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INFLUENCE OF PUMICE PARTICLES ON THE MECHANICAL AND MORPHOLOGY PROPERTIES OF POLYESTER-CORNHUSK FIBER COMPOSITES

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Abstract. *The purpose of this study was to look into the performance of a cornhusk fiber (CHF) reinforced polyester composite with pumice powder (PP) as a filler. The influence of varied PP volume fractions on composite tensile, bending, impact, and fracture morphology was studied. Using the hot press process, polyester-CHF composites with varied volume fractions of PP filler, namely 5%, 10%, 15%, 20%, 25%, and 30% wt, were created. The results showed that increasing the PP volume fraction from 5% to 15% enhanced the tensile strength of the polyester-CHF composite. The modulus of elasticity and bending modulus tend to grow when filler Pp decreases from 5% to 30%, but elongation value decreases. Furthermore, the best bending strength and impact toughness of the polyester-CHF composite were produced at a volume fraction of PP filler of 20%. SEM images indicate the presence of CHF pull out in all composite variations as well as the number of voids dependent on the PP filler volume.*

Keywords: *Polyester-CHF composite; Pumice particle (PP) filler; Hot press; Mechanical properties; Morphology.*

1. Introduction

The market growth for environmentally friendly materials has shifted the paradigm toward the use of renewable natural resources and the manufacture of environmentally friendly materials [1,2,3]. This stimulates academics and industrialists to continue developing and researching composites manufactured from natural waste that have the best qualities. Corn husk fiber-reinforced polyester composites have been produced, and their properties, such as environmental impacts, treatment, and the addition of other materials in CHF-composites, are of interest for further exploration. [4] investigated the swelling, compressive strength, and impact properties of corn husk fiber reinforced polyester composites. They found that after 24 and 72 hours of immersion, the water absorption and swelling parameters of polyester-CHF composites increased by 0.24%-1.38% and 0.08%-1.04%, respectively. Due to the weak polyester-CHF bond, the

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composite's impact toughness has increased while its compressive strength has diminished. [1,5] discovered that the 10% to 50% volume fraction of corn husk fiber was able to preserve steady mechanical properties due to UV light exposure or only experienced a 0.44 and 0.95% drop in tensile and bending strength (for the 30% CHF volume fraction). Polyester composites having a volume fraction of 30% CHF have optimal tensile strength when compared to volume fractions of CHF less than or more than 30% [4]. The properties of the polyester-CHF composite can be improved further by first altering the polyester polymer with organic or inorganic additives.

Pumice is a volcanic rock made of alumina silica, with the major constituent SiO_2 being abundant and easy to locate, with a porous structure, low density, and strong thermal insulation [6-7]. Using a twin screw extruder and injection molding machine, [6] created a composite of polyphenylenesulphide (PPS) and pumice powder with volume fractions of 0, 1, 3.5, and 10 wt%. Their research of the mechanical and thermal properties of the composites revealed that the thermal resistance and hardness of the composites increased with increasing volume percent of pumice powder. The tensile characteristics of the composite performed better than those of the composite without the pumice powder filler, with the highest tensile strength reached at 5%. (wt). [8] investigated the influence of volume fraction of pumice powder (0-40% wt) on the mechanical and thermal characteristics of polypropylene. They achieved the maximum tensile and bending strength of polypropylene at 26.5 and 46.4 MPa, respectively, with a volume fraction of 10% (wt) pumice powder. The storage modulus and loss modulus, as well as the decomposition temperature of polypropylene, rose with the addition of pumice powder to the polypropylene. Thermal conductivity properties of polypropylene composites rose by 35-75% for each volume fraction of 10-40% (wt), while crystallinity increased dramatically with the addition of pumice powder.

A hybrid composite of corn husk fiber with pumice powder (PP) as a polyester filler is an alternative to obtaining the best mechanical qualities of polyester-CHF, with CHF without chemical treatment whose residual waste is hazardous to the environment. As a result, the purpose of this paper is to examine the mechanical and morphological properties of CHF-polyester composites using PP. The influence of volume fraction (5, 10, 15, 20, 25, and 30% wt) on polyester- 40%CHF composites will be examined using SEM for tensile, bending, impact behavior, and composite fracture morphology characterization.

