



Determination of Tensile Properties for Twisted Fibre Bundles of Oil Palm Empty Fruit Bunch at Different Diameters

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Abstract: The potential use of natural fibre extracted from oil palm empty fruit bunches has gained wide attention among researchers. This natural fibre comes from fibrous strands which form fibre bundle after shredding process at a mill. The measurement of tensile properties is important to understand the mechanical performance of this fibre bundle. This study was undertaken to determine the tensile properties of the fibre bundle from oil palm empty fruit bunch (OPEFB). Fibrous strands of the OPEFB extracted from shredded empty fruit bunches were twisted to form fibre bundle specimens at different diameters varying from 1 to 5 mm. The tensile properties measured in this study including tensile strength, tensile load and tensile modulus. The measurements were performed using Instron Universal Test Machine (IUTM) model 5000. From the results, it was found that the specimens at 1 and 5 mm in diameter required 71.25 and 429.68 N of the tensile load to break, respectively. The specimen with 1 mm in diameter recorded the highest tensile strength of 90.72 MPa while the specimen with 5 mm in diameter recorded only 21.88 MPa. The highest tensile modulus with value of 662.50 MPa was obtained from the specimen with 1 mm in diameter while the specimen with 5 mm in diameter had the tensile modulus value of 157.47 MPa. It was also found that the tensile strength and tensile modulus decreased when the diameter of the specimens increased. The findings reported in this study can serve as an engineering basis for the design specification in the development of the future in-silo composting machine.

Keywords: Tensile properties, Oil palm, Fibre, Empty fruit bunch, Diameter.

Introduction

Oil palm (*Elaeis guineensis*) is one of the most significant crops in Malaysia. Oil palm tree is considered as one of the highest yielding edible oil crops in the world due to

its ability to typically produce about 4 to 5.5 ton of palm oil and palm kernel oil per hectare in a single harvest cycle (Hashim *et al.*, 2012). Awalludin *et al.* (2015) reported that the plantation of oil palm in Malaysia

covered the area of 5.39 million hectares with 426 palm oil mills were built throughout the country in 2014. In addition, the oil palm industry is the fourth largest sources of the national income and it's contributed over USD22.31 billion to the Malaysian's economy.

One of the critical issues in the palm oil industry is the production of huge amount of biomass waste. The typical wastes which are produced by this industry during the oil palm fruits harvesting, palm oil processing or during oil palm trees replantation were palm kernel shell (PKS), empty fruit bunches (EFB), palm oil mill effluent (POME), mesocarp fibre (MF), oil palm fronds (OPF) and oil palm trunks (OPT) (Awalludin *et al.*, 2015). Typically, the fresh oil palm fruit bunch comprises of 14-15% fibre, 21% palm oil, 6-7% palm kernel, 23% empty fruit bunch and 6-7% shell (Umikalsom *et al.*, 1997). Out of that, the EFB is regarded as a cheap and abundant biomass resource which can be utilised as an important feedstock to generate various products such as bio-hydrogen bio-syngas, bio-oil, bioethanol, bio-compost and bio-composite (Abdulrazik *et al.*, 2017).

Since several decades ago, numerous studies were carried out to increase the utilization of the EFB. The EFB is lignocellulosic rich material which is suitable for various application such as bio-plastic, natural fibre composite, pulp, source of enzyme and animal feed (Yeoh *et al.*, 2011). Natural fibre composites (NFCs) are attracting attention because they offer different benefits such as low cost, biodegradability, low density, better thermal and insulating properties and low energy consumption during processing (Jawaid *et al.*, 2010). The potential of NFCs to replace synthetic fibre was studied mainly in terms of

its mechanical performance, specifically its tensile properties (Gunawan *et al.*, 2009; Yusoff *et al.*, 2009; Jawaid *et al.*, 2010; Omar *et al.*, 2014; Zailuddin & Husseinsyah, 2016).

Yusoff *et al.* (2009) determined the mechanical performances and moisture content of a single oil palm fibre with a diameter ranged from 250 to 610 μm and 2.2 to 9.5%, respectively. In the study, it was found that the average values of the Young's modulus, tensile strength, and elongation at break were 1703 MPa, 71 MPa, and 11%, respectively. In a similar study, Ramlee *et al.* (2019) studied physical, tensile and morphological properties of EFB and sugarcane bagasse (SCB) fibre for the fabrication of hybrid composites. The authors concluded that the hybridization of EFB/SCB fibre composites offered better performance and properties as compared to pure fibre composites. Anuar *et al.* (2019) compared the morphological and mechanical properties of oil palm EFB fibres and kenaf fibres in non-woven reinforced composites. The study concluded that the EFB has good potential applications as nonwoven fabric and alternative reinforcement material in nonwoven composites.

