EFFECT OF INGREDIENT PARTICLE SIZES ON SURFACE ROUGHNESS CHARACTERISTICS OF PKS BRAKE LINING

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ABSTRACT

Besides pad failure due to thermal damage, brake pads can also experience mechanical damage when they are exposed to a corrosive environment. A typical solid surface like a brake pad has a complex structure and complex properties depending on the nature of the solids, the method of surface preparation, and the interaction between the surface and the environment. The surface roughness of a novel friction linings prepared using varying palm kernel shell (PKS) powder particle sizes (0.300 mm, 0.425 mm and 0.850 mm) as reinforcements were investigated. The investigation was conducted via a profilometer dotted with a diamond stylus at a speed of 0.2 mm/s. The determined surface roughness parameters values were in ascending order with $S_{0.300}$ having the least values (Ra = 6.13 µm, Rz = 24.04 µm and Rmax = 37.3 µm) and $S_{0.850}$ having the highest values (Ra = 9.87 µm, Rz = 37.28 µm and Rmax = 53.8 µm). This was an indication that the roughness characteristics of the reinforced composite were associated to the presence of pulverised PKS particles. It was further shown by scanning electron microscope images that pulverised PKS grain sizes by nature have rough surfaces and this could have contributed to the overall roughness behaviour of the reinforced composite since PKS was the only ingredient with grain size variation in the experiment.

INTRODUCTION

Roughness, is a component of surface texture which is a collection of international standards relating to the analysis of surface roughness (1). It is quantified by the deviations in the direction of the normal vector of a real surface from its ideal form. If these deviations are large, the surface is rough; if they are small, the surface is smooth (1 - 3). Roughness plays an important role in determining how a real object will interact with its environment. Rough surfaces usually wear more quickly and have higher friction coefficients than smooth surfaces (3 - 5). Surface Texture standards support two evaluation methods: contact type (stylus method) and non-contact type (optical probe). In contact-type instruments, the stylus tip makes direct contact with the surface of a sample. The detector tip is equipped with a stylus, which traces the surface of the sample. The vertical motion of the stylus is electrically detected. Contact-type surface roughness testers provide reliable measurement, because they directly touch the sample. However, direct contact also causes disadvantages. Non-contact type instruments include atomic force microscopy, white-light interferometer, 3D laser scanning microscope (1, 6 and 7). Brake pads have rough surfaces and generally also low reflectance. A major reason for the lack of publications on the surface characteristics of brake pads, is the fact that the analysis is a difficult task to perform. The composition of the pad, the rough surface structure and the differences in mechanical properties of the different constituents all constitute obstacles for different measurement techniques (8 - 9). According to (8), the friction behaviour of automotive brakes is determined by the character of the active surfaces of the disc and pad and third bodies between these surfaces. In their work on tribological surfaces of organic brake pads, they used both a white-light interferometer to explore the surface contact of the brake pads and found that the tribological conditions of the pad material results in a rough surface, with a typical Ra-value of 2 µm. Neis et al. (10) investigated the different structures existing on the worn surface of a non-asbestos organic and low metallic brake pads using image segmentation based on a Matlab script. They identified deformable and non deformable primary plateaus as well elastic highlands on the surfaces of the brake pads. The surface morphology after burnishing of some commercial brake pads was examined using a laser confocal microscope by Lee et al. (11). The specimen showing narrow height distribution indicated a smooth surface. Atomic force microscopy was used by (12) to study the surface roughness of an unworn disk pad. An average roughness value of 70 nm (5 measurements) was arrived at and it was uniform compared to the other surfaces. Note that the above works were conducted on either polished samples or samples that had undergone wear test and none of them used a profilometer.

This work seeks to add to the body of knowledge of the information on the nature of the surface structure of a non-asbestos organic (NAO) brake pad treated as received from factory. Processes of sample preparation through polishing, finishing and even subjecting the sample to wear test inadvertently affect the initial structure of the surface and having surface texture information prior to those practice may be useful in further understanding subsequent behaviour of the material.

Because of the reliability of the contact type surface roughness tester, a profilometer with stylus is used in this work. .

