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FRICTION MATERIALS REINFORCED BY PALM FIBRES

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ABST RACT
The present work discusses the possibility of replacing the asbestos based friction materials by proposed friction materials free of asbestos to eliminate the health hazards caused by asbestos fibers which may cause asbestosis, mesothelioma, and lung cancer. The performance of the proposed friction materials consisting of fibrous reinforced organic and natural fibres such as date palm leaves, banana, coconut and sugar cane. Besides, the proposed composites contain barium sulphate, oxide, copper, iron, sand and phenolic resin. The friction and wear of the proposed composites have been investigated at different values of applied loads.

The experiments revealed that friction coefficient displayed by composites filled by rubber nanoparticles and reinforced by palm fibres (PF) displayed the highest values of friction coefficient. Minimum wear values were observed for composites reinforced by PF, while they showed the relatively highest friction values followed by coconut fibres for aluminium filled composites. The lowest wear was exhibited by composites reinforced by 40 wt. % PF. Composites filled by copper particles represented lower values of friction coefficient than that represented by aluminium filled composites, where minimum wear was observed for 20 wt. % PF reinforced composites. Besides, for composites filled by iron, PF showed relatively the highest values of friction coefficient and showed stable trend at fibre content ranging from 20 to 40 wt. %. Minimum wear can be obtained for composites reinforced by 20 wt. % PF.

KEYWORDS
Friction material, friction coefficient, wear, natural fibres, phenole formaldehyde, iron, copper and aluminium.

INTRODUCTION
Asbestos fibres reinforced friction materials were extensively used since 1905 because of the good properties of asbestos such as thermal stability, relatively high friction, reinforcing capability due to its morphology, and wear resistance. Asbestos based organic friction composites were proved to be health hazard. Efforts exerted by Environmental Protection Agency, [1], forced the friction composites industry to seek other fibres. In the last decade, a large number of asbestos free friction composites have been successfully formulated and patented.

Different friction materials free of asbestos were proposed to replace the asbestos due to the health hazards caused by its fibres which may cause asbestosis, mesothelioma, and

lung cancer. Asbestos free friction composites were proposed to replace asbestos based brake linings. The proposed friction materials are divided into non-toxic fibre reinforced organic, semi-metallic and metallic materials. A typical brake lining formula includes phenolic resin mixed with metal powder, inorganic fillers and fibers. Friction materials made of pure phenolic resin are poor in toughness. It was observed that, nanopowdered rubber can substantially improve properties of friction materials, [2, 3], where the friction coefficient varied steadily with the change of temperature, and the wearing rate of friction materials was relatively low by using nanopowdered rubber. Friction composites were reinforced by agricultural fibres of corn, palm, and sugar bars, [4]. It was found that, addition of agriculture fibres increased friction coefficient and decreased wear. Friction coefficient slightly increased, while wear drastically decreased with increasing fibres content.

Urea formaldehyde and phenol formaldehyde were used to manufacture laminated veneer lumbers from oil palm trunk, [5 - 8]. Phenol resorcinol formaldehyde bonding laminated veneer lumber showed relatively higher shear strength. The effects of fiber type, size, and content on mechanical and physical properties of HDPE was reinforced by natural fibers were investigated, [9]. It was found that higher fiber size produces higher strength and elasticity but lower energy to break and elongation. It was revealed that fiber-polymer compatibility can be enhanced by selecting suitable coupling agents, [10], where, fiber dimension, strength, variability, and structure are important factors. It was reported that differences in morphology, density, and aspect ratios across wood species account for varying reinforcement properties in thermoplastic composites.

Polypropylene was reinforced by date palm and coir fibres, [11 – 16]. Treated fibres showed better mechanical properties compared to the raw fibres, while composites reinforced by coir fibres had better mechanical properties than palm fibres. Low density polyethylene was reinforced by palm flax and hemp fibres, [17]. The physical and dielectric properties of the tested composites were studied. Fibres of oil palm bunch reinforced polyurethane were discussed, [18, 19]. Generally, the composites with treated fibres showed higher tensile and flexural properties than those without treatment.

The aim of the present work is to develop asbestos free friction composites reinforced by natural fibres such as date palm, coconut, sugar cane and banana. The proposed composites contain barium sulphate, aluminium, copper and iron particles ranging from 30 – 50 µm as well as phenolic resin as binder. The friction and wear of the proposed composites were investigated at different values of natural fibres content.

EXPERIMENTAL

Experiments were carried out using pin-on-disc wear tester. It consists of a rotary horizontal steel disc driven by variable speed motor. The details of the wear tester are shown in Fig. 1. The test specimen is held in the specimen holder that fastened to the loading lever. Through two thin spring steel sheets, where strain gauges are adhered, friction force can be measured. Friction coefficient was determined through the friction force measured by the deflection of the spring steel sheets by strain gauges. The load is applied by weights. The counterface in form of a steel disc, of 100 mm outer diameter, was fastened to the rotating disc. Its surface roughness was about 3.2 µm, R_a. Test specimens were prepared in the form of a rod of cylindrical cross section of 8 mm diameter and 30 mm length, Fig. 2. The test specimens were loaded against counterface

of cast iron disc (3.3 % C, 1.7 % Si, 0.7 % Mn, 0.3 % P, 0.1 % S and 93.9 % Fe) of 2000 N/mm^2 hardness.

