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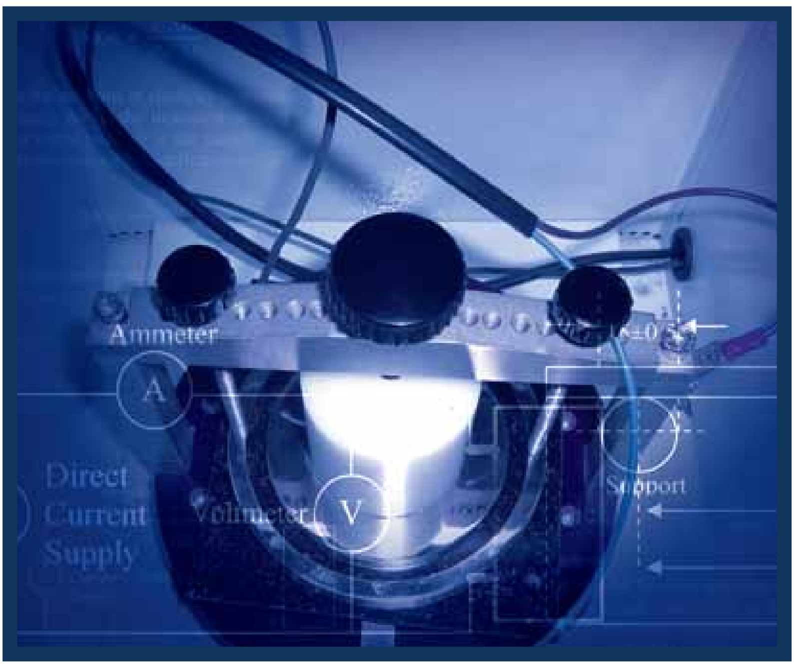

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Electrical Resistivity and Flexural Strength of Plastic Composites Reinforced with Pineapple Leaf Particles

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ABSTRACT

The electrical resistivity and flexural strength of plastic composites reinforced with pineapple leaf particles (PCPLP) is presented. PCPLP were produced using different plastic materials; Polyethylene (PE) and Polypropylene (PP), and different plastic-pineapple leaf particle ratios; 50:50 and 70:30. The PCPLP were tested and evaluated with respect to electrical resistivity and flexural strength according to ASTM D257 and D790, respectively. The results indicate that PCPLP made from PP exhibits better electrical resistance than PE, which may be attributed to the better frequency insulation behaviour of PP. PCPLP using the higher ratio of 70:30 also exhibited better electrical resistance than the lower 50:50 ratio. Cellulose materials inherently influence the electrical resistance of plastic composites, due to their natural propensity to absorb moisture. The PCPLP produced using a ratio of 50:50 for both PP and PE composites exhibited better MOE results than the 70:30 composites, however the converse is true with respect to the MOR. MOE of PCPLP was increased with increasing pineapple leaf particles content due to the greater matrix stiffness of this natural particle with respect to plastic matrix. However, high percentage of filler particles in the matrix (70:30 ratio) has reduced the toughness in the composite structure due to the lost of physical contact between high accumulated particles.

Keywords: *electrical resistivity, flexural strength, polypropylene, polyethylene, pineapple leaf particles*

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Introduction

Pineapple is classified under the genus *ananas*, characterized by the unique features of its inflorescence, which fuses into a multiple fruit or syncarp [1]. World production of pineapple has more than tripled over the past 40 years; equating to 3,833,137 tonnes in 1961, 13,738,735 tonnes in 2001 [2], and 15,288,018 tonnes in 2004 [1]. In Malaysia a total area of approximately 11,684 ha. of pineapple has been planted equating to the production of ca. 265,680 tonnes per year for food purposes [3]. The pineapple has been exploited materialistically in several ways, including the use of its leaves as a fabric [1]. Pineapple leaves are residual material generated during pineapple fruit harvesting and are available in abundant quantities in many parts of the tropics. Pineapple leaf particles are categorized as waste and are therefore cheap possessing significant potential to be recycled and used in the polymer composite industry. Consequently the utilization of natural materials, such as agricultural waste in plastic composite manufacturing, should be studied, since plastic composites mixed with agricultural waste materials is of importance with respect to sustainability and the minimization of agricultural waste. The production of composites produced from plastics and agricultural waste are suitable for low load bearing applications, such as electrical or electronic components, but must satisfy specific criteria with respect to electrical resistivity and flexural strength. In this work plastic composites reinforced with pineapple leaf particles (PCPLP) have been produced by compressing the particles along with plastics modified with respect to pressure, heat and time. The consequent conducted study has evaluated the electrical resistivity and flexural strength of PCPLP with respect to the plastic component and composite ratio.