NOMENCLATURE

Ra – Roughness Average.
Rz – Average Maximum Height of the Profile
Rmax – Maximum Roughness Depth

MATERIALS AND METHODS

The non-asbestos organic (NAO) brake pads used in this work were manufactured through powder metallurgy techniques as described in (13) and labeled **$S_{0.300}$**, **$S_{0.425}$** and **$S_{0.850}$**. Pulverised palm kernel shell was mixed with other ingredients at room temperature and the mixed cold pressed for 2 – 3 seconds at pressure of 0.4 – 0.6 MPa. The resulted preform was then hot pressed at 165 °C for 10 minutes (time within which there was 1 minute breathing) at a pressure of 20 MPa. Afterwards, the product was postcured for 2 hours at a temperature of 250 °C. Finishing and packaging then followed.

No prior treatment was done on the samples used as the work focused on as received from factory samples against most of the surface roughness works based on worn or polished brake pads. Samples of 10 mm width and 10 mm length (Figure 1) were cuts and used in the experiment. Figure 1 shows the complexity of the friction material with visible mixture of shiny metallic constituents and non-metallic particles within a polymeric binder.

Figure 1: Developed NAO friction lining cut into experimental size of 10 x 10 mm

Surfaces of the developed composites examined with the help of the scanning electron microscope showed a homogeneous distribution of ingredients as seen in Fig. 2. It is assumed the black, rough edges shaped material with varying sizes as indicated on the micrograph are the palm kernel shell particles as it was the only ingredient with varying size in the composites. Furthermore, it made up about 50% of the total mix. The resin used as binder and other ingredients are not easily visible and this may be attributed to the magnification.

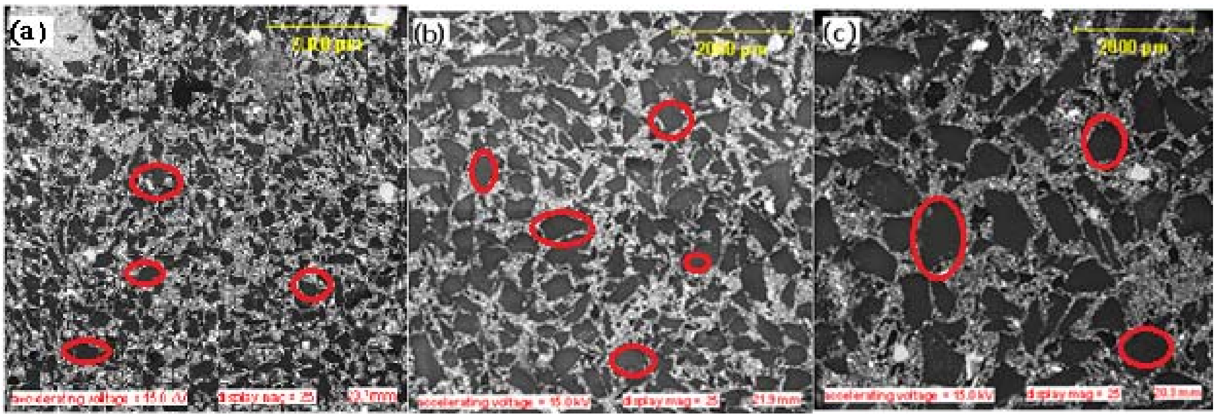


Figure 2: SEM micrograph showing various grain size particles of PKS included in the friction material composites (a) 0.300 mm (b) 0.425 mm (c) 0.850 mm (Fono-Tamo and Koya, 2017).

A Hommel-Etamic T8000 profilometer (Fig. 3) using a diamond stylus and connected to a desktop computer with an integrated software to plot the results was used for the roughness test. Various steps were followed to get the equipment running. Prior to running the roughness test, a coarse leveling adjustment of each sample needed to be done. This consisted of setting the specimen on the testing area, setting the stylus on the specimen and clicking coarse leveling on the test window opened on the computer monitor. Several runs were made and the assumed lowest reading on the micrometer was an indication that the specimen was sufficiently set for the roughness test. Thus the Run Test was clicked for the proper roughness test. The experimental conditions were such as transverse length was set at 2 mm while the speed was 0.2 mm/s. The test was replicated 3 times for each sample for proper representation and the average calculated.