Friction and wear tests were carried out under constant sliding velocity of 2.0 m/s and 20 N applied load. Every experiment continued 300 seconds. Wear was measured by the difference between the weights of test specimens before and after test using an electronic balance of ± 0.1 mg accuracy. All measurements were performed at 25 ± 5 ºC and 30 ± 10 % humidity.

Asbestos was replaced by the tested natural fibres such as date palm, coconut, sugar cane and banana. The fibres were dried in a furnace of 105 ºC temperature and cut in length up to 2.0 mm. The fibre content was 5, 10, 15, 20, 25, 30, 35 and 40 wt. %. Silicon oxide, aluminium, copper and iron in form of particles of (30 - 50) µm size were added to the composites, while the binding material was phenol formaldehyde. Styrene butadiene nanopowdered rubber of 0.1 – 0.5 µm particle size (25 wt. %) was added as friction modifiers. The concentration of the constituents, Table 1, was considered relative to the gross weight of the test specimen. Test specimens were prepared by the conventional powder metallurgy (P/M) process, which involved the steps of mixing, pressing and sintering. The compaction process of test specimens occurred at temperature of 130° C for 20 minutes. The compaction pressure was 1.7 N/mm^2. The two ends of the test specimens were polished before the test by cotton textile.

Rubber	Phenolic Resin	Metallic Content	Barium Sulphate	Silicon oxide	Natural Fibres
10 wt. %	20 wt. %	20 wt. %	10 wt. %	40 wt. %	0 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	35 wt. %	5 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	30 wt. %	10 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	25 wt. %	15 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	20 wt. %	20 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	15 wt. %	25 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	10 wt. %	30 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	5 wt. %	35 wt. %
10 wt. %	20 wt. %	20 wt. %	10 wt. %	0 wt. %	40 wt. %

Table 1 Constituents of the tested composites.

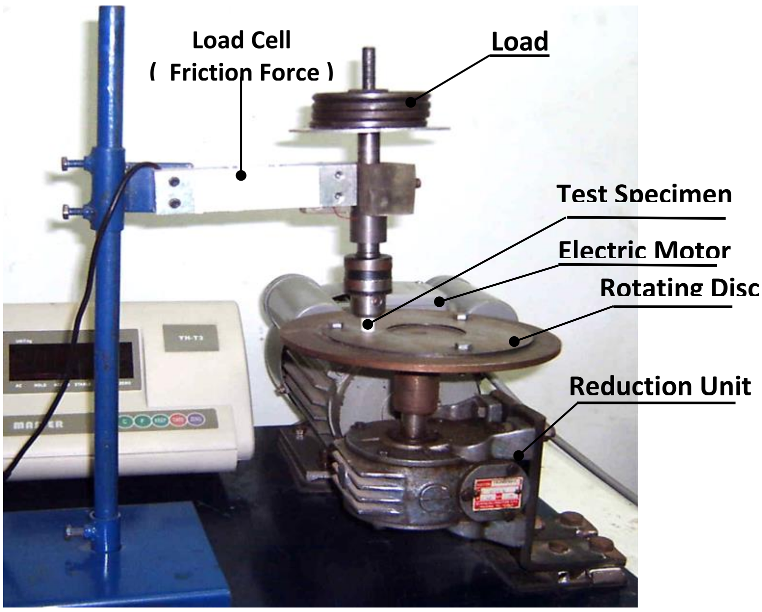

Fig. 1 Arrangement of the test rig.

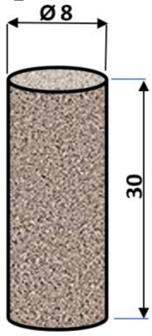

Fig. 2 Test Specimen.

RESULTS AND DISCUSSION

Friction coefficient displayed by composites filled by rubber nanoparticles is shown in Fig. 3. The highest values of friction coefficient were displayed by composites reinforced by PF followed by coconut then sugar cane while the lowest values were shown for banana fibres. The maximum values of friction coefficient reached 0.75. It seems that rubber nanoparticles were responsible for the relatively high friction values