2. Methods

2.1 Materials

The corn husk fiber used in this investigation was obtained from Pagesangan, Mataram, Indonesia. Polyester resin was acquired from PT. Justus Kimia Raya with a density of 1.2 x 10-6 kg/cm3, tensile strength of 8.8 kg/mm2, and bending strength of 2.5 kg/mm^2 [1,9]. Pumice, which was used as a filler in this work, contains 74.10% SiO_2, 13.45% aluminum oxide, 4.10% potassium oxide, and 3.70% sodium oxide [8].

2.2. Extraction of Corn Skin Fiber

Freshly harvested corn husks were chosen, and the three outer shells were collected. Corn husks are washed and steeped for 10 days. They are combed with a steel brush to remove lint. Corn husk fiber (CHF) is then cleaned with clean water, sun-dried, and stored in a cardboard box.

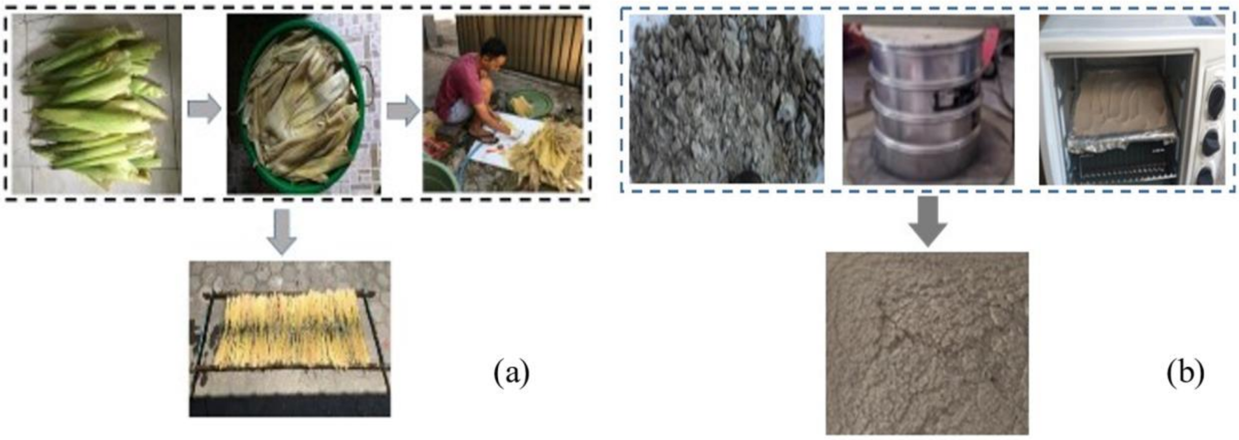

Figure 1. The extraction of corn husk fiber (a) and the treatment of pumice particles (b).

2.3 Pumice particle treatment

Pumice stone (figure 1b) was collected and physically cleaned of clinging soil and sand with running water, followed by drying. Following that, the pumice stone was crushed with a hammer and sieved through a 200 mesh sieve. The pumice powder was then dried in an oven at 105 0C for 60 minutes before being sealed in airtight plastic

2.4 Composite fabrication

The composite test samples were generated with the volume percent of CHF (30%) and PP changed, namely 0, 5, 10, 15, 20, 25, and 30% (wt), with the sample codes PC, PCA, PCB, PCD, PCI, PCJ, and PCK, respectively. CHFs are placed in a steel mold that has been lubricated with lubricant to allow sample disassembly. The polyester was manually mixed with PP until homogenous, and then 1% of the polyester volume was combined with a catalyst (MEXPOSE). The dough is then poured into the mold until it equally moistens the corn husk fibers. The mold was then covered with a steel plate and pressed for 5 minutes in a hot press machine at 105 0C, 5 MPa. After that, the composite test sample is removed from the mold and finished in accordance with the size and specifications.