However, most of the previous researches only studied the tensile properties of an individual fibrous strand. There were no available studies reported the tensile properties of EFB in a form of a fibre bundle. In practice, the EFB discharged from a palm oil mill comes in a bulk and shredded form. Each shredded EFB comprises of thousands of fibre strands which were naturally twisted and mixed together. Therefore, instead of measuring the tensile properties for an individual fibre strand, it is also significant to determine the tensile properties of a bulk and twisted fibre bundle. Tensile properties of a

bulk fibre bundle will serve as an engineering basis for the design specification in the development of the future an in-silo composting machine, EFB cutting machine and EFB chopping machine. Therefore, the objective of this research was to determine the tensile properties (tensile strength and tensile modulus) of EFB fibre bundles at different diameters.

Materials & Methods:

Sample preparation

In this study, shredded EFB samples were supplied by Prestige Central Management Sdn. Bhd., located in Kok Foh, Bahau, Negeri Sembilan, Malaysia. The shredded EFB contained fibre strand from stalks and spikelet. The samples were randomly taken so that the results obtained from this study would represent the behaviour of all shredded EFB available at the mill. The samples collected from the mill were transported to the laboratory for further analysis. In the laboratory, the shredded EFB samples were first cleaned, sorted and air-dried before the individual fibre strand was extracted.

A scissors was used to cut each fibrous strand at 15 cm length. The extracted fibrous strand was again cleaned, sorted and air-dried, and twisted together to form twisted fibre bundle specimens with a diameter of 1, 2, 3, 4 and 5 mm (Fig. 1). The formation of the fibre bundle specimens was made based on a typical diameter of the shredded fibre bundles observed at the mill. The fibre bundles were decreasingly twisted from 0.6, 0.5, 0.4, 0.3 to 0.2 twist.cm⁻¹ with the increasing diameters from 1 to 5 mm, respectively. The diameter of the specimens was measured using a vernier calliper. Three specimens were produced for each diameter, producing 15 specimens altogether. The fibre bundles for each diameter were replicated three times so that an average value can be obtained during the testing process. A plastic cable tie was used to tie the specimens at the both ends with the distance between the cable ties was kept at 5 cm. The cable tie was placed at 5 cm distance apart from each other to prevent slippage during the tensile test.



Fig. (1): Specimens of twisted fibre bundles at different diameters.

Tensile test procedure

Instron Universal Test Machine (IUTM) Model 5000 with a 5 kN load cell was used to measure the tensile properties of the specimens. A 10 mm/min of the crosshead speed was used in this test. All measurements were conducted at the room temperature. All the reported values were the average of three specimens. The specimen was attached to the IUTM at an initial distance of 50 mm (Fig. 2).

$$E = \frac{\text{stress}}{\text{strain}}$$

The stress in the specimens was measured as the tensile strength, MPa and the strain was given by the maximum tensile strain, mm/mm. Fig. (2 shows how the specimen was placed during the tensile test by the

The test was started with the specimen with 1 mm diameter, followed by 2 mm, 3 mm, 4 mm and ended with 5 mm. The data were recorded by using the software (Bluehill v2.5, Instron). The software recorded the values of mechanical properties of the specimens such as tensile load (N), tensile strength (MPa), and maximum tensile strain (mm/mm). Tensile modulus (MPa) was calculated by using Equation (1):

$$\text{Eqn. 1}$$

UITM to determine the properties of the fibre extracted from the EFB. The data obtained from the tensile test are tabulated in Microsoft Excel for further analysis.



Fig. (2): The specimen during the tensile test by UITM.

