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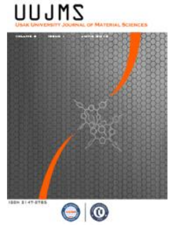

Research article

Evaluation of the wear and thermal properties of asbestos free brake pad using periwinkles shell particles

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Abstract

The use of asbestos fiber is being avoided due to its carcinogenic nature that might cause health risks. A new brake pad produced using periwinkles shell particles to replace asbestos and thermoset resin as a binder was investigated. The periwinkles shell particles were varied from 710-125 μm. The surface morphology, wear test and thermal analysis of the samples were examined. The results showed that there was good interfacial bonding as the particle size of periwinkles shell decreased from 710-125 μm. The wear rate increased as the load and periwinkles particles size increased. The co-efficient of friction obtained was within the recommended standard for automobile brake pad. The temperature of maximal decomposition of periwinkle shell was higher than asbestos and many agro-wastes currently used in the production of brake pad materials. It means that periwinkle shell can withstand higher temperature than asbestos. The results of this research indicated that periwinkles shell particles can be effectively used as a substitute for asbestos in brake pad manufacture.

Keywords: *Brake pad, morphology, periwinkles shell, thermal analysis and wear*

1. Introduction

Brake pads are important parts of the braking system of all types of vehicles that were equipped with disc brakes. Brake pads consist of steel backing plates with a wear resistance material bound to the surface facing the brake disc [1]. The generally consist of asbestos fibers embedded in the polymeric matrix along with several other ingredients. The use of asbestos fiber is avoided due to its carcinogenic nature. A new asbestos free friction material and brake pads have been developed. It is envisioned that future developments in the trend of brake friction materials will closely mimic the current trends in the automotive industry [2].

Although the use of asbestos for brake pads has not been banned, most of the brake pad industries are now moving away from asbestos brake pads because of concerns regarding airborne particles in the factories and the disposal of wastes containing asbestos. There are several patents for asbestos free organic friction materials [3,4].

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Changes in brake pads formulation were also driven by the promulgation of the corporate average fuel efficiency requirements in the late 1970's and mid 1980's. These requirements led the automobile industry to switch from rear wheel drive cars to front wheel drive cars. This switch required more front braking which resulted in higher temperatures and a preference for semi-metallic brakes [5-7].

A lot of researches have been carried out in the area of development of asbestos-free brake pads; Luo and Jang [8] studied the friction and wear of friction materials containing two different phenolic resins reinforced with aramid pulp, investigated the friction and wear characteristics of automotive materials containing two different phenolic resins (a straight resin and a modified novalac resin) using a pad-on- disk type friction tester. Smart and Chugh [9], worked on the development of fly-ash based automotive brake linings. They developed friction composite using fly ash obtained from a specific power plant in Illinois. Additives such as phenolic resin, aramid pulp, glass fiber, potassium titanate, graphite aluminum fiber and copper powder were used in the composite development phase in addition to fly ash. The developed brake lining composites exhibited consistent coefficient of friction in the range of 0.35 – 0.40. Peter *et al.* [10] worked on friction layer formation in a polymer composite material for brake applications. The characterization of the properties of polymer matrix composite friction layer was carried out. Satan and Bijwe [11] carried out a study of the friction materials based on the variation in the nature of organic fibers fade and recovery behavior. They investigated the influence of four selected organic fibers Viz, Aramid (AF), PAN (Poly-acrylo-nitrile), carbon (COF) and cellulose (SF), on the N-fade and N-recovery behavior. Dagwa and Ibhadode [6] developed asbestos free friction lining material from palm kernel shell. In the study the mechanical and physical properties as well as the static and dynamic performance was compared well with commercial asbestos-based lining material.