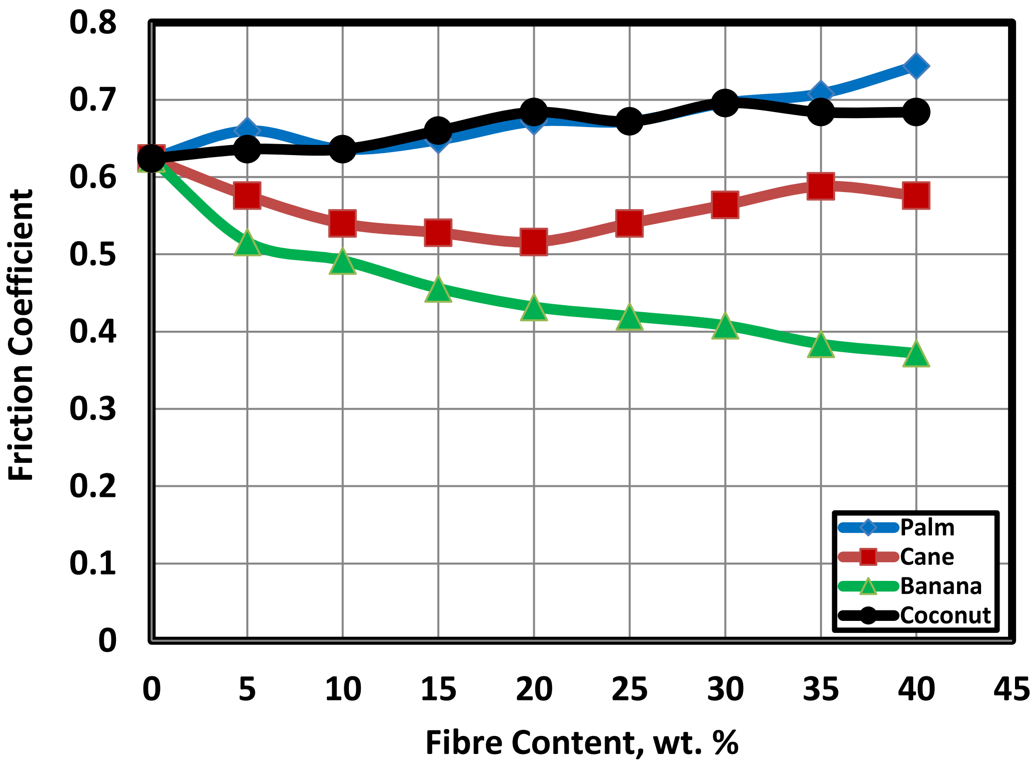

Fig. 3 Friction coefficient displayed by composites filled by rubber nanoparticles.

Wear of the tested composites is shown in Fig. 4. Minimum wear values were observed for composites reinforced by PF type followed by banana, coconut and sugar cane. It is shown that increasing fiber content decreases wear for palm and banana fibres, while

increases for sugar cane and coconut. The improvement in wear resistance observed for palm and banana fibres may be attributed to the ability of the fibres to stop the initiated crack growth in matrix of the composites. Besides, fibres reinforcement decreases the formation of flaws in the matrix and provides more uniform stress distribution in the matrix. On the other hand, the drop in wear resistance observed for sugar cane and coconut may be caused by fibres agglomeration which causes stress concentration that accelerates crack propagation.

Composites free of rubber nanoparticles showed lower friction values than that observed for composites filled by rubber, Fig. 5. Friction coefficient slightly increased with increasing fibres content for palm and coconut. Lowest friction values were displayed by composites free of fibres. In contradiction to that, banana fibres showed a decreasing trend with increasing fibres content, while sugar cane displayed consistent vales of friction.

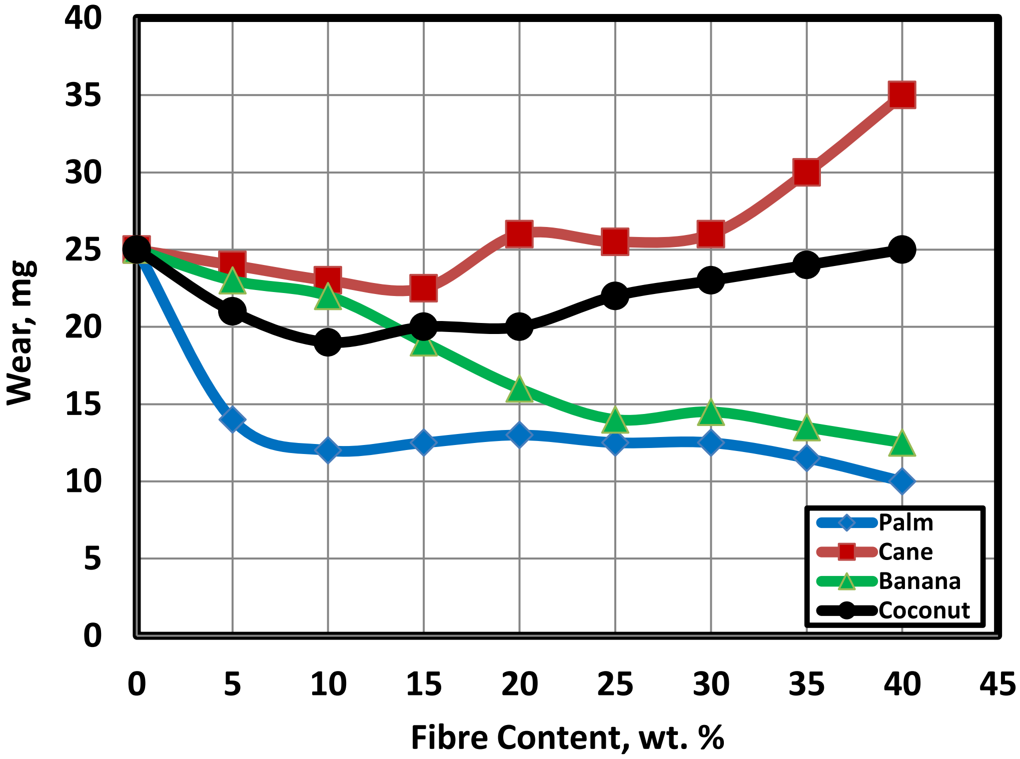

Fig. 4 Wear of composites filled by rubber nanoparticles.

