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ANALYSIS ON THE HARDNESS CHARACTERISTICS OF SEMI-METALLIC FRICTION MATERIALS

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ABSTRACT

In this work, seven samples of newly developed friction material formulations were subjected to Rockwell hardness tests in accordance with Malaysia standard MS 474, Part 2. 2003. The samples were developed through powder metallurgy technique consisting of the following processing stages; powder selection, weighing, compaction, post baking and finishing. The Rockwell hardness of the samples was measured before and after the swell and growth tests. The indention spots after the hardness tests were also observed using scanning electron microscope (SEM) and the elemental compositions on that area were analyzed using Energy Dispersive X-ray (EDX). This paper will discuss the hardness characteristics of the friction materials with regard to the microstructure and elemental composition.

INTRODUCTION

Friction materials are composed of a mixture of five main constituents, namely; (i) fibers, (ii) binder, (iii) additives, (iv) filler, and (v) modifier [1]. Combinations of these materials provide unique material properties such as improved friction, wear, hardness, shear strength and thermal stability. These properties can be enhanced by achieving uniform dispersion of filler materials with plastic matrix [2]. Generally, the harder the metal materials, the lower will be the frictional resistance than those of softer metal [3]. Filip et al. (1995) found that hardness of brake lining materials cannot be simply related to the content of structural constituents, and there is no correlation between hardness and wear resistance [4]. In another study, Talib and Ramlan (2002) also concluded that there is no simple correlation between the hardness with the friction and wear of the brake friction materials [5].

Friction material is a heterogeneous material and composed of a few elements. Therefore, the selection of material and weight percentage used in the friction

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formulation will significantly affect the tribological behaviour of the brake pad [6]. Swell and growth represents the expansion of the friction material sample when it was heated to 400°F. Swell is the temporary expansion of brake lining due to temperature but it will disappear (dimension returns to original) when the temperature returns to ambient. Growth on the other hand is the expansion of brake lining material due to temperature which does not return to its original shape when temperature reverts to ambient. Swell is often less on metallic, semi-metallic and asbestos free friction materials as a result higher thermal conductivity where volatile is more completely eliminated [7]. Venting to remove all the gasses generated by the organic materials during press curing will be quicker and faster with higher thermal conductivity friction materials.

In this work, the effect of hardness characteristics of brake pad materials after expose to heat will be discussed. SEM with EDX attachment will be used for microstructural examination and elemental composition on the indention spots.

EXPERIMENTAL METHOD

Seven brake pad materials developed through powder metallurgy technique consisting of the following processing stages; powder selection, weighing, compaction, post baking and finishing were subjected to Rockwell hardness test in accordance with Malaysia Standard MS 474. Part 2. 2003 [8]. The hardness tests were conducted on sample before and after they were subjected to swell and growth tests. The samples were marked as S14 until S20. Elemental compositions are shown in Table 1. Hardness test on the brake pad was performed on Rockwell hardness tester model MIKATA scale S (applied load of 100 kgf and ball diameter of 12.7 mm). Swell and growth tests were performed in accordance with SAE J160 [9].

Table 1: Elemental composition of the samples

Material	S14	S15	S16	S17	S18	S19	S20
Resin	9.0	9.0	9.0	9.0	8.0	9.0	9.0
Organic fiber	4.0	10.0	12.0	10.0	8.0	4.0	10.0-
Metallic fiber (steel wool, copper fibre)	34.0	28.0	25.0	29.0	24.0	34.0	23.0
Abrasive (Alumina oxide, silica)	1.0	5.0	5.0	6.0	4.0	1.0	5.0
Antimony	3.0	-	3.0	-	-	3.0	3.0
Metal modifier(Iron oxide, iron powder, friction dust, zinc oxide)	18.0	9.0	20.0	8.0	22.0	18.0	11.0
Solid lubricant (graphite, mica)	7.0	13.0	13.0	13.0	11.0	7.0	13.0
Organic fiber (rubber, NIPOL)	3.0	3.0	3.0	3.0	3.0	4.0	3.0
Inorganic filler (Barium, wollstonite, fillite)	21.0	23.0	10.0	22.0	20.0	20.0	23.0
TOTAL	100	100	100	100	100	100	100

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The test sample for swell and growth test was conducted on a fresh product of brake pad with backing plate on it. The swell and growth test procedures are as follows;

i) The sample thickness was measured to the nearest 0.01mm at room temperature at six points
ii) The sample was placed in an oven and the oven temperature was increased to 204 ± 2.8 ºC within ½ to 1hour. Then the sample was soaked in the oven for 30-40minutes
iii) The sample was removed from the oven and while still hot, the thickness was measured at again at the same points. The increase in thickness was recorded as swell.
iv) The sample was allowed to cool down in still air to room temperature and the thickness was measured and recorded as growth.

RESULTS AND DISCUSSION

Swell, growth, and hardness test results are represented in Table 2. It can be seen from the table that sample S18 recorded the highest swell and growth. However, swell and growth test results on all the developed samples are less than 2.7%. Swell should not be more than 2.7 % to ensure that the brakes do not drag as a result of lining expansion, and if not above this range could cause problems particularly on brakes fitted with automatic slack adjuster [7]. Table 2 also shows that there is no correlation between hardness and swell and growth. For example, although sample S15 and S17 have the same weight percentages of metallic content in the composition, sample 15 became expanded whereas sample S17 became shrunken. Theoretically, swell is less with higher metallic contents in the composition as a result of higher thermal conductivity where volatility is more completely eliminated during the manufacturing process. Higher thermal conductivity will provide more through heating during press curing, thus the volatiles or gasses are much easier to diffuse to the edge or surface of the sample where they can escape. Swell and growth depend on the metallic content and the distribution of ingredient in the composition as well as the heating and curing process of the finished product.