2.5 Characterization of composites

2.5.1 Tensile, bending, and impact strength

The Charpy testing machine (model IT-3) was used to assess the impact toughness of the composite. The impact test composite samples are shaped and dimensioned in accordance with the ASTM D256 standard (figure 2a), with the length, width, thickness, depth, and angle of the notch being 55 mm, 10 mm, 10 mm, 2.5 mm, and 45°, respectively. Tensile and bending tests were performed using an universal tensile machine RTG1310 with a loading speed of 10 mm/min. The tensile test specimen was in accordance with the ASTM D3039/D3039M17 standard (figure 2b), and the bending specimen was in accordance with the ASTM D790 standard (figure 2c).

2.5.2 SEM Morphology

A Hitachi S-4000 SEM microscope with an emission current of 18 mA and a voltage of 10kV was used to examine the fracture surface of the composite from the tensile specimen. To make the test sample conductive, the composite was sliced to a length of 1 cm2 and coated with platinum.

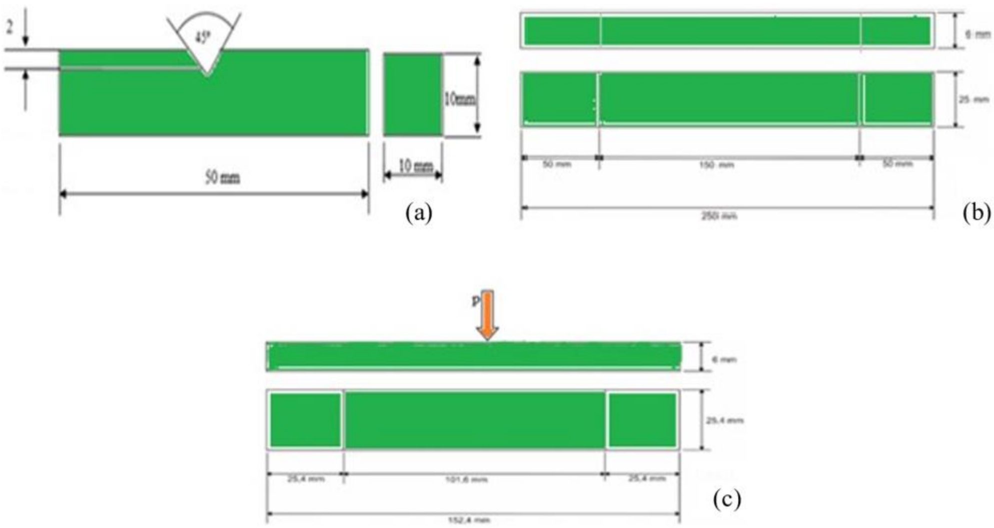

Figure 2. Specimen shape and dimensions, a) impact test, b) tensile test, c) bending test [10].

3. Results and Discussion

3.1. Tensile Strength Analysis

Figure 3a depicts the tensile strength of the polyester-CHF composite after increasing the filler volume percent from 5% to 15% (wt), with an increase of 0.18%, 15.65%, and 6.498% from the prior composite. This is most likely owing to the capacity of the polyester-Pp combination to wet CHF, resulting in a good bond between polyester-CHF-PP, which can tolerate higher tensile loads than other composites. While increasing the volume fraction of Pp from 20% to 30% causes a loss in tensile strength due to the lack of wettability of Pp by polyester, resulting in weak polyester-CHF-Pp interface contacts and more rapid formation of cracks that cause failure [11, 12]. Composites with a higher PP content cause the resin to be unable to wet the majority of the PP, causing more voids to be trapped and the composite to fail sooner than other composites.