Wear of composites free of rubber nanoparticles is shown in Fig. 6. Wear drastically decreased down to minimum than significantly increased with increasing fibres content. The minimum wear was observed for PF. Wear decrease may be attributed to the ability of the fibres to redistribute the stresses, where the matrix can withstand higher stresses. Besides, increasing interfacial bonding between the fiber and matrix will increase the capability of the fibre to be loaded and consequently the mechanical properties increase. The presence of fibres in matrix decreases the voids and cracks and increases the ductile behaviour. Wear increase may be attributed to the probability of fiber agglomeration which causes stress concentration that accelerates crack propagation due to the presence of voids around the fibres which decrease adhesion between fibres and matrix.

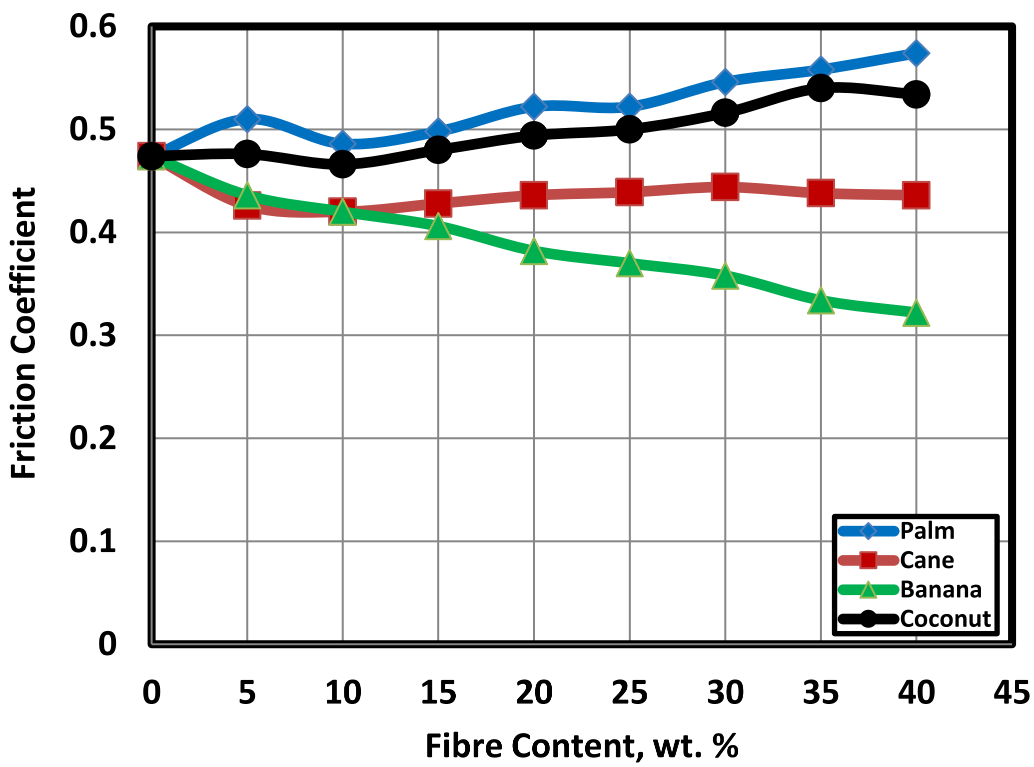

Fig. 5 Friction coefficient displayed by composites free of rubber nanoparticles.

The effect of addition of metallic content on the matrix of the tested composites is illustrated in Figs. 7 - 12. For aluminium, Fig. 7, friction coefficient experienced slight increase with increasing fibre content, where PF showed the relatively highest friction values followed by coconut fibres. The highest friction values was 0.63 for 40 wt. % PF content.

Wear of composites filled by aluminium is shown in Fig. 8. The lowest wear was exhibited by composites reinforced by 40 wt. % PF followed by coconut, banana and sugar cane fibres. Wear resistance can be improved by selecting the proper fibres content, where increasing the content would increase the probability of fiber agglomeration which causes stress concentration that accelerates crack propagation causing significant wear increase.

Composites filled by copper particles represented lower values of friction coefficient than that represented by aluminium filled ones. The maximum value of friction coefficient recorded during the test was 0.6 for PF of 40 wt. %, Fig. 9. It can be seen that friction coefficient slightly increased with fibres content for date palm and coconut fibres. The increase of friction coefficient can be attributed to the interaction of fibre materials into the steel surface. As for banana fibres, friction coefficient decreased with increasing fibres content. The decrease of friction coefficient may be from the sliding properties of the banana fibres.

