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Effect of fibre contents toward manufacturing defects and interfacial adhesion of *Arenga Pinnata* fibre reinforced fibreglass/kevlar hybrid composite in boat construction

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Abstract. In recent years, *Arenga Pinnata* fibre has been found with great potential to be used as fibre reinforcement in material matrix composites. This study investigates the effect of fibre contents toward manufacturing defects and interfacial adhesion of *Arenga Pinnata* fibre reinforced Fiberglass/Kevlar hybrid composite material in boat construction. The composite testing coupons were prepared based on the volume fraction of *Arenga Pinnata* fibre which are 30%, 45%, 60%, and 75%. The long Arenga Pinnata fibre was placed and arranged into the mould by hand lay-up technique. The testing coupon have been arranged with a thickness of 5mm. Manufacturing defects and interfacial adhesion had determined by Scanning Electron Microscopy (SEM) techniques. The SEM results showed that specimen D (60%) of Arenga Pinnata exhibits the less manufacturing defects with a good interfacial and well bonding between the fibre and matrix among other testing specimens. Meanwhile, specimen E (75%) shows the highest manufacturing defects. As a conclusion, 60% of *Arenga Pinnata* fibre contents showed less manufacturing defects and exhibited good interfacial adhesion. SEM had significantly determined the manufacturing defects and interfacial adhesion of *Arenga Pinnata* fibre reinforced Fiberglass/ Kevlar hybrid composite material.

1. Introduction

Several problems were studied on the current material applications in the maritime field. Among the mainly used material in the maritime field is steel. However, steel encounters corrosion problems and high maintenance costs. Recently, *Arenga Pinnata* fibre has been found with great potential to be used as fibre reinforcement in material matrix composites. Natural fibres will lead reinforcement fibres in the field of composite materials because of their competitive advantages when these disadvantages are solved [1,2]. In this study, *Arenga Pinnata* is the natural fibre that have their own characteristics (i.e., low weight, low density, low cost, biodegradable, and good thermal characteristics. Moreover, epoxy resin was used because it is a non-corrosive material. Within the make of watercraft structures, natural fiber is seen as a conceivable substitute. In spite of the fact that natural fibre have the focal points of being eco-friendly, low-cost and low-density, they are not free from the issues.To avoid the problem occurred in natural fibre reinforced composites, the hybridization of natural fibre and synthetic fibre was introduced in polymer composites. Hybrid composite materials have all these common properties, plus other qualities, including compressive strength and impact strength, increased ductility, and a strong tensile modulus [3]. Hybrid composites also have low costs, reduced synthetic fibre use, impact resistance, simple processing, and other suitable physical and mechanical characteristics [4]. A serious problem of natural fibre hybrid composite that will be faced particularly during the fabricating handle is delamination and it gets to be the foremost common sorts of disappointment in composite materials. In any case the material disappointment is not as it were influenced by delamination of the composites, but it moreover impacted by fabricating defects that inhibit amid the process of fabricating. Ordinarily, it is conceivable to discover the defects caused by a generation handle such as gap, misaligned strands, resin-rich zone, undispersed crosslinker pocket, and region where epoxy has been disgracefully wetted fiber. All these imperfections contribute to the low performance of the fibre reinforced hybrid composite's composite quality and mechanical properties [5]. Therefore, this study investigates the effect of fibre contents toward manufacturing defects and interfacial adhesion of *Arenga Pinnata* fibre reinforced Fiberglass/Kevlar hybrid composite material in boat construction.

2. Methodology

2.1 Materials
In this study, the hybrid composite was fabricated using *Arenga Pinnata* fibre (natural fibre) with Kevlar and Fibreglass (synthetic fibre) as reinforcement. The matric used is epoxy. *Arenga Pinnata* fibre purchased from Hafiz Adha Enterprise, Negeri Sembilan, Malaysia. The epoxy utilized as a polymer matrix, Fibreglass and Kevlar in this study were provided by Miracon (M) Sdn. Bhd., Selangor, Malaysia. The proportion of epoxy resin to hardener was 2:1. Table 1 shows the properties of epoxy resin and hardener. The density of the materials utilized in this research is shown in Table 2.

Table 1. Properties of epoxy resin and hardener.

Property	Epoxy resin	Hardener (%)
Form	Liquid	Liquid
Density (g/cm^3)	1.21	1.03
Curing time (hours)	24	24
Ratio	2	1

Table 2. The density of the materials.

Material	Density (g/cm^3)
Arenga Pinnata	1.29
Kevlar	1.44
Fibreglass	2.44
Epoxy resin	1.21

2.2 Fabrication of composites

The composite testing coupons were prepared based on the volume fraction of *Arenga Pinnata* fibre which are 30%, 45%, 60%, and 75%.

The long *Arenga Pinnata* fibre was placed and arranged into the mould by hand lay-up technique. The testing coupon have been arranged with a thickness of 5mm. Table 3 tabulated the specimen fabrication parameter for each testing coupons.

