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Mechanical Properties of Hybrid Composites Reinforced with Oil Palm Empty Fruit Bunches/Fly Ash

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Abstract. The utilization of natural fiber from oil palm empty fruit bunch (OPEFB) into composite materials can increase the economic value of EFB waste. OPEFB fibers can be turned into useful materials by combining them with other polymers, such as polyester resins, to produce better composite boards. This study aimed to determine differences in weight percent of OPEFB fiber and fly ash on polyester composites on mechanical properties. OPEFB fiber was first treated with alkali to reduce the lignin content before mixed with polyester resin and pressed by a press machine for 24 hours. The open mold method was used in this study. In this study, four hybridization compositions of OPEFB fiber /fly ash filler were studied, which are 10/1, 10/5, 20/1, and 20/5 (wt%) with polyester resin as a binder. Several mechanical properties such as tensile strength, tensile modulus, flexural strength, and flexural modulus were studied in this research. Tensile and flexural strength properties were tested using a Universal Testing Machine (MTS). The results showed that the hybridized OPEFB/fly ash fiber composition affected the performance of the composite. OPEFB/fly ash fiber hybridization improved the composite performance compared to pure polyester composites. The highest tensile strength and tensile modulus were in the OPEFB/fly ash fiber hybridization (10/1). The flexural strength of OPEFB/fly ash fiber hybridization (20/1) and the flexural modulus at (20/5).

INTRODUCTION

In recent decades, the use of natural fibers such as flax fiber, kenaf fiber, cotton fiber, sisal, and palm oil is in great demand because of their environmentally friendly and renewable nature. Natural fibers have many advantages, including high specific modulus, lightweight, low cost, and the fiber has resistance to deformation [1]. Several studies use natural fibers to manufacture composites, one of which is oil palm empty fruit bunches. Natural fibers produced from OPEFB have great potential to substitute for synthetic fibers due to the abundance of the OPEFB [2]. OPEFB consists of high cellulose content, namely 48%, 49.8%, and 65%. Due to the high cellulose content, OPEFB can become a raw material that can be used as a filler in biocomposites [3].

In addition to having many advantages, OPEFB fiber has the disadvantage of high water absorption, which causes a decrease in the quality of the biocomposite [4]. Therefore, it is necessary to treat modifications with the addition of fly ash to improve the mechanical performance of the composite. Fly ash is a by-product of coal combustion, which accumulates due to the electrostatic deposition of flue gases in thermal power plants. Fly ash particles contain a lot of silica, alumina, and FeO/Fe₂O₃. Adding fly ash as reinforcement to the composite hybrid will encourage better use of this solid waste for environmental protection [5]. Fly ash has the advantage of having a low price and high performance [6].

This modification process will produce a hybrid composite polymer. This study on the development of hybrid composites offers benefits for developing composite products with better strength and flexibility for various industrial, experimental applications [3].

Based on the description explained, the manufacture of hybrid composites reinforced with OPEFB fiber filler as organic waste and fly ash as inorganic waste, and polyester as a matrix will be studied by researchers in this study. This research uses thermoset and thermoplastic polymers, namely polyester as a matrix reinforced by fly ash as inorganic filler and OPEFB as natural (organic) fibers. The modification is expected to improve the mechanical performance of the composite hybrid board.

METHOD

OPEFB Preparation

OPEFB before processing is first cleaned and dried at room temperature for seven days. OPEFB was ground to obtain a particle size of 40 mesh. OPEFB fiber with alkaline treatment using 1% NaOH for 3 hours. Then washed with distilled water repeatedly and dried using an oven dryer at a temperature of 80 °C for 24 hours [7].

Composites Hybrid Manufacture

The composite hybrid was made by hand lay-up method using a stainless mold measuring 20 cm x 20 cm x 0.5 cm and pressed with a hot press. The polyester resin was mixed with fly ash and 1% methyl ethyl ketone peroxide (MEKP) catalyst. OPEFB fibers are arranged in a mold, the resin is poured into the fiber, and then the mold is closed for drying (curing) for 24 hours using a press machine. The open mold method was used in this study. For variations in the composition of OPEFB/fly ash fibers was showed in Table 1.

TABLE 1. Composition comparison in hybrid composites.

Sample	Polyester (%)	OPEFB (%)	Fly ash (%)
PE	100	-	-
PE/OPEFB10	100	10	-
PE/OPEFB10/FA1	100	10	1
PE/OPEFB10/FA3	100	10	3
PE/OPEFB20 /FA5	100	10	5
PE/OPEFB20/FA1	100	20	1
PE/OPEFB20/FA5	100	20	5

The composite hybrid was then evaluated for its mechanical properties, including tensile strength and flexural strength tests. The tensile strength test followed ASTM D638-10 using the Universal Testing Machine (MTS). Flexural strength testing follows ASTM D790 using the INSTRON 8874 Universal Testing Machine.

