

Fig. 4 detected the surface morphology of sample 60% showed the fibre pull-outs from the specimen.

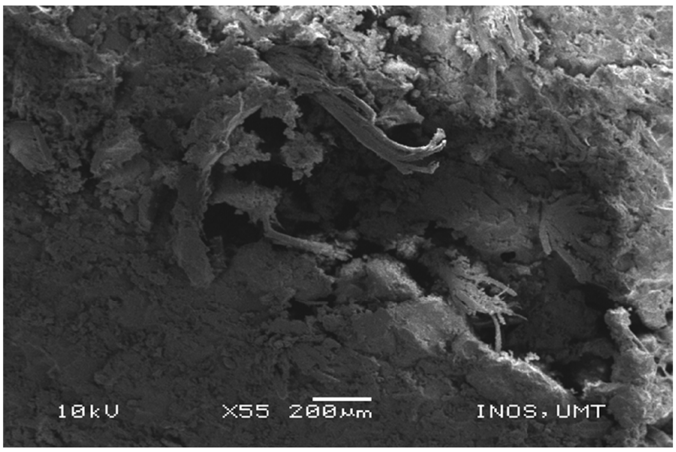

Fig. 4. Fibre pull-outs from the 60% of specimen after impact test due to poor interfacial adhesion

Hydrophilicity of natural fibre lead the weakness that happened on the sample because of poor interfacial adhesions between fibre and matrix [16]. Other researcher claimed through their research, that one of the defects of plant fibres is poor compatibility with its matrix [17]. Thus, this situation lead to poor fibre distribution and fibre–matrix interfacial adhesion that subsequently producing the fibre pull-outs.

The common situation in liquid composite hand lay-out processes is the resin-rich area which cause unwanted remaining stress and distortion and part-to-part variation [18]. In previous study presented the cracking in the field of resin-rich areas. It was also claimed that because of the existence of water, the swelling of the resin caused distortion in the resin-rich area. Fig. 5 shows resin rich-zone in specimen 15%.

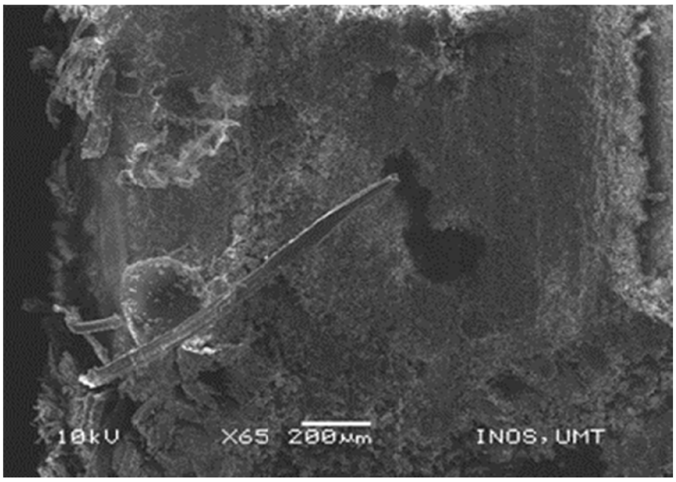

Fig. 5. Resin rich-zone and matrix crack in specimen 15% after impact test

Fig. 6 shows the misalignment of woven kenaf/fibreglass that occur in samples 45%. The effects of poor interfacial adhesions of fibre-matrix, led to the misalignment of fibres in woven kenaf/fibreglass reinforced polyester composites. Furthermore, this might happen because of poor distribution of fibre-matrix [18].

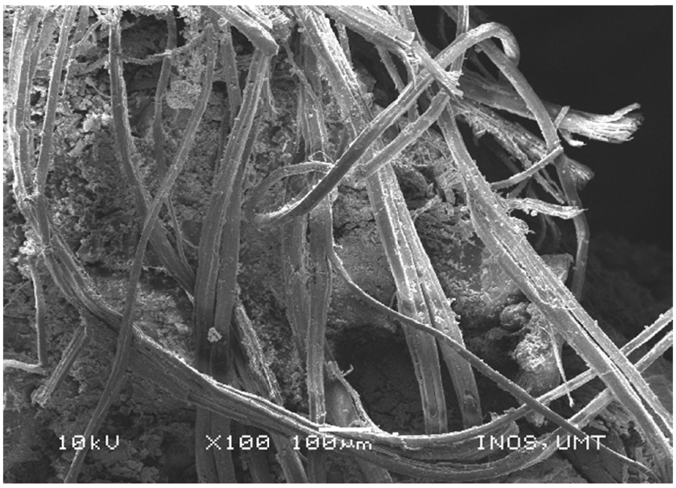

Fig. 6. Misalignment fibres in specimen 45% of woven kenaf/fiberglass

Fig. 7 illustrates the absorption of energy woven kenaf/fibreglass polyester composite materials.

