Characterization of brake pad friction materials

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Abstract

Due to health-related problems as well as the requirements for better quality products, many material formulations for high performance asbestos-free materials are being introduced in Light Rail Transit (LRT) brake pads. This paper reports four new formulations of brake friction materials, which are made using the following ingredients: Resin, Iron oxide, Steel fiber, Ceramic fiber, Organic fiber, Magnesium Oxide, Aluminium Oxide, Barium, Sulphur, Graphite, Rubber, Novacite, Nipol and friction dust. Values of Hardness, Specific Gravity and Transverse Rupture strengths of these formulations are reported. The friction and wear test results of these formulations viz., A, B, C and D are included. The effects of physical properties, mechanical properties and morphology of the formulations on their friction and wear behavior are discussed. Scanning Electron Micrographs (SEM) and EDAX analysis of a formulation is included. It is found from the analysis that formulation B possesses better friction and wear properties compared to the other three formulations.
Keywords: characterization, friction materials, brake pad, wear rate, SEM, EDAX, physical properties, Light Rail Transit.

1 Introduction

Light Rail Transit (LRT) is an emerging mode of public transportation in Malaysia. Currently there are three commercial LRT Operators namely, STAR-LRT, PUTRA-LRT and KL Monorail, which provide commuting service in and around Kuala Lumpur. The braking systems of all these LRT trains incorporate commercial brake pads that are imported. The life span of commercial brake pads varies from one system to another depending on the materials constituent besides braking procedure and maintenance requirements.

There are different types of friction materials on the market, which can be classified into the following three categories: Semi Metallic (SM), Non Asbestos Organic (NAO) and Sinter Metal. They are mainly composed of a relatively large amount of iron powder and steel fibers, some graphite, rubber, organic fibers, ceramic materials, abrasives, lubricant and filler. The mixture is bonded together by a thermosetting phenolic resin. A wide variety of elements are employed in the making of the brake pads to obtain the necessary performance criteria for efficient braking criteria.

1.1 Railway brake pad

Figure 1 shows a brake pad used in the PUTRA-LRT trains running in Kuala Lumpur. Two such brake pads are used in every hydraulic brake unit. There are 16 brake pads in every train. 35 trains operated by PUTRA-LRT in and around KL are fitted with this type of brake pads. These brake pads are non-asbestos, non-lead and semi-metallic.

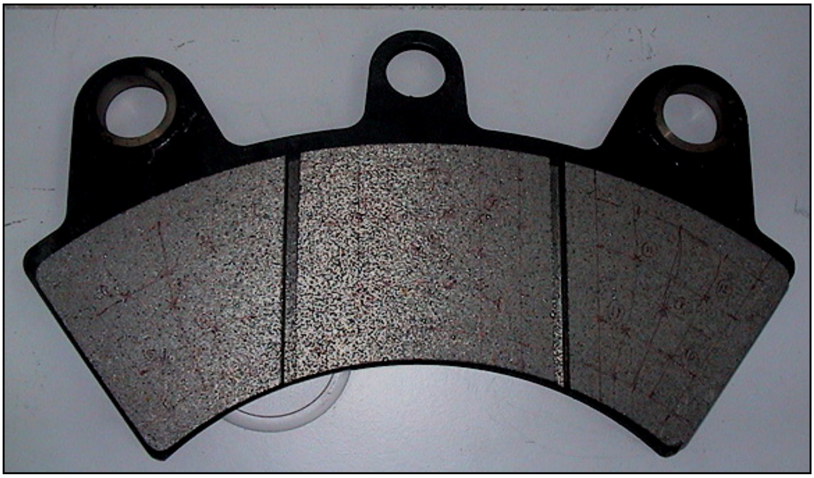

Figure 1: A Railway brake pad (non-asbestos, non-lead and semi-metallic).

1.2 Brake lining requirements

The following are the requirements of brake linings for efficient braking operations:

- The brake lining having a higher coefficient of friction contribute to more efficient braking
- Lining materials should have less wear rate to increase the life the brake lining and thus reducing the frequent changing of the brake lining – saving the time and money.

