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Mechanical Properties of Untreated Buffing Dust (UBD) Reinforced Waste High Density Polyethylene (wHDPE) Composites for the Manufacturing of Boot-last

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Abstract: The utilization of buffing dust as reinforcement fibre in waste high-density polyethylene (wHDPE) was analysed by examination of the composites produced. The composites were compounded using two roll melt mixing machine and compression moulding technique in the following weight percent of the fibre loading: 10 %, 20 %, 30 %, 40 % and 50 %, respectively. The composites were analysed based on their mechanical properties. The results obtained indicated an increase in the mechanical properties of the buffing dust reinforced high density polyethylene as compared to the control sample (unreinforced wHDPE). The optimum tensile strength was 18.08 MPa at 10 % fibre loading compared to 17.92 MPa obtained as control. Also, the stiffness properties of the composites obtained at optimum was 1.46 GPa at 50 % weight fraction as compared to 0.96 GPa of the control sample with an optimum impact energy of 2.7 J/mm^3 at 10 % wt. The results obtained implies that, there is improvement in the mechanical properties of the composites as weight fraction increases and the composites can therefore be suitable for the manufacturing of boot-last. Nigeria has no standard military combat boot-last that represent the morphological shape of the Nigerian foots, its either United Kingdom, Italy or Indonesia made last. Therefore, it becomes imperative to have a proper recycling of our wastes to manufacture shoe-lasts that have the blue-print of the country.

Keywords: *Composites, buffing dust (BD), wHDPE, Weight fraction, Fibre loading, Untreated buffing dust (UBD), Boot-last.*

1. Introduction

Solid wastes create a major problem for leather and plastic industries in terms of both their variety and quantity. These solid wastes constituted a fundamental problem to the environment. For every ton of hide or skin processed, about 2 – 6 kg of buffing dust is generated as solid waste. Incineration of these solid wastes (Leather and Plastic wastes) causes serious air pollution because of the release of toxic gases (Sekaran *et al*., 1998). It is possible to recycle these products and even use them as raw materials for different industries (Colak *et al*., 2005). Leather buffing dust is regarded as a fine powder of collagen fibril waste from milling and buffing operations and constitutes an important part of solid wastes generated from chrome tanned leather production processes (Kilic *et al*., 2020). Shoe last is the reproduction of the heart and single most important element of the shoe (Majbaur, 2015). It is the most scientific and complex part of the whole shoe making process and it is the foundation upon which much of the shoe related foot health depends (Cheng and Pemg, 1999). Shoe-last is said to be responsible for the size, fit, shape, feel, wear, style, tread and even the making of the shoe (Ye, 1994). Right from independence to date, Nigeria continues to depend on importation of goods and essential commodities and out of these goods is the Nigerian Military combat boots. The shoe-last, the footwear manufacturing industries used as major element in the manufacturing of footwear are also imported. Nigeria has no standard military combat boot-last that represent the morphological shape of the Nigerian foots, its either United Kingdom, Italy or Indonesia made last. Therefore, it becomes imperative to have a proper recycling of our wastes to manufacture shoe-lasts that have the blue-print of the country.

2. Methodology

2.1 Sourcing and preparation of buffing dust

Buffing dust will be locally sourced from Panshekara Industrial Layout, Kombotso L.G.A of Kano State. It will then be filter to remove debris and sand and sun dried for 3 days. Appropriate mill grinder was used to convert the fibre into powder and then sieved to a particle size of 2 mm.

2.2 Experiments

2.2.1 Fourier Transform Infrared Spectroscopy (FTIR)

The change in functional groups of the buffing dust (BD) were studied using FT-IR analysis, it was performed using Agilent Technologies, Cary 630 FT-IR, ABU Multi-user Laboratory Zaria, Kaduna State; Nigeria with spectrophotometer resolution of 8 and ranging from 4000-650.

2.2.2 Tensile Strength

To determine the tensile strength of the leather, the test samples were cut according to a total length of 100 mm and gage length of 47 mm. The testing of the samples was done at Department of Polymer and Textile Engineering, Ahmadu Bello University, Zaria-Kaduna State, Nigeria in accordance with ASTM D638 (2014) standard. The samples were machined to dumb bell shape and then placed in Tensile Strength Test Machine TM2101-T7 model and the tensile strength and modulus were evaluated.