Table 3. Specimen fabrication parameter.

Specimen	*Arenga Pinnata (%)*	Fibreglass (%)	Kevlar (%)	Epoxy resin+ Hardener (%)
A (Control)	0	5	5	90
B (30)	20	5	5	70
C (45)	30	5	5	55
D (60)	50	5	5	40
E (75)	65	5	5	25

2.3 Determination of Surface Morphology

The surface morphology was conducting by capturing the images on top surface of all the specimens after fabrications are completed by using Scanning Electron Microscopy (SEM). The SEM test determined the manafacturing defects and interfacial adhesion occurred at the testing coupon. This manufacturing defects was related to the defects that always occurred during the manual fabrication of composites known as “lay-up”.

The SEM test was started by coating the non-metallic specimen with pure gold by using a sputter coater machine. This step is crucial to make the specimen conductive and ready to be observed under the SEM. The test was started by running the software on the computer, then the specimens were put in the beam properly. After that, the “start” button on the software was clicked to run the system. The result was shown when the image of the specimen was on the computer screen. The magnification, image focus, and brightness must be considered to give the best specimen’s defect images.

3. Result and discussion

The increased of manufacturing defects in the specimen caused the mechanical damage in the and the reduction of the mechanical properties of the composites [6]. The SEM micrographs shows the surface morphology of specimens A, B, C, D and E.

It was revealed that the specimen D had the least manufacturing defects. This led to better mechanical properties, as specimen E possessed the highest manufacturing defects and interfacial adhesion. This demonstrated that each fibre contents influenced the manufacturing defects and interfacial adhesion.mould by hand lay-up technique. The testing coupon have been arranged with a thickness of 5 mm. Table 3 tabulated the specimen fabrication parameter for each testing coupons.

3.1. Voids

Normally, voids can be portrayed as a condition when there are air bubbles caught within the framework whereas the composite experiences manufacture which caused by a few factors [7] such as curing pressure, resin system and environmental condition. It moreover gets to be a common deformity that can easily be presented into the material amid the fabricating process [8].

Within the fabricating prepare, porosity also known as void is one of the harmful deformity that will arise and in structural composites, it plays a major part in its mechanical performance [8,9]. Figure 1 depicts voids obrserved in specimen E (75%) of *Arenga Pinnata.*

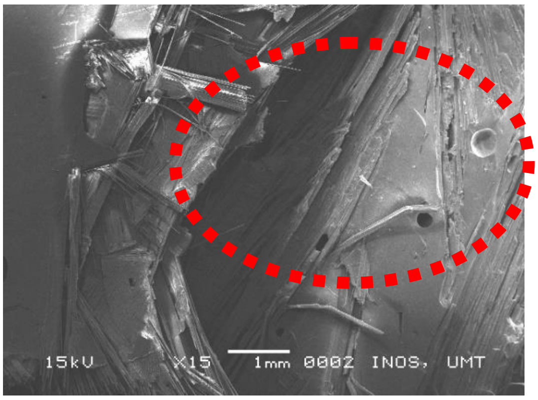

Figure 1. Voids observed in specimen E (75%) of *Arenga Pinnata.*

3.2. Fibre pull-outs

Figure 2 observed the surface morphology of specimen E (75%) indicated by the fibrepull-outs from the specimen due to poor interfacial adhesion. The defect that occurred on the specimen was poor interfacial adhesions because of the hydrophilicity of natural fibre [10]. Abu Bakar et al. [11], through their study, reported that one of the flaws of natural fibers is poor compatibility with its matrix. Therefore, this phenomenon led to poor fibre dispersion and fiber–matrix interfacial adhesion that consequently causing the fiber pull-outs. The phenomenon of fibre–matrix debonding can cause fractures in composites (i.e., fiber pull-out, fiber breakage, and matrix fracture) before the fiber breakage under the applied load [12].

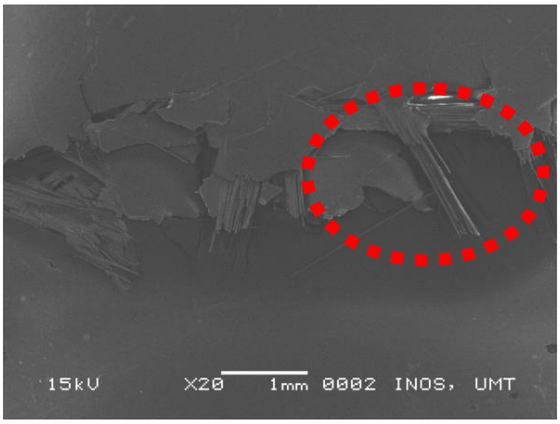

Figure 2 Fibre pull-outs of specimen E (75%).

