The Effect of UV Irradiation on Tensile Strength of Polypropylene Reinforced Kenaf Fiber and Peat Soil

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Abstract. Nowadays, natural fiber polymer composites have been widely used in many industries and applications because of their low cost, renewable and eco-friendly. However, exposing this material to the outdoor environment will affect the material properties as it is exposed to various situations such as ultraviolet exposure, raining, etc. This paper studies the degradation of kenaf fiber, polypropylene strengthened with peat soil combustion at 600ºC upon ultraviolet exposure. The wood–plastic composites (WPCs) produced into two batches, kenaf fiber mixing with polypropylene and kenaf fiber and peat soil mixing with polypropylene. All the specimen has exposed in ultraviolet (UV) irradiation at 0 hour, 100 hours, and 200 hours, respectively. The UV irradiation accelerated weathering tester machine was conducting the water spray cycle, which is 4 hours of water spray and 8 hours without water spray continuously until achieved the target time. The finding obtained from the tensile test, the composition with the highest contain of kenaf fiber in a polymer composite, has the lowest tensile strength after exposed with 200 hours of UV irradiation, which is 20.23 MPa. While the adding peat soil as reinforcement has shown the increasing the percentage of tensile strength after 200 UV exposure.

1. Introduction

Wood is made from natural polymers such as lignin, cellulose, and various hemicelluloses, but its properties vary significantly from those of the most commonly mixed synthetic polymers [1]. The effective structure and morphology make it a rigid, solid, durable, and lightweight material that can effectively perform functions that are necessary for the survival of the tree, such as moisture transport. For decades, it has been a useful structural material due to its excellent performance and low cost. However, some of the same material behavior in a composite material, such as moisture sorption, that occurs naturally could be troublesome [2]. To enable the effective use of wood as a filler or reinforcement in polymers, an understanding of its material behavior is essential.

Wood–plastic composites (WPCs) are being used, showing, in reality, an extremely wide variety of possible applications on the market in many sectors [3-5]. In outdoor construction, about two-thirds of
WPCs are used as decking, siding, and roof tiles [6]. Degradation of WPCs can result in outdoor use of abiotic agents such as moisture, sunlight, and temperature [6,7]. Fading color and loss of WPCs mechanical properties caused by outdoor weathering has become a significant concern, and the WPCs weathering accountability mechanisms need to be enhanced [8]. Methods developed to increase their weathering resistance.

In this study, WPCs weather capability was assessed through natural and accelerated weathering monitoring. WPCs discoloration (whitening) was caused by the deterioration of both wood and plastic during test exposure. Darker color pigments as additives enhanced WPCs color stability, but chalking was still observed on the surfaces. WPCs color consistency was improved during the pre-mixing phase by adding the ultraviolet stabilizer. The application of the UV stabilizer in WPCs had a beneficial effect on color consistency and prohibited external use of the composites chalking.

2. Experimental Material and Procedure

2.1. Materials
Polypropylene is used as polymer reinforcement, while kenaf fiber and peat soil is used as a reinforcement material. This project uses a granulator machine to blend kenaf fiber reinforced with polypropylene with peat soil. Peat soil has been crushed and undergoes the burning process at 600ºC.

2.2. Mixing Process
Peat soil, kenaf fiber, and polypropylene are mixed in this mixing process by using Bra-bender roll mixer machine. The speed parameter was set at 190°C and 200 rpm temperature. For stabilization, approximately 30 minutes time needed. Then it is necessary to pour the polypropylene moderately into the machine and let it liquefy. The combination of peat soil and kenaf fiber is then slowly poured and allowed to melt and blend well for around 6 minutes. The composite component must be taken out immediately to prevent overheating.

2.3. Injection Molding
An injection molding machine was used to produce a specimen in dog bone shape. The process that involves forming the specimen is quite sensitive and needs more focus as its materials are kenaf fiber, polypropylene, and peat soil. The specimen type to be produced will be followed for time-keeping of the process cycle. Therefore, it is very important to set the temperature and observe it frequently to avoid any defect that has a bubble, hollow, or wrapped up the specimen.

2.4. Ultraviolet (UV) Irradiation Test
The UV irradiation accelerated weathering Tester, model LUV was used to measures the materials at regulated and elevated temperatures by exposing them to alternating cycles of UV light and moisture. It simulates sunlight's effects with fluorescent ultraviolet lamps and simulates dew and rain according to the ASTM D4329-99 standard by condensing moisture and/or water spray. Types of damage include color changed, gloss loss, chalking, cracking, crazing, hazing, blistering, fragility, strength loss, and oxidation. It was used to irradiate the specimen into ultraviolet light to mimic the real sunlight at predetermined temperatures and hours.

