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Short Communication

Effect of load on the wear behaviour of polypropylene/carbonized bone ash particulate composite

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ABSTRACT

The effect of applied load on the wear behaviour of polymer matrix composites produced using carbonized bone particles (CBp) as reinforcement has been studied. The addition of the CBp ranges from 5 to 20 wt% in the polypropylene matrix. The composites were produced by compounding and compressive moulding. The wear test was conducted by varying the applied load from 5 to 15 N. Microstructures of the worn surface were assessed with high resolution scanning electron microscopy (HRSEM/EDS). The wear rate increased with increases in applied load from 5 to 15 N and decreased with increasing in CBp from 0 to 15 wt%. The work has established that carbonized bone can be use in increasing the wear resistance of polypropylene composites.

1. Introduction

The use of composites as another class of engineering materials is very vital to the success of any industrialized nation. Numerous research institutes adopted the challenge of developing and improving the existing composites. Record available shows that the present global consumption is continually increasing [1,2].

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Aigbodion et al. [3] studied the tribological behaviour of recycled low density polyethylene (RLDPE) polymer composites with bagasse ash particles were studied using a pin-on-disc rig. There results showed that the addition of bagasse ash in RLDPE composites increased the wear resistance of the composite.

Vishwanath et al. [4] reported on wear of both polyester and phenolic reinforced glass fibre composites. They observed that in both case of composites 30 wt% of resin gives low wear and coefficient of friction, also with resin beyond 30 wt% resulted to a higher wear rate.

Unal et al. [5] studied pure polytetrafluoroethylene (PTFE) and its composites and noted that with increase in load the friction coefficient decreased. In case of wear rate, maximum reduction occurred with 17 wt% glass fibre reinforced PTFE. Also it is reported that adding fillers such as carbon and bronze along with PTFE, reduction in wear rate was found to be better.

Suresha et al. [6] reported that increase in sliding velocity/load increases the sliding wear loss. In particular, the sliding wear behaviour of 10 wt% graphite filled glass epoxy composites was better when compared to unfilled and lower graphite filled carbon fibre reinforced epoxy composites.

Nagaraju et al. [7] carried out wear studies on polyester resin filled with ZnO nano particles. It is shown that the addition of filler graphite improves the wear resistance to a much greater extent along with glass fibre reinforced epoxy composites when compared with other sample combinations.

Basvarajappa et al. [8] carried out wear studies on glass fibre reinforced epoxy composites along with fillers of SiC and graphite. The wear resistance of the composites increases by the addition of fillers to a greater extent. In addition using Taguchi approach the optimal parameters on the wear studies were reported. It is also reported that load and sliding distance were the factors that influence the wear more rather than the sliding velocity.

Mahapatra and Vedansh Chaturvedi [9] studied the abrasive wear behaviour of untreated sugarcane reinforced polymer composite and developed empirical model using neural network. Also using Taguchi method the optimal parameter of wear was reported.

Atuanya et al. [10] reported on the empirical models for estimating the thermal and wear properties of developed composite material from recycled polyethylene/Breadfruit seed hull ash particulate (BFSHAp) composites. There results obtained showed that for the thermal analysis the temperatures of weight loss range from 10 to 100%. The wear rate, the sliding speed ($p = 0.0021$), applied load ($p = 0.0060$), BFSHA $p(0.0060)$ has the great influence on the wear behaviour of the developed composites. The interaction between applied load/BFSHAp (0.0061) also has an influence on the wear.

Recent publication of the author and his co-workers [11] studied the effect of bone powder on the physical and mechanical properties of polypropylene composite. From this survey it is clear that work on wear behaviour of cow bone powder has not been reported by researchers. Hence an investigation is prepared to carryout experimentation on wear behaviour of carbonized bone particles reinforced polymer composites.

2. Materials and method

2.1. Materials

Polypropylene, cow bone (carbonized), set of sieves, hacksaw, wear tester, two roll mill, hydraulic press, crucible furnace and scanning electron microscope.

