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STUDY ON THE EFFECT OF ADDING COUPLING AGENT (TITANIUM DIOXIDE) ON THE RHEOLOGICAL, THERMAL AND ELECTRICAL PROPERTIES OF COMPOSITE MATERIAL (PE-WOOD)

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Abstract: In this study, the effect of a commercially available titanium dioxide (TiO_2) as a coupling on wood filled polyethylene (PE) was investigated. The study revealed that the viscosity of the PE decreased with the addition of the TiO_2. The coupling agents helps to improve the dispersion quality of the PE. The increase in the temperature of the wood filled PE resulted in a corresponding decrease in the viscosity decreases. The thermal conductivity was found to increase with an increase in the volume fraction of the TiO_2. Finally, the electrical resistivity of the wood filled PE decreased with increasing volume fraction of the TiO_2.

Keywords: *Titanium Oxide, Polyethelene, Composite, Coupling Agent.*

1. Introduction

There is an increase in research interest on the applications of wood plastic composites (WPC) in the past one decade [1]. This is due to its numerous advantages as an essential engineering materials [2]. Studies have shown that some of the advantages of WPC include low cost, substantial strength and stiffness, moisture, abrasion and insect resistance [3]. In addition, WPC has the merit of having a widespread wood fillers as well as being a renewable raw material [4]. The wood fiillers has been reported to ehance the matrix polymer which often leads to reduction of ductility, poor impact resistance and high viscosity [5]. The WPC also tend to exhibit the rheological properties comparable to other types of suspensions of polymeric matrices [6]. Studies have shown that wood flour filled polyethylene (PP) and polypropylene possesses increased viscosity [7]. Similarly, wood flour and styrene/metallic anhydride copolymer as well as PVC/wood composite have reported to exhibit shear thining behaviours

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during melting [8]. Wood loading and the nature of the wood fiber to fiber interactions were found to influence the viscosity of wood flour/PP composites [9]. The use of 7-15% elastomeric modifiers was reported to enhanced the flow of wood flour/PP composites [10]. When the matrix or wood was treated by Corona, the viscosity of the wood flour/PP composite was observed to reduce [11]. The reduction in the viscosity was ascribed to formation of low-molecular weight moieties on the polyethelene amd wood fiber surfaces during the corona treatment. The composites formed was expected to have the features of a lubricant at the polymer-fiber interface. The rheology and melt elasticity behavior of isotactic polypropylene (IPP) filled talc and untreated $CaCO_3$ particles in variohs amount of fillers have been investigated using conctric rheometer. The findings revealed that the shear viscosities of the composite decreases with shear rate [12-14]

The flow properties of mica–reinforced polypropylene melts using the weissenberg Rheogoniometer at two temperatures (180 ^oC and 220 ^oC) has been investigated by Chapman and Lee [15]. The findings revealed that there was a decrease in the viscosity of the composite with an increase in the shear rate. The authors explained the behaviour of the composite in terms of the flake interactions. The flake interactions was found to have the tendency to draw the flakes into orientations unfavorable for flow, resulting in high viscosity at low shear rates. However, at high shear rates, there was predominance of the viscous stresse over the particle interactions. The alignment was found to be greater and the viscosity is lesser. The behaviour of the composite at 180^oC revealed that the mica content was high, hence the flakes tend to agglomerate in to a network structure which was readily destroyed by shear.

In a similar study, Ahmed and Abdul-Muhsien [16], investigated the effect of additing titanium dioxide the electrical properties of polystyrene. The findings revealed that the increase in temperature and conctration of the titanium dioxide resulted in a corresponding increases in the electrical conductivity of the polysterene. Extensive review by Progelhof er [17] on the prediction of thermal conductivity of composite systems revealed various theoretical and empirical models with a brief description focusing the relative merits.

2. Experimental

2.1. Materials

Low density polyethylene (LDPE) possesses a density range of 0.910–0.940 g/cm^3. At room temperature, the LDPE is non-reactive but when in contact with a strong oxidizing agent, and some solvents could result in swelling. The LDPE can withstand temperature up to 80^oC continuously and 95^oC for a short period. With a translucent or opaque variation, the LDPE is flexible, and tough nevertheless its breakable. The commercial form of the wood flours is light weighted, non-corrosive as well as less abrasive to process equipment. In the study, commercial titanium oxide (99.5%, M/S Trioxide UK) was utilized.