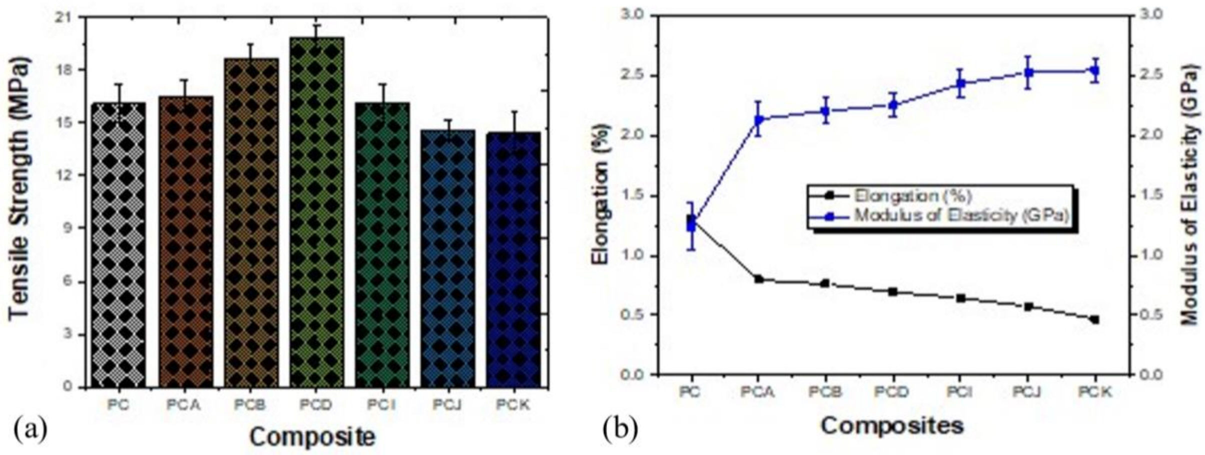

Figure 3. Tensile strength, elongation, and elastic modulus of different composites.

Figure 3b depicts the elongation and elastic modulus values of the polyester/CHF composite as the PP volume % changes. The PC sample had the maximum elongation value of 1.303%, and the elongation value decreased as the volume percent of PP increased from 5% to 30%. The decrease in elongation value in the composite with the presence of PP is owing to the amorphous character of PP, which makes the composite more brittle [10], as well as the low interfacial bond between the fiber and the matrix, which results in rapid failure [13].

Figure 3b depicts the elastic modulus of composites with various PPs. When the PP content is increased, the composite elastic modulus follows a different pattern than the composite elongation value. The elastic modulus of the composite increased as the PP content increased. The PC sample has the lowest elastic modulus value (1,241 GPa). The modulus of elasticity of the composite when the PP content is between 5% and 30% (wt) or increases between 2,136 and 2,545 GPa. This is due to the rigidity of PP, which improves the stiffness of the composite [14].

3.2 Bending strength analysis

Figure 4a illustrates the lowest bending strength value obtained by the PC sample of 30.2 MPa, then the bending strength value rose with the addition of PP content. The addition of PP 5% - 20% (wt), or 34.3 MPa - 42.1 MPa, increased the bending strength of the composite. This rise is owing to the interaction between the CHF-matrix, which is assumed to be due to the specific surface area of the composite increasing with the addition of PP [15]. When the volume fraction of PP is larger (25 - 30% wt), the bending strength of the composite drops.

This phenomenon is most likely produced by the low interface between the matrix and the fiber as a result of the matrix's low wettability and the presence of many voids in the composite. Furthermore, the inclusion of CHF that had not been alkali-treated was less than optimal in giving reinforcement to the composite, which was suspected to contain lignin content in the fiber, resulting in low bonding with the resin and, ultimately, low mechanical strength.

