Millet Husk Fiber Filled High Density Polyethylene Composites and its Potential Properties

Hammajam, A.A, Ismarrubie, Z.N, S. M. Sapuan

***Abstract*— This paper presents investigations on the potential properties of agro waste fiber (millet husk) filled high density polyethylene thermoplastic composites. The SEM, impact and flexural properties were studied. The fiber loading effects as well as fiber sizes were also investigated. Different fiber sizes were applied. The composites were prepared by the use of internal mixer, followed by compression molding process. Up to 40 wt % of fiber loading was used. The results indicate increased in the bending strength and modulus as the fiber loading increased. It was also observed that impact strength decrease considerably as fiber loading increases.**

***Index Terms*— Composites, Impact analysis, Mechanical properties, Millet husk**

I. Introduction

It is an agro-waste product obtains from the milling process of grain cereal millet. Agro waste and natural fiber composites are not altogether a new phenomenon. The interest in superior material started to grow as a result of environmental safety and industrialization. Nevertheless, grain cereals have similar chemical, physical and mechanical properties whereby comparison on the bases of composites formation and methodology will be place in the context of rice husk, wood and natural fiber. [1], [3].

Grain millet (pennisetum glaucum) like sorghum and maize is a staple food for a large population in Africa, India, and semi - arid part of tropics [3]. In the last few decades, natural fibers have assumed reasonable attention because of their better properties and environmental issues [1–4]. Fiber loading is critical parameter in thermoplastic composites applications due to its stress transfer function between the fiber and polymer matrix. Flexural modulus is used as an indication of a material's stiffness when flexed. Polyethylene plays crucial role in thermoplastic composites production because of it suitable characteristics such as temperature resistance, melt flow index and density. Polyethylene filled rice husk [5], barley husk [6] are few examples from several studies. Millet husk is introduced base on it annual availability, thermal stability and environmental effects. Millet and other cereal agro wastes fibers, invariably can act as vital substitute of wood and natural fiber that poised threat to environment [7]. For effective utilization of cereal agro waste fiber filled/reinforced composites, certain parameters are paramount to be considered; strength, stiffness, and toughness. Understanding these parameters is critical in strategizing composites material applications [8]. Several studies were performed on the loading effect of fibers on mechanical properties. Thus, this study aims to evaluate the effect of millet husk fiber in mechanical properties of thermoplastic composites.

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II. Experimentals

Materials. Millet husk was collected from farm site at Bulumkutu Kasuwa Maiduguri, Borno State Nigeria. High density polyethylene (HDPE Titavene HD5218EA) with density of 0.960 g/cm^3 and melt flow index of 8.2 g/10 min (190 $^{\circ}$C, 2.16 kg) was purchased.

Fiber sizing. Millet husk was pulverized into different sizes; 250 µm, 500 µm, and 750 µm using Fritsch Pulverisette P15/P16 mill. The pulverized samples were subjected to 105 $^{\circ}$C temperature for 24 hrs in an industrial oven in order to remove moisture before blending with the high density polyethylene.

Composites fabrication. Millet husk (MH) and high density polyethylene (HDPE) were compounded by mixing, followed by compression molding process. Labquip scientific 40 ton compression molding machine was used in hot pressing the test specimens. The samples were pre–heated for 3 min at 170 $^{\circ}$C. Venting time was set to 3 min and final press temperature of 170 $^{\circ}$C for 3 min. Finally, the samples were cold pressed for 5 min at room temperature.

Mechanical properties. The flexural test was done by using Instron 3365 machine with the application of 3-point bending method base on ASTM-D790 standard test procedure. The specimens were tested with a crosshead speed of 3 mm/min and load cell of 5 kN and span of 50 mm. While Instron 9050 was used for the impact test by applications of 2.75 J pendulum arm.

III. Results and Discussion

Effect of fiber loading and size on flexural strength. It was observed in Fig 1. that flexural strength increased as fiber loading increased. These differences in flexural strength were due to fiber sizes. This could be attributed to the contribution provided by high strength millet husk fibers. This again, is only possible if there is stress transfer from matrix to fiber through a fairly strong interfacial bond. Bond cleavage leading to failure is not obtained in bending test as the maximum strain applied is only 5 % [9]. It could be inferred that 5 % strain was insufficient to cause a failure. Hence, in the case of flexural strength, interfacial interaction between millet husk fibers and HDPE matrix had only served to transfer stress. Further improvement in the strength might be brought by increasing millet husk fiber loading above 40 %