Material and Method

Pineapple leaves were collected from a pineapple plantation in Sabak Bernam, Selangor and transported to the Bio-Composite Laboratory, UiTM Shah Alam, Selangor. The leaves were milled and ground into pineapple leaf particles (PLP) using a crusher and screened to ensure particle size homogeneity. The PLP were dried to achieve a 1 – 3 % moisture content using oven dryer over the period of a week. The PLP were separated using 20, 30, 40 and 50-meshes; only the PLP collected from 50-mesh screen were used as the raw material in this study. The plastic materials chosen for this study were polypropylene (PP) and polyethylene (PE) supplied by a local manufacturer and combined with the PLP in the 70:30 and 50:50 ratios (w/w ratio).

Processing of PCPLP was conducted at Polymer Technology Laboratory, UiTM Shah Alam, Selangor. The PLP were combined in predetermined quantities (30 and 50 %) with molten plastic using a dispersion mixer (Model D1-5) to produce a homogeneous composite. The temperature of the mixer was maintained at 200 °C for PP and 180 °C for PE. The homogenous composite was rolled on a plate to produce thin pieces of plastic composite for the purposes of crushing to produce small plastic composite particles. The plastic composite particles were then pressed using hot press machine at 190 °C for 7 minute at 30 – 35 bar using 150 × 150 mm mould of thickness 4 mm. The resultant PCPLP was then allowed to cool to room temperature and cut into the required sizes for electrical resistivity and flexural strength testing. All samples were conditioned in a conditioning chamber for approximately 2 weeks before testing (humidity = 65 ± 5 %, temperature = 20 ± 2 °C). Figure 1 presents a typical PCPLP produced and tested in this study.

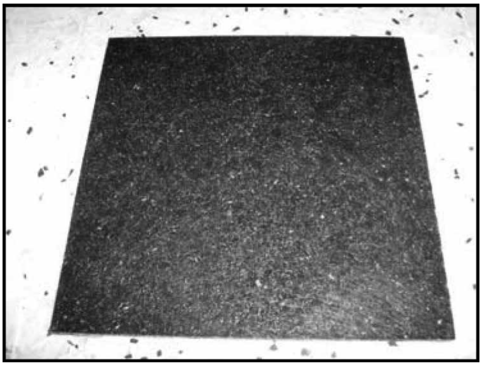


Figure 1: A typical PCPLP produced and tested in this study

The electrical resistivity testing was conducted at the Plastic Technology Laboratory, Standard and Industrial Research Institute of Malaysia (SIRIM), Shah Alam, Selangor. Samples were required to be 110 × 110 mm and their resistance to an electrical current was determined according to the standard testing method, ASTM D257 [4]. The electrical testing circuit comprised of the plastic composite test sample, ammeter, voltmeter and power supply as presented in Figure 2(a). The electrical resistance was determined with respect to Equation 1:

$$P_s = PR_s/g \tag{1}$$

where P_s is the surface of resistivity (Ω/square), g is the distance between the measurement electrode and the guard ring (maintained at 0.578 cm), R_s is the measured resistance (Ω), and P is the perimeter of the guard ring (29.36 cm).