2.2.3 Hardness Test

The hardness test of composites is based on the relative resistance of its surface to indentation by an indenter of specified dimensions under a specified load. Samples of 30mm x 30mm x 5mm will be tested for shore hardness values with a Durometer Shore 'A' ASTM D2240 (2015) at the Materials laboratory, Nigerian Institute of Leather and Science Technology (NILEST), Zaria-Nigeria. Measurements were carried out on three different points on the samples and the average was taken as the hardness of the composites.

2.2.4 Impact Energy test

The reliability of a material can be determined by measuring its resistance to fracture, either ductile or brittle and fracture toughness. The impact test on the developed composite samples will be carried out using a fully instrumented Charpy impact testing; CAT NR412 model according to ASTM F2231-02

(2013) at the Department of Metallurgical and Materials Engineering, Ahmadu Bello University, Zaria. The dimensions, gauge length and V-notch were chosen according to the standard. The specimen was placed between a sample holder with the notch oriented vertically and towards the origin of impact. The specimen was struck by a "tup" attached to a swinging pendulum. The specimen breaks at its notched cross-section upon impact, and the upward swing of the pendulum was used to determine the amount of energy absorbed in the process and the results was recorded in Joules (J).

3. Results and Discussion

3.1 FTIR of the untreated buffing dust

Figure 1. represent the FTIR spectrum of untreated buffing dust. The peaks at 3295.0 cm^{-1} and 1636.30 cm^{-1} are due to the presence of –OH and –C=O groups respectively. The hydroxyl (-OH) groups indicated the hydrophilicity of the buffing dust fibres.

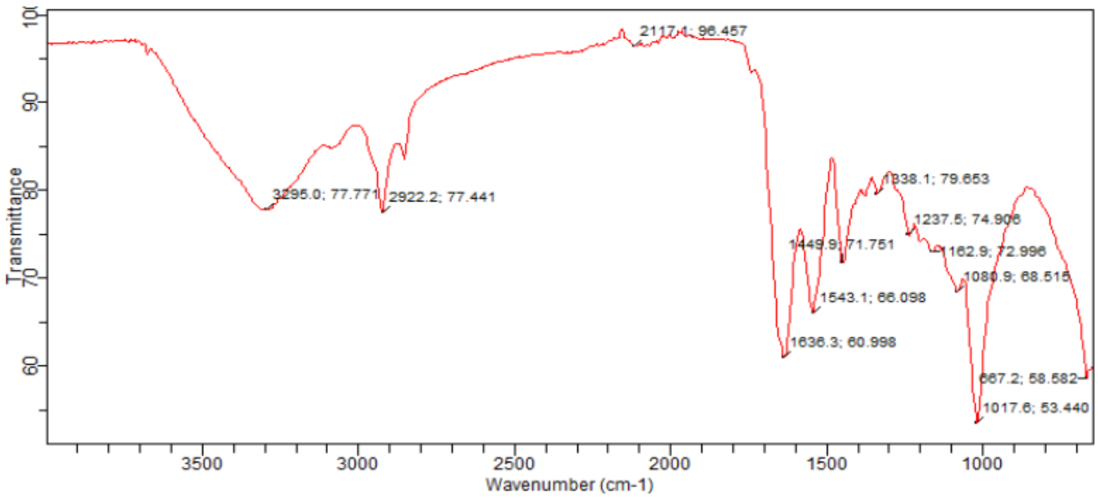

Figure 1: FTIR spectrum of untreated buffing dust

3.2 Effect of buffing dust on the tensile strength of waste HDPE

The tensile strength of material is the maximum amount of tensile stress it can withstand before failure. The tensile strength of BD-wHDPE reinforced composites is shown in figure 2. The results indicated that, the ultimate tensile strength decreases as the weight fraction of the fibre increases. Another reason could be as a result of increase in the brittleness of the composites as the fibre weight fraction increases thereby decreasing the ductility of the composites. Similar situation was reported by Peretomode *et al*., (2019). The untreated fibres at 10 wt % fraction showed improvement in ultimate tensile strength of 18.08 MPa as compare to the unreinforced (control) sample having a tensile strength of 17.92 MPa.

