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EFFECT OF CHOPPED KEVLAR TO WEAR AND BRAKING PERFORMANCE

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Braking system is the most important safety feature of every vehicle on the road. The braking system is composed of many parts, including friction pads on each wheel, a master cylinder, wheel cylinders, and a hydraulic control system. The disc braking system uses brake pads with lining, where linings are typically comprised of sub-components such as abrasive, lubricants, fillers, binder and reinforcement. In this research, firstly Kevlar fabric was made chopped and then chopped Kevlar was mixed with graphite, barite, phenolic resin, tin, brass and alumina. Finally, the mixture was pressed under 10 MPa pressure and two brake pad samples were obtained with different Kevlar mass ratio. Wear percentage, braking force, lining and disc temperatures of samples were determined under different braking loads. The experimental results indicated that the wear percentage and temperature changes of disc and brake lining of samples are directly proportional to the applied load. Also the sample with 0.5% mass Kevlar exhibited better braking performance comparing with 1% mass Kevlar sample.

Keywords: Brake performance, Disc temperature, Kevlar, Lining, Wear.

1. Introduction

The disc braking system uses brake pads with lining, where semi-metallic linings are used in common because of their ability to withstand higher operating temperatures. When pressing brake pads against the rotating wheel disc, the disc actually rubs against liner/disc and dissipates the energy of the moving vehicle due to this friction between the linings, resulting in deceleration. Hence brakes decelerate a vehicle by transforming kinetic energy to temperature, via friction, and dissipating temperature to the surroundings [1, 2].

Brake linings typically comprise the following sub-components; abrasives, lubricants, fillers, binders and reinforcements. Mixture of abrasives and lubricants determine the frictional properties of the brake pad linings. Fillers reduce the cost and improve the manufacturability of brake pads; Binders (matrix) hold components of a brake pad together; Reinforcing fibers provide mechanical strength [3, 4].

Wear of the brake friction materials with straight phenolic resin, silicon modified phenolic resin, or boron–phosphorous modified phenolic resin were investigated by Honga et. al. [5]. Their results showed that the thermal degradation of the binder resin determined the change of the friction coefficient as a function of temperature. The temperature resistant phenolic resins showed the peak friction coefficient at higher temperatures and exhibited better friction stability with temperature. The friction materials with the temperature resistant resins were more resistant to wear and the wear resistance was more pronounced at elevated temperatures above the thermal decomposition temperature. The wear rates at moderate temperatures were not affected by the resin type, indicating that the binder would play a minor role in the wear resistance of the friction material at normal braking conditions.

Sampath (2006) investigated the wear and friction characteristics of non-asbestos based friction composites with glass- and Kevlar-fiber embedded in a phenolic resin matrix for automotive friction applications. The results showed that the Kevlar-reinforced composites show comparatively smaller rates of wear at all temperatures unlike those reinforced with glass fiber, and the wear and friction characteristics of the friction composites are greatly influenced by a complex or mixed mode of adhesive and abrasive types of wear taking place at the surface.

Wu et. al. (2006), investigated the effects of Kevlar pulp content on tribological properties of the composites. The results show that the incorporation of Kevlar pulp into epoxy contributed to improve the friction and wear behavior considerably. The maximum wear reduction was obtained when the content of Kevlar pulp is 40 vol%. The friction coefficient of epoxy and its composites increased with load while increasing in the sliding frequency induced a reverse effect. Fatigue wear and scuffng were notable for the neat epoxy. The fatigue cracks were greatly abated when the filler content was 40 vol%. The wear grooves appeared on the worn surface at higher filler content.

This research aims to reveal Kevlar mass ratio effect on breaking performance such as wear percentage, changes of lining-disc temperatures and braking force of brake pad linings where chopped Kevlar used as an ingredient in friction materials composed of graphite, barite, phenolic resin, tin, brass and alumina.

