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Uncertainty Factors and Their Effects in Experimental Results of Composite Structures

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Abstract: ***Uncertainty factors can be considered as major factors influencing experimental results. This article reviews the potential impact of uncertainty in manufacturing composite structures. It also describes the impact of the following factors on the testing process: Void content, curing time, tester calibration read error, interlinear bond, and mixed striping. Test specimens of hexagonal tubes were selected for testing. Test specimens are tested under axial compression tests. Observation and test results showed that the un-certainty factor significantly influenced the final result. Furthermore, the possible reasons for these findings and their implications were discussed.***

Index Terms: ***Uncertainty Factors, Experimental Process, Curing Time, Mixed Striping.***

I. INTRODUCTION

Uncertainties can be introduced in the design phase before the application begins. This uncertainty is determined by how the manufacturer determines and assigns design values to the material used, or the typical value of the material being used. The properties of the cured composite material are highly dependent on the Specimen's parameters.

According to previous literature, to set up a specific design or good manufacturing product the experimental work and the fabrication process for the final product can be affected by several factors including Raw material, void content, curing time, calibration of test equipment, misreading, inter-layer adhesion and striping of the mixture. There are several ways to build composite structures such as hand Lay-up [1-3] injection molding [4] and filament winding [5]. Jing Xu et al, fabricated five tubes using the filament winding method [6]. samples were arranged with length of about 50 mm and then tapered at 45° chamfering on the compression head. As shown in Fig 1.

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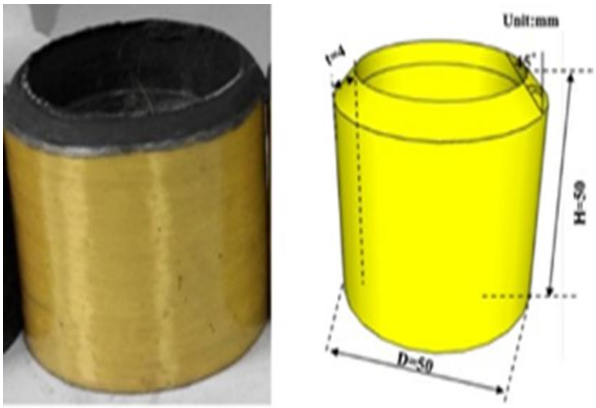

(a) Realistic appearance (b) Schematic diagram

Fig. 1 Chamfering on the compression head [6]

In another study, a low-cost filament winder was designed and developed to obtain regular winding and surface roughness [7]. A control device was provided to control the entire process of the manufacturing pipe and a round shaped specimen.

Void contents in the composite structure occur due to the manufacturing process. The air trapped inside the layer escapes during the drying cycle or brushing epoxy resin on the fiber in the early stages of the damage test [8].

Carla et al, experimentally studied the behavior of tubular under compassion and unstated test [9]. The results showed that the Circular tubes appear to have the lowest quality due to void and resin-rich areas. This article examines the potential impact of manufacturing uncertainty on composite structures.

II. METHODS

Material

Kenaf fibers (nonwovens and yarns) were provide by local company named Innovative Pultrusion Sdn. Bhd (IPSB). Located in in Malaysia the 4 mm thick mat like form unwoven kenaf shown in Fig. 2, finely fitted with shape dimension. The matrix used is D.E.R. ™ 331 ™ liquid resin and the curing agent/curing agent Joint mine 950-3S950-3S. Were provided by Dow Chemical Pacific, company. Table 1 lists mechanical properties of natural kenaf fiber used in this study.

Fig. 2 Typical example of unwoven kenaf

Table. 1 Mechanical properties of natural kenaf fiber

No.	Mechanical properties of natural kenaf fiber		
	Formulation		Ref.
1	Bulk Density (g/cm3)	0.13-0.17	[10], [11], [19], [20]
2	Modulus of electricity (GPa)	53	[4], [12]
3	Elongation at break (%)	1.6-3.5	[4], [13]
4	Tensile strength (MPa) Paragraph	630-930	[4], [14], [15]
5	Moisture Content (%)	74	[16]

Fabrication

Wet lapping warping by traditional methods was implemented to make a nonwoven and fiber/epoxy composite hexagonal tubes. By referring to supplier tips and technical manual book, the ration to get an optimum specification 2: 1 as shown in fig 3. The mixture was then stirred for about five minutes and randomly applied to the fibre laminate by normal brush, a nonwoven kenaf fiber fibre laminate was placed on the mould then the matrix immediately applied to the fibres. After that, the rollers were hard-pressed and rolled over the composite and laminated to an appropriate thickness. Before starting the weight of fiber was documented and recorded.

To get the fibre loading with value of 28% the material must dial with high car to ensure the mixture fully special care was needed to ensure that the mixture was saturated. Lastly, the composite was compacted to eliminate trapped bubbles. (8-8.5) mm thickness was fain by combined two layer of fibre . Specimens were made to obtain results for several parameters, and previously studied results were published in [3 – 6, 19].