- Brake lining materials must have the capability to work at high temperatures without much change in the coefficient of friction and wear rate. High speed vehicles generate more heat during braking
- The brake lining material should have a high thermal conductivity to dissipate the heat produced.
- The brake lining material should not be hazardous and should be free from asbestos. Asbestos dust can cause serious health problems if inhaled. Breathing asbestos dust can cause upper and lower respiratory and gastrointestinal diseases

1.3 Literature review

Yusli *et al.* [1] reported the details of the fabrication of brake pad friction materials using powder metallurgy techniques. Morphology of samples was observed by SEM. The microstructures of the samples show heterogeneous mix due to complex formation of composite materials. Mohamed *et al.* [2] measured the porosity, density and hardness of four new formulations of brake friction materials and compared the values with that of a commercial specimen. Wan *et al.* [3] reported the friction and wear results of four new formulations and compared the values with that of a commercial specimen; even though all the new formulations have higher coefficient of friction values, two formulations have higher wear rate, one formulation has the same wear rate and the other formulation has a lesser wear rate.

Morshed *et al.* [4] have investigated and compared the physical and chemical characteristics of four commercial automotive brake shoe lining materials used in heavy vehicles. The swell resistance of the locally produced friction material compares favorably with that of the imported materials, but its bulk density was the lowest and its water absorption the highest. Hee and Filip [5] claim that despite the number of research studies completed on the mechanism of friction in automotive brake lining materials, the phenomenon is still not fully understood. Complex mechano-chemical processes occurring on the friction interface of a composite friction material make it difficult to understand the correlation between the formulation of brake lining and the frictional performance. Analysis of their experimental results shows that the brake lining material containing potassium titanate significantly improved the stability of the friction coefficient, fade and wear resistance. Kazuhisa and Buckley [6] found that the coefficients of friction of metals are related to the theoretical tensile, theoretical shear and actual shear strengths of metals. The higher the strength of the metal, the lower the coefficient of friction.

1.4 New formulations of brake friction materials

In this paper, four new formulations of brake friction materials are presented, which are made using the following ingredients: Resin, Iron oxide, Steel fiber, Ceramic fiber, Organic fiber, Magnesium Oxide, Aluminium Oxide, Barium, Sulphur, Graphite, Rubber, Novacite, Nipol and friction dust. Values of

Hardness, Specific Gravity and Transverse Rupture strengths of these formulations are compared with that of a commercial brake pad and the formulation which has its properties comparable with the commercial pad is identified.

2 Elements present in new formulations

The type and exact composition of the formulations are kept confidential as Intellectual Property. The samples of the formulations were analyzed by Scanning Electron Microscope. Yusli *et al* [1] and Mohamad *et al.* [2] have carried out the EDAX analysis to find the elements available in the commercial brake pad and in the formulations. Table 1 gives the amount of elements presenting the Commercial brake pad and in the formulations A, B, C & D.

Table 1: Amount of elements present in each formulation (% weight) [1,2].

Element	Commercial	A	B	C	D
Carbon	60.9	55.12	54.63	56.86	53.44
Oxygen	8.2	18.89	13.14	20.6	12.84
Magnesium	0.9	1.2	-	0.21	0.87
Aluminium	0.4	2.36	0.83	1.69	1.32
Sulfur	0.6	1.99	-	-	2.5
Iron	25.6	20.44	27.43	16.06	20.45
Bariuim	2.9	-	3.97	-	2.91
Copper	-	-	-	-	5.97
Calcium	-	-	-	2.16	-
Zinc	-	-	-	2.42	-

3 Physical and mechanical properties of formulations

3.1 Shore hardness

Hardness values of a commercial sample and four formulations viz., A,B,C and D are tested using a Shore Hardness tester. Figure 2 shows the mean and standard deviations of shore hardness values of the commercial sample and of the formulations.

We can compare the hardness values to find those formulations that are better than the commercial sample. It can be seen that formulation A and C have higher hardness values as compared to the commercial sample. Specimen B has the lowest standard deviation even though the mean hardness value is less than that of the commercial sample.