2. Material and Method

2.1. Sample Production

Basic mixture of the brake lining was composed of 30% brass powder, 30% phenolic resin, 15% alumina, 10% tin, 10% barite and 5% graphite in mass. Kevlar fabric was compressed under 10 MPa pressure and the mold was chopped by rasp. 0.5% (wt) Kevlar fabric was added into the basic mixture to prepare A-sample and 1% (wt) Kevlar fabric was added for B-sample. Components were mixed in V-type mixer at 1000 rpm. After the mixing process, the mixture was put in a 30x20 mm dimensioned mould and compressed by a single way hydraulic press under 10 MPa pressure.

2.2. Testing Apparatus

Testing apparatus consists of disc, caliper, hydraulic unit and an electric motor which enable the disc motion and computer for recording data. All the elements of a vehicle brake system were present on the produced testing apparatus and brake vacuum amplifier was canceled in order to eliminate the losses. Also a 380 volt, 50 Hz, 86 A, 4kW three-phase electric motor for turning the brake disc and two load-cells for measuring brake pedal force and braking moment were available on testing apparatus. Testing apparatus schematic view can be seen on Figure 1.

Shimpo brand FGN-50B model force meter was used to measure the brake pedal force and wear rates of the samples were determined by weighing all the samples before and after the experiments by using electronic weighting scale having 0.001gr sensitivity. Wear rates of the brake linings were determined after every 10 minutes continuous braking at maximum electric motor speed while applying 100-200-300-400-500 N brake pedal forces respectively.

During experiments, the temperature of the brake lining was determined by means of K type thermocouples placed in a 2 mm diameter 3 mm depth hole on the brake lining. Obtained temperature data per second were transferred to the computer with the help of a data logger. Braking performance was determined by measuring the compression force of brake lining on the disc via 200 kg capacity load-cell. 600 inputs were acquired during the 10 minutes test and the averages of these inputs are illustrated in graphics.

All samples are operated under 200 N brake pedal force and 4.5 m/s brake disc peripheral speed until contact area between disc and lining reached 95% before experiments.

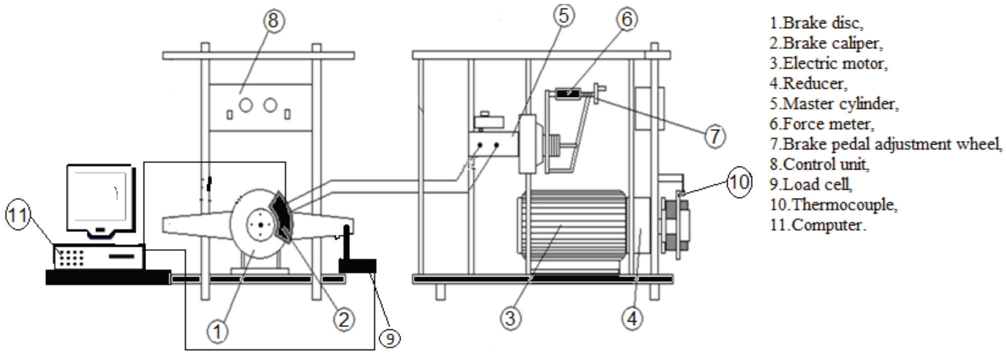

Figure 1. Schematic view of brake testing apparatus.

3. Experimental Results and Discussion

3.1. Brake Lining and Disc Temperatures

Brake linings were overheated because of the constant braking pedal load during ten minutes testing time. The temperature changes occurred on the samples during experiments are shown on the below graphics. On the graphics, brake lining and disc temperature changes of samples are shown separately. The temperature changes of the brake lining samples containing 0.5% and 1% chopped Kevlar are shown on Figure 2.