Recently Aku *et al.* [12] studied the characterization of periwinkle shell as asbestos-free brake pad materials**.** They found out that Periwinkle shell is an agricultural waste. The waste is produced in abundance globally and poses risks to human as well as the environment. Thus their effective, conducive, and eco-friendly utilization have always been a challenge for scientific applications. Those various results obtained are comparable with asbestos commonly used in brake pad product. The results confirmed that periwinkle shell can be used as a material for brake pad production. Based on the forgoing researchers that motivate this present work, which is the study of the wear and thermal behavior of asbestos free brake pad using periwinkles shell.

2. Experimental Procedure

The materials and equipment used during the course of this work were: Phenolic resin (phenol formaldehyde), periwinkle shell, Hydraulic press, Brake pad mold, Heater, Scanning Electron Microscope (SEM), Denver Cone Crusher, Denver Roll Crusher, Denver Ball Milling Machine, and a set of Sieves, Digital Weighing Machine and Pin on Disc Machine.

50 kg of weighed dried Periwinkle shell was sun dried, followed by oven drying at 105°C for 5 hours until the moisture was ensured to have greatly reduced towards zero percent. This was then charged into Denver cone crusher and was reduced to between 4 mm to 3 mm. This was further charged into roll crusher that now reduces the size of periwinkle shell to between 2-1 mm.

The product of roll crusher was transferred into ball milling machine and was left in the mill for 2 hours; after which the product was transferred into set of sieve of; +710 µm, +500 µm, +355 µm, +250 µm, +125 µm, and was sieved for 30 min using sieve shaker machine for 30 min. While the oversize at +710 m was returned or recycled for regrinding until it passes through the sieves.

XRD analysis of the periwinkle shell particles was carryout to determine the various element and phases distribution in the periwinkle shell particles. The test was carried out on a Philips X-ray diffractometer. The X-ray diffractograms was taken using Cu Kα radiation at scan speed of 3°/ min [7].

The Periwinkle shell sieve sizes of 125 µm, 250 µm, 335 µm, 500 µm and 710 µm, were mixed with the 35 wt% phenolic. Thirty test samples from each of the sieve size were then produced. Each composition was blended homogeneously in a mixer for a period of five minutes before transferring it to a mold kept at 225 lb at a temperature of 160°C for 1.5 h. The samples were post cured at 140°C for 4 h [4].

The microstructure and the chemical compositions of the phases present in the test samples were studied using a JOEL JSM 5900 LV Scanning Electron Microscope. The SEM was operated at an accelerating voltage of 5 to 20 kV. The test was carried out in University of the Witwatersrand, Johannesburg, South Africa.

A pin-on-disc test apparatus was used to investigate the dry sliding wear characteristics of the samples as per ASTM G99-95 standards [2]. Wear sample 20 mm in diameter and 40 mm high were used. The disc used was En-32 steel hardened to 62 HRC, 120 mm track diameter and 8 mm thick. The initial weight of the samples was measured using a single pan electronic weighing machine with an accuracy of 0.0001 g. During the test, the pin was pressed against the rotating disc. Wear tests were conducted with loads ranging from 392 to 1176 N, speed of 2.4 m/s and constant sliding distance of 500 m.

Thermal decomposition (TA) was observed in terms of global mass loss by using a TA Instrument TGA Q50 thermo gravimetric analyzer. The test was carried out in University of the Witwatersrand**,** Johannesburg, South Africa. The apparatus detected the mass loss with a resolution of 0.1 as a function of temperature. The samples were evenly and loosely distributed in an open sample pan of 6.4 mm diameter and 3.2 mm deep with an initial sample weight of 8-10 mg. The temperature change was controlled from room temperature (25±3°C) to 900°C with a heating rate of 10°C/min. High purity Argon was continuously passed into the furnace at a flow rate of 60 ml/min at room temperature and atmospheric pressure. Before starting of each run, the Argon was used to purge the furnace for 30 min to establish an inert environment in order to prevent any unwanted oxidative decomposition. The TG and DTA curves were obtained from TGA runs using universal analysis 2000 software from TA Instruments [4,5].