Figure 2 (b) presents the flexural strength testing set-up, whereby test samples of length 84 mm and width 12.7 mm were evaluated in accordance with the standard testing method, ASTM D790 [5], using a universal testing machine. The flexural samples were placed on supports 64 mm apart with an over-hang of 10 mm beyond at each end. The load was applied at the centre of the span at a speed 10 kN/sec until failure occurred; the consequent flexural strength properties, modulus of elasticity (MOE) and modulus of rupture (MOR), were determined according to Equations 2 and 3:

$$\mathrm{MOE} = \frac{y^3 \Delta W}{4bt^3 \Delta S} \tag{2}$$

where MOE is the modulus of elasticity perpendicular to the plane (N/mm^2),
y is the span length (mm),
ΔW is the increment of load on the straight line portion of the load deflection curve (mm),
b is the sample width (mm),
t is the sample thickness (mm), and
ΔS is the increment of deflection at the mid-point of the test sample.

$$\mathrm{MOR} = \frac{3F_{\max} y}{2bt^2} \tag{3}$$

where MOR is the bending strength (N/mm^2), F_{max} is the maximum load (N), and y is the span length (mm).

Statistical Analysis Software (SAS) was used to analyze the test results and evaluate any significance with respect to t-test. The null hypothesis for which was that the plastic material and ratios of plastic-pineapple leaf particles had no significant effect on electrical resistivity, MOE and MOR.

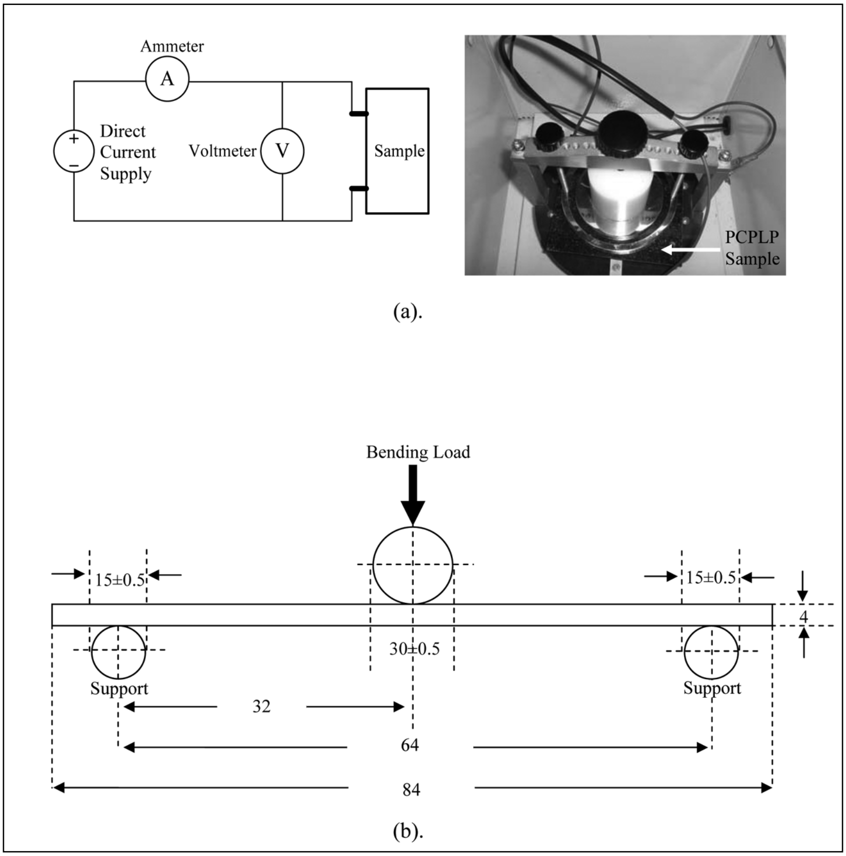
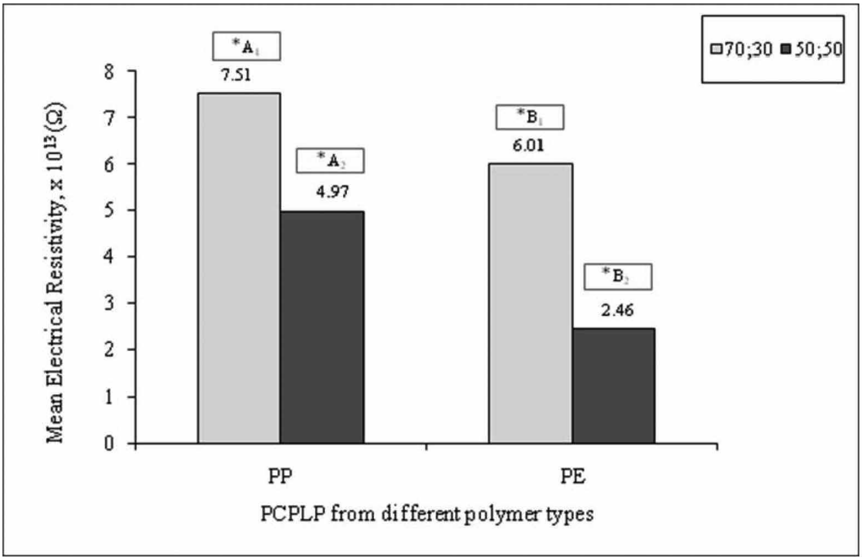