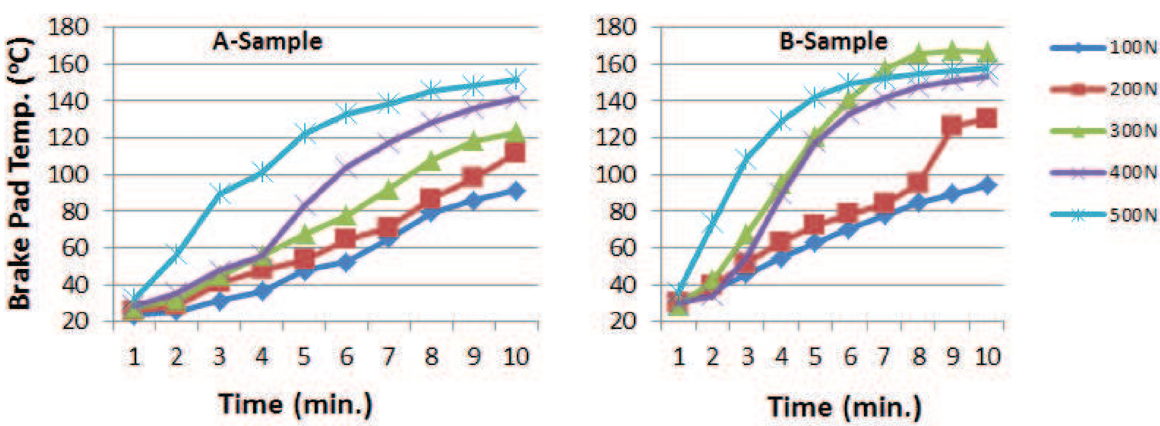

Figure 2. A and B samples' temperature changes according to the applied pedal forces.

All the samples showed similar brake lining temperature changes depending on time. However, for all A-sample pedal forces, temperature changes seem to be more stable. The samples which were applied 100 N pedal force showed minimum temperature increase because of low braking pressure.

Temperature differences (in ^{o}C) between the beginning and end of the experiment were 64.7, 99.6, 137.55, 123.73 and 121.8 for A-sample, 67.82, 85.81, 95.3, 112.71 and 119.31 for B-sample at all pedal forces, respectively. For all pedal forces of A-sample, temperature increases were linear, but for B-sample, temperature increase slowed down after the third minute. A-Sample at 500N pedal force, the maximum temperature value was 151.98 ^{o}C, but B-sample at 300N pedal force, the maximum temperature value was 167.42 ^{o}C. Temperature change was slower in the A-sample because of its chemical composition.

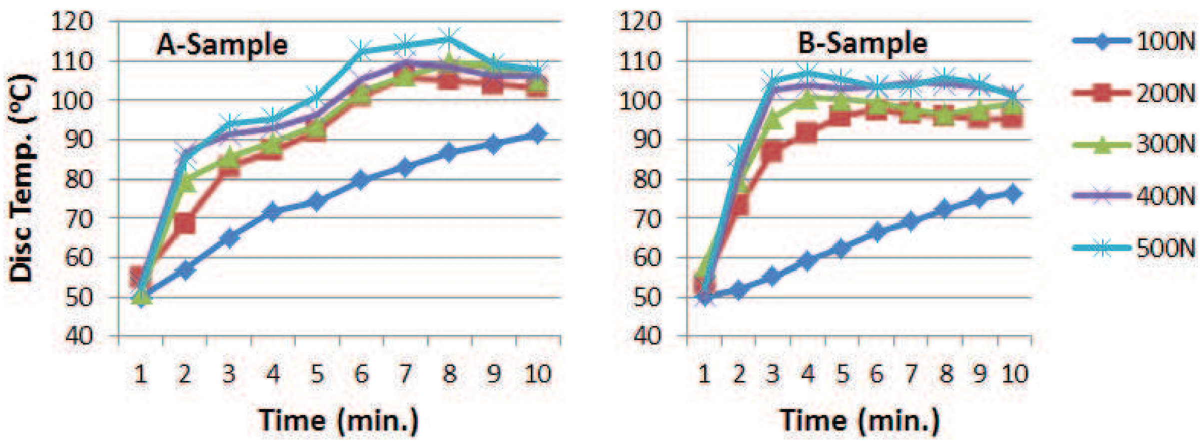

Figure 3. Disc temperature changes of the A and B-samples.