3. Results and Discussion

The XRD pattern (see Fig. 1) obtained reveal that, the major diffraction peaks were: 42.5°, 16.15°, 30.90°, 34.47° and 54.08° and their inter-planar distance are: 2.13 Å, 5.49 Å, 2.89 Å, 2.58 Å and 1.69 Å and phases at these peaks are: Magnesium manganese oxide, calcium silicate quartz and titanium oxide while each of these phases have a score shown in (see Table 1 and Fig. 2).

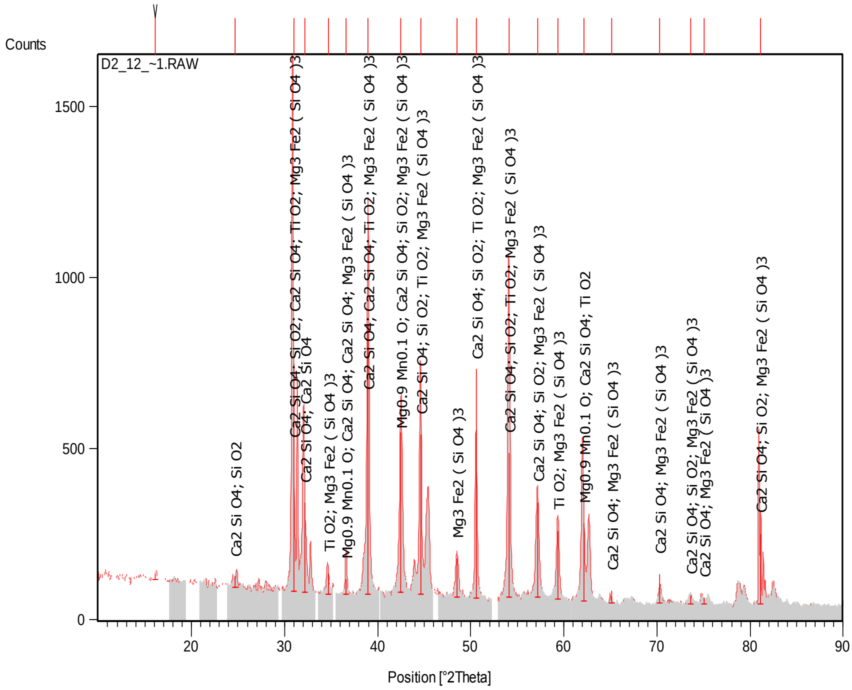
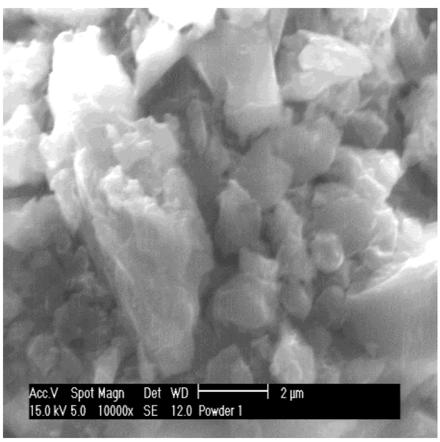
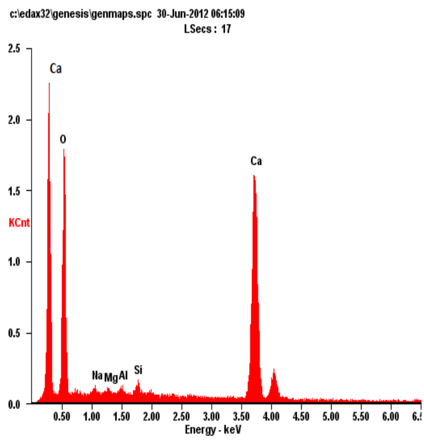


Fig. 1 XRD spectrum of Periwinkle shell particles

Surface Morphology of periwinkle shell particles is seen in back scattered electron (BSE) as shown in Fig. 2. Periwinkle shell particles were observed to be solid in nature, but irregular in size. Some spherical shape particles can also be seen in the Fig. 2. The chemical analysis of periwinkle shell particles morphology consists mainly of Ca, Fe, Si, Mg, and K as shown in the EDS scan (see Fig. 2). The results are consistent with XRD and XRF analysis of other biomass by [3,4].