2.1. Methods

The polyethylene (PE)-wood floor - titanium dioxide (TiO_2) were mixed in correct proportion and subsequently sun dried. Thereafter, the dried composite was blended and the then compounded using 25 mm single screw extruder. Thermostat was employed to monitor and control the barrel and the die temperature. The die temperature was alongside with the barrel temperature to give a uniform output.

Thereafter, the extruded sheets were cooled in water and subsequently cut into smaller pieces and placed in the mold. To prepare a sheet with 3-4mm thickness, the extruded sheet was hot pressed between the hydraulic press at 170 ^oC to form the PE/wood floor-TiO_2 composite.

In order to allow the PE/wood floor-TiO_2 composite to melt and spread between the plates, a pressure of 20 kg/cm^2 was supplied for 5 minutes. The pressure was gradually increased to 200 kg/cm^2 for another 5 min and thereafter stopped. Finally, the mold sheet was quenched in water at room temperature.

3. Results and Discussion

3.1. Thermal Conductivity

Figure (1) depicts the effect of changes in TiO_2 content on the thermal conductivity of the PE/wood composite. The increase in thermal conductivity of the PE/wood composite might have led to the formation conductive chains as a result of the presence of the TiO_2. The increase in the TiO_2 content resulted in a corresponding increase in the chances of forming the TiO_2 conductive chains. This trend is consistent with that reported by Agari et al. [18].

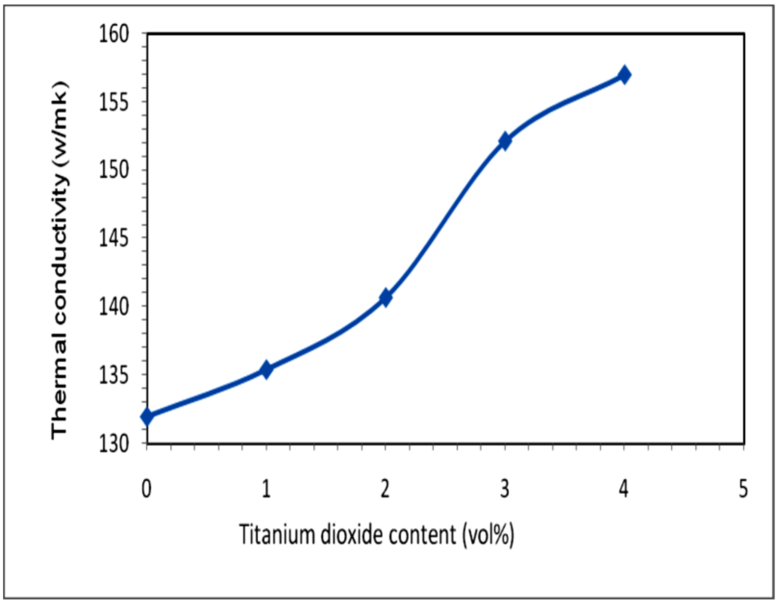

Figure 1. Thermal conductivity versus volume fraction of TiO_2

3.2 Electrical Resistivity

Figure (2) shows the effect of variation in the TiO_2 on the electrical resistivity of PE/wood composite. The electrical resistivity of the PE/wood composite decreases with increase in the TiO_2 content. At a lower amount of TiO_2, a high electrical resistance was observed while a higher amount of TiO_2 resulted in low electrical resistivity. This results in an indication that an electrical resistivity in composite with less than 2% (volume fraction) of TiO_2 is extremely high. When PE/wood/ TiO_2 composite contains about 2% TiO_2, it can be treated as electrically insulating materials.

On the contrary, a sudden change in the electrical resistivity occurs when the TiO_2 content increases from 2% to 3%, which is termed the percolation threshold range. This observation is consistent with that reported by Ahmed [5] and Leng [19].

