Tensile Mechanical Property of Oil Palm Empty Fruit Bunch Fiber Reinforced Epoxy Composites

A L Ahmad Ghazilan$^{1,a}$, H Mokhtar$^{1,b}$, M S I Shaik Dawood$^{1,c}$, Y Aminanda$^{1,d}$ and J S Mohamed Ali$^{1,e}$

$^1$Department of Mechanical Engineering
Kulliyyah of Engineering, International Islamic University Malaysia
Jalan Gombak, 53100 Kuala Lumpur, Malaysia

E-mail: $^a$ahmadluqman141@gmail.com, $^b$hananm@iium.edu.my, $^c$sultan@iium.edu.my, $^d$yulfian@iium.edu.my, $^e$jaffar@iium.edu.my

Abstract. Natural, short, untreated and randomly oriented oil palm empty fruit bunch fiber reinforced epoxy composites were manufactured using vacuum bagging technique with 20% fiber volume composition. The performance of the composite was evaluated as an alternative to synthetic or conventional reinforced composites. Tensile properties such as tensile strength, modulus of elasticity and Poisson’s ratio were compared to the tensile properties of pure epoxy obtained via tensile tests as per ASTM D 638 specifications using Universal Testing Machine INSTRON 5582. The tensile properties of oil palm empty fruit bunch fiber reinforced epoxy composites were lower compared to plain epoxy structure with the decrement in performances of 38% for modulus of elasticity and 61% for tensile strength.

1. Introduction
Natural fiber from various biodegradable natural resources have offered potential improvement in reinforcing material compared to synthetic fiber reinforced matrix composites. Advantageous properties of low cost, low density, biodegradability, and better insulating and thermal resistance have served for improvement in natural fiber reinforcement. Through a remarkable development locally and globally, these materials have become preferable choices which undergo extensive research, application and transformation. With non-renewable, non-degradable and expensive resources of synthetic fiber, natural-recycled resources of natural fiber is becoming an important engineering material with a wide range of properties. From the engineering, technological and structural perspective, natural fiber is accepted due to its properties of stiffness, flexibility, impact resistance and modulus of elasticity. Several applications of industrial natural fiber reinforcements have been realized lately, such as the use of flax-sisal fiber mat reinforced epoxy matrix to produce door panels for Mercedes Benz E-Class, flax fiber reinforced polypropylene composite for rear shelf trim panels for the year 2000 model Chevrolet Impala, and natural fiber reinforced composites in structural applications such as ceiling and partition boards [1].

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Depending on the utilization of natural fiber, the classification of the plants is divided into two distinguished parties which are the primary and secondary. Primary plants are classified so as the plants are grown only for their fiber content, i.e. jute, hemp, kenaf and sisal plant. The secondary classification consists of the fibers obtained as a secondary product, i.e. pineapple, coir and oil palm plants. Six common types of natural fiber which can be extracted from plants are the bast, leaf, seed, core, grass and reeds [2]. The growing interest in investing towards the development of natural fiber, especially oil palm fiber from empty fruit bunch, is mainly due to its vast availability from biodegradable waste, environmental advantages, economical production, and low specific weight with high specific strength when compared to conventional synthetic fibers. However, its natural property of hydrophilicity makes the natural fiber high in moisture absorption, and its weak adhesion ability to hydrophobic matrices needs special treatment to enhance the performance of reinforced natural fiber [3]. The mechanical performance of lower ultimate strength, lower elongation properties, large variability of performance prediction and poor weather resistance have restricted natural fibers in handling loading applications. Therefore it is essential to improve the mechanical performance of oil palm fiber in natural fiber reinforced matrix composites.

Oil palm (Elaeis Guineensis) is planted in 42 countries. Malaysia, Indonesia, West Africa, Latin America and India are the leading countries that produce oil palm products [4] [5]. 73% of fibrous sources can be extracted through the separation of fibrous mass of its full fruit bunch [6] by using extraction methods of physical or chemical retting process. The exceptional performance possessed by oil palm empty fruit bunch reinforced composite for structural loading application have been reported to have a similar performance to that of coir fiber which has high specific strength [7]. In fact, the high cellulose content and toughness value of oil palm empty fruit bunch fiber makes it suitable for composite application. However, the overall limitation of its mechanical performance needs specific modification to drop the hydrophilicity factor of oil palm fiber by physical and chemical treatment such as corona, plasma, silane, alkaline, acetylation, coupling agent and enzyme treatment method. High interlocking and adhesive capability with matrix material has made alkaline treatment the most effective method in treating most natural fibers [8]. Vacuum bagging techniques for fabricating natural fiber reinforced composite will provide good physical and mechanical performance compared to wet lay-up process due to its process control, improved equipment and cost effective method [9].

The major performance of natural fiber reinforced composite depends on the composition properties of natural fiber and polymer synthetic matrix material. Mostly, the strength and stiffness of the structural load is carried by its fiber whereas the shape, surface and environmental resistance is carried out by its matrix. Thermoplastic and thermosets are the two type of dominating matrix materials that offer various potential in natural fiber reinforced composite applications. Epoxy resin as matrix material is suitable for natural fiber reinforced composite due to its good adhesion capability, good heat and chemical resistance, exemplified electrical insulator properties and superior mechanical performance [10]. It has been reported that mechanical properties of tensile strength for oil palm fiber-epoxy resin decreases from 47.78 MPa to 46.10 MPa with the increasing amount of oil palm fiber from 35% to 55% respectively [11]. Another study on the mechanical properties of oil palm fiber epoxy composite of 10% fiber, reported that a 7m T-Beam is able to support 200kg of load with a maximum deflection of 0.2mm, thus suggesting the potential usage of oil palm fiber-epoxy resin composite for intermediate load bearing bridge application [12].