The temperature changes of same brake disc for different force values applied to the brake pedal are shown in Figure 3. Temperature changes of A-sample under all pedal forces applied showed regular and stable increase depending on time. Minimum temperature changes of the disc were observed with 100 N pedal force because of low pedal pressure. The temperature changes of the disc are proportional with time for A-sample. For B-sample, brake disc temperature was increased suddenly comparing with A-sample and it reached to almost its maximum at third minute. A and B-Samples reached the maximum temperature value on 500N pedal force at eighth minute (115.6 ^{o}C) and fourth minute (106.88 ^{o}C), respectively.

3.2. Wear

Wear rates of the samples were determined from weight change by measuring the samples before and after the experiments with 0.001 g sensitivity balance. Graphics on the Fig.4 are prepared by taking the average percentage values of weight measuring data.

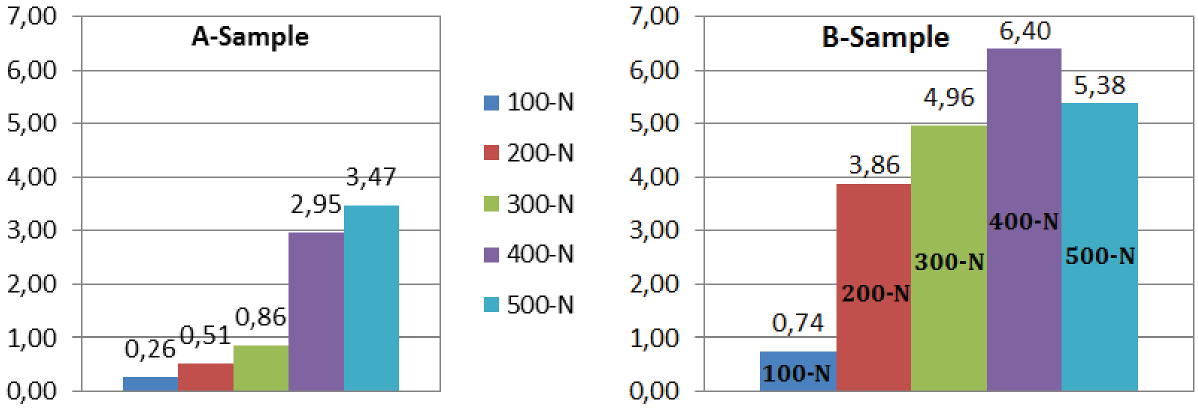

Figure 4. Wear percentages of A and B-samples.

Wear percentages of samples also increased according to Kevlar ratio in sample. This situation can be assessed as insufficient lubrication due to decreasing lubricant materials ratio in B-samples. As wear percentage of A-samples increased linearly, a sudden increase occurred after 400N. Total wear percentages of samples were 8.05% for A-samples and 21.34% for B-samples during experiments.

3.3. Braking Force

At the beginning of the experiments, braking force increased for all brake pedal loads. After a maximum point, brake fade begins due to continuous contact with the disc and brake lining as a result of excessive rise in temperature.

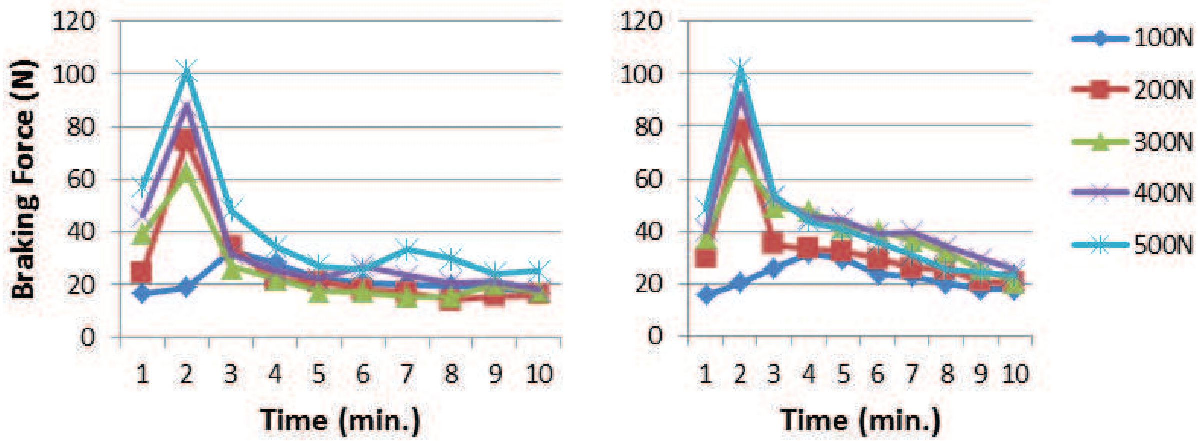

Figure 5. Braking force of A and B-samples.