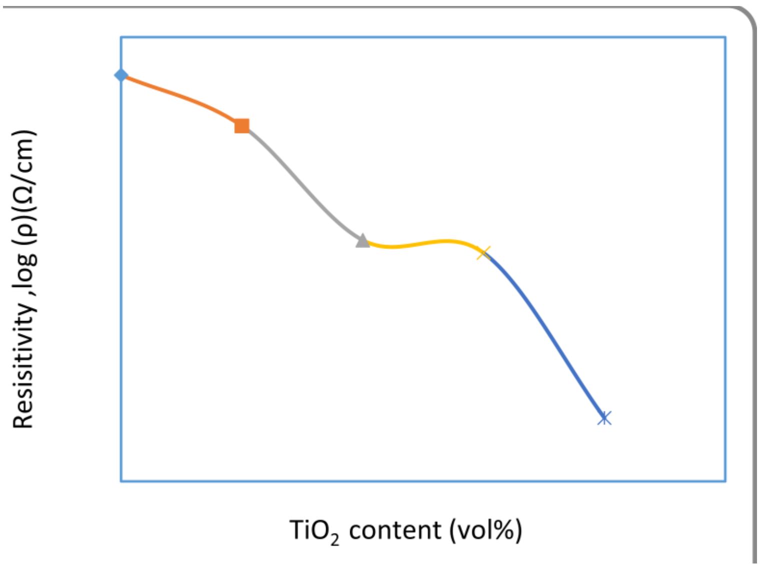

Figure 2. Resistivity (ρ) versus volume fraction of TiO_2

3.3 Rheological Behaviour

Figures (3)-(7) depicts the variation in the viscosity of the PP/wood composite with shear rate at different temperatures (240 ^oC, 250 ^oC and 260 ^oC) and the amount of TiO_2. Obviously, the viscosity of the PE/wood composites increases as the amount of TiO_2 increased. The viscosity increases rapidly, at a low shear rate.

This behavior can be explained in terms of interaction of the TiO_2 in the PE/wood mix which makes the TiO_2 into an orientation unfavorable for flow, resulting in high viscosity. The composite viscosity is more influenced by the strength of bonding in the network structure at low shear rate which appears to be relatively independent of temperature. This trend is consistent with the results obtained by Minagawa [20].

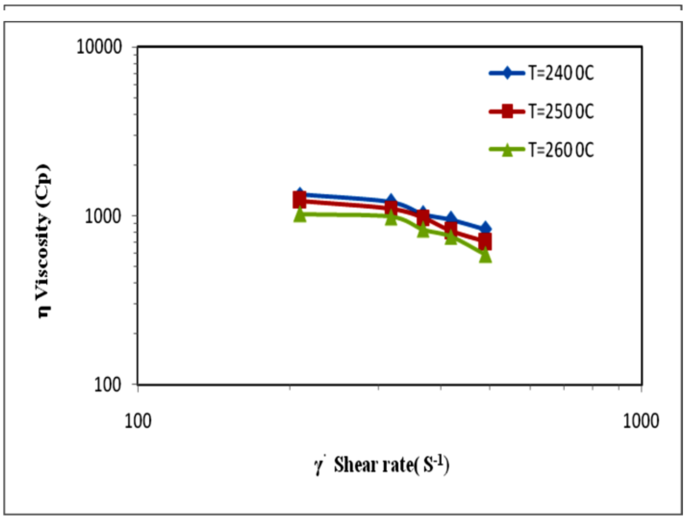

Figure 3. Viscosity (Cp) of PE/Wood =80/20 versus Shear Rate (S^{-1}) at different temperatures are (240 °C,250°C and 260 °C)

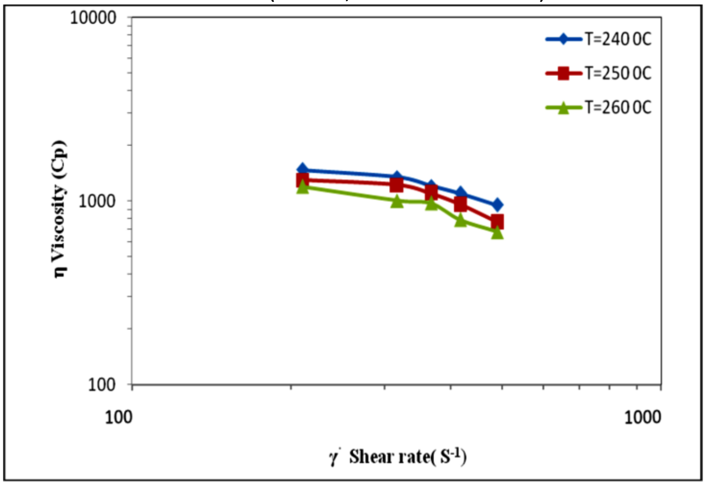

Figure 4. Viscosity (Cp) of PE/Wood /TiO_2 =80/18/2 versus Shear Rate (S^{-1}) at different temperatures are (240 °C,250 °C and 260 °C)