Results & Discussion:

Tensile properties of the EFB fibre bundles

The values of mean and standard deviation of the tensile properties in terms of the tensile strength, tensile load and tensile modulus for the EFB fibre bundles at different diameters are shown in (Table 1). The values of the tensile properties for each specimen at different diameters were averaged from three

replications. From the table, it is obvious that the tensile properties of the EFB fibre bundles are dependent on the diameter of the specimens. It is clearly shown that the tensile load increases as the diameter of the specimen increased. When the diameter is increased from 1 to 5 mm, the tensile load also increases from 71.25 to 429.68 N, whereas for the tensile strength, the values decrease when the diameter of the specimens

increased. For example, the tensile strength decreases from 90.72 to 21.68 MPa when the diameter of the specimens increases from 1 to 5 mm. For the tensile modulus, the trend is

similar to the tensile strength. The tensile modulus decreases from 662.50 to 157.47 MPa when the diameter of the specimens increases from 1 to 5 mm.

Table (1): Tensile properties for EFB fibre bundles at different diameters.

Diameter of specimens (mm)	Tensile Load (N)		Tensile Strength (MPa)		Tensile Modulus (MPa)	
	Mean	SD	Mean	SD	Mean	SD
1	71.25	19.62	90.72	24.9	662.50	178.14
2	90.54	9.15	28.82	2.91	257.15	60.40
3	188.02	45.45	26.60	6.43	186.69	22.10
4	186.29	6.09	14.83	2.48	146.73	16.52
5	429.68	93.12	21.88	4.74	157.47	44.51

* SD = Standard deviation

Tensile load

Tensile load refers to the force needed to break the specimens under the pulling force. The tensile load recorded for the specimens at different diameters used in this study are shown in the scatter plot as shown in (Fig. 3). The trend of the plot shows that the tensile load increases gradually with the increase in specimen's diameter. For example, specimen at 1 mm diameter required only 71.25 N of tensile load while the specimen at 5 mm

diameter required 429.68 N of tensile load. This data can be used to select an optimum required torque for the cutting machine to break the fibre bundle into small pieces. According to Wong *et al.* (2008), the tensile load of the fibre depends on many factors such as the length, diameter and filler loading. For example, a longer fibre requires less load to break it as compared to a shorter fibre. In terms of a diameter, a fibre bundle with a bigger diameter will require a higher load to break the samples (Islam *et al.*, 2019).

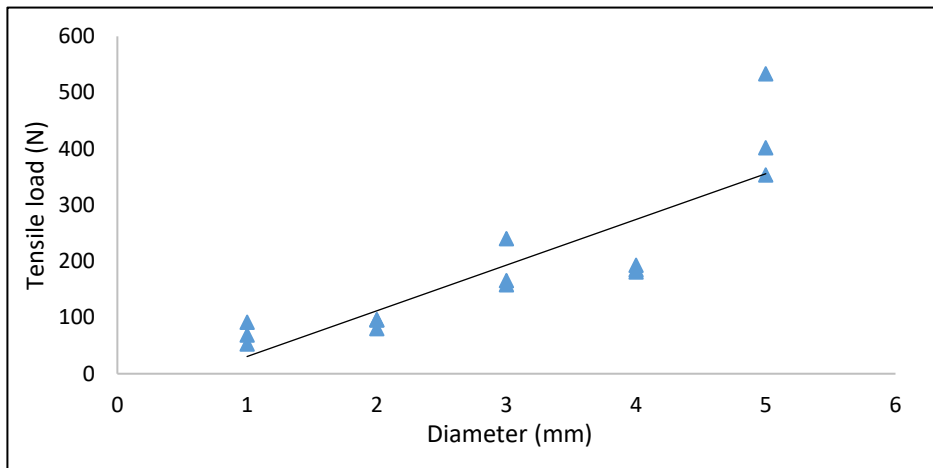


Fig. (3): Tensile load versus EFB fibre bundle diameter.

Tensile strength

Tensile strength refers to the maximum stress which can be withstood by the specimens during stretching or pulling before breaking. The tensile strength (MPa) for the EFB fibre bundles at different diameters used in this study are shown in the scatter plot as shown in fig. (4). The highest value of the tensile strength was 90.72 MPa belong to the fibre bundle with a diameter of 1 mm. While the lowest tensile strength of 21.88 MPa was recorded for the fibre bundle with 5 mm

diameter. Based on the graph, it can be concluded that the tensile strength decreased as a diameter of fibre bundle increased. Gunawan *et al.* (2009) and Yusoff *et al.* (2009) reported the same pattern of tensile strength versus diameter for single strand of EFB fibre. Gunawan *et al.* (2009) claimed that the trend was due to void present in the larger diameter of the fibre. Apart from that, the non-uniform behaviour of the multiple fibre in the bundled sample might also contributed to the variations of tensile strength obtained from the test.