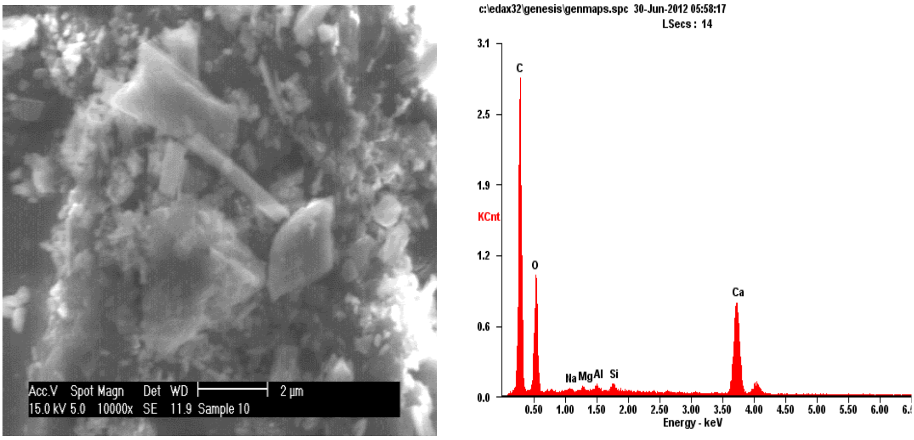




(a) (b)

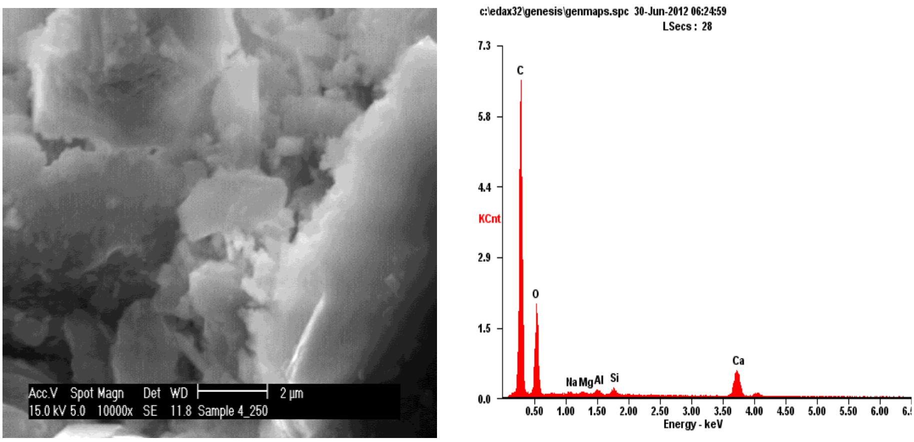
Fig. 2 SEM (a) and EDS (b) of the periwinkle shell particle

The SEM/EDS surface morphology of the developed brake pad materials were shown in Figs. 3,4. The resin is seen as a dark region along with periwinkle shell particles distribution in white region. From the SEM, it can be postulated in generally; the microstructures of the samples showed the homogeneous distribution as the sieve size of the periwinkle shell particles decreased (compare Fig. 3 with Fig. 4).



(a) (b)

Fig. 3 SEM (a) and EDS (b) microstructure of developed brake pad with 710 µm periwinkle shell particles



(a) (b)

Fig. 4 SEM (a) and EDS (b) microstructure of developed brake pad with 125 µm periwinkle shell particles

Good interfacial bonding between the resin and periwinkle shell particle was seen, this bonding increased as the particles size decreased. This is as a result of proper bonding between the periwinkle shell particles and the resin as the sieve grade decrease and closer inter-packing distance.