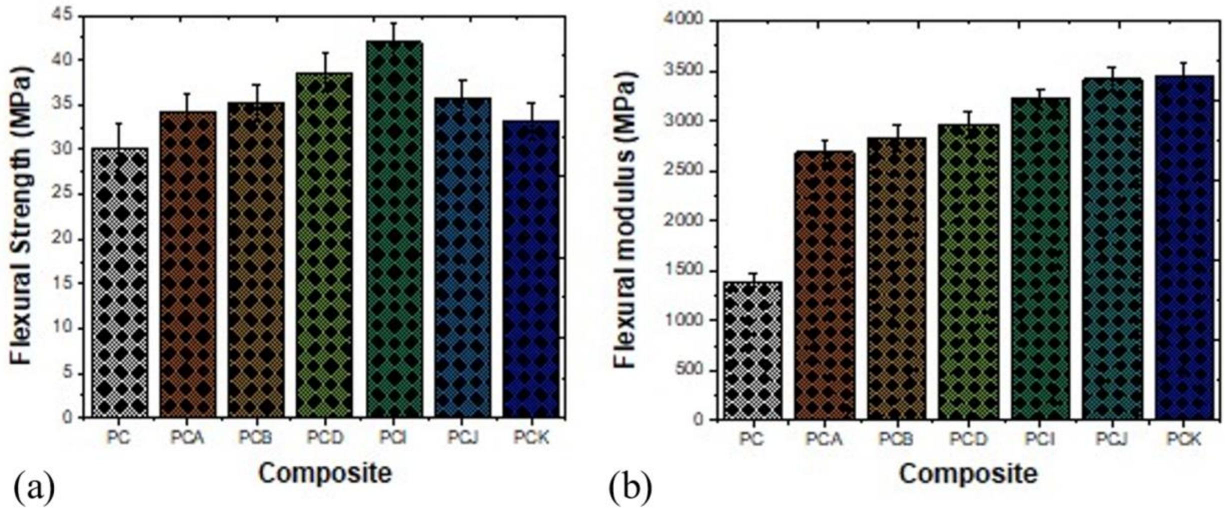

Figure 4. Bending strength of a polyester/CHF composite with varying PP content.

Figure 4b depicts the flexural modulus of the polyester-CHF composite with PP. The investigation's findings revealed that adding PP had a substantial effect on boosting the composite bending modulus value. Bending modulus increased 113.35%, 5.29%, 4.76%, 8.84%, 6.06%, and 1.18% for PCA, PCB, PCD, PCI, PCJ, and PCK composites, respectively. This rise in the bending modulus figure indicates that it correlates with the elastic modulus value in the tensile test due to the 15% PP content being able to improve the distribution of CHF in a more homogeneous polyester composite. This raises the composite bending modulus [16].

3.3 Impact Resilience

Figure 5 depicts the impact toughness of composites made with various PPs. The impact toughness of the composite was reduced by 13.64% after the addition of 5% PP, from 9.97 kJ/m2 to 8.61 kJ/m^2. Meanwhile, the impact toughness of the composite increased following the addition of 10%, 15%, 20%, 25%, and 30% PP, respectively. This suggests that the use of PP filler can improve the toughness of polyester as a composite binder. The maximal impact toughness obtained in the PCI sample is 16.18 kJ/m2. It is speculated that the CHF in these polyester composites has a vital role in impact load resistance. The presence of fibers in the composite has been shown to limit the creation and propagation of cracks from the matrix as well as transmit stress to the entire composite surface [17,18], enhancing the toughness of the polyester. The decrease in impact toughness values in PCJ and PCK could be attributed to an excessive volume fraction of PP, which reduces the permeability of CHF by polyester [16].