Figure 2: (a) Electrical Resistivity Testing Circuit and Set-up, and (b) Flexural Strength Testing Set-up (all dimensions are in mm)

Results and Discussion

Electrical Resistivity of PCPLP

Figure 3 presents the mean electrical resistivity values for the manufactured and tested PCPLP samples. It is evident that the mean electrical resistance (7.51×10^{13} Ω) for the PCPLP composed of PP with a 70:30 ratio of PP:PLP was significantly higher than that determined for the corresponding 50:50 ratio (4.97×10^{13} Ω). The results for the corresponding PE PCPLP samples also indicate decreasing resistance with increasing PLP content; 6.01×10^{13} Ω and 4.06×10^{13} Ω for 70:30 and 50:50 ratios, respectively. These finding are in good agreement with the work of Chan and Jhod [6], and Guo *et al.,* [7] who stated that the volume electric resistance of polyethylene terephthalate (PET) composites declined sharply at bamboo charcoal addition of 3 wt% (in the case of PET-bamboo charcoal composites) [7]. Lin *et al.,* [8] in a similar study on PET/polypropylene/bamboo charcoal (BC) composites stated that the electrical resistivity of composites were higher than 10^{12} Ω/sq, when the BC content was 4 wt % or less. The rationale for such a decrease has been proposed by Chan and Jhod [6] who stated that cellulose materials have a great tendency to absorb moisture, which inherently influences the low surface resistivity of these types of plastic composite.



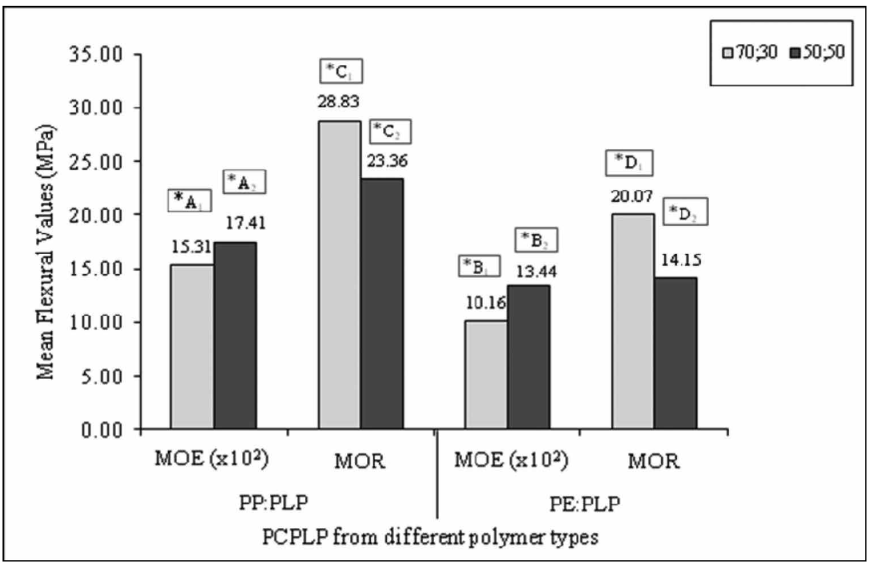
* Mean with the same letter are for comparison between two variables, different numbers indicate the variables are significantly different at $\alpha = 0.05$

Figure 3: Mean electrical resistivity for PCPLP samples.