2.5. Tensile Test
The Universal Testing Machine (UTM) is used to determine the specimen's tensile strength. This testing uses SHIMADZU AGS-J Universal Testing Machine that follows ISO 527-5. This test feature is subjected to controlled stress as a sample before failure occurs. Analysis of the tensile stress was done to get where the plastic specimen would be broken. This experiment was carried out with 1 mm/min crosshead speed parameters that were applied with 5 KN of force that surrounded (25°C) of temperature, where the specimen is gripped by an adjustable upper and lower crosshead at the pump. The upper and lower crossheads move moderately, and the specimen is slowly pulled apart. At the breaking point, the measurement was taken.
3. Results and Discussion

3.1. Color Degradation after UV Exposure
Wood Polymer Composite contains the composition of natural fiber theoretically can provide desirable unique strength, modulus at a lower cost [9-11]. The most significant change is when increasing the composition of kenaf fiber in WPCs. This can be seen starting with the combination of 30% KF + 70% PP and become worst with 40% KF + 60 PP after 200 hours of UV exposure, as shown in Table 1. The biggest change in color due to the higher lignin content in kenaf fibers.

| Samples | 0 | 100 | 200 |
|---------|---|-----|-----|
| 10% KF + 90% PP | ![Image](image1.png) | ![Image](image2.png) | ![Image](image3.png) |
| 20% KF + 80% PP | ![Image](image4.png) | ![Image](image5.png) | ![Image](image6.png) |
| 30% KF + 70% PP | ![Image](image7.png) | ![Image](image8.png) | ![Image](image9.png) |
| 40% KF + 60% PP | ![Image](image10.png) | ![Image](image11.png) | ![Image](image12.png) |

3.2. Tensile Test
The mechanical test has been done for all specimens' carbon peat soil reinforced with kenaf fiber and polypropylene that already done for UV irradiation exposure. This test is be done to investigate which combination of materials still have withstood with the best strength after exposure to UV irradiation.

Table 2 shows the result average of strength of combination kenaf fiber with polypropylene upon UV irradiation exposure. From Figure 1, it can be seen that the graph shows non-linear for all specimens after UV exposure. Before exposed to the UV, the result shows that the best composition for kenaf fiber is 30% mixing with 70% PP with the highest tensile strength, 21.03 MPa. Previous studies have shown that the best composition for kenaf fiber mixing with polypropylene is 30% KF + 70% PP [12]. From observing within this short range of time, which is 0 to 200 hours of UV exposure, some of the specimens changed in terms of mechanical properties. The variation strength and strain changes are because void formation occur between fiber and matrix while exposed with UV irradiation that can affect the flexural strength [13]. The material that shows the increment of strength from 0 to 200 hours of UV exposure is 10% KF + 90% PP, 20% KF + 80 PP, and 40% KF + 60% PP. The only
one combination 30% KF + 70% PP experiencing a decrease in strength is about 3.8%, even this composition has the best tensile strength before UV exposure.

After exposure to 200 hours of UV irradiation, the highest maximum strength is 22.78 MPa which is the combination of 10% KF + 90% PP. While the lowest tensile strength after 200 UV exposure is 20.23 MPa, which is 40% KF and 60% PP. This means that the best composition of kenaf fiber with polypropylene within 200 hours of UV exposure is 10% KF + 90% PP. This composition has the least kenaf fiber content will degrade with the increment of UV exposure [14]. This is because in UV accelerated weathering tester, tensile specimen experiencing UV exposure with the cycle of water sprinkle. So once the kenaf fiber composite exposed with the moisture, water penetrates and attaches onto hydrophilic fiber groups that create intermolecular hydrogen bonding with fibers and decreases fiber-to-matrix interfacial adhesion, resulting in poor transfer stress from the matrix to fiber and lower kenaf composite tensile strength.

Table 2. Result average of strength of combination kenaf fiber with polypropylene upon UV irradiation exposure.

| Samples          | Mechanical Properties | Hour | Decrease/Increase (%) |
|------------------|-----------------------|------|-----------------------|
|                  |                       | 0    | 100       | 200       |                               |
| 10% KF + 90% PP  | Max. strength (MPa)   | 20.47| 22.75     | 22.78     | Increase (11.28)              |
|                  | Max. strain (%)       | 10.23| 10.14     | 10.12     | Increase (1.08)               |
| 20% KF + 80% PP  | Max. strength (MPa)   | 20.43| 22.78     | 21.92     | Increase (7.29)               |
|                  | Max. strain (%)       | 7.92 | 7.82      | 7.02      | Decrease (11.36)              |
| 30% KF + 70% PP  | Max. strength (MPa)   | 21.03| 18.66     | 20.71     | Decrease (1.52)               |
|                  | Max. strain (%)       | 5.21 | 5.13      | 5.18      | Decrease (0.58)               |
| 40% KF + 60% PP  | Max. strength (MPa)   | 19.65| 18.37     | 20.23     | Increase (2.95)               |
|                  | Max. strain (%)       | 4.52 | 4.40      | 4.68      | Increase (3.54)               |

Figure 1. Maximum strength (MPa) of 10% KF + 90% PP, 20% KF + 80% PP, 30% KF + 70% PP and 40% KF + 60% PP samples of UV irradiation exposure (hours).