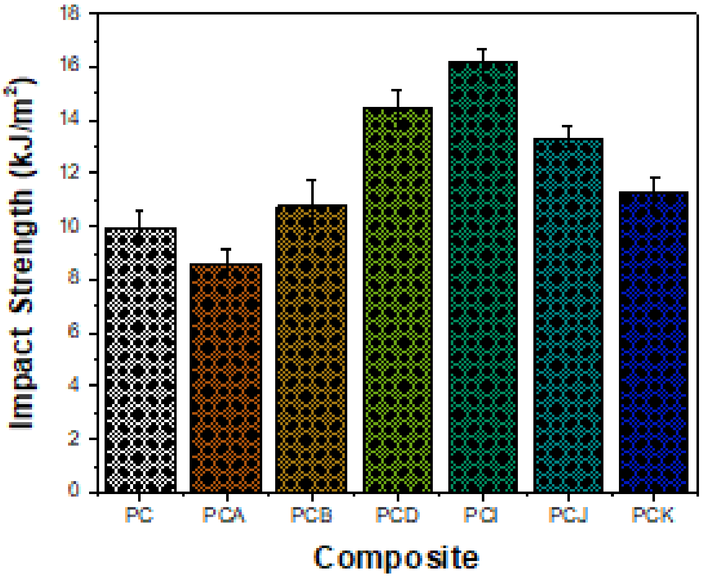

Figure 5. The impact strength of a polyester/CHF composite with various PP

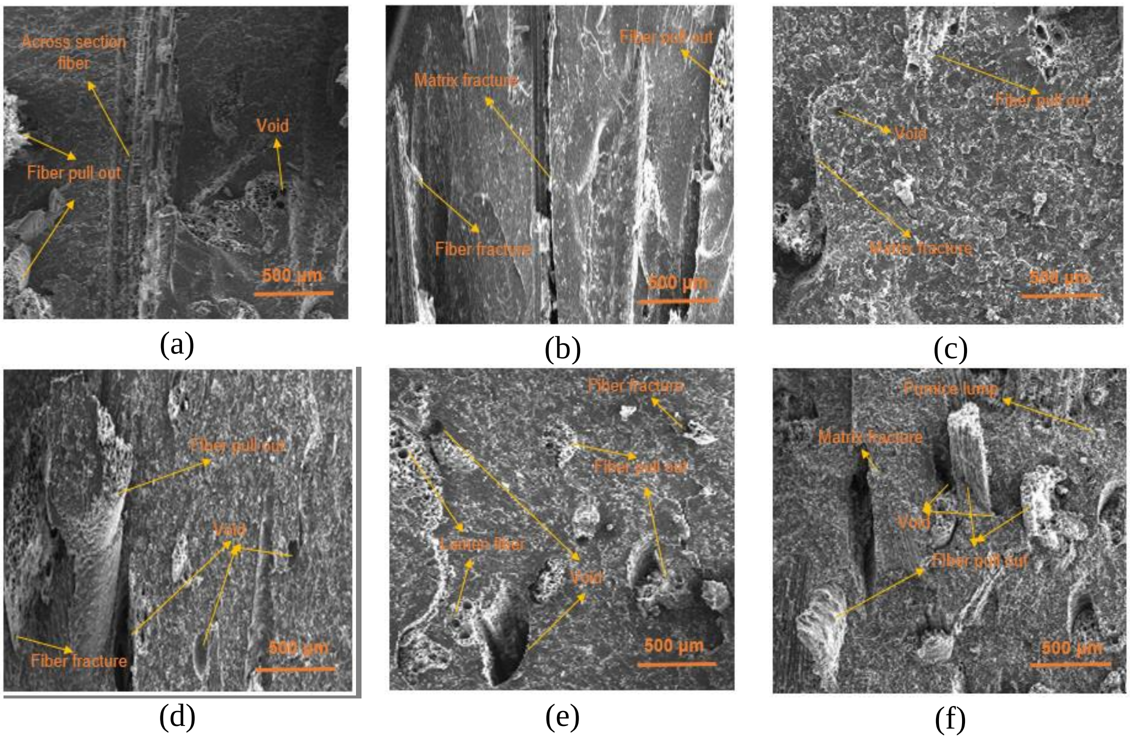

Figure 6. SEM images of polyester-CHF composite fractures with various Pp, (a) PCA, (b) PCB, (c) PCD, (d) PCI, (e) PCJ, and (f) PCK.

3.4 SEM Morphology Analysis

Figure 6 shows SEM images of several composite fracture morphologies. Figure 6a depicts a surface with a high concentration of polyester resin, while Figures 6b and 6c depict a composite with a PP content of 10% and 15%, respectively. The fracture surface was discovered to be relatively tight, which boosted the resulting tensile strength, however CHF pull out occurred in all composite fracture surfaces due to not being treated with chemical fiber since the fiber surface was slick where there was still a lot of lignin. Figures 6d, 6e, and 6f illustrate that as the PP component rises to 30% wt, polyester loses its ability to bind CHF and interacts more with PP, causing the fibers in the composite to pull out more and have more voids. As a result, the mechanical properties of the material are poor.

4. Conclusions

When the PP percentage was increased from 5% to 15%, the composite's tensile strength increased (wt). The maximum tensile strength was 19.89 MPa, and it declined as the PP content increased from 20% to 30%. (wt). The elastic and bending moduli of the composites increased as the PP volume % increased. At roughly 20-30% CHF PP, the best bending strength and impact toughness were 42.01 MPa and 16.18 MPa, respectively. SEM photo observations on composite fractures revealed that PP content levels of 15% and 20% provided the best conditions for polyester to bind CHF and PP firmly. Meanwhile, as the PP concentration increased, CHF underwent a pull out and certain voids were entrained in the composite.

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