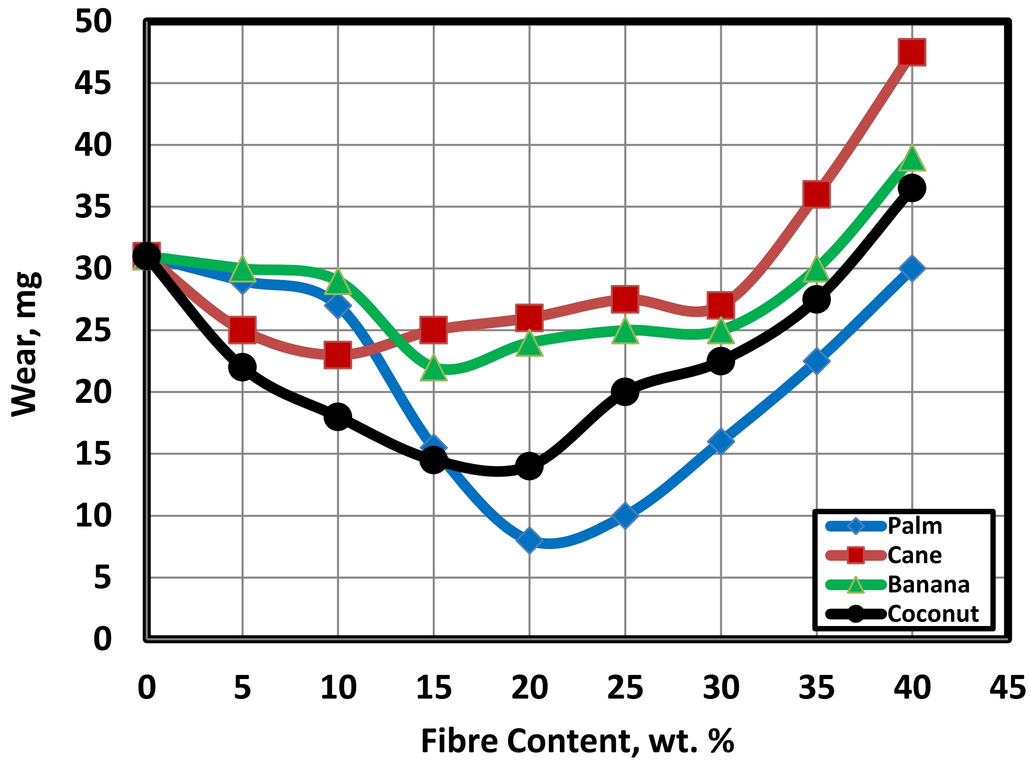

Fig. 6 Wear of composites free of rubber nanoparticles.

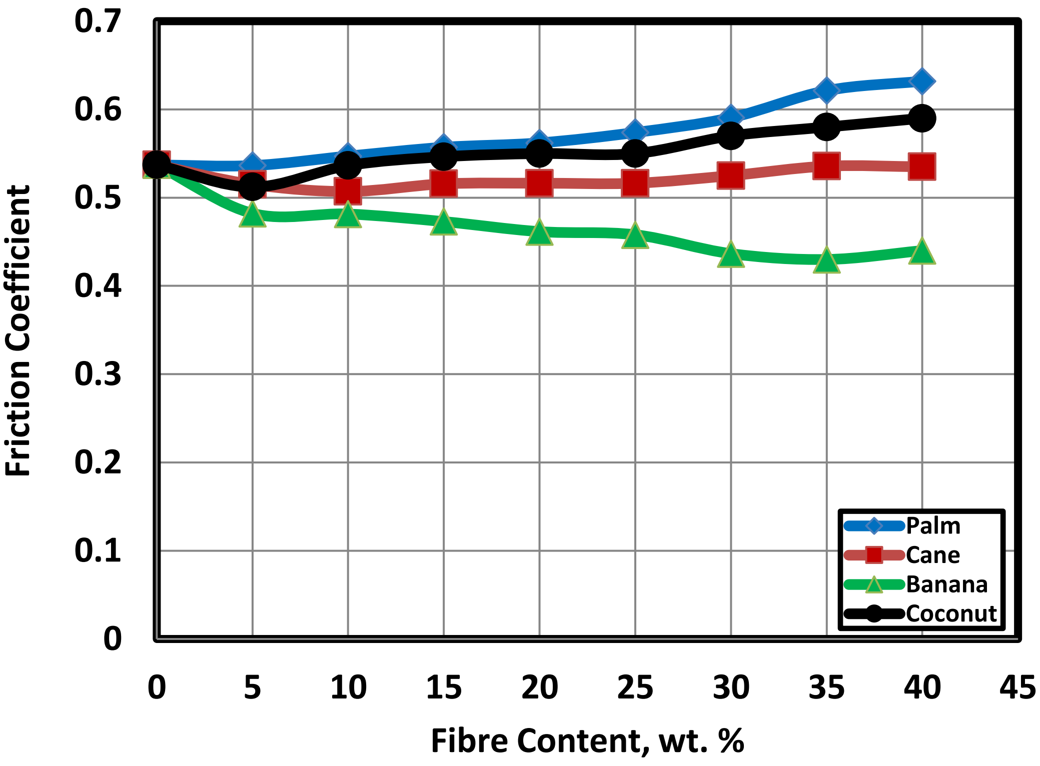

Fig. 7 Friction coefficient displayed by composites filled by aluminium.