3.3 Effect of buffing dust on percentage elongation of waste HDPE

Percentage of elongation of a material is the ability of the material to extend when subjected to a mechanical force. The result of the effect of untreated buffing dust and weight percentage of reinforcement on the % elongation at break of BD-wHDPE composites shown in Figure 3. Depicts a decrease in elongation (%) at break as the weight fraction of BD increases. The decrease observed is supposedly dependent on the amount of BD incorporated. Increase in weight percentage of the reinforcement lead to the hardening and stiffening properties of the composites. This reduced its toughness and resilience, thus lowers elongation at break (Cao *et al*., 2021).

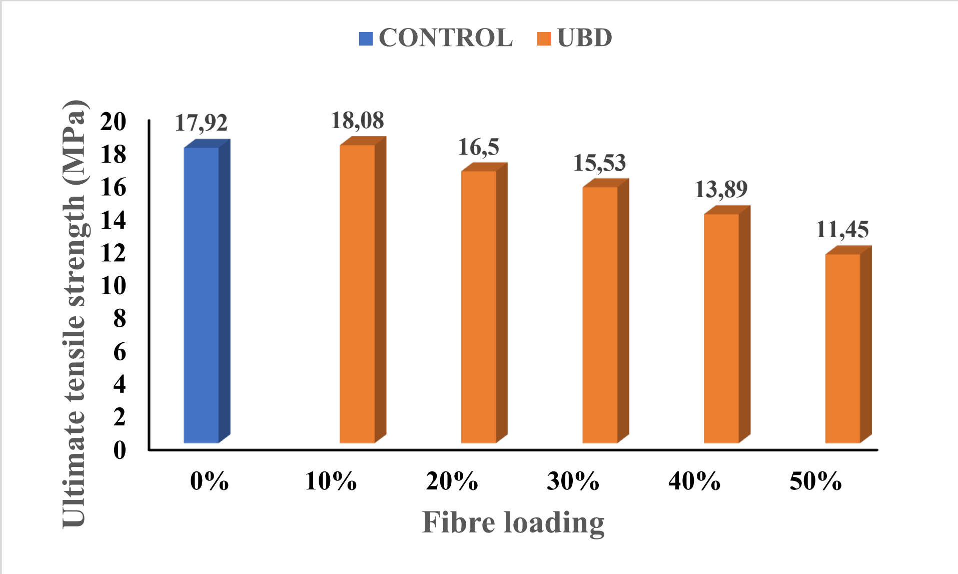

Figure 2: Effect of untreated buffing dust on tensile strength of wHDPE composites

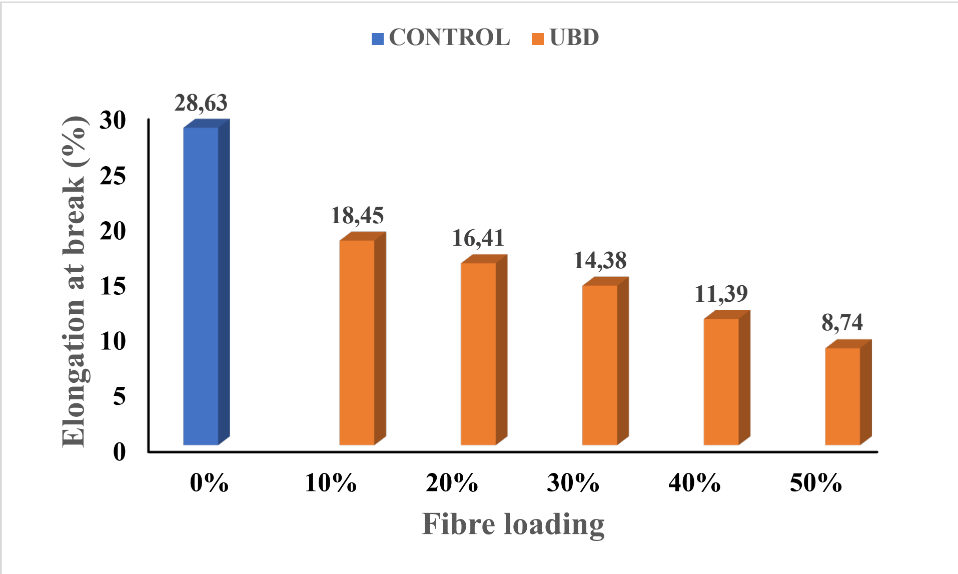

Figure 3: Effect of untreated buffing dust on elongation at break of wHDPE composites

3.4 Effect of buffing dust on the elastic modulus of waste HDPE

Figure 4. indicated the elastic modulus of BD-wHDPE composites. It could be observed that, increasing the weight fraction of the reinforcement lead to increase in the elastic modulus (Adeniyi *et al*., 2022). This could be attributed to the increase in stiffness properties of the reinforcing fibres as the weight fraction increases. At 40 % fibre loads, a sharp decrease in the elastic modulus was observed. The decrease could be as a result of uneven dispersion of the fibre in the matrix during compounding (Salleh *et al*., 2020).

