Experimental testing of oil palm fibre composite manufactured via vacuum bagging method

N S Binti Mohd Hafidz, M S Bin Mohamed Rehan
Department of Mechanical Engineering, Kulliyyah of Engineering, International Islamic University Malaysia, Malaysia
nurulyszwanihafidz@gmail.com

Abstract. The objective of this research is to compare tensile strength of oil palm fibre composite produced from oil palm fibre of different configurations. Compressed random oil palm fibre and uncompressed random oil palm fibre reinforced polyester composite were manufactured using vacuum bagging technique. The volume fractions of the fibre to the resin were 6.6:93.4 and 17:83 for compressed fibre and uncompressed fibre composites, respectively. The ratio of the polyester to hardener is 100:2. Tensile properties obtained via tensile tests as per ASTM D 638 specifications using Universal Testing machine INSTRON 5582. Load-displacement plots show that the fracture load and the slope for specimens from the same plate vary with a significant range. Stress-strain plots also have the same issue. With such data direct comparison of average value may not be giving a conclusive comparison, with a big standard deviation for both sets of specimens. Furthermore, there are two simultaneous factors in this study, namely the configuration of the oil palm fibres used and the volume ratio of the composite. Further testing and analysis is deemed to be necessary to further fine tune the fabrication process, for a conclusive comparison.

1. Introduction
1.1 Background
Even back in 2006 natural fibre composites was reported to have been embraced for a decade by European car manufacturers and suppliers for door panels, seat backs, headliners, package trays, dashboards and interior parts [1]. While stating natural fibres do offer such benefits as reduction of weight and cost, it was also stated that several major technical considerations must be addressed before a wide scale acceptance, particularly in exterior parts where a Class A surface finish is required. Among the challenges mentioned were the homogenization of the fibre’s properties and a full understanding of adhesion between the fibre and matrix.

There has been a great development in natural fibre composites, and a lot of studies have been done on their mechanical performance [2]. The focus for this study will be in the application of oil palm empty fruit bunch (OPEFB) as reinforced material in composite materials. A review by Mahjoub et al. [3] focusing on the properties of OPEFB fibre and mechanical properties of OPEFB composites in term of tensile and flexural properties highlighted that previous studies show the impact properties of OPEFB composites are better than pure resin that it can be interesting factor for special industries for using new material to make products such car bumper and dashboard. However, it was also noted that more studies are needed to find out and verify the predictions. A review study on the potential of OPEFB as
reinforcing materials in polymer composites for energy absorption during low-velocity impact by Faizi et al. [4] suggests high potential applications of OPEFB as reinforcing materials in composite structures.

Mohamed Yusoff et al [5] have studied the mechanical properties of short random oil palm fibre reinforced epoxy composites, where empty fruit bunch was selected as the fibre. The composites were fabricated by hand lay-up techniques, and composite plates of four different volume fractions were fabricated. The study observed that the tensile and flexural properties showed a decreasing trend as the fibre content increased.

Al-Oqla and Sapuan [6] have published their work to analyze the feasibility of date palm fibres for sustainable automotive industry. In this work they stated to have successfully able to categorize and tabulate the criteria that affect natural fibre reinforced polymer composite materials in distinguished levels for the first time. For date palm fibre they found that they have very competitive properties suitable for automotive industry.

Sahari and Maleque [7] have investigated the mechanical properties of oil palm shell composites with different volume fraction using unsaturated polyester as matrix. The study found that the tensile strength of the composite increased with oil palm shell content. The study also mentioned that SEM analysis indicates that the filler detached from the fracture surface which proved the poor filler-matrix interfacial bonding.

Jawaid et al [9] have studied the effect of addition of jute fibres to oil palm composite and found that it increases the storage modulus. The overall use of hybrid system was found to be effective in increasing tensile and dynamic mechanical properties of the oil palm-epoxy composite probably due to the enhanced fibre/matrix interface bonding. They did mention that while many automotive manufacturers try to replace synthetic fibres with natural fibres, it is not comparable in properties, and stated that fabricating hybrid composites by the combination of two natural fibres gives them advantages to replace synthetic fibres.

1.2 Mechanical Properties of Oil Palm Fibre

Mahjoub et al. [3] have compiled the fibre properties of oil palm empty fruit bunch fibre gathered from various researchers, and reported results are not identical because of variation in the kind of oil palm fibre used. Additional factor of irregular sectional area was also mentioned [10]. Consequently, some of the references reported wide range of value for mechanical properties.

1.3 Tensile Properties of Oil Palm Fibre Composites

Tensile strength and tensile modulus are considered as major properties of materials by engineers. Mahjoub et al. [3] have compiled the tensile properties of oil palm composites obtained from various researchers. They have noted that the compiled results indicate that adding oil palm fibre to polymer causes the reduction of tensile strength of pure resin.