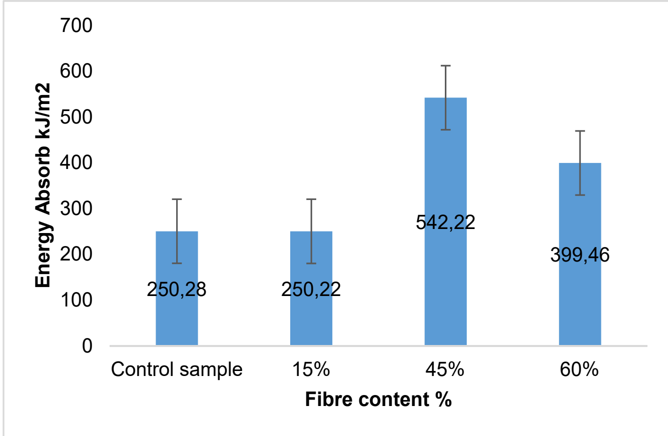

Fig. 7. The result of energy absorption in impact test of woven kenaf/fiberglass polyester composite materials

The energy absorbed of impact test showed highest in 45% of kenaf fibres content. It depicted 542.22 kJ/m^2 result of impact test. The 15% of fibre content kenaf showed the lowest of energy absorption which is 250.22 kJ/m^2. The sample with 45% kenaf fibre had significantly higher impact strength amount than the other samples. Generally, the fibre content percentage has an important effect on the impact energy [18].

The 60% of kenaf fibre showed decrement due to more presence of plant fibre and more weaknesses happened in the sample. Previously, in other research, the impact strength of the composites had been reported to increase with bamboo fibre loading, achieve an optimum, and then lower with additional bamboo fibre loading [12].

The percentage of water absorbed increased with soaking time and stabilised after saturation and the weight content percentage also influenced the moisture uptake. Basically, the chemical properties of natural fibres also give effect on water absorb [12,19]. The existence of hydroxyl group in the plant fibre also known as hydrophilic which it is tend to attract with

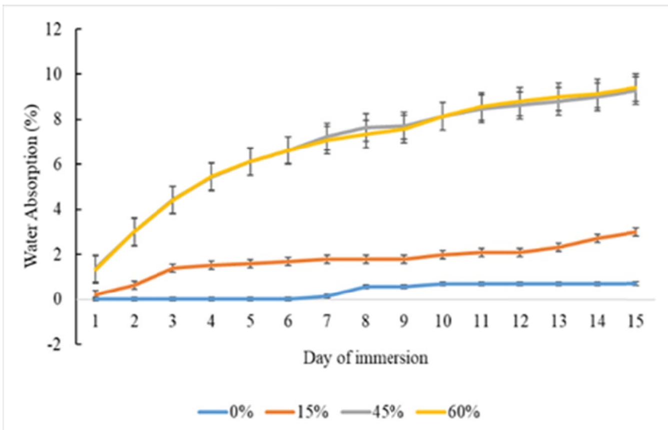

Fig. 8. The result of water absorption of woven kenaf/fiberglass reinforced polyester composite materials

water. The factors that can decrease water uptake in composite are the treatments of fibres. Hybridisation between natural and synthetic fibre in composite also increase the mechanical properties [4]. Fig. 8 illustrated the result of moisture uptake of woven kenaf/fibreglass reinforced polyester composite materials.

The increase of weight content fibres in the specimen permitted more water diffusion into the interface via micro-cracks and water absorption become increase in day 15 [20]. The 0% weight content sample exhibit least moisture absorption which is at 0.70% because there is no plant fibres in the specimen.

The lowest moisture uptake kenaf fibres showed in 15% of fibre content which is 2.97%. The properties of the 45% fibre content samples after they had been submerged in water for 15 days was observed. The water absorb revealed that the samples had a linear rise in water uptake and it showed 9.26% weight gain. The water absorption for 60% fibre content was 9.39% on day 15. High existence of natural fibres in the sample also influenced the weight gain of composites. Earlier study claimed that more fibre content in the samples permitted more water diffusion into the interface via micro-cracks and led to composite break [21]. In other work [22-24], the Fickian's behaviour was discovered in water uptake behaviour of kenaf fibre-reinforced polyester, where equilibrium was reached at a specific soaking time.

4. Conclusions

This research was conducted to determine manufacturing defects, interfacial adhesion, impact, and water absorption properties. The highest impact properties were revealed in the sample 45% of woven kenaf/fibreglass reinforced polyester composite materials of 542.22 kJ/m^2. Moreover, the less moisture uptake percentage exhibited the greatest water resistance for the material composites. Some of the factor that affects the presentation of plant fibre hybrid composite materials was uneven distribution of fibres in the specimen, which caused defects, and when the load is applied to the composite, it led to composite failure. The composite has undergone manufacturing defects due to manual fabricating of composite and weak interfacial adhesion that directly influenced the performance of physical and mechanical properties. A better composite mainly comprises of the least manufacturing defects.

The defects and interfacial adhesion were observed on the specimen by IR thermal imaging and SEM technique. The consequence of fibre contents had crucially effect towards manufacturing defects and interfacial adhesion of composite testing coupon. It was revealed that specimen (45%) demonstrated less manufacturing defects and possesses a good interfacial adhesion, while specimen (60%) shows the highest manufacturing defects. For future developments, the study will be improved by monitoring the environment factors effected the curing process of matrix.

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