

Brake Disc Variability: Effect on Friction and Wear

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ABSTRACT

Two sets of OE quality brake discs were evaluated for their equivalence in friction and wear under a humidity controlled condition in order to avoid the influence of humidity on friction and wear. These discs were received from two different suppliers located in two different countries. Small differences were found in disc chemistry and microstructure, which resulted in differences in disc properties, and friction and wear characteristics. It is recommended that extreme care must be exercised in determining the performance equivalence of one disc from one supplier against another disc from a second supplier.

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INTRODUCTION

There have been anecdotal cases in which brake discs seem to affect friction and wear characteristics of foundation brakes. This investigation was undertaken to clarify this issue.

Libsch and Rhee [1] demonstrated in their publication in 1981 that small intentional variations in minor alloying elements in standard cast iron discs affected friction and wear characteristics of heavy truck disc brakes, which incorporated NAO disc pads. For example, when the sulfur content was increased by 0.12 wt% while lowering the manganese content by 0.26 wt%, the disc wear increased while the pad wear decreased and the friction level went down. Similarly when the carbon content was increased by 0.54 wt% while increasing phosphorus by 0.05 wt%, the disc wear increased while the pad wear decreased and the friction level went up.

Grochowicz et al. [2] showed in their publication in 2010 that a given passenger car brake system exhibited significant repeatability issues as well as reproducibility issues when tested at various laboratories.

Kim et al. [3, 4] reported in 2011 and 2012 that environmental humidity influenced in a measurable way friction, disc wear, pad wear, DTV, pad weight, pad thickness, pad hardness, pad compressibility, pad natural frequencies and brake noise.

As Libsch and Rhee [1], and also Grochowicz et al. [2] did not control humidity during testing, the influence of humidity as a variable on their test data is unknown. In this

investigation, the humidity and temperature of the cooling air were kept constant in order to eliminate this uncertainty.

One of the main purposes of this investigation was to find out if two "equivalent" OE discs, which might have possibly small unintentional compositional/microstructural variations as they were coming from two different foundries/fabricators located in two different countries, would produce the same test results or not.

MATERIALS AND EXPERIMENTAL

A front disc brake system of a passenger car of GVW 2150kg was selected for this investigation. The NAO disc pads with no noise shims used in this investigation were taken from a single lot in order to minimize variability. 4 16-inch brake discs labeled as A#1, A#2, A#3 and A#4 were selected from a single lot, which were received from the A foundry/fabricator, and the other 4 discs labeled as B#1, B#2, B#3 and B#4 from the B foundry/fabricator; all OE quality discs. A single caliper was mounted on Link Dynamometer 3331 for testing. The SAE J2522 test procedure was used and the cooling air was kept at 30°C and 55%RH. 3 separate tests were run using 3 separate new discs from the A foundry and also from the B foundry, with new pads from a single lot each time. The tests were randomized by testing the A#1 disc first, followed by B#1; then B#2 and A#2; and A#3 and B#3. In addition, an OEM test procedure was used for A#4 and B#4.

Friction, disc wear, pad wear, disc hardness, disc natural frequencies, disc surface roughness before and after testing,

Table 1. Disc & Pad Weight Loss after Performance Testing

Disc Wear	A			B		
	Before test (g)	After test (g)	Loss (g)	Before test (g)	After test (g)	Loss (g)
#1	8386	8380	6	8382	8372	10
#2	8415	8410	5	8365	8355	10
#3	8403	8396	7	8375	8362	13
Total	25,204	25,186	18	25,122	25,089	33

Pad Wear	A						B					
	Inner			Outer			Inner			Outer		
	Before test (g)	After test (g)	Loss (g)	Before test (g)	After test (g)	Loss (g)	Before test (g)	After test (g)	Loss (g)	Before test (g)	After test (g)	Loss (g)
#1	436.11	433.80	2.31	436.93	434.39	2.54	435.66	432.88	2.78	438.05	435.58	2.47
#2	436.22	433.36	2.86	436.91	434.19	2.72	435.88	433.00	2.88	437.70	435.14	2.56
#3	436.42	433.80	2.62	437.87	435.01	2.86	435.26	432.09	3.17	437.80	435.24	2.56
Total			7.79			8.12			8.83			7.59
Grand total	15.91						16.42					

