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EFFECT OF *PROSOPIS AFRICANA* WOOD FILLERS ON THE MECHANICAL PROPERTIES AND CREEP RESISTANCE OF POLYVINYL CHLORIDE COMPOSITES

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ABSTRACT

Mechanical and creep behavior of *Prosopis africana* (PA) wood reinforced polyvinyl chloride composite has been examined. The PA fibre was treated with sodium hydroxide solution so that compatibility between the hydrophilic natural fibre and the hydrophobic polymer matrix is enhanced. The percentage fibre loading was varied from 0, 4, 8, 12, 16, 20 to 24. The mechanical properties, ultimate tensile strength (UTS), elastic modulus and hardness showed significant improvement compared to the unreinforced polyvinyl chloride. Flexural strength showed a sharp increase but decreased steeply with increased fraction of reinforcement. Creep behavior of the composite showed a better load bearing capability at elevated temperature compared to unreinforced PVC. This indicates that *Prosopis africana* was observed to improve the mechanical properties of PVC suitable for partitions and as ceilings in buildings. Best mechanical properties were observed at 8%, 12% and 16% weight fraction of reinforcements. A gradual and momentous increase in elastic modulus from 1.4 GPa to 4.5 GPa was achieved.

Keywords: Creep resistance, mechanical properties, polyvinyl chloride, *prosopis africana* wood.

INTRODUCTION

Poly (vinyl chloride), PVC is one of the most commonly used plastics in our society. Its main applications include pipes, electric wires, window profiles, siding, etc. [1]. Wood fibre reinforced PVC is becoming more popular because of its acceptable mechanical properties, moisture and fungus resistance, long life and recyclability [2]. The term wood plastic composite (WPC) refers to any composite that contains plant (including wood and non-wood) fibres and thermoplastics or thermosets [3]. This property allows other materials, such as wood fibres to be mixed with the plastic to form a composite. WPCs are environmentally friendly materials composed of wood powders or fibres reinforced thermoplastic resins [3]. WPCs inherit the intrinsic properties from constituents. For example, they are resistant to corrosion and humidity, and are durable and recyclable. Compared with wood, WPCs are resistant to cracks and bending properties; compared with traditional plastics, WPCs are easier to process and hence, WPCs have outdoor applications such as decking, trails and landscape gardening [3]. Some weaknesses of this material include low impact strength and thermal stability which signals need for additional research on this important product [1].

Recent years have witnessed a massive surge in WPCs in the conventional building market place. However, owing to the poor understanding of the mechanical properties and long-term behavior of the WPCs, their usage is limited in structural applications. Therefore, this study is to investigate how *Prosopis africana* could enhance the mechanical properties of PVC as well as the creep behavior of the composites.

MATERIALS AND METHODS

Log of wood of *Prosopis africana* (Kiriya in Hausa, Ubwa (Igbo) and Ayan in Yoruba) was sourced from Hannu-Tara in Dansadau, Maru Local Government, Zamfara State, Nigeria. The wood was cut into pieces and then sun-dried for 7 days to eliminate moisture content before it was pulverized into powdery form. It was then sieved into 150 µm particles size.

Chemical treatment of *Prosopis africana* powder

In order to reduce potential surface hindrances and increase compatibility between hydrophilic natural fibre and hydrophobic polymer matrices, the wood powder was treated with sodium hydroxide solution. The powdered sample, 50g each was put in a 10% NaOH solution for 5 hours with continuous stirring. It was then rinsed with distilled water until the solution became neutral. The powder was then filtered out and dried in vacuum at 80 ℃ for 5 hours for further use [4, 5].