2. Study Methodology

In this study two types of oil palm fibre were used, which were compressed random oil palm fibre and uncompressed random oil palm fibre. There were four stages in doing this research, which are the compressed oil palm fibre and uncompressed oil palm fibre preparation, oil palm fibre reinforced polyester composite fabrication process, cutting process of the composites by using CNC milling machine and the last stage was tensile test was done. It was to obtain mechanical characteristics of oil palm fibre reinforced polyester composite.

2.1 Fibre material

Untreated oil palm fibre is obtained from Malaysia Palm Oil Board in Bangi, Selangor, Malaysia. The raw fibre is obtained in two types as shown in Figure 1, where the first one is random uncompressed fibre, and the second is compressed into a mat of certain roughly uniform thickness. The uncompressed
random fibre obtained in bundles, tangled and intermixed between its fibres. In order to prepare the uncompressed random fibre, the fibre needed to be combed so that it would produce untangled and more uniformly distributed fibre. On the other hand, compressed random fibre obtained is very compact and dense in nature.

![Figure 1](image_url)

**Figure 1.** Oil palm fibre obtained in the form of (a) uncompressed random fibre and (b) compressed random fibre.

### 2.2 Fabrication of oil palm fibre composites

The oil palm fibre reinforced polyester composites were manufactured using vacuum bagging fabrication technique. The fabrication technique was same for both types of oil palm fibres, where some of the main steps are shown in Figure 2.

![Figure 2](image_url)

**Figure 2.** Fabrication process of the oil palm fibre composite plates; (a) mixed polyester resin and hardener was impregnated through the layer of the fibre, (b) vacuum pump draws out the air inside the confined space, and (c) sample oil palm fibre composite plate.

A 320 mm x 220 mm aluminium tray was used as a mould to fabricate the composites. A layer of mylar sheet was placed on each side of the plate as a releasing agent. Polyester resin and hardener solution were mixed thoroughly according to specific fibre-matrix volume fraction ratio, as shown in table 1. The mixed solution is then poured into the tray until it fully filled the whole tray. The fibre was then placed in the tray and soaked it thoroughly until all the fibres are covered with resin. The mixed solution was then impregnated through the layer of fibres. Vacuum bagging materials was placed on top of the wet fibres. Vacuum bagging film enclosed the lay-up to provide a confined space which is sealed using sealant tape. A vacuum pump draws out the air inside the confined space to produce an airtight vacuum bag until curing process is done.
| Parameter          | Uncompressed Random Fibre | Compressed Random Fibre |
|--------------------|----------------------------|-------------------------|
| Weight of fibre, $W_f$ | 15.3                      | 47.5                    |
| Volume Ratio       | (6.6/93.4)                 | (17/83)                 |
| Mass Ratio         | (15.3/424.8)               | (47.5/453.8)            |
| Test Specimen      | R1 R2 R3 R4               | M1 M2 M3 M4             |
| Weight of composite, $W_c = W_f + W_r$ | 440.1 g | 501.3 g |

### 2.3 Cutting of specimens

There were two different plates which were uncompressed random fibre plate and compressed random fibre plate. Each plate was cut into four specimens. Hence, the total of the specimens were eight. Tensile test specimen was prepared according to the standard size and specification of ASTM D 638 using CNC milling. Table 2 shows the dimensions for each of the plate.

![Figure 3. Specimen Dimensions.](image)

### Table 2. Specimen Dimensions.

| Dimensions (mm) | Uncompressed Random Fibre | Compressed Random Fibre |
|-----------------|---------------------------|-------------------------|
| WO              | 19                        | 19                      |
| L               | 57                        | 57                      |
| LO              | 165                       | 165                     |
| $W_c$           | 13                        | 13                      |
| T               | 5                         | 6.5                     |

### 2.4 Tensile test

Tensile strength and modulus of elasticity for uncompressed random fibre and compressed random fibre reinforced polyester composite were tested by using INSTRON 5582 Ultimate Testing Machine. This measurement was conducted according to ASTM D 638 procedures at a test speed of 5mm/min. Four specimens were tested for each case and its average value is tabulated accordingly.

### 3. Results and Discussion

#### 3.1 Load vs. Displacement Plot

The plots of load against displacement are as presented in Figure together with the images of the fractured region. One major contrast between specimens fabricated from uncompressed random fibre and from compressed random fibre is the specimens from uncompressed fibre tend to break into two separate pieces when they fractured, while for specimens from compressed fibre the fracture across the width of the specimen can be seen, but the specimen still is intact, illustrating that the compressed fibre is not totally cut separated when the fracture occurs. This may be due to the fact that the compressed
fibre specimens have the fibres tangled with one another in a very compressed manner, as compared to the uncompressed fibre where the individual fibre can be cut off more easily when fracture occurs.