The presence of voids in the composite reduces the mechanical and physical properties of the composite. The trapped air or other volatile material will form in the composite while the fiber is impregnated into the matrix or the fiber-reinforced composite is being produced. The most common cause of voids is the failure of the matrix to remove all entrained air in the kenaf or chopped strand. In order to avoid void content when the fibers pass through the matrix impregnation [20].

Fig. 3 Fabrication steps

The most important factor is the energy absorption capacity of the fiber during impact to determine the energy dispersion rate for the crushing load [6]. In addition, it corresponds to the energy to absorb when the structure fails [24, 25].

III. RESULTS AND DISCUSSION

Effects of Void Content in Specific Energy Absorption Capability

According to the fiber content of the tube, hexagonal tubes with larger average impact loads Tube nonwoven with different fiber content have a significant reduction in the ability of the kenaf/epoxy reinforced hexagonal tube to absorb energy.

From the result, the maxi-mum amount of energy that can be absorbed (145 kJ) occurs when the fiber content is 25%. Nonwoven Kenaf fibers/epoxies contain a large amount of matrix resin that allows the fibers to adhere well. Fig. 5 shows that early-manufacturing defective composites have reduced the mechanical properties.

In addition, defective composites in use energy absorption that much in the case of defects formed during use, the strength is further reduced. This is because the following defects services can extend faults more easily and easily prior to crushing. So the composite should be protected from the formation of holes in manufacturing process.

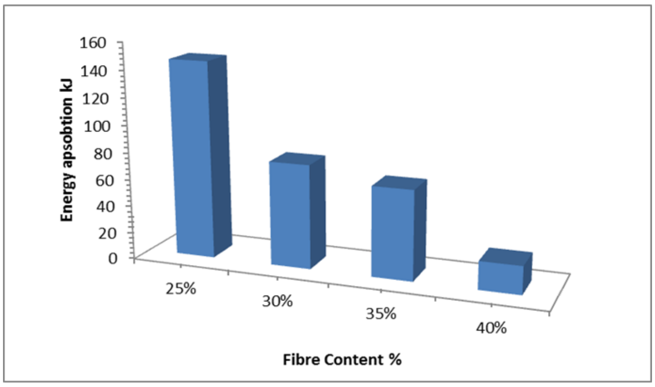

Fig. 4 The effects of void content in specific energy absorption capability

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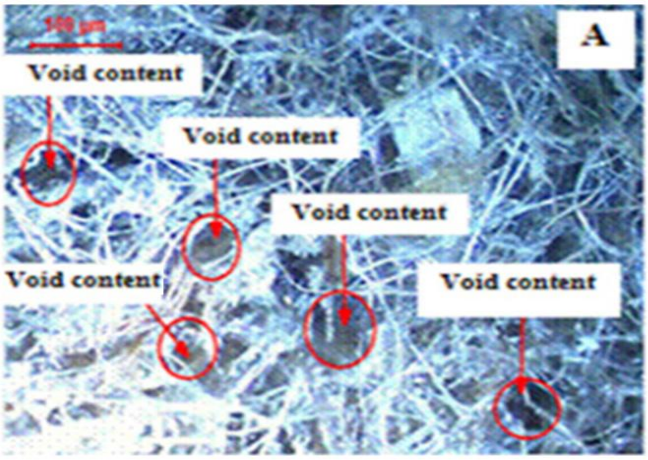

Fig. 5 Fracture in the fiber surface of the non-woven kenaf fiber/epoxy packing walls

Curing Time

Curing is the process of controlling the rate and extent of moisture loss from a composite structure when the drying process is not sufficient. It affects the result while maintaining moisture between layers as shown in Fig 6. The curing time can achieve by two methods:

The first method is that of natural hardening which depends on humidity and temperature (24 to 48 hours). To prepare for the test, the Kenaf fiber / epoxy composites were dried at normal room temperature two days based on the the Malaysian Meteorology Department (MMD), where the annual main HR Recorded between 65-93%.

The second method is oven dry method. The oven-dry process, combined with the compression or stress test, is a very useful tool. The oven operates to have shorter time for drying and content temperature to disposal for void between layers.

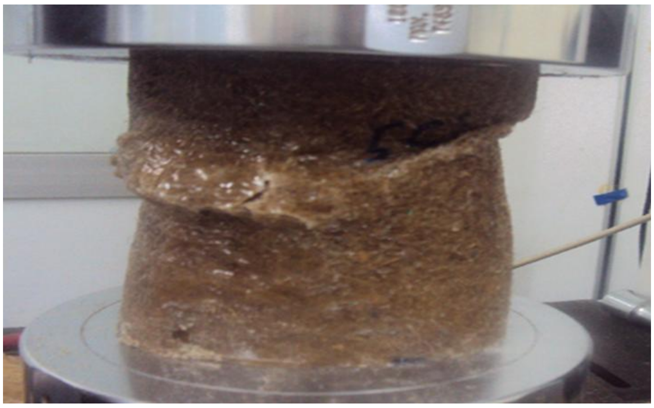

Fig. 6 Specimens with high void contents

Calibration of testing machine

The Instron Machine was calibrated by the transducer load cell every three months. The regular calibration processes increasing the accuracy of the test result and avoid the error.