DISCUSSION

Tensile Analysis

Table 2 compares the effect of the OPEFB/fly ash fiber ratio on the tensile strength and Young's modulus in composite hybrids. Based on the values obtained, the difference is that the OPEFB/fly ash fiber filler ratio affects the tensile strength and Young's modulus. Figure 1. shows the tensile strength of

various samples obtained from different values. The highest tensile strength was shown in the PE/OPEFB10/FA1 sample variation, which was 22.05 MPa. This is followed by 20.93 (PE/OPEFB20/FA1); 19.79 (PE/OPEFB10); 18.15 (PE/OPEFB10/FA3); 16.98 (PE); 14.90 (PE/OPEFB20/FA5) and 13.51 MPa (PE/OPEFB10/FA5). The increase in tensile strength in hybrid composites is due to the hybridization between OPEFB fiber and fly ash, increasing the transfer of stress from the resin to the fiber. In addition, fiber hybridization also increases the ability of stress transfer from OPEFB fiber to fly ash which causes the composite to withstand higher forces before fracture. This phenomenon proves that the fiber fraction significantly affects the hybridization limit in providing better tensile strength properties for the resulting composite [8].

In addition to OPEFB fiber, the composition of fly ash added to the composite hybrid will also affect the tensile strength. The greater the ratio of fly ash added, the lower the tensile strength will be. The addition of fly ash will cause the tensile strength to decrease; therefore, it is important to ensure the compositional limits of fly ash so that its use is effective to obtain the desired properties [9]

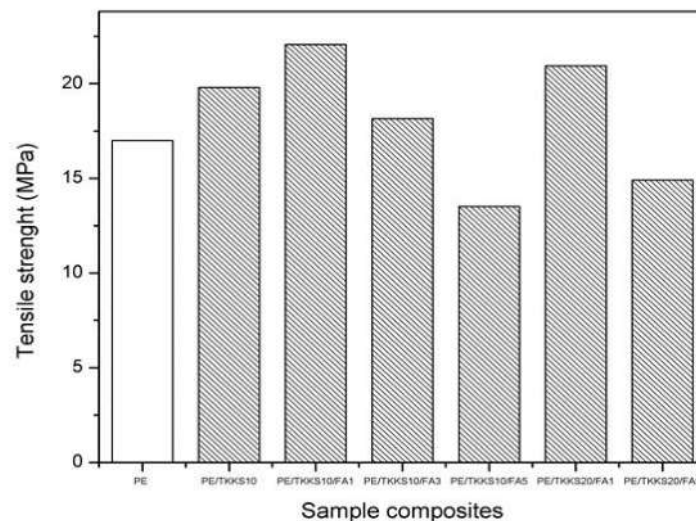
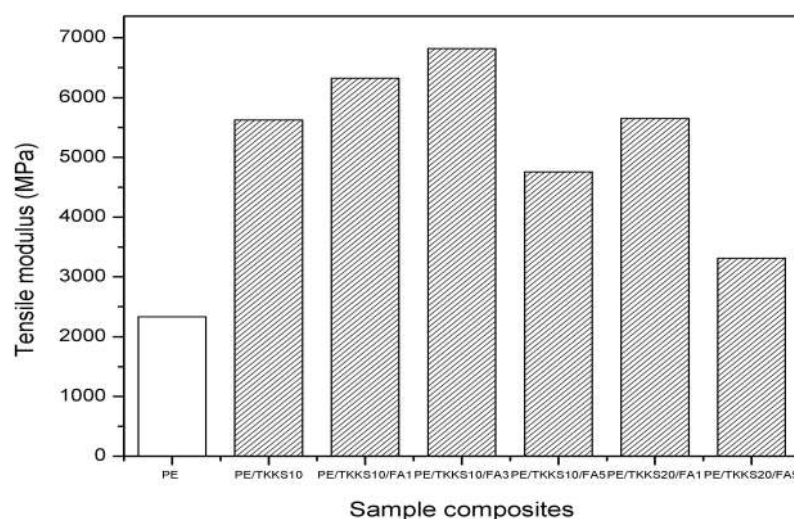


FIGURE 1. Tensile strength in various variations of composite hybrid samples

In Figure 2, the tensile modulus of the hybrid composite shows a trend that is almost the same as the tensile strength. Tensile modulus in each variation of the composite hybrid board sample shows different values, as shown in Table 1. The results showed that the highest tensile modulus was found in the PE/TKKS10/FA3 sample, 6817.37 Mpa. Tensile modulus is increased when compared to pure polyester composites. The high tensile modulus was caused by the increase in the hybridization composition of the composite. However, the PE/TKKS 20/FA5 composite hybrid showed a decrease in the tensile modulus. The insufficient amount of resin can explain this phenomenon to wet the fibers in samples with a higher fiber weight fraction [8].