Braking force was decreased due to brake fade after the first six minutes although ideal braking occurred in the first five minutes of the experiments. For A-sample, the difference between minimum and maximum braking forces was 57.7% for 100N brake pedal force. Maximum-minimum differences for the other brake pedal forces were in the range of 25-30%. For B-sample, the difference between maximum and minimum braking forces was 52% in 100N brake pedal force and others remained around 20%.

4. Conclusions

In this work, the availability of using chopped Kevlar as a brake lining ingredient was studied. Firstly it was decided that the base formula was composed of graphite, barite, phenolic resin, tin, brass and alumina as other ingredients. When Kevlar ratio in the mixture is greater than 1% (wt), the amount of powder in the base formula is insufficient to hold on to the Kevlar fibers. According to the test results of measured properties of the samples such as wear percentage, braking force, lining and disc temperatures;

- Minimum wear amount occurred in A-sample. Wear rate increased due to decrease in the amount of lubricant in composition when Kevlar amount was increased. The amount of wear rate can be reduced by increasing lubricating materials ratio.
- When instantaneous data is taken into consideration A-samples showed better braking performance than B-samples.
- Kevlar fibers and powder materials in A-samples have formed a better bond than B-samples since A-samples had better brake-disc temperatures, wear percentages and braking performance values than B-samples.

- To find the ideal values of wear percentage and braking performance of the linings, experiments must be repeated by adding Kevlar fibers to the base formula step-by-step with 0.1% ratios.
- Brake fade occurred quickly because lining-disc counterparts were continuously in contact for ten minutes under a certain brake load.

Acknowledgements

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References

1. Sivarao M., Amarnath M., Rizal M.S. and Kamely A., 2009. An Investigation Toward Development of Economical Brake Lining Wear Alert System, International Journal of Engineering & Technology IJET Vol: **9** No: 9, p.251–256.
2. Junus Y.M., Ishak M.I. and Semalat M.S., 2006. Friction and Wear Characterization of LRT Brake Pad Based on Fast Test, J. solid sci. technol. Letter,vol. **12**, No.1, p.115–120 .
3. Jang H. and Kim S.J., 2000. The Effects of Sb2S3 and Zirconium Silicate ZrSiO4 in the Automotive Brake Friction Material on Friction Characteristics, Wear **239**, p.229–239.
4. Anderson A. E., 1992. ASM Handbook, 19 th ed., p. 569–577, ASM International, Cleveland, OH.
5. Honga U.S., Junga S.L., Choa K.H., Choa M.H., Kimb S.J. and Jang H., 2009. Wear Mechanism of Multiphase Friction Materials with Different Phenolic Resin Matrices, Wear Vol.**266**, Issues 7–8, p.739–744.
6. Sampath V., 2006. Studies on Mechanical, Friction, and Wear Characteristics of Kevlar and Glass Fiber-Reinforced Friction Materials, Materials and Manufacturing Processes, Vol.**21**, Issue 1, p.47–57.
7. Wu J. and Cheng X.H., 2006. Friction and Wear Properties of Kevlar Pulp Reinforced Epoxy Composites Under Dry Sliding Condition, Tribology Letters, Vol. **22**, No.3, p. 259–263.
8. Lu Y., 2006. A Combinatorial Approach for Automotive Friction Materials: Effects of Ingredients on Friction Performance, Composites Science and Technology, Vol. **66**, Issues 3–4, p.591–598.
9. Kurt A. and Boz M., 2005. Wear Behaviour of Organic Asbestos Based and Bronze Based Powder Metal Brake Linings, Materials and Design, Vol. **26**, Issues 8, p.717–721.