Preparation of PVC-*Prosopis africana* Wood Composites

The PVC resin and *Prosopis africana* were prepared by compounding and compression moulding techniques on a Two Roll Mill (Model number 5183, New Jersey, USA) at the Polymer Recycling Laboratory, Department of Polymer Technology, Nigeria Institute of Leather and Science Technology (NILEST), Zaria. The composite samples were produced by the addition of the PVC resin while the rolls were in counter clockwise motion for of 10 minutes at a temperature of 250 ℃. Immediately a paste-like matrix was achieved, the filler (*Prosopis africana* powder) was gently and manually introduced as the rolls rotated at a rate of 500 rpm. The fibre loading was varied: 0, 4, 8, 12, 16, 20, and 24 % while the percentage of PVC was 96, 92, 88, 84, 80 and 76% respectively. Control sample is represented by 0%. The compounded samples were cured on hydraulic machine (hot press) at 4 MPa for 10 minutes. Finally, the cured samples were removed from the mould after cooling and cut according to ASTM standard for characterization and mechanical test [6].

Mechanical Property Test

Tensile Test

The tensile testing of the samples was conducted at the Engineering Materials Development Institute, Akure, Ondo State, Nigeria, according to ASTM D638, [7] standard. A dog bone-shaped specimen was cut and then placed in Instron universal testing machine 3369 model. The tensile strength and elastic modulus were evaluated.

Flexural Strength

Flexural strength of the composites was carried out at the Strength of Materials Laboratory, Department of Mechanical Engineering, Ahmadu Bello University, Zaria, Nigeria, according to ASTM D790 [8].

Hardness

The hardness test of a composite is based on the relative resistance of its surface to indentation by an indenter of specified dimensions under a specified load [5]. Samples of 30 mm x 30 mm x 4 mm were tested for shore hardness values with a Durometer Shore "A" model number 1531, USA. Three different measurements were performed on the sample at different spots and the average of the values was taken as the hardness of the sample.

RESULT AND DISCUSSION

Mechanical Properties

Tensile Test

Figure 1 represents the tensile strength of PA-PVC composites with increasing fibre loading. A steady increase in tensile strength could be observed up to 12% fraction of reinforcement and a steep decrease at 16%. This could be related to wearing of the interfacial adhesion of the constituent composition as the fraction of the PVC is reduced with increasing weight fraction of reinforcement. Similar observations have been reported [5, 9, 10].