2. Material and Method

2.1 Material
Untreated oil palm empty fruit bunch fiber is obtained from Malaysia Palm Oil Board in Bangi, Selangor, Malaysia. Zeepoxy HL002 TA/B epoxy resin, epoxy hardener, vacuum bagging consumables and materials was supplied by Sky Tech Enterprise.
2.2 Fabrication of Oil Palm Composites

Tangled and intermixed oil palm empty fruit bunch fiber was carded and combed using an electrical motor carding machine to produce untangled and organized fiber layer. For the fabrication of oil palm empty fruit bunch fiber composite, a 400 mm x 400 mm bottom stainless steel plate and 300 mm x 300 mm upper stainless steel plate, and four 200 mm x 5 mm flexible resin stopper were used as a mold. A layer of mylar sheet was placed on each side of the plate as a releasing agent, and the epoxy resin and hardener were mixed thoroughly according to its specific fiber-matrix volume fraction ratio. Layers of oil palm empty fruit bunch fiber were stacked accordingly on the bottom plate and the epoxy resin and hardener mixture was impregnated through the layers of fiber. Vacuum bagging materials were then placed on top of the wet fibers and then covered by the upper plate mold. Vacuum bagging film encloses the lay-up to provide a confined space which is sealed around the edges of the mold by using sealant vacuum bag. The vacuum pump will draw out the air inside the confined space to produce an airtight vacuum bag until the curing process is done.

2.3 Tensile Characterization of Composites

Tensile test specimen was prepared according to the standard size and specification of ASTM D 638 [13] using CNC milling. Tensile strength and modulus of elasticity for plain epoxy matrix as well as for empty fruit bunch fiber reinforced composite were tested by using INSTRON 5582 Ultimate Testing Machine, quarter bridge BX 120-3AA strain gauges and D4 Data Acquisition conditioner. This measurement was conducted according to ASTM D 638 procedures at a test speed of 5mm/min. Five specimens were tested for each case and its average value is tabulated accordingly.

3. Results and discussion

Measurement of load and strain data were made simultaneously during tensile testing process. Tensile strength is calculated by dividing the maximum load by the average cross-sectional gauge length area of the specimen. Modulus of elasticity is calculated by extending the initial linear portion of stress-strain curve then by dividing the difference in stress corresponding to the section on this straight line by the corresponding difference in strain value. Cross-plot graphs of stress and strain data of plain epoxy and EFB palm fiber composite specimen from tensile testing are plotted on Figure 1. Results of tensile tests of plain epoxy and empty fruit bunch fiber reinforced composite at 20% fiber volume are shown in Table 1.

![Figure 1. Tensile Stress vs Strain Curve.](image-url)
Table 1. Tensile test results.

| Composites      | Tensile Strength (MPa) | Tensile Modulus (MPa) |
|-----------------|------------------------|-----------------------|
| Pure Epoxy      | 25.889                 | 2805.09               |
| EFB Composite   | 10.064                 | 1712.13               |

It can be observed that tensile strength decreases by 61% and modulus elasticity decreases by 38% when oil palm fiber composite is compared to plain epoxy which is similar to findings of previous studies which reported that the ultimate tensile strength decreased by 24% when comparing plain epoxy resin to 35% fiber content of oil palm fiber epoxy composite [11]. Previous studies on short and randomly oriented fiber composite such as oil palm fiber reinforced composite, found that the axial load applied on the composite structure are first exerted on the matrix material and then transferred to the fiber throughout the fibers end and cylindrical surface. Therefore the load carrying capability and capacity is mainly carried out by the matrix rather than the fiber, which is completely different to the load carrying capability of synthetic or conventional long and unidirectional fiber composites.

The hydrophilic factor or poor adhesion capability between oil palm fiber and epoxy matrix will lead to inefficient stress transfer from epoxy matrix during loading conditions. In another research, it was also reported that the value of composite tensile strength decreased from 111 MPa to 24 MPa when glass fiber is replaced by oil palm fiber during tensile loading conditions [14]. This reduction of strength is due to the strong pectin interface bonding of oil palm individual fibers which cause fiber to not be loaded uniformly to each other, which then structurally failed to support stress transferred from the epoxy matrix. Hence, the incorporation of oil palm fiber in reinforced composite fails to act as a major reinforcement compared to synthetic fiber composite such as carbon or glass fiber composite. Thus, more advanced method of fiber treatment or hybrid fiber combination need to be taken up in order to improve the surface fiber adhesion capability and strength properties oil palm properties.

4. Conclusion
The performance of oil palm empty fruit bunch reinforced composites in this research was evaluated as a preliminary research on the tensile properties of EFB oil palm fiber reinforced composite. In this study the tensile properties of plain epoxy and oil palm fiber composites clearly indicates that empty fruit bunch oil palm fiber failed to act as major reinforcement for composite structure under tensile loading conditions whereby plain epoxy provide better tensile properties as stress is concentrated more in the epoxy matrix rather than fiber. Less surface interfacial adhesion capability with short and random fiber orientation also restrict the empty fruit bunch oil palm fiber to act as a strong alternative on reaching the desired specific properties under composite structure loading condition. Although empty fruit bunch oil palm fiber as a reinforcement fiber corresponds to a weaker tensile performance in composite structures, it has been reported that it thrives in impact strength when compared to pure epoxy due to its high fracture toughness [7]. With targets to provide superior mechanical properties and cost-effective fabrication method, more challenges need to be overcome in the development of natural fiber reinforced composite as an alternative to replace synthetic fiber reinforced composite.

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