

Brake Squeal and Wheel Dust vs. Disc Wear: No-Copper, Low-Copper and High-Copper NAOs

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ABSTRACT

In a previous investigation, brake squeal was found to be related to disc wear, but not to pad wear or in-stop average coefficient of friction as tested according to the SAE J2522 performance procedure, using Low-Copper NAOs. To further validate the disc wear - squeal correlation, a variety of formulations of No-Copper, Low-Copper and High-Copper NAO disc pads were made and tested to investigate friction, pad wear, disc wear, brake squeal and wheel dust formation. It is found that disc weight loss measured at the end of the burnish cycle of the SAE J2522 (AK Master) is closely related to dynamometer/vehicle brake squeal and vehicle wheel dust formation, and that there is a critical disc wear rate of approximately 1.0 grams for the current brake system, below which brake squeal and wheel dust are minimal. It is also found that there is no correlation between brake squeal and in-stop average friction coefficient, in-stop maximum friction coefficient or in-stop friction coefficient variations during the burnish cycle of SAE J2522 (AK Master).

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INTRODUCTION

An earlier publication [1] reports that for many passenger car brakes (all single piston calipers), brake squeal occurrence increases as disc wear increases whether due to disc wear resistance variation for a given NAO material or due to increased pad abrasiveness against the disc. Another publication [2] reports that there exists a correlation between disc weight loss and brake squeal for a twin-piston caliper brake of a pick-up truck run with Low-Copper NAO disc pads, according to the SAE J2522 schedule run on a performance dynamometer and also road vehicle tests.

The current investigation was undertaken to further validate and clarify the findings in the two previous publications, using all 3 types of NAO formulations; No-Copper, Low-Copper and High-Copper. According to Sriwiboon et al. [2], the squeal occurrence was measured throughout the SAE J2522 Performance Test Procedure (AK Master) and the disc wear at the end of the test. However, the squeal data indicate that most of the squeal occurs during the burnish cycle and not so many squeals after the burnish cycle. Thus this investigation was performed by dividing up the SAE J2522 procedure into two parts; the burnish phase and the after-burnish phase. For each phase, squeal occurrence, disc wear and pad wear were measured. Also a limited number of vehicle squeal tests were run to

see the dynamometer - vehicle reproducibility for squeal. As the dynamometer tests were divided up into two parts and respective wear data were collected, an attempt was made to find a correlation between disc wear or pad wear and wheel dust. In addition, dynamometer in-stop friction data were analyzed for possible correlation to brake squeal.

MATERIALS, HARDWARE AND EXPERIMENTAL

A total of 14 No-Copper (< 0.5 wt.%), Low-Copper (< 5 wt.%) and High-Copper (> 5 wt.%) NAO formulations were made and tested (Table 1). Brake testing was performed on an SNT inertia dynamometer, which was equipped to measure brake squeal, using the SAE J2522 performance procedure. The testing, however, was interrupted to measure disc wear and pad wear after the burnish phase, and then the testing resumed. A twin-piston caliper from a pick-up truck of GVW 3,200 kg was used in conjunction with the NAO disc pads, which had 2 vertical slots and a radial chamfer on each end. A new OE gray cast iron disc was used for each test and the disc diameter was 305 mm. The cooling air was kept at 30 oC at a relative humidity of 50%. The performance tests were run without a knuckle and the pads had no noise shims. All the equipment and hardware are shown in Figure 1.