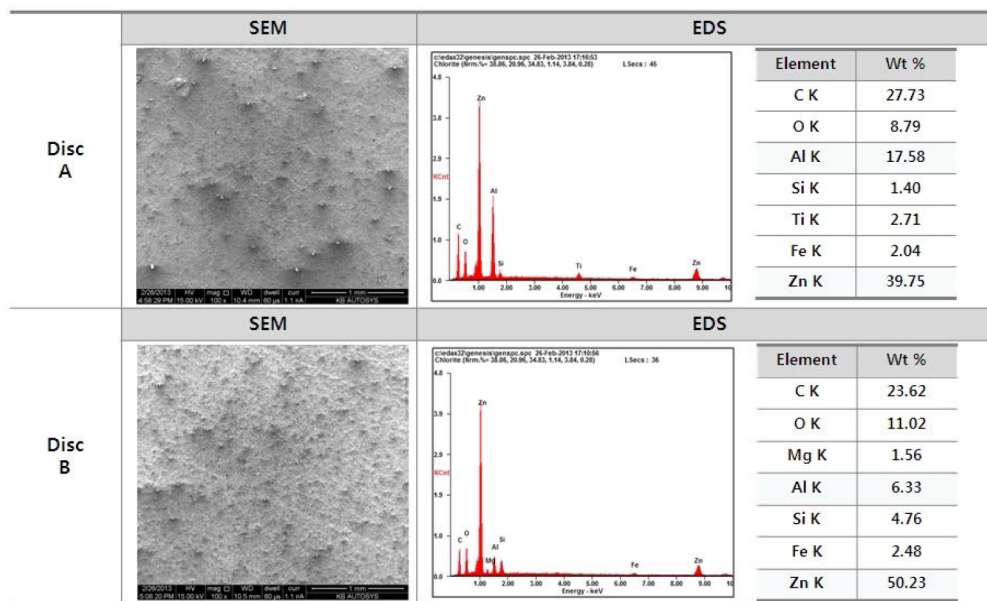


Figure 1. Unused disc Dacro analysis; EDS

analysis of anticorrosion Dacro coating and disc chemistry/microstructure were measured and determined.

RESULTS AND DISCUSSION

All the discs were weighed before testing to see if they were of the same weight. The measured weights are shown in Table 1.

All the discs had very similar weights. These discs were received with an anti-corrosion protection Dacro coating. The A discs had a thicker coating of roughly 30 μm while the B

discs had a thinner coating of roughly 10 μm [Fig. 1]. The chemical analysis performed on the coating by SEM/EDS is also shown in Figure 1. The Dacro coatings consist of zinc flakes and aluminum flakes bonded together by an organic binder. The A disc shows the zinc to aluminum ratio of roughly 2:1 while the B disc has a much higher concentration of zinc.

The friction results of A#1, A#2 and A#3 are summarized in Fig. 2. As can be seen, the repeatability is rather good. Fig. 3 shows the friction results of B#1, B#2 and B#3. In this case,