3.5 Effect of buffing dust on the hardness properties of waste HDPE

Hardness is a measure of the resistance of substance to deformation (Satish *et al*., 2019). The graphical presentation of hardness values of buffing dust reinforced wHDPE composites in figure 5. depict a stepwise increase in hardness with increase in weight percent of the reinforcement. The increase could be attributed to the increase in the brittleness and three-dimensional structure of the collagen fibres (Sasmaz *et al*., 2019). It is evident that, 50 wt % of the UBD composites recorded the highest hardness values of 99.00 Shores as compared to the 92.00 Shores of the unreinforced (control) sample.

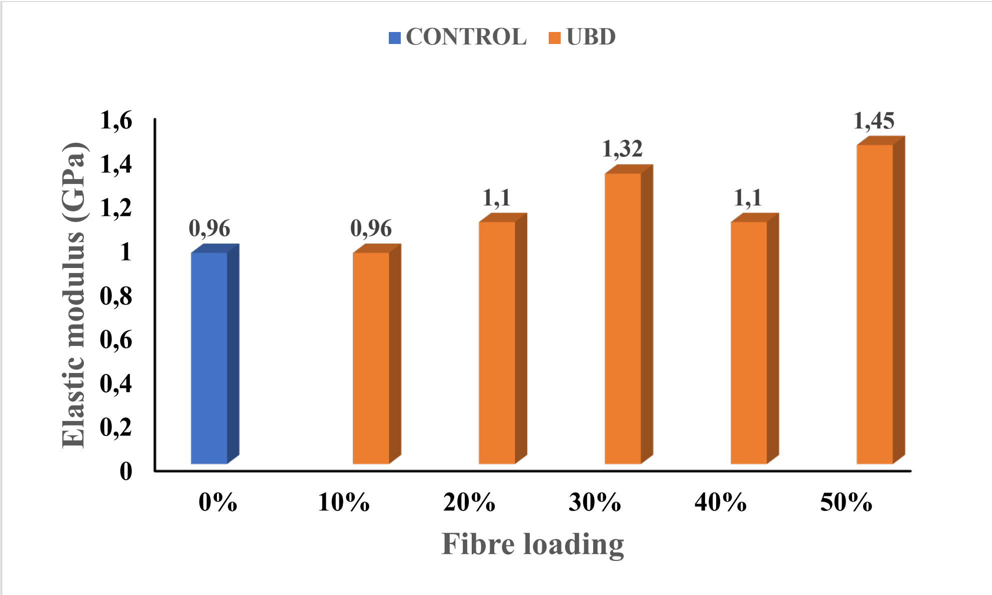

Figure 4: Effect of untreated buffing dust on elastic modulus of wHDPE composites