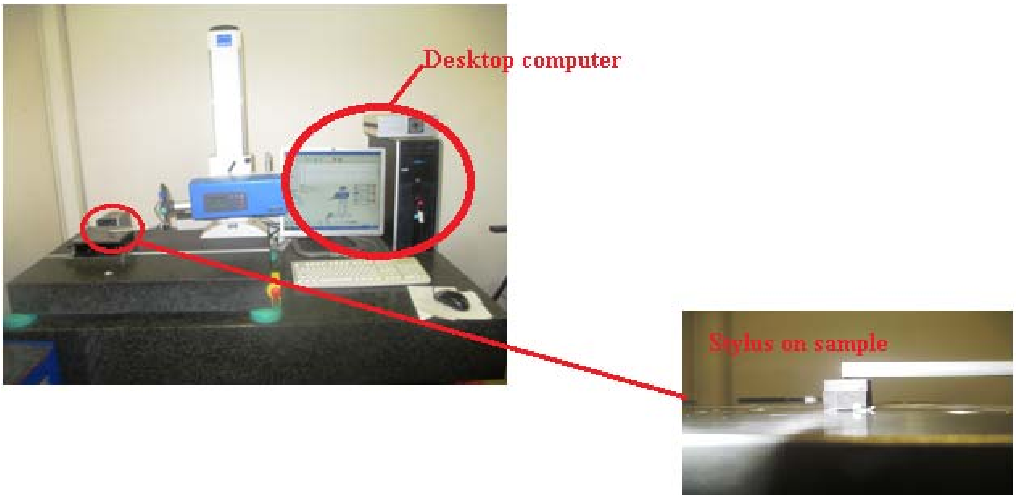
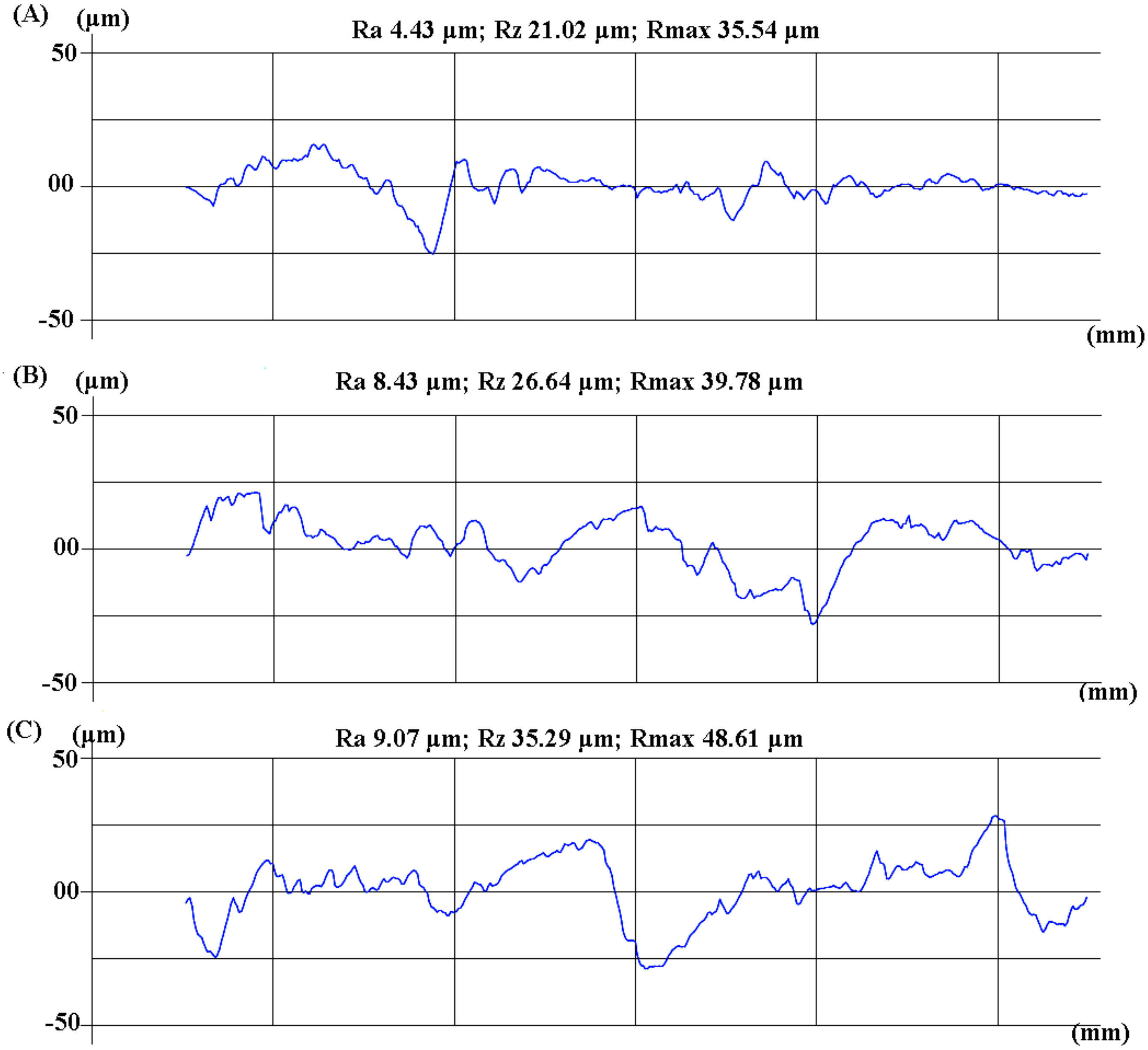