Sample S20 has the highest hardness, but after swell and growth test, sample S18 recorded the highest hardness. It was also observed the hardness of all samples increased after swell and growth test due to curing of the organic materials. However, the degree of increase in hardness could not be correlated with metallic contents, swell and growth of the samples developed. This could be due to non-homogeneous composition as reported by Filip et al (4). He concluded that the hardness of friction materials rapidly increases with increasing amount of steel fibers and iron powder only if their content is lower than 25%. In this works, the metallic content of the samples is more than 25%.

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Table 2: Swell, growth and hardness test results

Bil	Sample	Metallic contents (wt %)	Swell (µm)	Growth (µm)	Hardness (HRS)	
					Before swell and growth test	After swell and growth test
1.	S14	52	- 1	- 2	72.2	77.5
2.	S15	37	8	- 3	62.3	68.1
3.	S16	45	18	18	70.9	96.7
4.	S17	37	-1	- 6	74.2	77.5
5.	S18	46	20	19	83.6	101.3
6.	S19	52	5	-4	53.1	66.0
7.	S20	34	- 5	- 7	84.0	95.3

Figure 1 shows the micrograph of the indentation spot on sample S14 and Table 3 shows the EDX results on corresponding elemental composition. Indentation spot 1 is having higher iron content than spot 2, but the dispersion of iron and metallic content are not well distributed. SEM micrograph on this spot also shows distribution of small and large particles. Even though indentation spot 2 is having less iron and metallic content in the composition, this spot is having uniform dispersion of small ingredient in the matrix resulting higher hardness as compare with spot 1. This is a macro hardness test; thus the indentation spot is relatively big with the indention ball of 12.7 mm in diameter. Homogenously mixed spot will give higher result but it also depends on the weight percentage of the metallic content on that particular spot. Homogenously mixed formulation will also give uniform hardness throughout the surface of product.

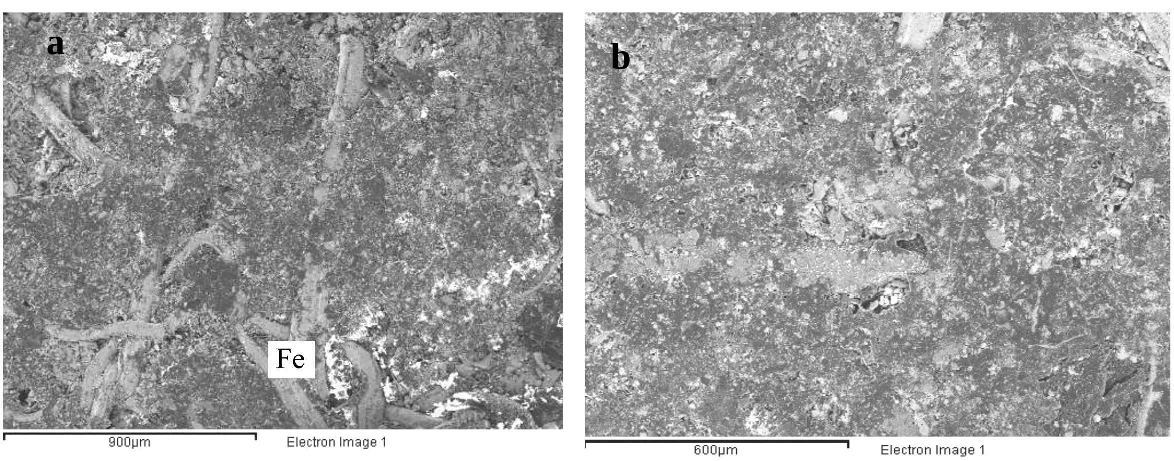

Figure 1: SEM micrograph of indentation spot sample S14. (a) Spot 1 hardness 57.3 HRS, (b) Spot 2 hardness 72.2 HRS

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Table 3: EDX results

Element	Sample S14	
	Hardness (HRS) 57.3	Hardness (HRS) 72.2
C K	56.24	66.99
Al K	1.05	1.46
Si K	1.30	1.20
P K	0.85	1.32
S K	3.03	3.83
Ca K	1.35	1.26
Fe K	22.16	7.85
Cu L	-	3.07
Sb L	2.11	2.30
Ba L	11.92	10.78
Totals	100.0	100.0

CONCLUSIONS

Based on test results, the following phenomena could be concluded;
(a) Friction material is heterogeneous materials, the hardness of the friction material depend on many factors such as the type of ingredients and percentage used in the composition and the dispersion of the ingredients in the composition
(b) There is no simple correlation between hardness and swell and growth characteristics of friction materials. It depends on the manufacturing process as well as on how homogenous is the ingredient in formulation developed
(c) Microstructure of the friction material plays an important role in getting uniform hardness even though microstructure characteristic is not representing the bulk proprieties.

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