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Effect of the particle angularity on friction coefficients and grit embedment of brake pad material

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ABSTRACT – Effect of hard particle angularity on frictional coefficients and grit embedment of brake material was investigated. The particles used in this study were silicon carbide, silica sand and garnet with drag and stop mode test. The spike parameter quadratic fit (SPQ) method was applied to characterize the particles angularity. Results showed that particles angularity exhibited a great influence in modifying the effective contact, wear generation and friction coefficient. Good correlation between pad specimen weight loss and grit embedment was found. Signs of formation and disintegration of contact plateaus correlated well with angularity, suggesting the grit embedment role as wearing mechanism.

1. INTRODUCTION

Due to the fact that the brake interface is hidden, covered and buried between the pad and the disc, friction behavior of brake pad material during braking post the most interesting but yet not a fully understood problem [1]. It becomes very challenging to exactly know what really happen to the contact plateaus and material interaction at the brake interface. In addition, brake frictional materials are designed to provide stable frictional performance over a range of vehicle operating conditions and to exhibit acceptable durability [2]. In braking, the abrasion at the friction interface is caused by the abrasive and hard particles that are included in the composition of the brake pad. In normal braking (without external particle), the hard and abrasive particles embedded in the pad will involve in the friction process and get released due to pyrolysis of phenolic resin especially at elevated braking temperature. Hard particles like aluminum oxide and silicon oxide will retain their original size, while the soft particles like copper and metal sulfides will be milled with other wear particles [2]. They mix and wear the brake gap at different length and time scales by different mechanisms. These particles are used to control the level of friction force and to remove friction films forming at the sliding interface [3]. However, contaminants and hard particles from environment also contribute to the abrasion process at the brake interface.

The particles size and shape of hard particles are two important parameters that can affect friction and wear rate in sliding couple [4]. In this work, abrasive particle such as zircon, silicon carbide and alumina with different sizes are used to study the friction wear properties of brake materials.

2. METHODOLOGY

A schematic diagram of the test rig is shown in Fig. 1. A hopper is fitted at the end shaft support to hold and disperse the hard particles. A hard particle feeder tube is attached to the hopper to direct the hard particles to the gap between the brake pad and the disc. A manually controlled valve is used to regulate the amount of hard particles delivered to the contact. The brake disc specimen is shielded by a transparent cover to avoid splashing of the hard particles during the experiments.

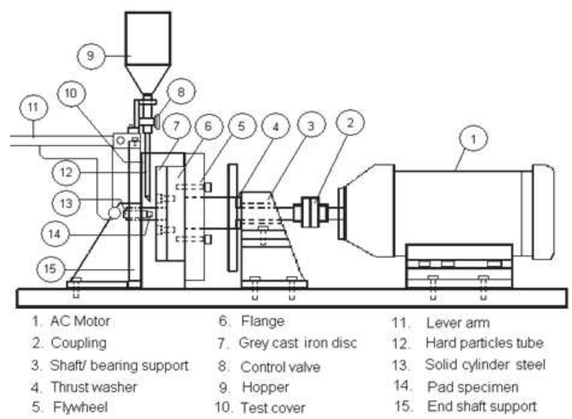

Figure 1 Brake test rig.

2.1 Testing Procedures

Drag tests at four different sliding speeds of 4, 8, 10 and 12 m/s at constant pressure of 0.6, 0.8 and 1.0 MPa was used to evaluate the effects of hard particle grit shape on friction stability.