Fig. 5 shows the wear of the produced samples. The wear decreases as the particles size of the periwinkles decreased from 710-125 µm. This may be attributed to higher/closer packing of the microstructure which has affected stronger bonding of periwinkles shell particles with the resin.

The decrease in wear rate of the brake pad formulation may be attributed to high load bearing capacity and better interfacial bond between the particle and the resin, which reduced the possibility of a particle pull out which may result in high wear (see Fig. 5). The wear mechanism reported was adhesion and delamination [6,7]. This observation is in par with the work of Aigbodion *et al* [4]. It is well known that wear process involves fracture, tribochemical effects and plastic flow. Transitions between regions dominated by each of these commonly gave rise to changes in wear rate with load.

The positive effect of the periwinkles shell particles size in reducing the wear of materials can be seen. When load applied is low, the wear loss is quite small, which increases with increase in applied load. It is quite natural for the wear to increase with applied load. A similar trend was also observed independently for different wear as a function of load (20 N) and speed (5.02 m/s) [13,14]. Consequently, the effect of particles size on the brake pad composite wear resistance is better for low loads. With high loads contact temperatures become high and plastic deformation occurs with consequence of very high wear.

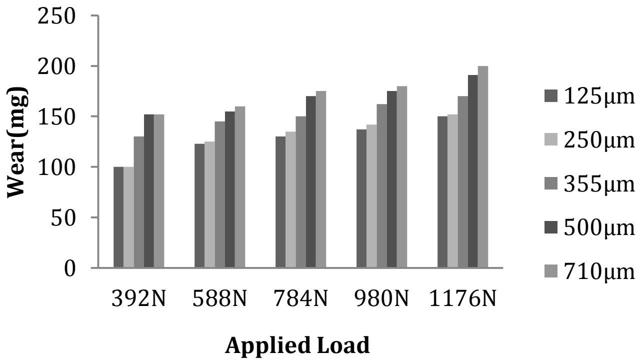


Fig. 5 Wear (mg) at varying load at constant speed 2.4 m/s, time 45 min at 250°C

Fig. 6 shows the variation of co-efficient of friction with different applied load. The co-efficient friction of the samples decreases as the applied load increases, and decreased with increased in periwinkles shell particles size.

The brake pads with 125 µm periwinkles shell particles size gave the greater friction coefficient than that of 710 µm periwinkles shell particles size. Increases in friction coefficient does not tend to have higher wear rate, the above results are consistent with the work reported by [14]. The friction coefficient fall within the industrials standard ranges of 0.30-0.45 for automotive brake pads system [14,15].

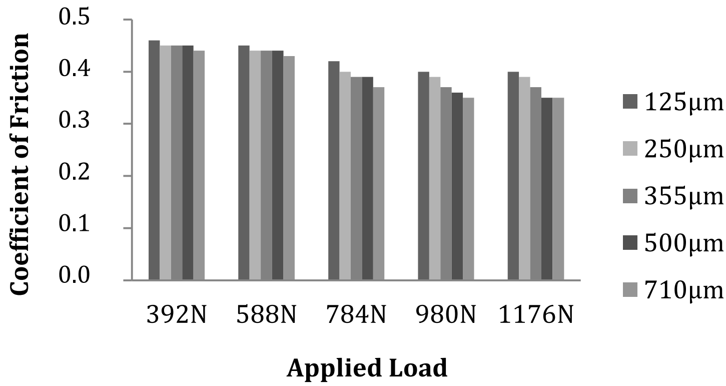


Fig. 6 Coefficient of friction at varying load at constant speed and time at 250°

The temperatures of destruction (T_{des}) of the periwinkle shell particles and the developed brake pad, subject to investigation, were determined from DTA/TGA curves. DTA/TGA data recorded on "Derivatograph OD 102", at heating rate of 10°C/min in argon. The results of the DTA/TGA scan of the periwinkle shell particles and developed brake pad were shown in Figs. 5-7. From the Fig. 5, the TG/DTA curve of periwinkles shell particles shown three weight loss steps, while the thermal decomposition occurs in one stage. The TG/DTA curve of developed brake pads showed three weight loss steps, while the thermal decomposition occurs in two stages (see Figs. 7-9).