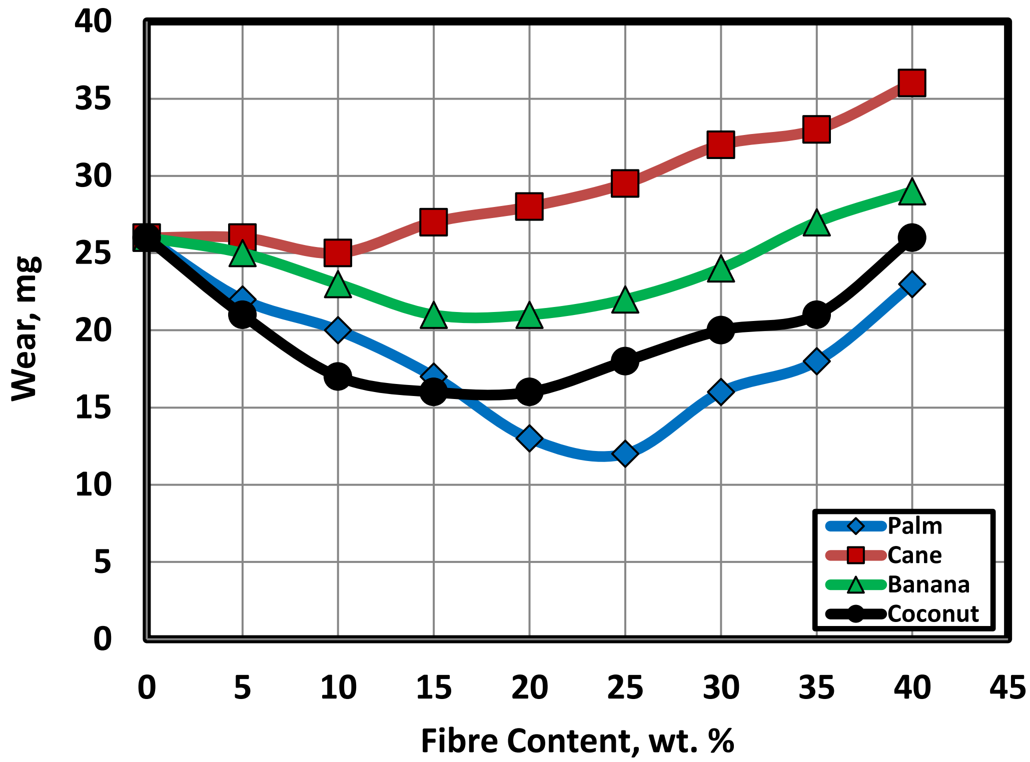

Fig. 8 Wear of composites filled by aluminium.

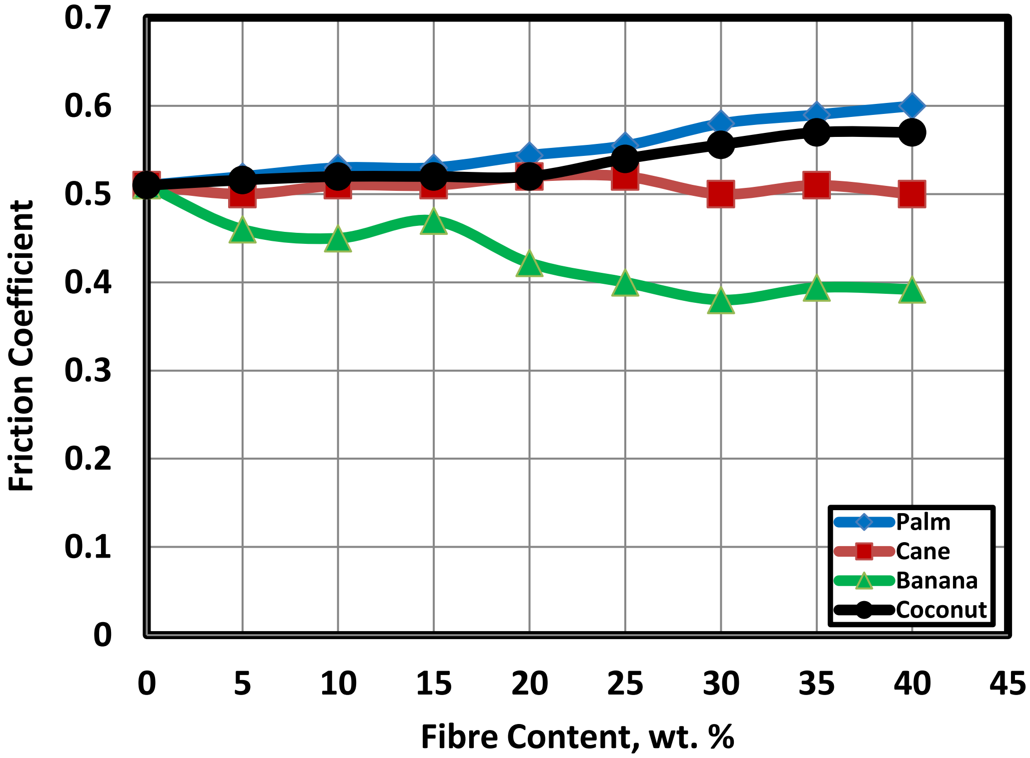

Fig. 9 Friction coefficient displayed by composites filled by copper.