Flexural Strength of PCPLP

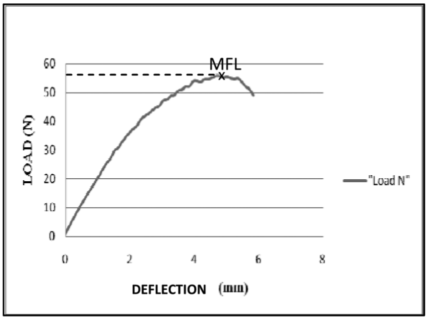
Figure 4 present the mean MOE and MOR results for the PCPLP samples from which it is evident that higher MOE and lower MOR values are obtained for composites containing larger quantities of pineapple leaf particles. Yasin and Zuhal [9] and Kai *et al.,* [10] identified similar trends in the case of polypropylene/carbon black composites and hybrid fillers polymer composites, respectively, specifically the Young's modulus increased with increasing carbon black content due to the greater exhibited matrix stiffness of carbon black with respect to polypropylene [9]. It was also noted by Nurazreena *et al.,* [11] that the Young's modulus increases with increasing filler content, which indicates increased elasticity due to improved binding between the composite components.

An evident consequence of increased particle composition is the decrease in strength, which has been neatly summarised by Magnus *et al.,* [12] in that increased fibre loading increases stiffness, but at the cost of reduced toughness. Figure 5 presents two typical flexural load-deflection plots for PCPLP samples with a 70:30 and 50:50 compositions, for which the former exhibits a higher maximum loading limit. Jamaludin *et al.,* [13] stated that reduced rupture is a consequence of decreased deformability of rigid interphases between the composite components. According to Mohd Suzeren [14] reduction in flexural strength may be attributed to the highly porous structure of filler particles in the matrix, which form domains that act like foreign bodies, which weaken the composite structure due to decreased physical contact between adjacent aggregates. Lu *et al.,* [15] performed a study on wood-based plastic composites and concluded that there was an increase in mechanical properties, but only at low weight percentages of wood filler for which the tensile and flexural strength were maximised at 15 and 35 % wood particle contents, respectively, beyond these values mechanical properties decreased. Janecska *et al.,* [16] stated that the reason for this decrease in strength at larger compositions is due to the inability of particles to sustain the stress within the matrix. As in the electrical resistivity analysis, the PP-based PCPLP samples outperformed the PE samples.

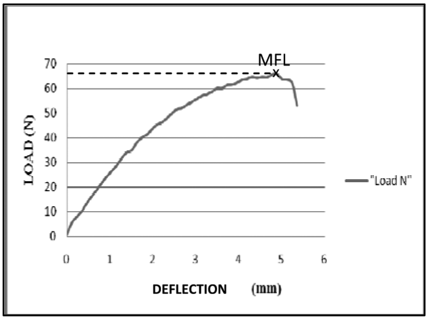


* Mean with the same letter are for comparison between two variables, different numbers indicate the variables are significantly different at α = 0.05

Figure 4: Mean MOE and MOR Values for PCPLP Samples



(a)



(b)

Figure 5: Typical flexural load-deflection plots for (a) a PCPLP 50:50 and (b) a PCPLP 70:30 composition sample (MFL = Maximum Flexural Load)

Conclusion

Composites composed of plastic and pineapple leaf particles have successfully been manufactured. The results indicate that increased pineapple leaf particle content reduces electrical resistivity due to their inherent moisture absorption behaviour. The results of the mechanical testing indicate that the composites exhibit greater flexural strength, but reduced toughness with higher pineapple leaf particle content, which may be attributed to the disruption of the rigid interphase between the particles and the polymer, which affected the porous structure of the filler particles within the matrix. It is of note that the PP composites consistently outperformed the PE composites, which may be a consequence of greater interparticle interactions between the plastic and particles.

Acknowledgements

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