The total burning and degradation of the residual resin (dehydrogenation) took place at temperatures interval of 200-300°C. The initial weight loss (~ 5%) observed between 100°C and 250°C is attributed to the vaporization of the water from the samples, while degradation of the sample started at higher temperature, precisely at 300°C - 400°C for the brake pads samples and 600°C for the periwinkles shell particles. Above this temperature, the thermal stability of periwinkle shell particles and developed brake pad gradually decreased and degradation of the sample occurred.

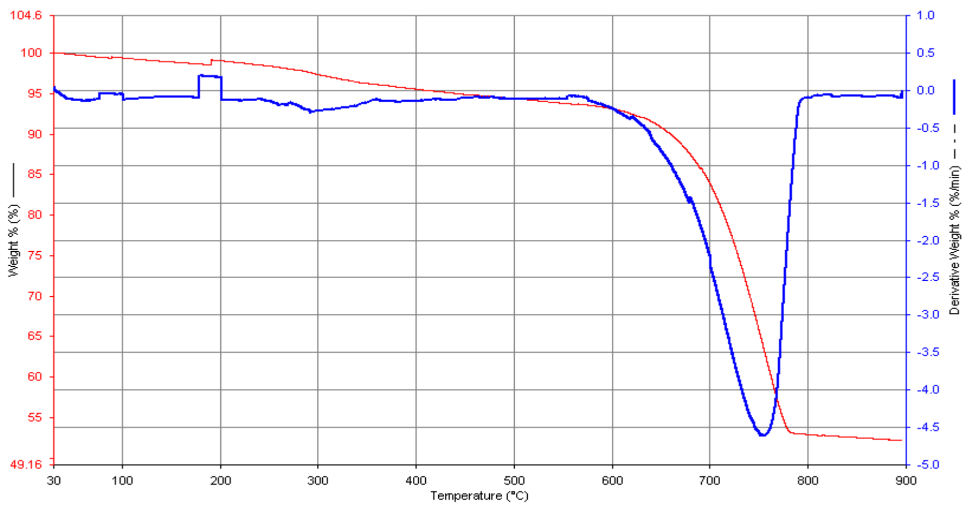


Fig. 7 DTA /TGA pattern of periwinkle shell particles

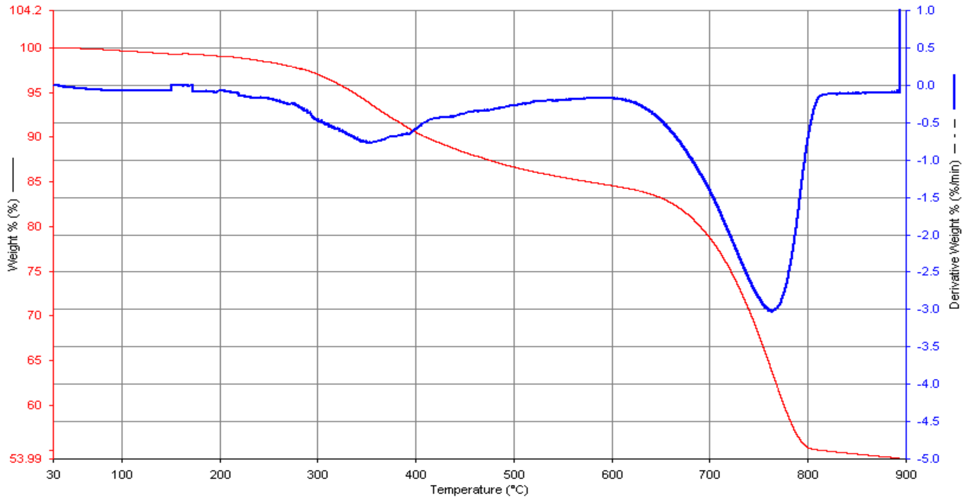


Fig. 8 DTA /TGA pattern of developed brake with 125 μm periwinkle shell particles