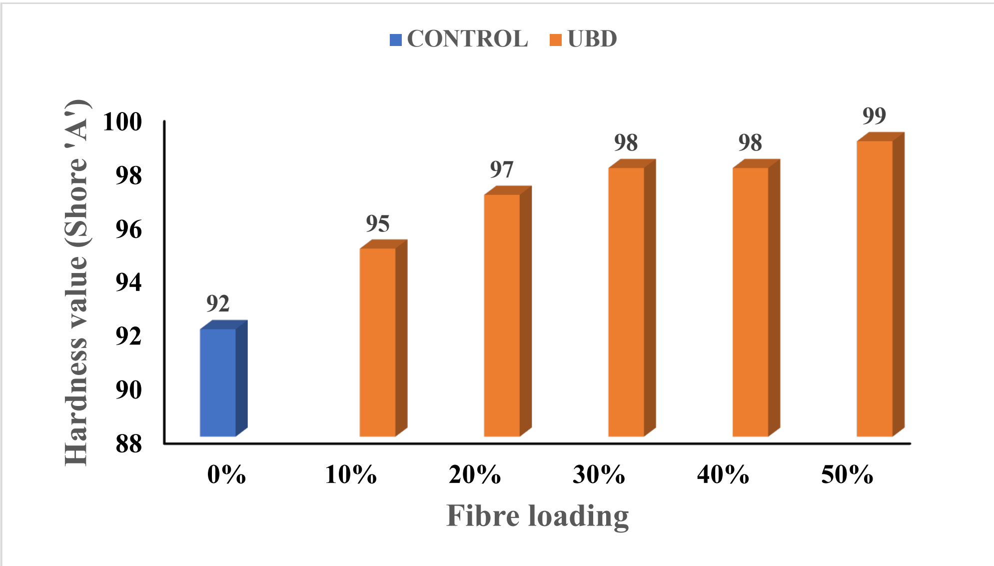

Figure 5: Effect of untreated buffing dust on hardness value of wHDPE composites

3.6 Effect of buffing dust on the impact strength of waste HDPE

Impact energy is the ability of material to absorb energy without breaking. Figure 6. shows the impact strength of buffing dust (BD) reinforced wHDPE composites. In this case, it could be observed that the impact energy tends to decrease as the fibre loads increases. Increasing the weight fraction of the fibre, implies decrease in the amount of thermoplastic content of the composites, which has the capacity to absorb the stress more efficiently than the fibre. This is in agreement with the work of El-Shekeil *et al.* (2012) who stated that, increase of fibre loading has resulted to decline in impact strength of the kenaf fiber reinforced thermoplastic polyurethane composites.

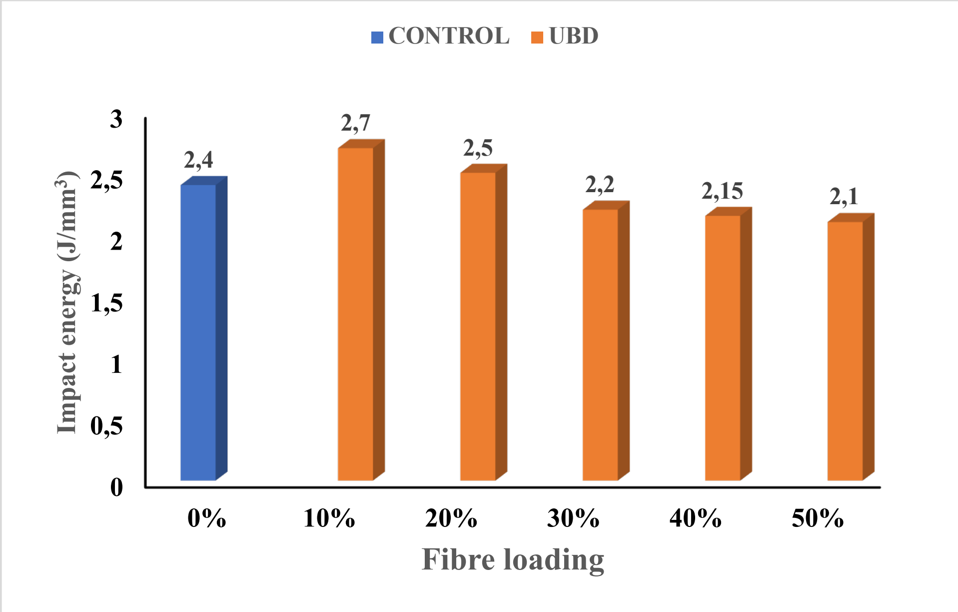

Figure 6: Effect of untreated buffing dust on impact energy of wHDPE composites

Conclusion

From the results of characterization of the composites, the following conclusions were drawn:

- The ultimate tensile strength of the UBD-wHDPE composites at 10 %wt is 18.08 MPa which is higher than 17.92 MPa tensile strength of the unreinforced (control) sample. Also, the optimum % elongation at break of the composites is 18.45 % which is lower compare to the 28.63 % of the unreinforced sample.
- At 10 %wt fraction, the composite has the ability to absorb the impact energy due to the even distribution of stress between the polymer matrix and fibres.
- Thus, the mechanical properties of the composites obtained, gives us an indication that, the 10 %wt composites formulation can be use in the manufacturing of Boot-last, owing to the fact that, the tensile strength is close to the 19.00 MPa minimum required tensile strength of pure HDPE for the production of last.

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