Another observation that can be made is that the specimens from the same fibre type do have a big range of both fracture load and the slope of load-displacement curve. Based upon visual inspection, it is quite unclear what the factor behind the difference of fracture load is. It can be argued that the random nature of the alignment of the fibre throughout the length of the specimen and between specimens inevitably lead towards the difficulty to have an exact uniform behaviour between specimens.

3.2 Stress vs. Strain Plot

The plots of stress against strain are as shown in Figure 5. The range of the values of slopes between specimens of the same fibre type is also quite big. With this observation it is a big question whether oil palm composite plates like these can have a material property or it will be diverse throughout the plate due to the random characteristic of the fibre.

**Figure 4.** Load vs. Displacement plots for specimens produced from (a) uncompressed random fibre and (b) compressed random fibre.

**Figure 5.** Stress vs. Strain plots for specimens produced from (a) uncompressed random fibre and (b) compressed random fibre.
3.3 Modulus of elasticity

From the graph stress vs. strain as shown in figure 5, modulus of elasticity can be obtained. One aspect that can be observed from the plots shown in figure 5 is the fact that it is difficult to distinguish the linear elastic region for each curve. This has a direct impact on the calculation of tensile modulus. Hence, the calculation of modulus is based on the slope of the tangent to the stress-strain curve at a low stress. Based on table 3, it shows the average tensile modulus for uncompressed random fibre composite and compressed random fibre composite. Figure 6 shows more clearly the average tensile modulus in a bar graph.

Table 3. Modulus of elasticity and standard deviation for uncompressed random fibre and compressed random fibre.

| Parameter                     | Uncompressed Random Fibre | Compressed Random Fibre |
|-------------------------------|---------------------------|-------------------------|
| Average Tensile Modulus (MPa) | 4171.98                   | 3476.63                 |
| Standard Deviation            | 221.072                   | 705.259                 |

Figure 6: Average Tensile Modulus.

With these observations, it is deemed important to further analyse the fabrication process as well as the composition of the oil palm fibres in the composite. The future analysis will also benchmark the tensile behaviour to that of pure polyester and also glass fibre composite, to analyse its potential in term of its application.

4. Conclusion

Two types of oil palm fibres have been used to fabricate specimens of oil palm fibre reinforced polyester composite. Tensile tests were performed to analyse the tensile mechanical properties between the two sets of composite. Load-displacement plots show that the fracture load and the slope for specimens from the same plate vary with a significant range. Stress-strain plots also have the same issue. With such data direct comparison of average value may not be giving a conclusive comparison, with a big standard deviation for both sets of specimens. Furthermore, there are two simultaneous factors in this study, namely the configuration of the oil palm fibres used and the volume ratio of the composite. Further testing and analysis is deemed to be necessary to further fine tune the fabrication process, for a conclusive comparison.
References

[1] Holbery J and Houston D 2006 Natural-fibre-reinforced polymer composites in automotive applications 2006 J. Miner. Met. Mater. Soc. 58 80-86

[2] Pickering K L, Efendy M G A and Le T M 2016 A review of recent developments in natural fibre composites and their mechanical performance 2016 Compos. Part A Appl. Sci. Manuf. 83 98-112

[3] Mahjoub R, Yatim J M and Sam A R M 2013 A review of structural performance of oil palm empty fruit bunch fiber in polymer composites 2013 Advances in Materials Science and Engineering. 2013 9

[4] Faizi M K, Shahriman A B, Majid M S A, Shamsul B M T, Ng Y G, Basah S N, Cheng E M, Afendi M, Zuradzman M R, Wan K and Hazry D 2017 An overview of the oil palm empty fruit bunch (OPEFB) potential as reinforcing fibre in polymer composite for energy absorption applications 2017 MATEC Web Conf. 2016 1-9

[5] Yusoff M, Salit M S, Ismail N and Wirawan R 2010 Mechanical properties of short random oil palm fibre reinforced epoxy composites 2010 Sains Malaysiana. 39 87-92

[6] Al-Oqla F M and Sapuan S M 2014 Natural fiber reinforced polymer composites in industrial applications: feasibility of date palm fibers for sustainable automotive industry 2014 J. Clean. Prod.

[7] Sahari J and Maleque M A 2016 Mechanical properties of oil palm shell composites 2016 Int. J. Polym. Sci. 2016 7

[8] Jawaid M, Khalil H P S A, Bakar A and Khanam P N 2011 Chemical resistance, void content and tensile properties of oil palm/jute fibre reinforced polymer hybrid composites 2011 Mater. Des. 2 1014-1019

[9] Jawaid M, Khalil H P S A, Hassan A, Dungani R and Hadiyane A 2013 Effect of jute fibre loading on tensile and dynamic mechanical properties of oil palm epoxy composites 2013 Compos. Part B Eng. 2012 6

[10] Virk A S, Hall W and Summerscales J 2010 Failure strain as the key design criterion for fracture of natural fibre composites 2010 Compos. Sci. Technol 70 995–999