Figure 3: Experimental setup with stylus on sample

RESULTS AND DISCUSSION

Typical data acquired from the test of roughness parameters are the roughness average (Ra) which is defined as the arithmetic average of the absolute values of the profile heights over the evaluation length which is the most significant parameter, the average maximum height of the profile (Rz) and the maximum roughness depth (Rmax). Figure 4 shows the graph plot of some of the specimens tested with the profilometer. The first plot (A) appears smoother than (B) and (C) even though the beginning is rough. The picks in (B) and (C) are more obvious and extend on longer dimension on the lateral position of the graph.


(A) Ra 4.43 µm; Rz 21.02 µm; Rmax 35.54 µm

(B) Ra 8.43 µm; Rz 26.64 µm; Rmax 39.78 µm

(C) Ra 9.07 µm; Rz 35.29 µm; Rmax 48.61 µm

Figure 4: Profilometer plotting of surface roughness; (A) a run of $S_{0.300}$, (B) a run of $S_{0.425}$ and (C) a run of $S_{0.850}$

Detailed values derived including the calculated averages are represented in the Table 1. In this study, the obtained values of Ra, Rz and Rmax all show an ascending trend. For instance, **$S_{0.300}$** has the least value of Ra (6.13 µm) and thus can be considered the smoothest sample. Ra values for **$S_{0.425}$** and **$S_{0.850}$** are 8.40 and 9.87 µm respectively. Rz values for the samples follow an ascending trend as well with **$S_{0.300}$** again having the lowest value (24.04 µm) while those of **$S_{0.425}$** and **$S_{0.850}$** are 31 and 37.28 µm respectively. Values of Rmax are in the order **$S_{0.300}$** < **$S_{0.425}$** < **$S_{0.850}$**. This trend shows that the PKS particle size has a significant impact on the surface roughness of the pads meaning it can be a determining ingredient in the friction and wear of the composite. Literature has reported that narrower height distribution is associated with a smoother surface. This statement is true but when comparing the work of different authors, this becomes subjective. For instance, Eriksson and Jacobson (7) who worked on tribological surfaces of organic brake pads where they examined the tribological contact situation on a microscopic level classified the average roughness value of the pad (Ra = 2 µm) as rough when comparing it to that of the contact plateaus (Ra = 0.2 – 0.5 µm) and disc (Ra = 0.1 – 0.3 µm). Meanwhile, Lee et al. (11) categorized an average roughness value Ra = 2.04

µm of a commercial friction material as smooth when compared to other values obtained during the same experiment. It is therefore logical to say that although the average roughness values arrived at during the current experiment are much higher than that of Eriksson and Jacobson (7) as well as that of Lee et al. (11), the smoothness of the tested sample samples follow a logical trend whereby the sample with smaller grain sizes ($S_{0.300}$) is smoother with an average roughness value of 6.13 µm than others with Ra = 8.40 µm and Ra = 9.87 µm respectively ($S_{0.425}$ and $S_{0.850}$).