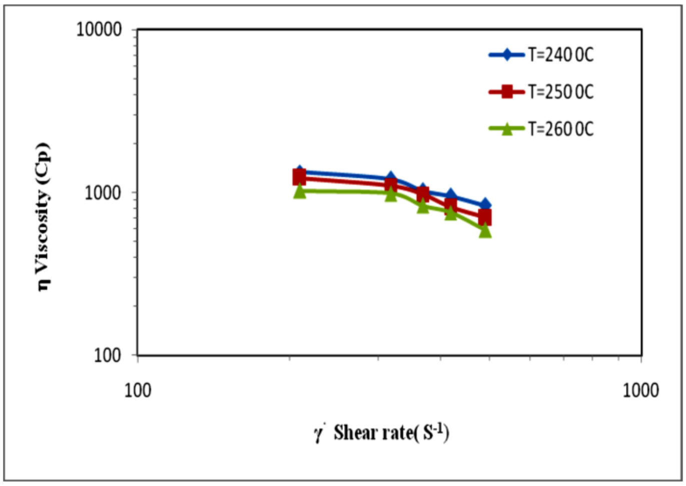

Figure 5. Viscosity (Cp) of PE/Wood /TiO2 =80/16/4 versus Shear Rate (S-1) at different temperatures are(240 °C,250°C and 260°C)

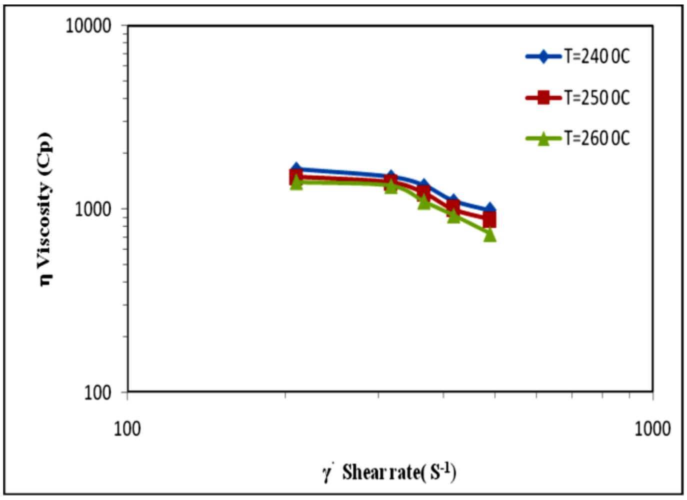

Figure 6. Viscosity (Cp) of PE/Wood /TiO2 =80/14/6 versus Shear Rate (S^{-1}) at different temperatures are (240 °C,250 °C and 260 °C)

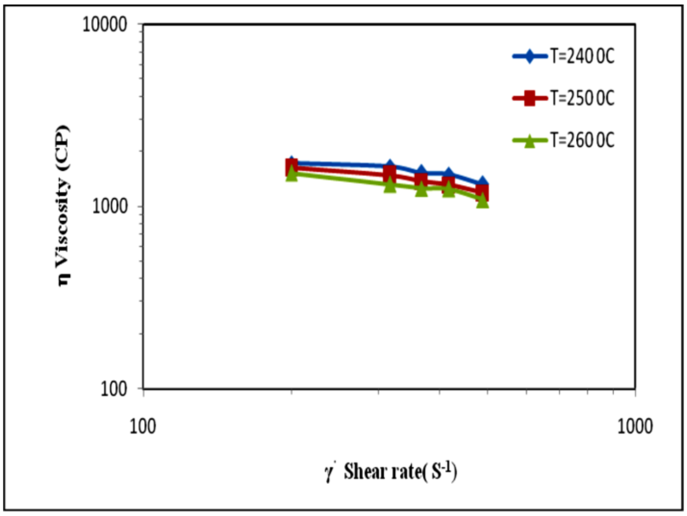

Figure 7. Viscosity (Cp) of PE/Wood /TiO_2 =80/12/8 versus Shear Rate (S^{-1}) at different temperatures are(240 °C,250 °C and 260 °C)

4. Conclusions

1-Therrnal conductivity increases with increasing volume fraction of TiO_2.
2-The electrical resistivity of the PE/wood increases by increasing of TiO_2 concentrations.
3- Viscosity increases by increasing of TiO_2 but decrease by increasing temperature.

Conflict of interest

The publication of this article causes no conflict of interest.

Abbreviations

A list of symbols should be inserted before the references if such a list is needed

A	coefficient matrix
E	modulus of elasticity
R_f	failure ratio
t	time
γ	unit weight of material
ν	Poisson's ratio
φ	friction angle
ε_v	volumetric strain

5. References

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