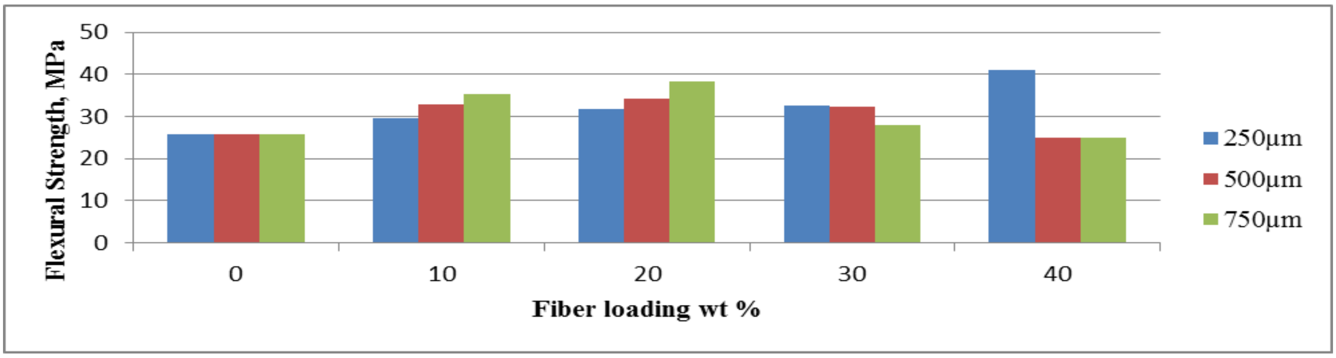

Fig 1. Flexural strength of MH–HDPE composites at various fiber loadings and size.

Effect of fiber loading and size on flexural modulus.

The flexural modulus was found to increase with increasing fiber loading as can be observed from Fig.2. Further, this could be attributed to the contribution made by fibers to impart its own property to the composite. The increase in the flexural modulus became pronounced for loadings greater than 10 %. Maximum flexural modulus of about 1988 MPa was achieved at 40 % fiber loading of 250 µm fiber sizes which amounted to about 64 % more than 0 % HDPE. The larger fiber size (750 µm) showed great increase in modulus at higher loadings, but had lower flexural modulus at loadings below 10 %

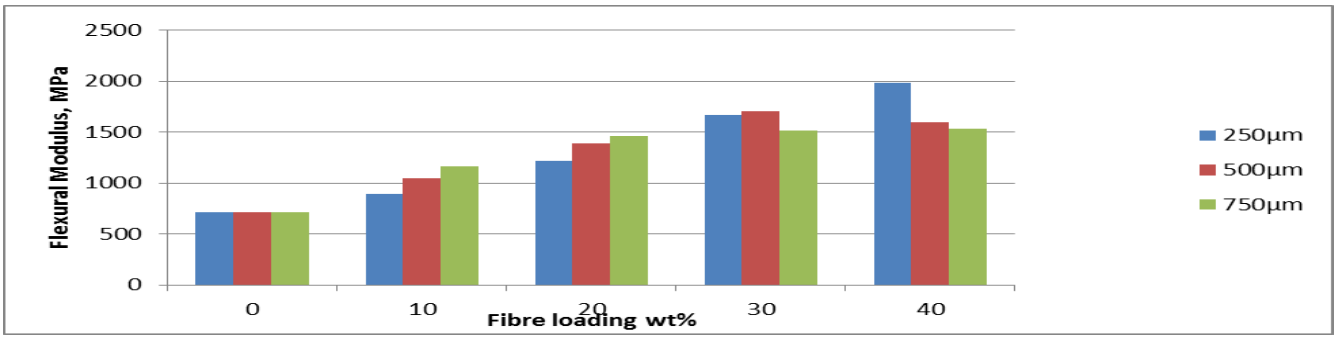

Fig. 2 Flexural modulus of MH–HDPE composites at various fiber loadings and size.

Effect of fiber loading and size on impact strength. MH-HDPE composites impact rates show that increase in fiber loading causes reduction in impact strength of the composites considerably for all fiber sizes. It is probably that this decrease is as a result of increased in fragility of the polymer matrix, because MH fiber concentration increased, so also plastic behavior of polymer matrix decreases. Hence from this study, toughness of MH-HDPE composites is dependent mainly on the stress-strain behavior of composite. Furthermore, impact strength of the unfilled HDPE composites is much higher than the MH-HDPE composites [10]. Although the fiber size play very little role in the impact properties of the composites.