Table 1: Roughness parameters

	$S_{0.300}$			$S_{0.425}$			$S_{0.850}$		
	Ra	**Rz**	**Rmax**	**Ra**	**Rz**	**Rmax**	**Ra**	**Rz**	**Rmax**
Run 1	8.26	32.12	41.90	8.43	26.64	39.78	10.47	39.25	54.58
Run 2	5.72	18.98	34.41	6.89	24.90	31.10	10.07	37.29	58.18
Run 3	4.43	21.02	35.54	9.87	41.12	57.34	9.07	35.29	48.61
Averages	**6.13±1.95**	**24.04±7.1**	**37.3±4.03**	**8.40±1.5**	**31±8.9**	**42.74±13.3**	**9.87±0.72**	**37.28±1.98**	**53.8±4.83**

In general, the surfaces of palm kernel shell based friction lining seem rough when comparing the average roughness values to those found in the work of the previous authors. This could be justified by the fact that at the microstructure level, the surface structure of ground palm kernel grains is rough and presents some asperities as seen in the micrograph (Fig. 5). Furthermore, the asperities contributing to the roughness of the surface is usually the sum total of the ingredients embedded in the composite. Such ingredients somehow are part of the asperities thus making their sizes the determining factor for the roughness level of the composite. In this case, PKS grains are not left out and given the fact that it is the only ingredient in the composite that has varying grain sizes, one can say that its significantly contribute to the roughness behaviour. The increase of the roughness parameters as the grain size increases is an indication that PKS grain size has strong effect on the surface roughness of the composite.

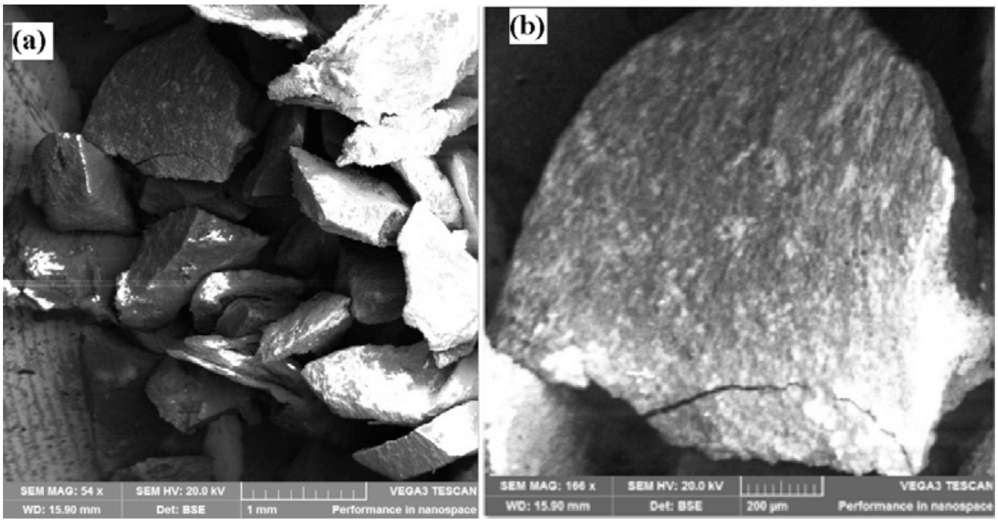


Figure 5: SEM micrograph of pulverised PKS seen at (a) 1 mm and 200 µm respectively.

This characteristic is thus manifested in the developed composite material. The direct implication of the studied composite having rough surface is that the coefficient of friction will be high which is a desired characteristic in friction material for automotive application. In the other hand, it may be disadvantageous because high coefficient of friction is more than often accompanied with excessive wear which is less desirable in automotive friction material. This causes a problem of efficiency versus durability of the PKS pads. But again, it all depends on the driving habit of the user as it is known that rough driving usually is accompanied with excessive braking which causes rapid pads to wear while gentle and conscious driving is the opposite.

CONCLUSION

This paper has shown that surface structure of brake pads when analysed as received without any form of treatment presents features that may not be seen when it has been polished or undergone wear test. For instance, polishing could smoothen the naturally rough surface of the PKS particle and the true reflection of it contribution to the total surface characteristic of the pad may not be attained. Specific surface roughness analysis of the PKS particle may be useful to understand its bondage to the resin and other ingredients in the composite and will certainly share more light on other properties such as physical, mechanical and even thermal properties. It may be assumed that deeper asperities will contribute to stronger bond of the PKS particle to other ingredients but again this will depend on the element composition of the PKS itself and the natural bond of its elements to what other ingredients are made of. These are all important to achieve a strong composite that can withstand mechanical stress and have good wear and friction properties as needed in pads materials

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