3.2 Transverse rupture strength of commercial sample and formulations

Transverse Rupture Strength of the commercial sample and of the formulations are found and shown in Figure 3. Since the brake pad may rupture only in the horizontal configuration, only the results of the tests conducted on the horizontal specimen configuration are reported. It is seen from figure 3 that, no formulation is better than the commercial specimen, when we compare the transverse rupture strengths of formulations with that of the commercial specimen. However formulation A has a higher transverse strength compared to other formulations.

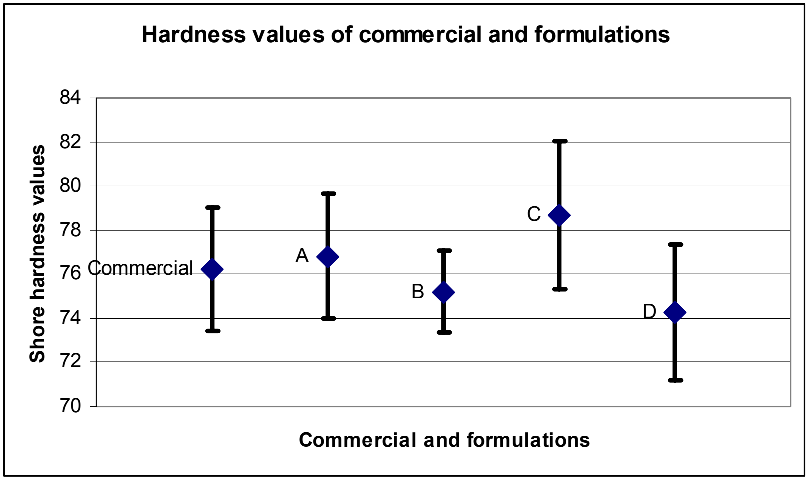

Figure 2: Shore hardness values of commercial and formulations. Data points show the mean of 15 measurements and the error bars indicate standard deviations.

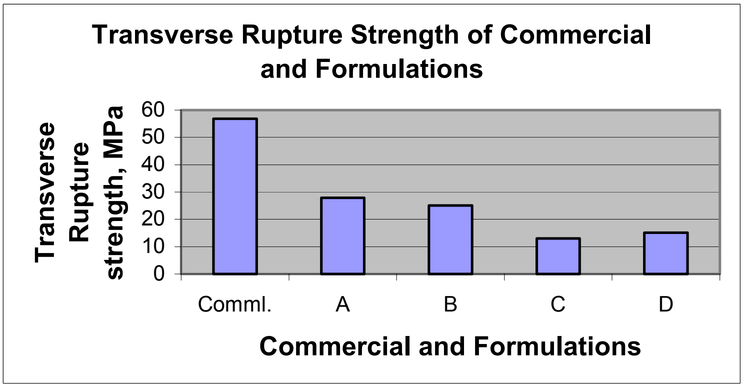

Figure 3: Transverse rupture strength of commercial and formulations.

3.3 Specific gravity of commercial and formulations

The specific gravity of the commercial and the formulations are shown in Figure 4. It is seen from Figure 4 that, no formulation is better than the commercial specimen, when we compare the specific gravity of formulations with that of the commercial specimen.

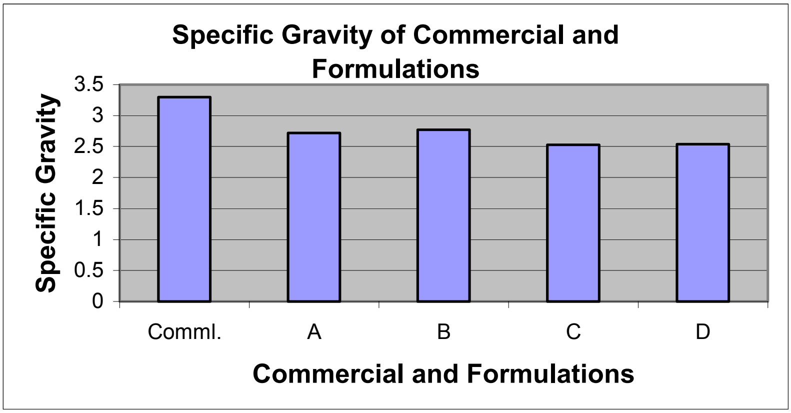

Figure 4: Specific gravity of commercial and formulations.