2.2. Method

Cow bones (limb bones) were washed and cleaned. The bones were carbonized in a crucible furnace at 550 °C for 45 min [6]. Bone crusher was used to crush the bones to particles size (≤2 mm) and ground to ≤1000 μm by replacing crusher sieve with 1 mm sieve. Sieving was done using set of sieves having mesh sizes of 1000, 750, 500, 250 and 100 μm diameter to obtained small particle size. After sieving, the under size of 100 μm was used as reinforcement.

Compounding was done not only to mix but also to ensure intimate mixing of composite forming constituents. The two roll mill machine, was switched on and set for preheat to a temperature of 180 °C for 1 h [4]. The polypropylene (Fig. 1a) was introduced when the two rolls were just closed by regulating the gap between them. After two minutes, measured amount of CBp (5, 10, 15 and 20 wt%) were introduced (Fig. 1b). The mixture was left for eight minutes to achieve effective homogenization. The mixture was then ejected and allowed to cool. The blend material was pressed using hydraulic press at elevated temperature (≈180 °C). The compact was removed while still hot to obtain smooth surface (Fig. 1b).

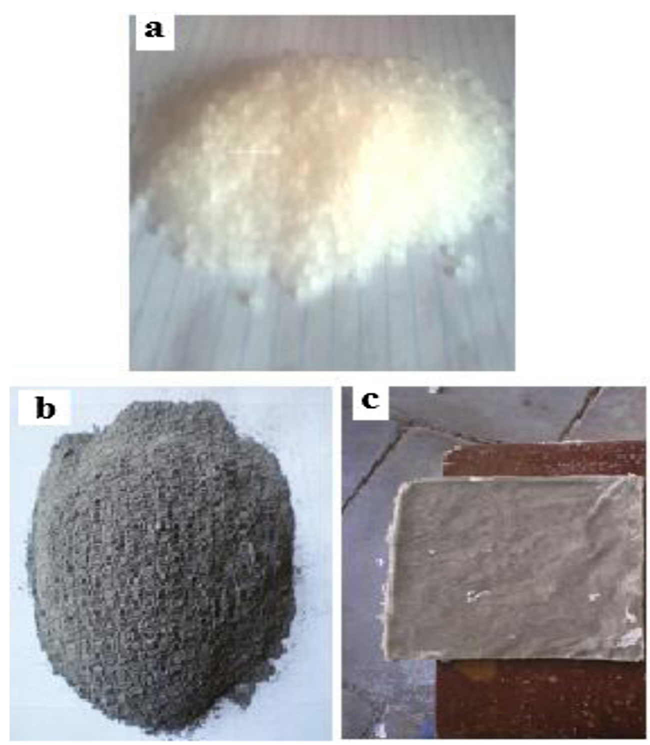

Fig. 1 – Photographs of a) polypropylene, b) carbonized bone powder (CBp), c) pressed PP/bone composite.

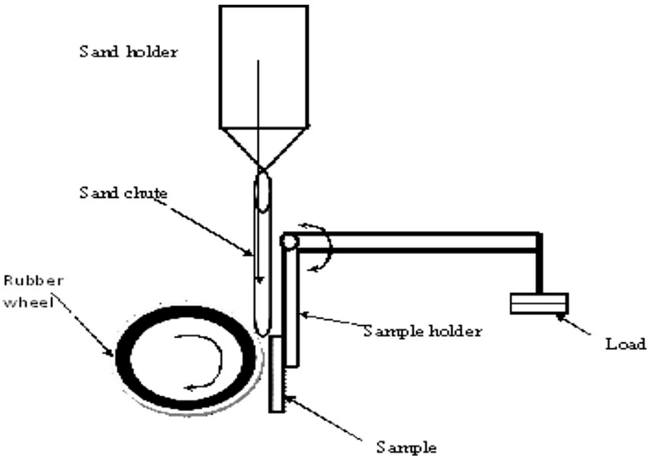

Fig. 2 – Three body abrasive wear test machine.