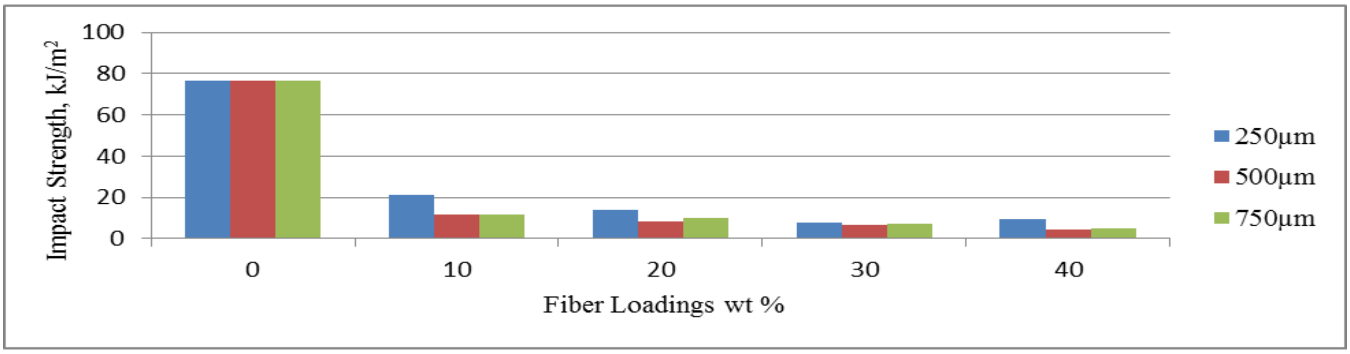

Fig. 3 Impact strength of MH–HDPE composites at various fiber loadings and size

Microstructures observation by scanning electron microscope (SEM)

The microstructure revealed formation of voids at the MH-HDPE interfaces from the SEM image (a). When strained these voids or fiber pull-out coalesce and lead to fracture of break. The fiber pull-out advanced with MH concentration hence decreasing the elongation at break. From the SEM images (b), it was revealed that small size fibers did not play important role in bringing about fracture. But at 10 % loadings, there were better dispersion of MH-HDPE formation with reduced fiber pull out and breakage. This is the main reason for improvement of bending strength at 10 % loadings for 250 µm fiber sizes.

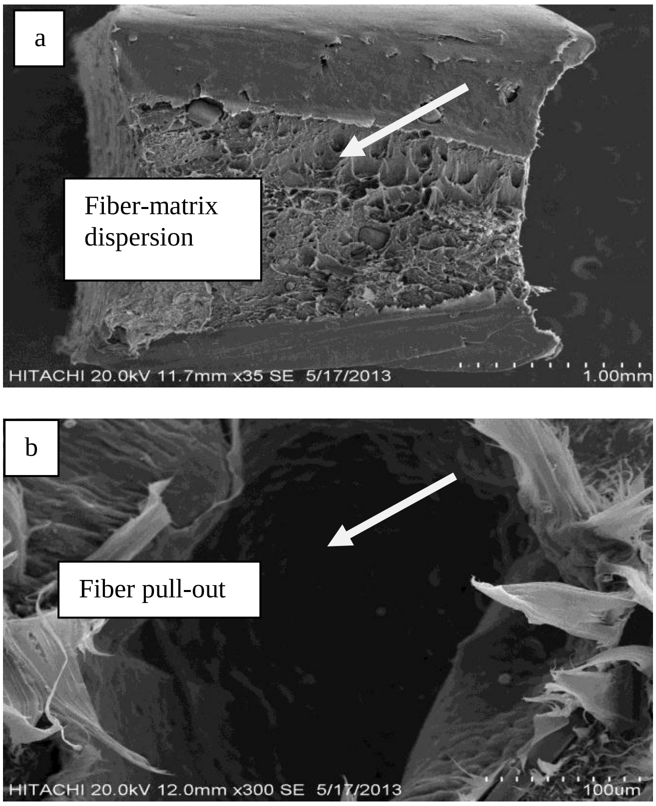

Fig.4 SEM Fractomirographs for Samples with Various Fibers loading; (a) 10 % (250 μm)

IV. CONCLUSIONS

From the above analysis, it was observed that increasing fiber loadings lead to increase the bending strength and modulus of the MH–HDPE composites. Consequently, impact strength decrease with increase in fiber loading, this is due to weak adhesion between MH and HDPE as seen from the SEM microstructure.

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