However formulation B has a higher Specific Gravity compared to other formulations. Wan *et al.* [3] have studied the friction and wear properties of these formulations and reported the following results: Table 2 shows the co-efficient of friction and wear values for the commercial as well as the formulations.

Table 2: Friction coefficient and wear rate of the commercial and formulations.

Formulation	Friction coefficient	Wear Rate (g/MJ)
Commercial	0.332	0.038
A	0.374	0.043
B	0.383	0.035
C	0.484	0.106
D	0.347	0.038

4 Discussions

When we compare the friction coefficient and wear rate values of the formulations with that of the commercial sample, we find that the co efficient of friction values of all the formulations are more than that of the commercial sample; The wear rate of formulation B is lower than the commercial specimen and the wear rate of formulation D is equal to that of the commercial specimen. We can choose formulation B in the first place and formulation D as the next choice. In Table 1 we see that the iron content in formulation B is higher than the commercial specimen; also it is higher when we compare formulation B with other formulations. The amount of oxide present in formulation B is the least as compared to formulations A & C. The amount of aluminium present in formulation B is lower compared to other formulations. We notice that Barium is present in formulations B and D whose amount is approximately equal to that present in the commercial specimen and this may contribute to the same or better wear properties.

From Figure 2 we see that the formulations B and D have average shore hardness values less than that of the commercial values. Uniform hardness values are observed in formulation B (the standard deviation is the lowest), which is an indication of good bonding between the constituents of the elements of the brake pad materials; this can be observed from the Scanning Electron Microscope shown in figure 5.

Even though the transverse rupture strength (TRS) of all the formulations are lower than that of the commercial specimen, the TRS of formulation B is higher than that of the formulation D. The specific gravity values of all the formulations are lesser compared to that of the commercial value. But the specific gravity of formulation B is higher than that of formulation D.

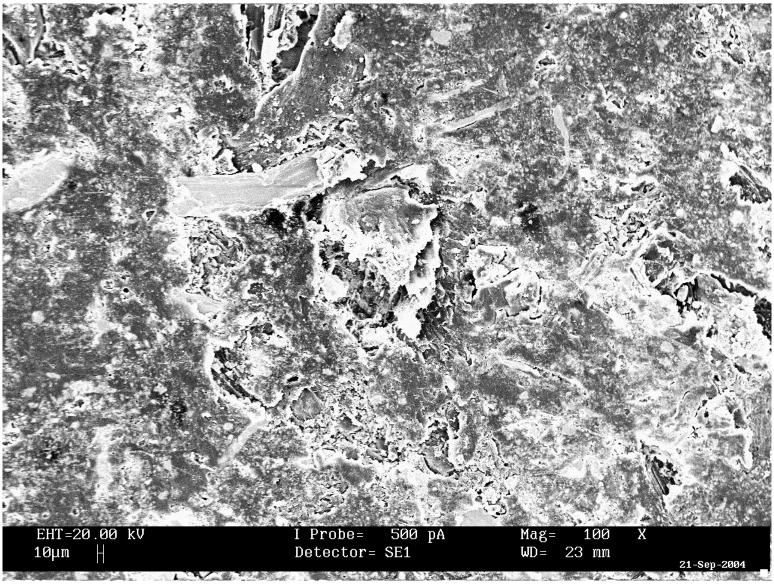

Figure 5: Scanning Electron Microscopy of formulation B (100X).

Good bonding between the elements is seen in the Scanning Electron Micrograph as shown in figure 5. Pores are not evident and uniform morphology is observed.

5 Conclusion

Four formulations A, B, C and D are compared with a commercial sample of a Brake friction Pad used in a Light Rail Transit (LRT). It is found that formulation B has higher friction coefficient and lower wear rate compared to the commercial specimen. Higher amounts of iron and Barium present in formulation B give superior friction and wear properties to the formulation B.

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