To ensure that manufactured parts are within tolerance (first production), high quality calibration processes must be performed to ensure the performance of the production machine. [21].

To verify that the machine has been calibrated, three specimens of the same specification were tested, and the results of the calibrated values were assessed for accuracy. Furthermore, if the machine does not compensate, the speed will change over time, which will affect the load displacement relationship

Reading error

Almost all of direct measurements involves the use of mathematical measuring tools (ruler, caliper or digital display). Read errors indicate uncertainty due to limitations of the measuring equipment. Reading errors affect the accuracy of the experiment. The need to interpolate between the uncertainties associated with reading the scale is relatively easy to predict. Fig. 7 showing cut point and length measurement.

Fig. 7 Cutting process

Error with cutting tube result to different length between hex-agonal sides. Accurate cutting correct leads to a good distribution of the vertical force on all surfaces of hexagon tube [17, 18]

Interlayer adhesion

Only the surface of the mold is smooth and sometimes no high adhesion between the structure layers can be obtained. This reduced the resistance of the tube to compression load.

Five types of carbon fiber reinforced composite (CFRPs) tubes were fabricated by the filament winding method, and they impact resistance performance. As a result, the fiber arrangement in tube manufacturing helps to increase energy absorption due to a good adhesion between layers.

The force –deformation progress for the tube used illustrated on in Fig. 8a. The curve utilized that the increasing load was behaved randomly at pre-crushing stage, the load fails sharply. Fig 8b pointed the type of failure which name progressive failure. Speed pick up was seen and the wall of tubular pulled out due to the transverse crack.

Four categories of cross-sectional tube engineering characteristics were investigated by Elfetori et al. the result came out from his investigation was observed that of tube failure with progressive at one or both ends of tubes [23]. Mahdi et al. Mahdi et al. noted that the tube progressively crushes down [24].

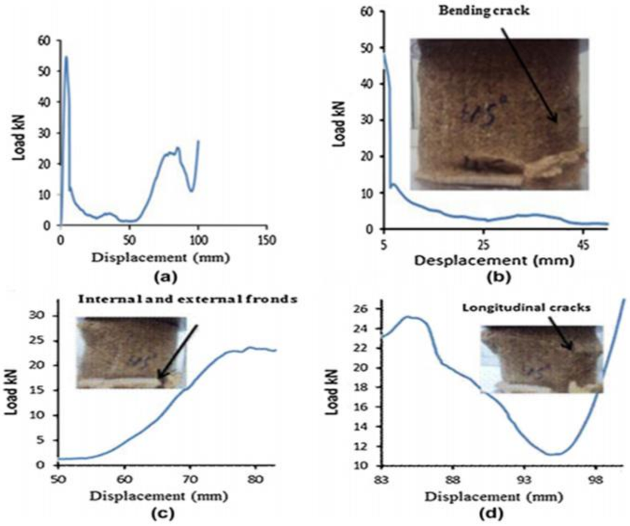

Fig. 8 The load–displacement curves for the hexagonal tube with angle

Mixed Striping

Unsatisfactory result will be seen if the mixture not mixing as standard. Well stratifying will come with a good result if followed the recommendation sheet such as time, sequences, carefully applied mixture on the surface of a wood mandrel. Since the trapped bubble at the end of the process strongly affects the outcome, the composite is the main step that must be compressed to remove trapped bubbles.

Shekeil et al. [20] studied the impact of content fibre the effect of fibre content (50, 40, 30 and 20 wt %) on fibre properties reinforced TPU composites. The specimens were prepared by using traditional method by hand and normal compressed the highest value was recorded by tube with 30% fibre content for all mechanical properties.

Different mixing of materials contents leads to different failure characteristics. This is the behavior of composite fiber due to some circumstance whereas different shape as well as geometry of voids in composite resulted in different energy absorption levels thus affect the inhomogeneity of fiber strength. With increasing thickness of the composite, peak load also can increase by 2 – 3 folds thus affects much on the uncertainty of experimental results.

IV. CONCLUSION

Based on the results obtained, the uncertainty of the current factors affects the results of the experiment. The observed major effect of void content on specific energy is absorption capability It can be notify that the best value of energy that can be absorbed (145 kJ) recorded with fiber content of 25%. Non-woven kenaf fibers or epoxy contain large amounts of matrix resin. Proper cutting ensures that the normal force is well distributed on all surfaces of the hexagonal tube.

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