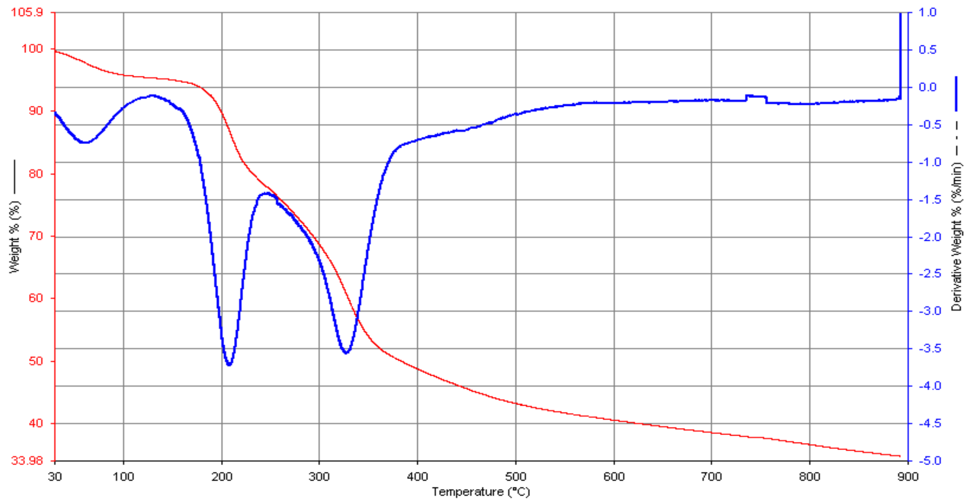


Fig. 9 DTA /TGA pattern of developed brake with 710 μm periwinkle shell particles

DTA curve showed that the temperature of maximal decomposition/ destruction were between 700°C -800°C for the periwinkles shell particles and developed brake pad at 125 μm (see Figs. 7 and 8) while that of developed brake pad at 710 μm were between 300°C -400°C (see Fig. 9). The presences of endothermic effects in the periwinkle shell particles and the brake pads samples were as results of two processes – dehydrogenation and evaporation of some non-cellulosic materials. This conclusion was confirmed by the decreased mass of the sample. In an inert atmosphere, the final products of the degradation of the samples consist in carbonaceous residues.

On the analogy of these results, it was assumed that the total burning/degradation of the residual samples took place in this temperatures interval of 700°C-800°C, in the last temperature interval the mass loss was minimal. The higher temperature of maximal decomposition of periwinkle shell than asbestos and many agro-wastes currently used in the production of brake pad materials means that periwinkle shell can withstand higher temperature than asbestos. Typical automotive brake lining materials are rarely subjected to temperatures larger than 389°C [1,3] but when such situation arises, it is not maintained for up to 90 min. Therefore, it is believed that the periwinkles shell-based brake pad will not degenerate under practical application temperatures and time duration.

4. Conclusions

From the results and discussion in this work the following conclusions can be made:

- Periwinkles shell particles brake pad was successfully developed using a compressive molding.
- There was good interfacial bonding as the particle size of periwinkles shell was decreases from 710-125 µm.
- The wear rate increases with increasing the load and periwinkles particles size.
- The co-efficient of friction obtained were within the recommended standard for automobile brake pad.
- The temperatures of maximal decomposition/ destruction were between 700-800°C for the periwinkles shell particles, developed brake pad at 125 µm and 300-400°C for 710 µm.
- The higher temperature of maximal decomposition of periwinkle shell than asbestos and many agro-wastes currently used in the production of brake pad materials means that periwinkle shell can withstand higher temperature than asbestos.
- The results of this research indicate that periwinkles shell particles can be effectively used as a replacement for asbestos in brake pad manufacture.

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