TABLE 2. Tensile strength and Tensile modulus hybrid composite

Sample	Tensile Strenght (MPa)	Tensile Modulus (MPa)
PE	16.98	2331.99
PE/TKKS10	19.79	5625.91
PE/TKKS10/FA1	22.05	6322.59
PE/TKKS10/FA3	18.15	6817.37
PE/TKKS10/FA5	13.51	4759.23
PE/TKKS20/FA1	20.93	5651.25
PE/TKKS20/FA5	14.90	3309.55

**FIGURE 2.** Tensile modulus in various variations of composite hybrid samples

Flexural Analysis

Figure 3 shows that the flexural strength of the hybrid composite increased with the addition of OPEFB fibers to its composition. It is caused by an increase in the flexural strength of the composite hybrid with the addition of filler compared to the polyester composite alone. The addition of fiber causes this increase will produce a good stress transfer between the filler and matrix [10]. The greatest flexural strength is 66.67 MPa in the sample (PE/OPEFB10). However, with the addition of 20% OPEFB fiber, the flexural strength decreased due to poor dispersion between fiber and matrix [10]. The addition of fly ash to the composite hybrid reduces its flexural strength [8].

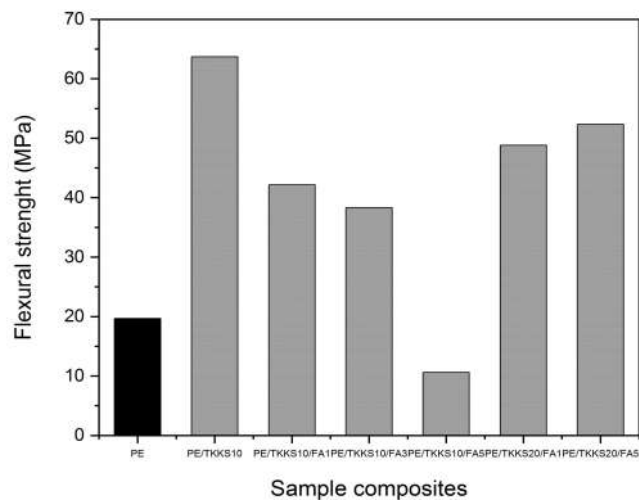


FIGURE 3. Flexural strength in various variations of composite hybrid samples

In Figure 4, it can be seen that each sample variation shows a different flexural modulus. The lowest flexural modulus is shown in the pure polyester composite, which is 2427.6 MPa. At the same time, the highest value is shown in the sample (PE/OPEFB10), which is 3824.12 MPa. It proves that the addition of OPEFB fiber will increase the flexural modulus, which can be attributed to the fact that the flexural properties of the composite depend on the interfacial bond between the filler and the matrix [11].

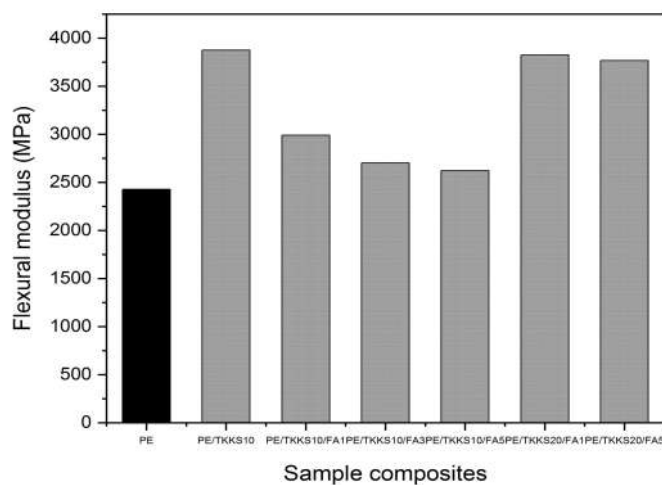


FIGURE 4. Flexural modulus in various variations of composite hybrid samples

CONCLUSION

This study discusses the hybridization of OPEFB/fly ash fibers at different compositions (10/1, 10/3, 10/5, 20/1, 20/5) in composites with 100% polyester weight fraction. Based on the results of the mechanical properties, the hybridization of OPEFB fiber in the composite hybrid succeeded in increasing the tensile strength and flexural strength. The addition of OPEFB/fly ash fiber filler increased the mechanical properties of the composite hybrid. The composite hybrid with the addition of 5% fly ash will cause a decrease in the tensile strength and flexural strength of the composite hybrid. These results can be concluded that hybrid polyester composites reinforced with OPEFB fiber filler/fly ash can be an alternative to overcome the waste problem and lead to green products.

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