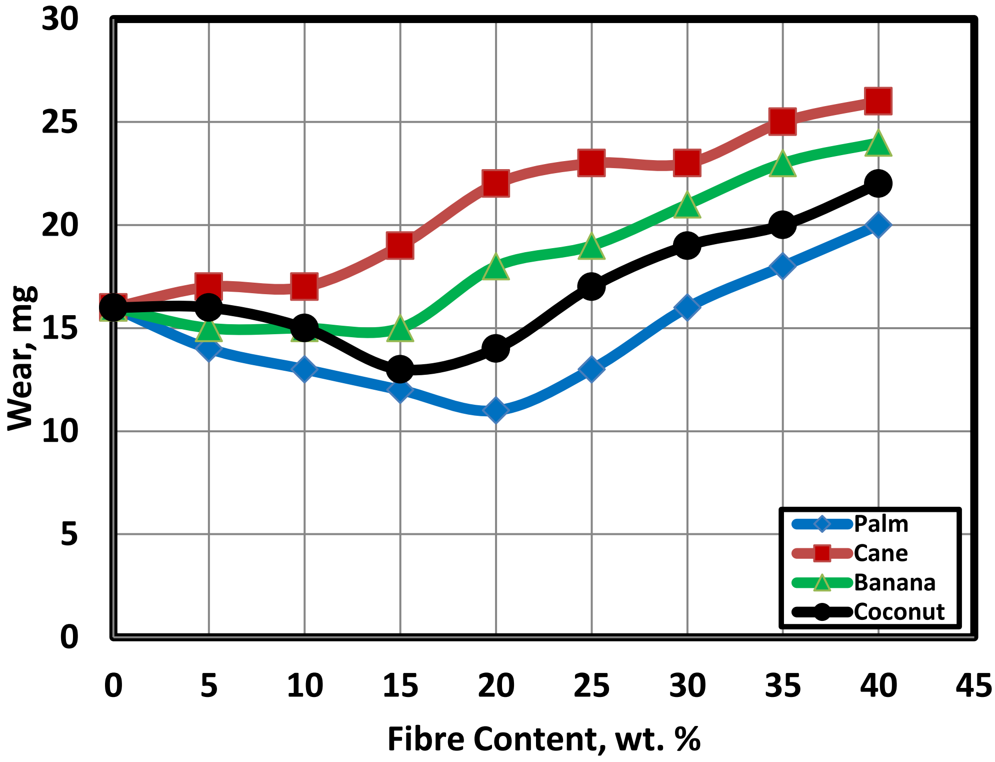

Fig. 10 Wear of composites filled by copper.

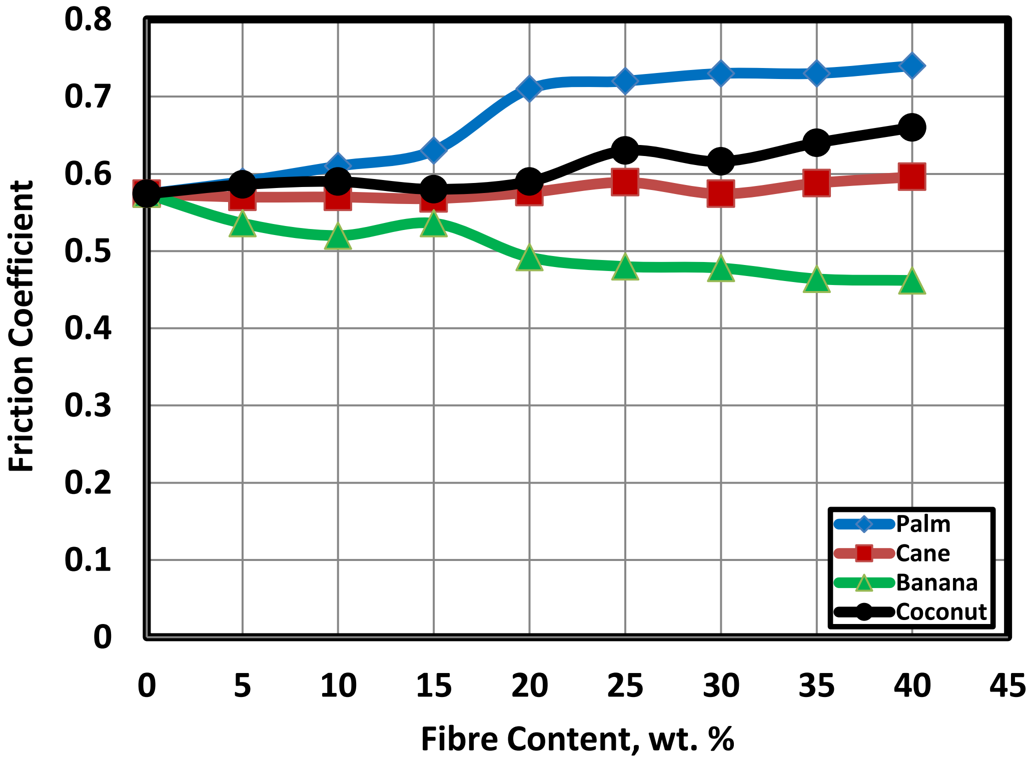

Fig. 11 Friction coefficient displayed by composites filled by iron.