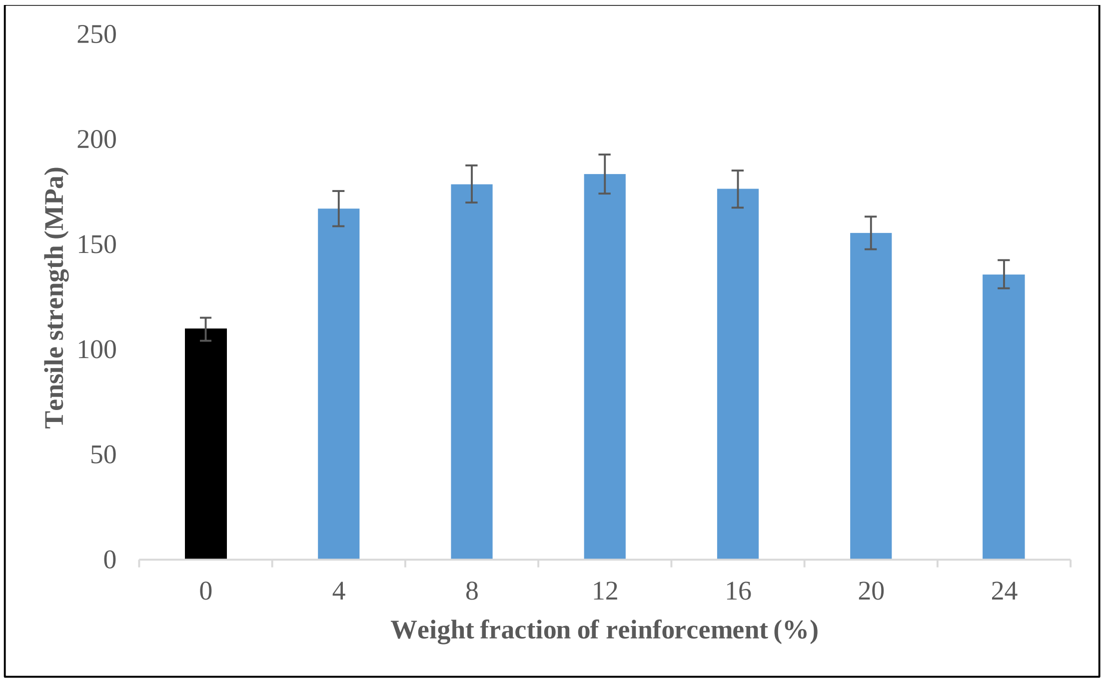

Figure 1: Tensile strength of PA reinforced PVC composites.

Elastic Modulus

Figure 2 portrays the elastic modulus of the composite with increasing weight fraction of reinforcement. It could be observed that, the elastic modulus of the composite maintains a trend with increasing weight fraction of reinforcement, with an increase from 1.4 GPa to 4.5 GPa. This well pronounced increase in the elastic modulus could be related to the better interaction between *Prosopis africana* fibre and the polymer matrix. Similar results had been reported [9, 5].

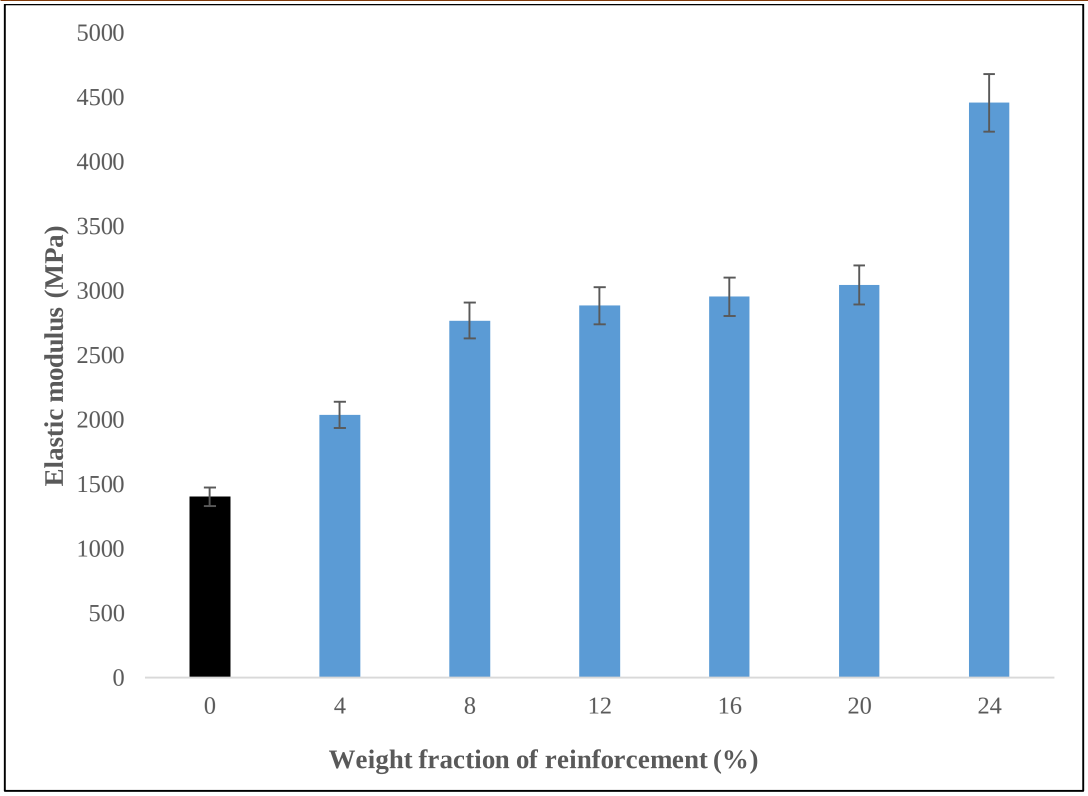

Figure 2: Elastic modulus of PA reinforced PVC composites

Flexural strength

Figure 3 indicates the flexural strength of the composite. From the figure, the flexural strength of *Prosopis africana* reinforced PVC composites was observed to increase with the incorporation of PA which is due to better interfacial adhesion between the PA and PVC matrix. However, at higher fraction of PA fibre, the flexural strength was observed to decrease due to poor fibre-matrix adhesion. The result is in conformity with other authors [11, 12].