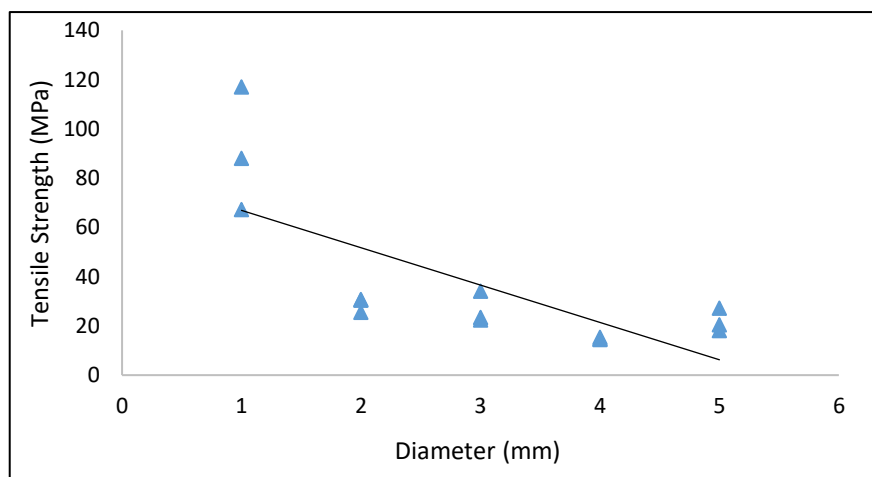


Fig. (4): Tensile strength versus EFB fibre bundle diameter

Tensile modulus

Tensile modulus or modulus of elasticity is one of the mechanical properties to measure stiffness of the fibre bundles based on the relationship between stress and strain in the specimens. The value of the tensile modulus indicates the ability of the specimens to resist elastic deformation. Fig. (5) shows the tensile modulus of the fibre bundles. The figure demonstrates that the tensile modulus of

the fibre bundles drops when the diameter increases. This finding is similar to the study reported by Hassan *et al.* (2018). According to the study, it was observed that the fibre with a higher diameter contained larger value of porosity so the tensile properties of the fibre samples will be reduced.

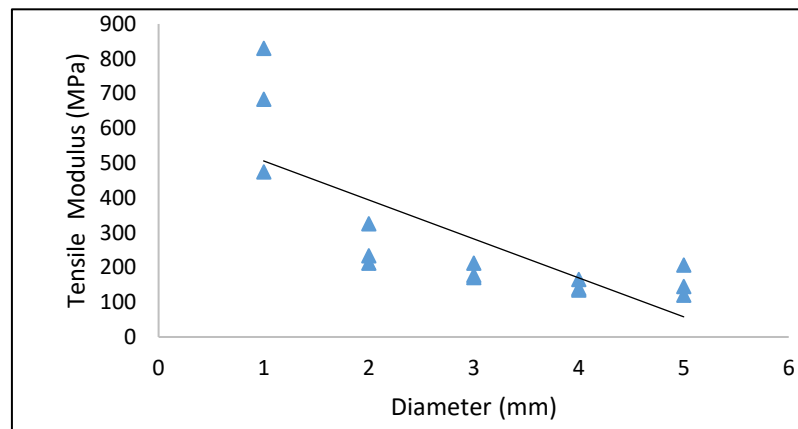


Fig. (5): Tensile modulus versus EFB fibre bundle diameter.

The highest tensile modulus at 662.50 MPa was recorded for the specimen with the diameter of 1 mm. The specimen with 5 mm diameter had tensile modulus value of 157.47 MPa.

Conclusions

This study describes the properties of tensile for the twisted oil palm fibre bundle at different diameters. The results show that the specimen with 1 mm diameter required 71.25 N of tensile load while the specimen at 5 mm required 429.68 N. For the tensile strength, the specimen with 1 mm diameter recorded the highest tensile strength of 90.72 MPa while the specimen with 5 mm diameter recorded only 21.88 MPa. In terms of the

tensile modulus, the highest value of tensile modulus was recorded for specimen with 1 mm diameter while the specimen with 5 mm diameter had tensile modulus value of 157.47 MPa. From this finding, it was found that the tensile strength and tensile modulus decreased when the diameter of the specimen increased. The findings reported in this study can serve as an engineering basis for the design specification in the development of the future in-silo composting machine.

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