3.3. Resin-rich zone

The frequent occurrence in liquid composite moulding processes is the resin-rich zones which iniate undesirable residual stress as well as deformation and part-to-part variation [13]. Furthermore, in their research, Dewimille and Bunsell (1983), [14] presented preferential cracking in the field of resin-rich areas. It was also alleged that, due to the presence of water, the swelling of the resin caused deformation in the resin-rich regions, meaning that the weaker interfaces near those zones were subject to higher stresses and were thus more likely to collapse or matrix crack. Figure 3 depicts resin rich-zone and matrix crack in specimen B (30%).

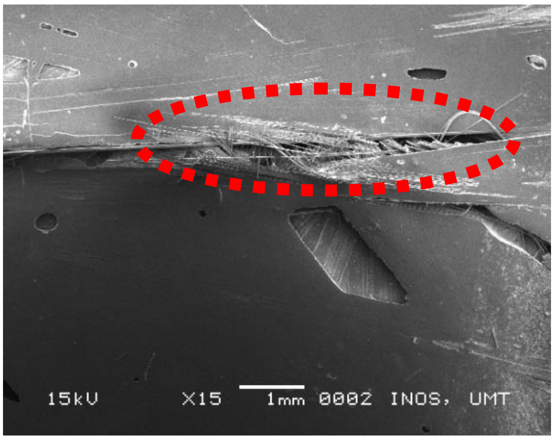

Figure 3 Resin-rich zone and matrix crack of *Arenga Pinnata* fibre in specimen B (30%).

3.4. Misalignment of fibre

One of the fibre defects is fibre misalignment and waviness, and broken fibres. In aircraft design, fibre that are considered straight, parallel, and oriented in planned directions in composites can diminish initial properties, especially compression quality and rigidity, limit load and ultimate load capacity design in servicing capacity due to misalignment and waviness. Moreover, this might occur because of poor dispersion of fibre–matrix [15,16].

Figure 4 below shows the misalignment *of Arenga Pinnata* fibre that took place in specimens D (60%) and E (75%) respectively.

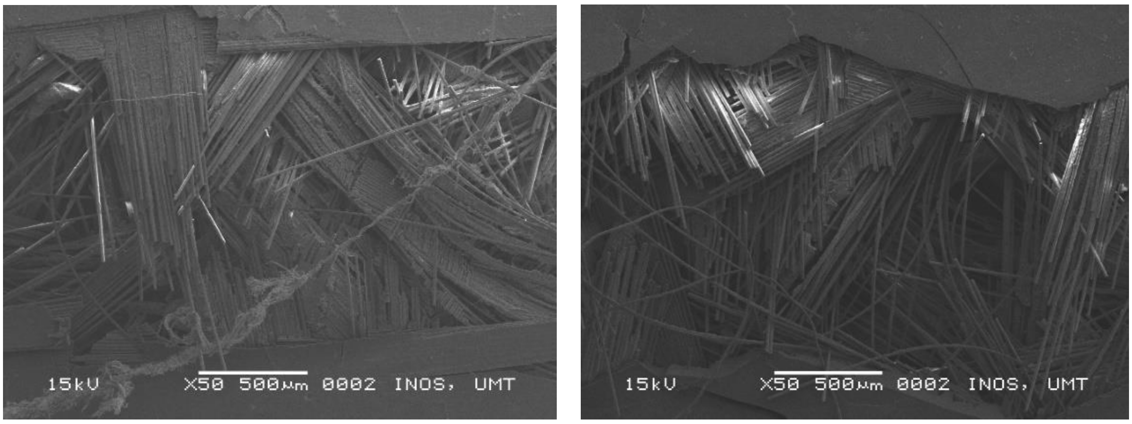

Figure 4. Misalignment of *Arenga Pinnata* fibre in specimen D (60%) and E (75%).

The results of weak interfacial adhesions of fiber–matrix could result in the misalignment of fibers in the natural fiber reinforced composites.

4. Conclusions

In this study, the manufacturing defects as voids, fibre pull-outs, resin-rich zone, misalignment fibre and interfacial adhesion were determined on the testing coupons by SEM. The effect of fibre contents had significantly influence towards manufacturing defects and interfacial adhesion of *Arenga Pinnata* reinforced Fibreglass/ Kevlar hybrid composite. It was revealed that specimen D (60%) demonstrated less manufacturing defects and possesses a good interfacial adhesion, while specimen E (75%) shows the highest manufacturing defects. Specimen D (60%) was proposed to be the optimum fibre composition related to the less defect that occurred by SEM observation. This led to better mechanical properties, as specimen D (60%) possessed the highest manufacturing defects and interfacial adhesion. This demonstrated that each fibre contents influenced the manufacturing defects and interfacial adhesion. SEM had significantly determined the manufacturing defects and interfacial adhesion of *Arenga Pinnata* fibre reinforced Fiberglass/ Kevlar hybrid composite.

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