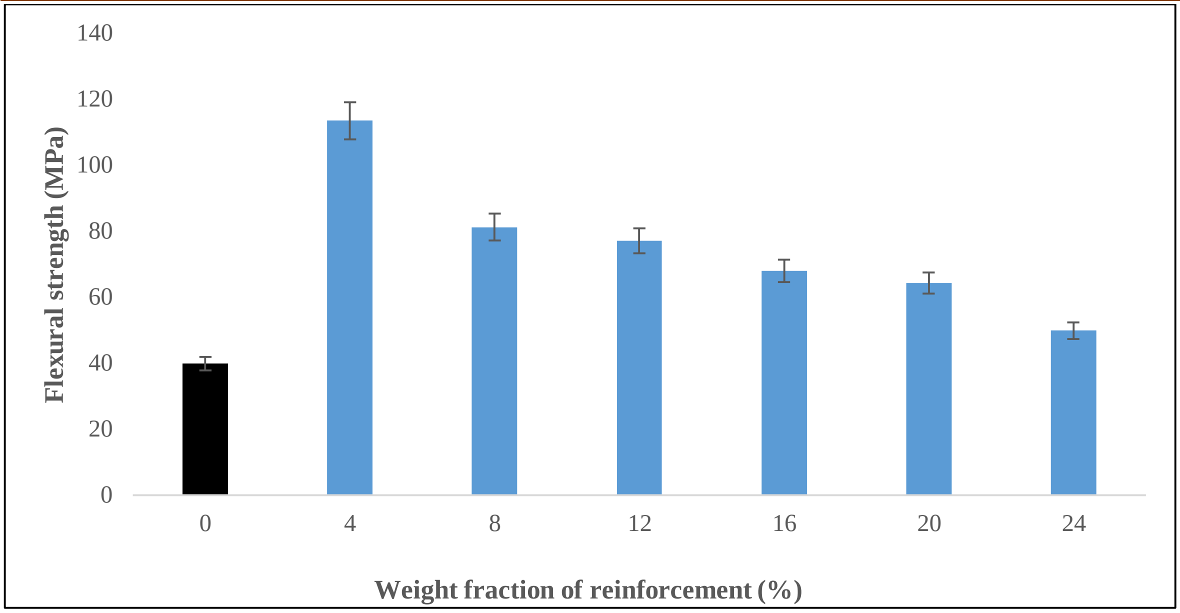

Figure 3: Flexural strength of PA reinforced PVC composites

Hardness Test

Figure 4 shows the hardness values of PA reinforced PVC composite. The composition with highest fraction of reinforcement appears to have the maximum value of 98. This is due to the better interfacial attraction between the *Prosopis africana* and the polymer matrix**.** This result is in conformity with the findings of Jacob *et al* [5], who reported the effect of plantain peel powder on the hardness value of recycled low density polyethylene composites.