Table 3 shows the result average of combination kenaf fiber and peat soil with polypropylene upon UV irradiation exposure. Figure 2 shows the increment value of maximum strength starting from 0 to
200 hours of UV exposure. This increments due to the addition of combustion peat soil at 600ºC. Contrast unexposed with UV irradiation, the value of tensile strength for 30% KF +70% PP and 40% KF + 70% PP are degraded with the addition of peat soil. The more significant change that occurs in tensile strength along the exposure of 200 hours of UV is the combination of 40% KF + 60% PP + 6% PS with the increment of 6.31%. After 200 hour of UV exposure, the highest maximum strength is 30% KF + 70% PS + 3% PS with the value 21.22 MPa of maximum strength because it has the least composition of kenaf fiber and the addition combustion of peat soil. Peat soil itself similar to any lignocellulose content when damp, but desiccation reduces its hydrophilicity which is drying ultimately leads to hydrophobic peat and high resistance to rewetting.

**Table 3.** Result average of strength of combination kenaf fiber and peat soil with polypropylene upon UV irradiation exposure.

| Samples                  | Mechanical Properties | 0  | 100 | 200 | Decrease/Increase (%) |
|--------------------------|-----------------------|----|-----|-----|-----------------------|
| 30% KF + 70% PP + 0% PS | Max. strength (MPa)   | 21.03 | 18.66 | 20.71 | Decrease (1.52) |
|                          | Max. strain (%)       | 5.21 | 5.13 | 5.18 | Decrease (0.58) |
| 30% KF + 70% PP + 3% PS | Max. strength (MPa)   | 20.11 | 20.77 | 21.22 | Increase (5.52) |
|                          | Max. strain (%)       | 5.45 | 5.37 | 4.82 | Decrease (11.56) |
| 30% KF + 70% PP + 6% PS | Max. strength (MPa)   | 19.98 | 20.57 | 20.66 | Increase (3.4) |
|                          | Max. strain (%)       | 5.31 | 4.97 | 4.46 | Decrease (16.01) |
| 40% KF + 60% PP + 0% PS | Max. strength (MPa)   | 19.65 | 18.37 | 20.23 | Increase (2.95) |
|                          | Max. strain (%)       | 4.52 | 4.40 | 4.68 | Increase (3.54) |
| 40% KF + 60% PP + 3% PS | Max. strength (MPa)   | 18.98 | 19.31 | 19.32 | Increase (1.79) |
|                          | Max. strain (%)       | 4.25 | 4.15 | 3.78 | Decrease (11.07) |
| 40% KF + 60% PP + 6% PS | Max. strength (MPa)   | 18.69 | 20.43 | 19.87 | Increase (6.31) |
|                          | Max. strain (%)       | 4.58 | 4.42 | 3.86 | Decrease (15.82) |

**Figure 2.** Maximum strength (MPa) combination of 30% KF + 70% PP, 40% KF + 60% PP with different percentage of PS added exposed with UV irradiation (hours).
4. Conclusion
In general, the physical characterization of wood polymer composites endurance to ultraviolet exposure has been successfully studied in this research. During this research, the use of kenaf fiber as a wood substitute in WPC has gained immense popularity, as it provides significant advantages such as being recyclable, environmentally friendly, and often low cost. Similar to the previous research, peat soil's effect reinforced with kenaf fiber and polypropylene was seen to contribute to new composite growth.

From the result obtained, the physical and mechanical properties of kenaf fiber reinforce with polypropylene changed with the exposure to 200 hours of UV. For the first batch that only contains kenaf fiber with 10%, 20%, 30%, 40% and 90%, 80%, 70%, 60% polypropylene, the result highest value of tensile strength after 200 hours UV exposure is 22.78 MPa that obtain from the least composition of kenaf fiber with polypropylene. This because the less composition kenaf fiber in a polymer composite, the lowest degradation occurs by increasing the UV exposure time. The result also shows the increment of composition peat soil into PP and Kenaf Fiber before UV exposure also does not increase the mechanical properties of WPC, but for the outside uses, the combination of peat soil is suitable material since it can withstand with UV exposure. This can be seen after 200 hours UV exposure will increase a little bit maximum tensile strength of WPC which is the highest tensile strength is 21.22 MPa that obtain from the 30% KF + 70% PP + 3% PS.

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