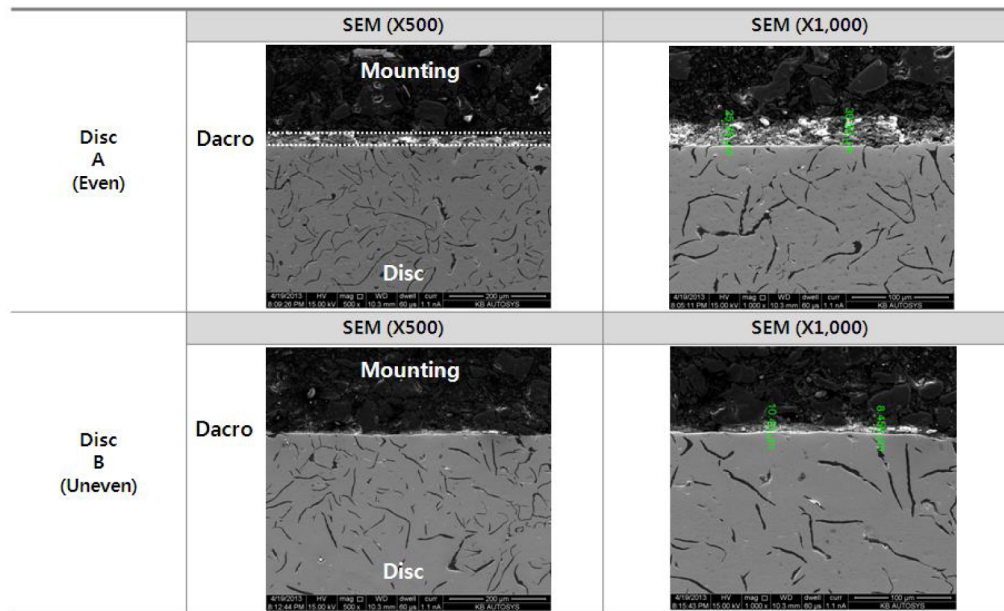


Figure 1. Unused disc Dacro analysis; thickness

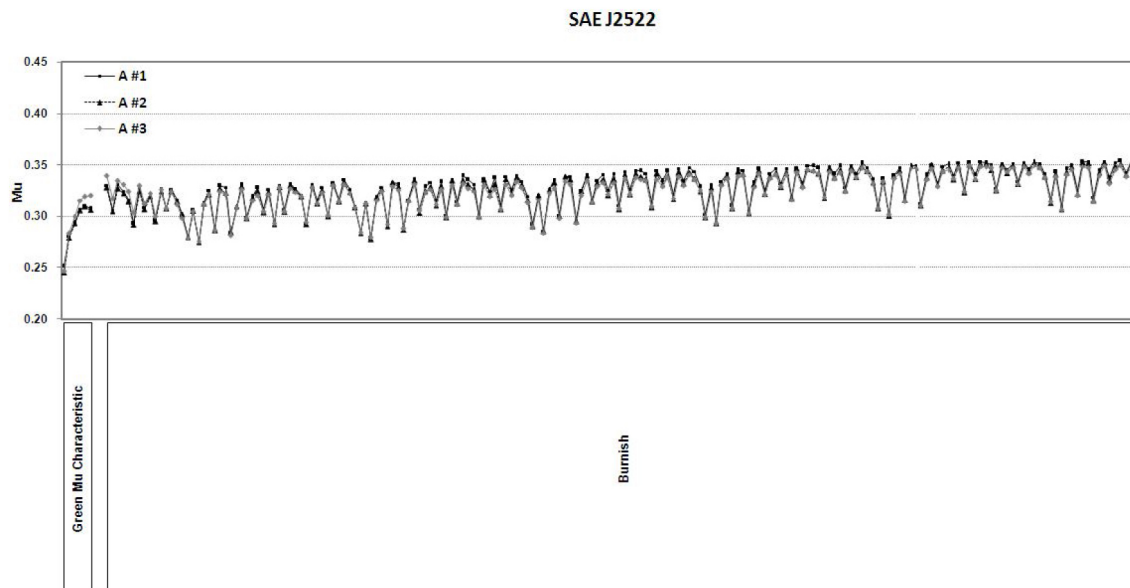


Figure 2. Disc A-Burnish; Cooling air temperature 30°C × RH 55% (AH 16.7g/m³ Air)

the repeatability is not as good as the A discs. In the Speed - Pressure Sensitivity section, the B discs show higher minimum friction and reduced pressure sensitivity. Also the B discs show higher friction levels in the Recovery 1 section and, also in the Temperature/Pressure Sensitivity - 100 °C, Pressure Line - 500 °C, Recovery 2 and Fade 2 sections. For clear comparison, some sections in Fig. 2 as well as some sections in Fig. 3 are selected and re-plotted in Fig. 4; 3 tests per condition are averaged into one. As can be seen, the B discs clearly show higher friction coefficients.

An OEM test procedure was adopted to see if the same trend persists as in Figs. 2 and 3. In this case, the cooling air was maintained at 20 °C and 40% RH, thus lowering the humidity to AH 7.9g/m³ air from AH 16.7g/m³ air in Figs. 2 and 3. Only some parts of the test results are shown in Fig. 5, due to confidentiality. Here again the B#4 disc clearly exhibits higher friction levels, and the difference in friction coefficient between A#4 and B#4 is much greater. In other words, the difference between A#4 and B#4 is much easier to see when the humidity of the cooling air is reduced. It