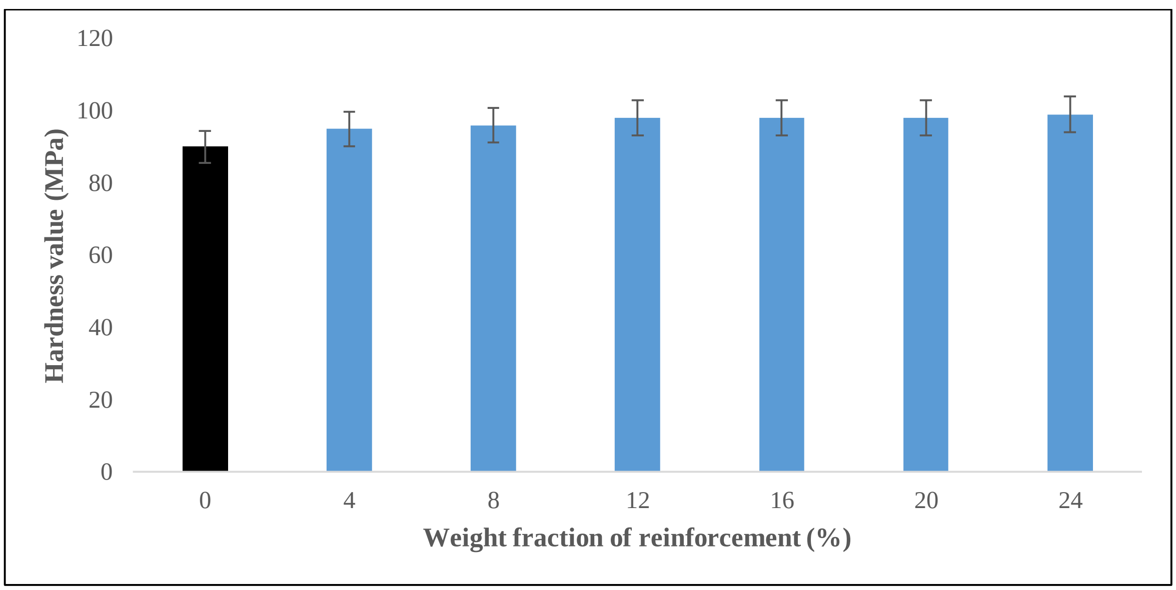

Figure 4: Hardness of PA reinforced PVC composites

Creep

Creep is deformation of material under constant stress, depending on time, stress, temperature and material properties, etc [12]. The creep curve of 16 % PA reinforced PVC at 70 is indicated in figure 5. A large vertical strain could be observed due to the applied load which then decreases with time up to 48.4 min known as the equilibrium strain rate. This stage is known as the secondary creep and is often considered in load bearing capability of the composites [6]. Similar results have been reported [9,12, 13].