Table 1 Testing procedure

	Drag test	**Hard braking**
Pressure (MPa)	0.6, 0.8	1
Speed (m/s)	4, 8, 10, 12	4, 8, 10, 12
Duration (s)	10 (three times)	8

3. RESULTS AND DISCUSSION

The effect of different particle angularity on friction stability was investigated during drag mode test. Short duration braking of 10 s was applied three times for every test to capture the changes of the coefficient of friction (CoF). From results obtained, silicon carbide grit particles seemed to generate higher CoF values compared to silica sand and garnet especially at high disc sliding speeds. At higher disc sliding speed, it was assumed that silicon carbide particles with higher SPQ value not only mixed with other wear debris faster, but their angularity resulted in higher micro-cutting process that increase the formation rate of effective contact and the generation of much smaller wear debris. Many loose wear debris of much smaller size, below 10 µm, were observed during the experiment with silicon carbide while silica sand and garnet seemed to generate less wear debris of the same size as shown in Fig. 2. The presence of larger quantity of small wear debris seems to fill the cavities at the brake pad surface to contribute to the increased of effective contact area before their ejection from the contact. Also, higher occurrence of grit fragmentation was recorded during the experiment carried out with silicon carbide and these fragmented grit particles could form additional effective contact to increase the CoF value.

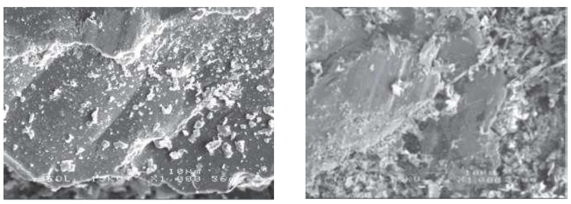

Figure 2 Wear debris observed.

The CoF values for the three grit particle types during drag mode and hard braking test are shown in Fig. 3. At low and medium disc sliding speeds, the effect of particle angularity was less significant on CoF due to slow mixing process of the particles with wear debris. In addition, more compacted wear debris was present to assist the friction. Slow mixing means that the rate of contact interaction of grit particles with wear debris was low and results in more effective load transmitted to the contact. More compacted wear debris could form a friction film to reduce the friction force and CoF. Silicon carbide particles resulted in higher pad specimen weight loss and contributed to greater formation of compacted wear debris at the brake surface. Hard braking test was carried out at braking pressure of 1.0 MPa until the disc was completely stopped. Increase in braking pressure resulted in more effective generation of much smaller wear debris. More silicon carbide particles were fully embedded (FE) into the pad surface or into the compacted wear debris as shown in Fig. 4. From the experimental results, it was found that higher SPQ value significantly affects the percentage area of grit embedment (GE). In drag mode test, silicon carbide recorded almost double the embedment of garnet and triple of that silica sand at low sliding speeds. At higher speeds, the embedment of silicon carbide was observed to be at least double of the garnet and silica sand. However, at lower sliding speeds, it appeared that the presence of compacted wear debris helped to provide softer platform surface for the particle GE.

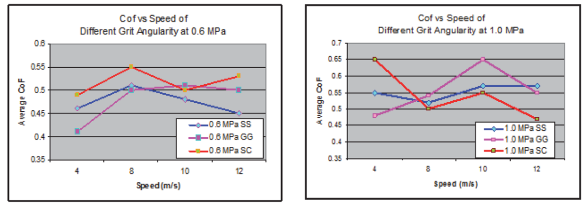

Figure 3 CoF values for drag and hard braking test.

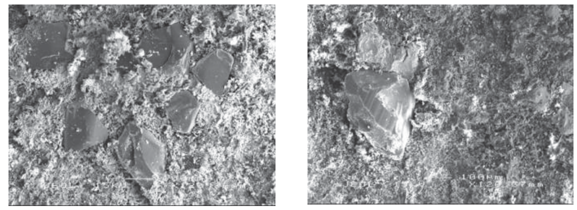

Figure 4 Fully and partially embedded particles.

4. SUMMARY

Silicon carbide grit particles generate higher CoF values compared to silica sand and garnet especially at high disc sliding speeds. At higher disc sliding speed, particles with higher SPQ value (i.e. silicon carbide) resulted in the increase of the rate of effective contact and the generation of much smaller wear debris. During hard braking test, silicon carbide resulted in lower CoF values compared to the other two grit particles especially at higher speeds. Grit particles with higher SPQ values embed more easily and their involvement in mixing and generating wear debris was limited.

5. ACKNOWLEDGEMENT

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