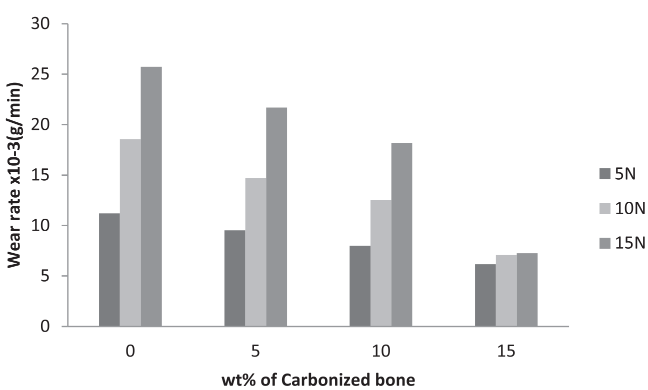

Fig. 3 – Comparative variation of wear rate under different load.

Three body abrasive wear tests were performed accordance with ASTM-G65 dry sand rubber wheel apparatus. Silica sand procured from Rolfes Silica with a particle size distribution between 300 and 600 microns was used as the abrasive material at a flow rate of 6.93 g/s [7,8]. Applied load of 5, 10 and 15 N with 250 rev/min rotational wheel speed were employed. The schematic diagram of the wear tester is shown in Fig. 2. The worn surface were examined using high resolution SEM/EDX (Model no. Joel JSM-7600F) [8].

3. Results and discussion

From Fig. 3, it was observed that the wear rate increased with increasing applied load and decreased as the CBp increased. E.g. wear rate of the composites at applied load of 5 N were 11.2×10^{-3} g/min and 6.16×10^{-3} g/min at 0 wt% and 15 wt% CBp respectively. As load was increased heavy noise and vibration were observed during the process and transfer of the pin material to the disc.

When load is low, the wear loss is quite small and increases with increased in applied load. It is quite natural for the wear rate to increase with applied load. A similar trend was observed independently for different wear distances as a function of load and speed [3–6].

The wear rate increased with increasing applied load and decreased with increasing weight percentage of the carbonized bone filler material. This may be due to the reason that addition of CBp resulted in a pronounced drop in ductility accompanied by an increase in hardness values [7,8].

The decrease in wear rate of the carbonized bone composites may also be attributed to higher load bearing capacity of hard material and better interfacial bond between the particle and the resin which reduced the possibility of particle pull out which resulted in higher wear [4–6].

From Figs. 4,5, It can be seen that the polypropylene matrix form a good thin and uniform transfer film (see Fig. 4). In the case of composite (see Fig. 5) there were some disruptions of transfer film for carbonized bone particles which has affected the wear rate performance. The worn surface of the