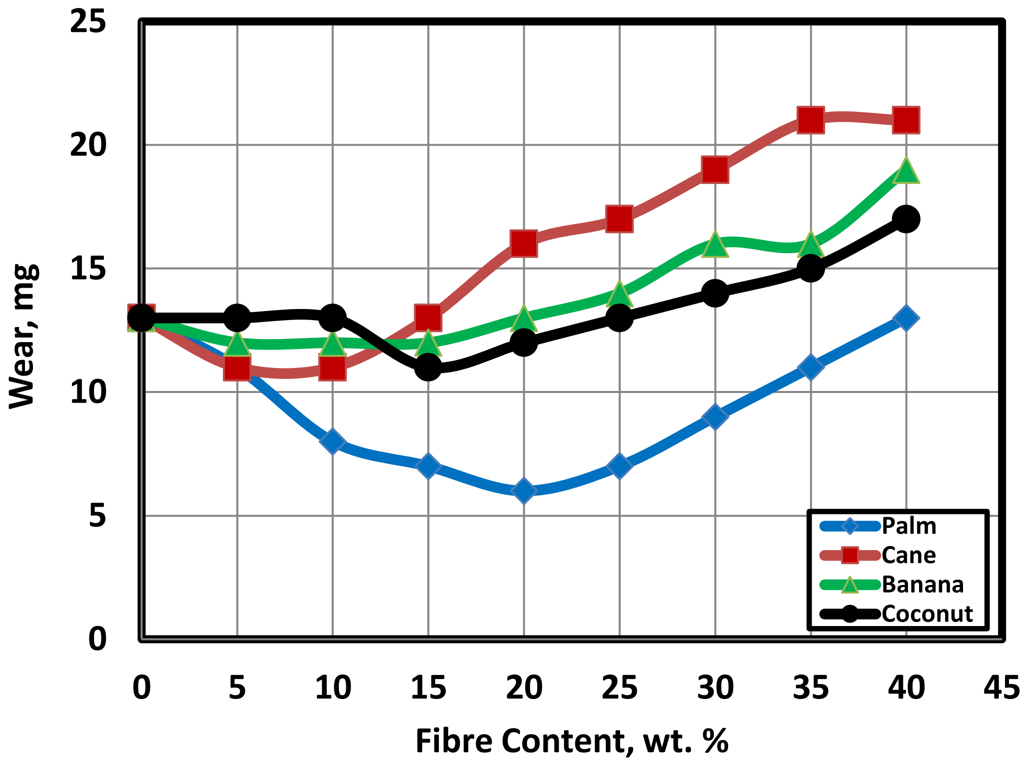

Fig. 12 Wear displayed by composites filled by iron.

Wear of composites filled by copper is shown in Fig. 10, where 20 wt. % PF exhibited minimum wear, while sugar cane displayed maximum wear. Wear reduction depends on the ability of fibres to redistribute the stresses, where composites can withstand higher stresses. Besides, increasing interfacial bonding between the fibres and matrix will increase the capability of the fiber to be loaded and consequently the mechanical properties increase. Copper filled composites showed lower wear than that recorded for aluminium filled composites.

Friction coeffficient resulted from the sliding of the tested composites filled by iron particles on the steel counterface is shown in Figs. 11. PF showed relatively higher values of friction than that displayed by the other tested ones, where maximum values of friction coefficient reached 0.74. Generally iron showed the highest friction compared to aluminium and copper. Also, friction coefficient showed consistent trend at fibres content ranging from 20 to 40 wt. %. Banana fibres presented the lowest value of friction coefficient.

Composites filled by iron displayed the lowest wear. Minimum wear can be obtained for composites reinforced by 20 wt. % PF. The favorite tribological behavior may be attributed to the interaction of iron particles into the cast iron counterface, where friction coefficient and wear resistance increased. The strengthening effect of the PF may be the reason for the enhancement due to the decrease of the flaws and gaps between fibres and the matrix.

CONCLUSIONS

1. Friction coefficient displayed by composites filled by rubber nanoparticles displayed the highest values of friction coefficient. Minimum wear values were observed for

composites reinforced by PF. Composites free of rubber nanoparticles showed lower friction values. Friction coefficient slightly increased with increasing fibres content for palm and coconut fibres. The minimum wear was observed for palm fibres.
2. For aluminium filled composites, PF showed the relatively highest friction values followed by coconut fibres. The highest friction values were 0.63 for 40 wt. % palm fibres content. The lowest wear was exhibited by composites reinforced by 40 wt. % PF followed by coconut, banana and sugar cane fibres.
3. Composites filled by copper particles represented lower values of friction coefficient than that represented by aluminium filled composites. Minimum wear was observed for 20 wt. % PF reinforced composites.
4. PF reinforced composites showed relatively higher values of friction than that displayed by the other tested ones when iron was the filler. Friction coefficient showed consistent trend at fibres content ranging from 20 to 40 wt. %. Banana fibres presented the lowest value of friction coefficient. Composites filled by iron displayed the lowest wear. Minimum wear can be obtained for composites reinforced by 20 wt. % PF.

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