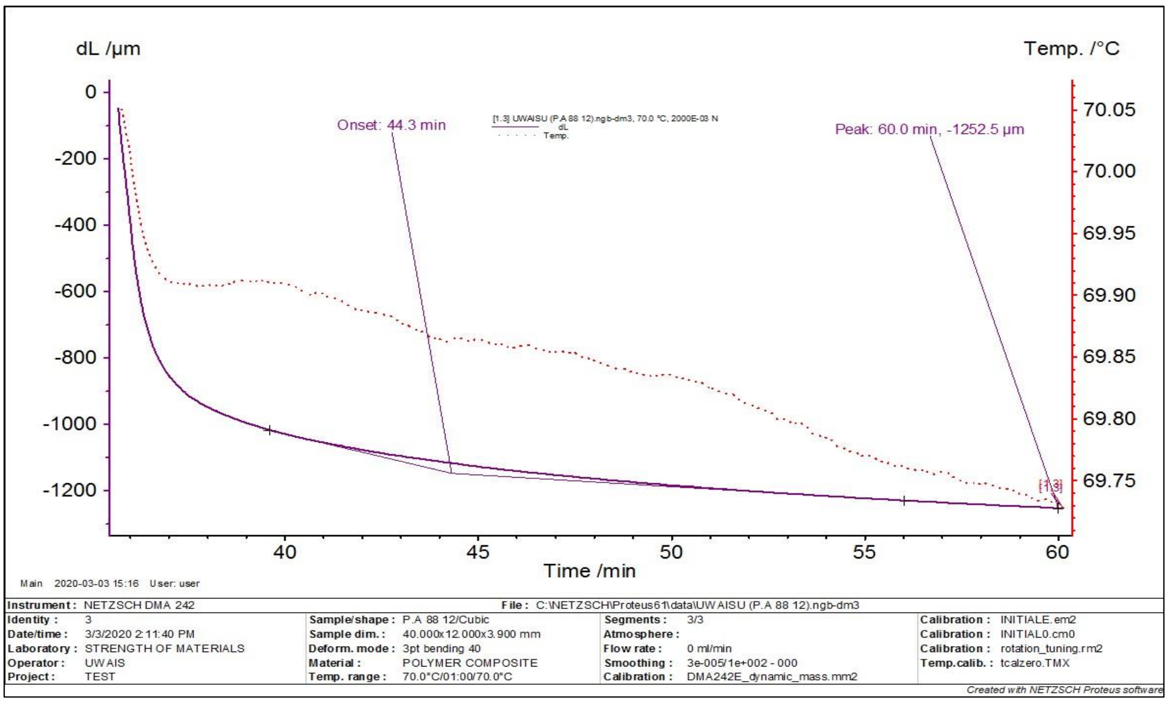

Figure 5: Creep curve of 16 % PA reinforced PVC composite

Figure 6 shows the creep curve of the control sample (PVC). The equilibrium strain rate occurred at 43.6 min which is lower than that of the composites. This is an indication of improvement in the load bearing capability of the PVC.

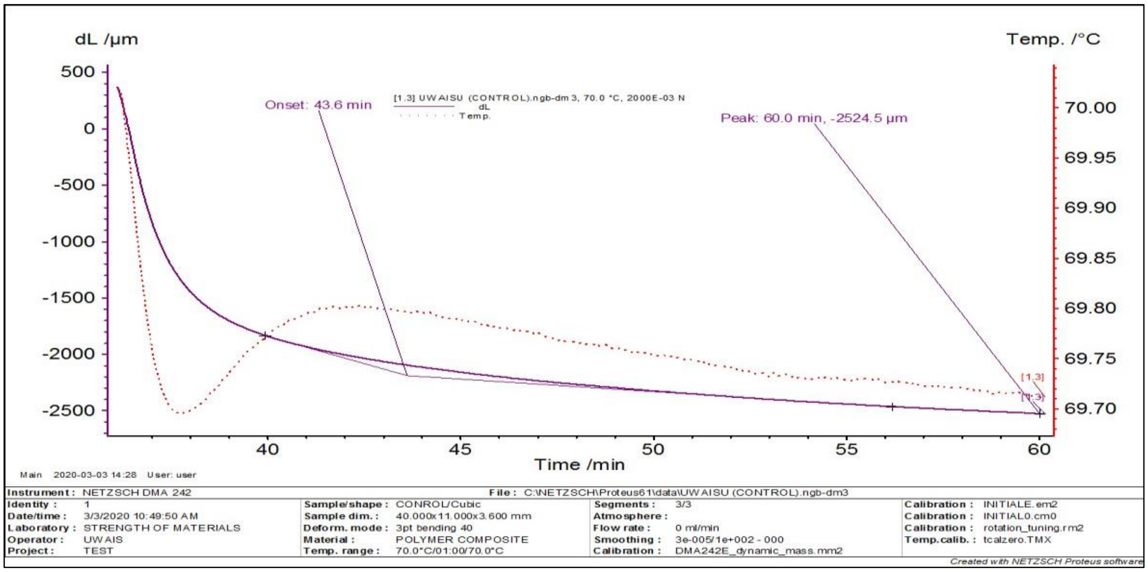

Figure 6: Creep curve of PVC

CONCLUSION

The *Prosopis africana* wood reinforced PVC was developed using locally available wood fibre and has shown to improve the mechanical properties and creep behavior of the PVC. Best mechanical properties were observed at 8%, 12% and 16% weight fraction of reinforcements. A gradual and momentous increase in elastic modulus from 1.4 GPa to 4.5 GPa was also achieved. The creep curve indicates a better creep stability of the composite at higher temperatures than the pure PVC. *Prosopis africana* wood is exploited as replacement for conventional fibres such as glass, aramid and carbon due to its advantages such as low cost and availability. A composite of PA filled PVC was observed to have improved mechanical and other superior properties suitable for a variety of applications such as partitions and ceilings in buildings.

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