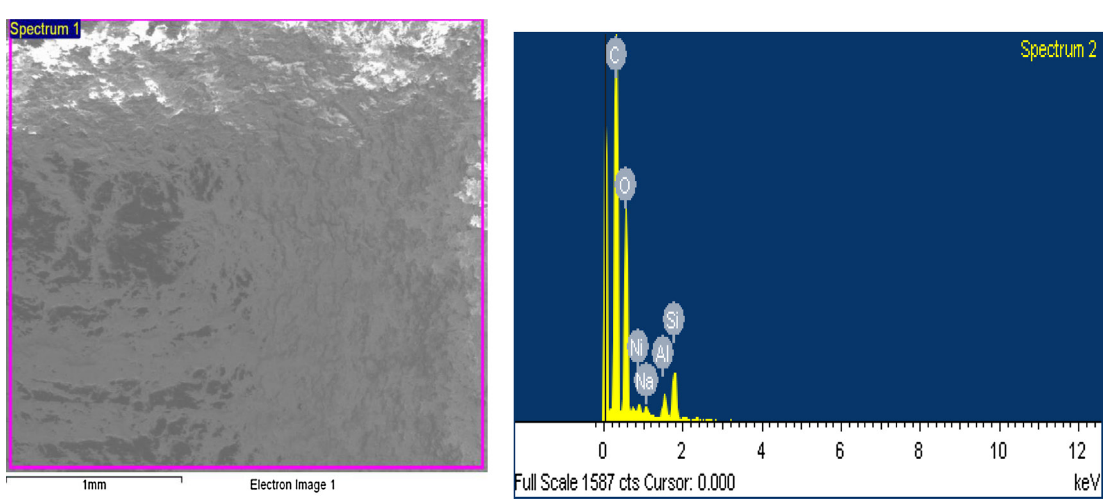

Fig. 4 – SEM/EDS micrograph of the worn surface of the polypropylene matrix at 15 N (×500).

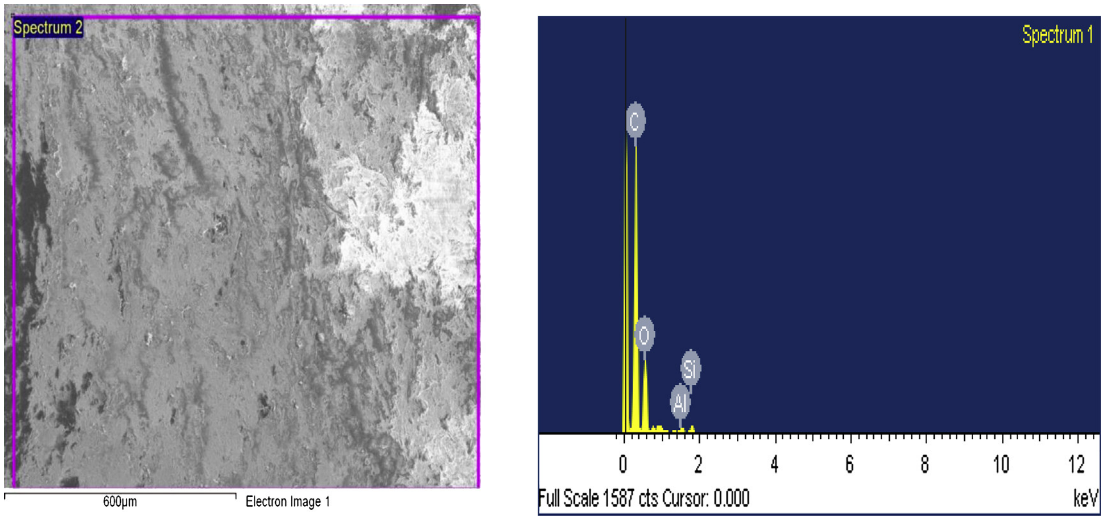

Fig. 5 – SEM/EDS micrograph of the worn surface of the polypropylene matrix with 15 wt% carbonized bone at 15 N (×500).

materials could be described as classical wear, as defined by [4–6]. The transition in wear rate observed in many polymer matrix composites is faster and believed to be the result of voiding/cracking between the reinforcement and the matrix, both of which lead to fragmentation and delamination of the surface [9].

The presence of carbonized bone particles in polypropylene matrix lowered the wear rate (see Figs. 4,5). This may be attributed to the fact that the composite materials are harder than the polypropylene matrix. Various researchers [8–10] have predicted that the presence of hard filler materials in polymer materials increases the dry sliding wear resistance. Also the decrease in wear rate of the composites may also be attributed to higher load bearing capacity of hard reinforcing material and better interfacial bonding between the particle and the matrix reducing the possibility of particle pull out which may result in higher wear [10].

4. Conclusions

From the results and discussion above the following conclusions can be made:

1. The incorporation of the carbonized bone particles in the polypropylene matrix as a reinforcement increases the wear resistance of the material.
2. The wear rate increased with increases in applied load from 5 to 15 N and then decreased with increased of carbonized bone particles from 0 to 15 wt%.
3. The work has established that carbonized bone particles can be use in increasing the wear resistance of polypropylene matrix composites.

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