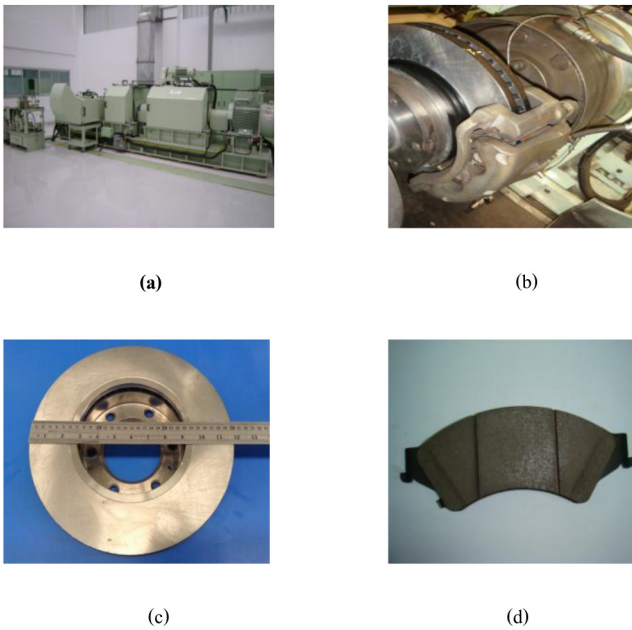


Figure 1. Hardware used - (a) SNT inertia dynamometer, (b) Twin piston caliper, (c) 305 mm - diameter disc (d) Pad with two vertical slots and radial chamfer without noise shims.

RESULTS AND DISCUSSION

Table 1 is a summary of all the dynamometer test results. The total number of brake squeals (≥ 70 dB) occurred during the burnish phase is plotted against disc weight loss in Figure 2. There were 2 high frequency squeals at 7.2 kHz and 8.2 kHz. As can be seen, up to approximately 1.0 grams of disc weight loss, there is not much brake squeal and thereafter the squeal occurrence begins to increase rapidly with increasing disc weight loss. In Figure 3, a similar plot is shown for the after-burnish phase. Here again brake squeal occurrence stays close to zero up to approximately 4.0 grams of disc weight loss and thereafter the occurrence begins to increase. As the after-burnish phase involves much higher brake line pressures than the burnish phase, the brake system becomes more rigid and more damped, which leads to a reduced number of squeal occurrences although the disc weight loss is much higher than in the burnish phase. In Figure 4, brake squeal occurrence is plotted against disc weight loss for the entire SAE J2522 procedure. In this case, the critical disc weight loss is at approximately 5.0 grams, which is in good agreement with the results reported on Low-Copper formulations earlier; approximately 6 grams [2]. The results suggest that for a given brake system under fixed braking conditions, there exists a threshold disc weight loss, beyond which brake squeal occurrence begins to increase steadily with increasing disc weight loss, and that disc weight loss is an important factor in affecting brake squeal excitation.

Table 2 is an analysis of the number of squeals occurred during the burnish phase. 9 formulations out of 14 exhibit more squeal occurrences in the first half of the burnish phase as compared with the second half while only 3 out of 14 formulations exhibit less squeal occurrences in the first half of the burnish phase. It can be said that in

general, the first half tends to generate more number of squeals, but not for all the samples. The increased tendency of noise generation in the first half of the burnish phase probably is related to higher disc wear rates in the first half of the burnish phase than in the second half. Now referring to Table 1, all the samples show reduced number of squeal occurrences during the after-burnish phase except for one sample (HC-4) as compared with the burnish phase.

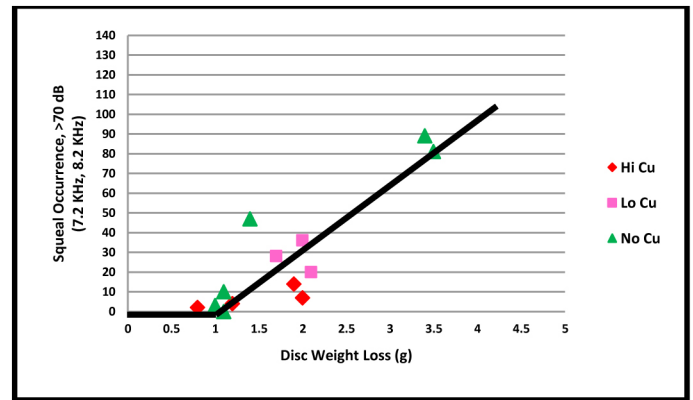


Figure 2. Brake squeal occurrence vs. disc weight loss; SAE J2522 burnish

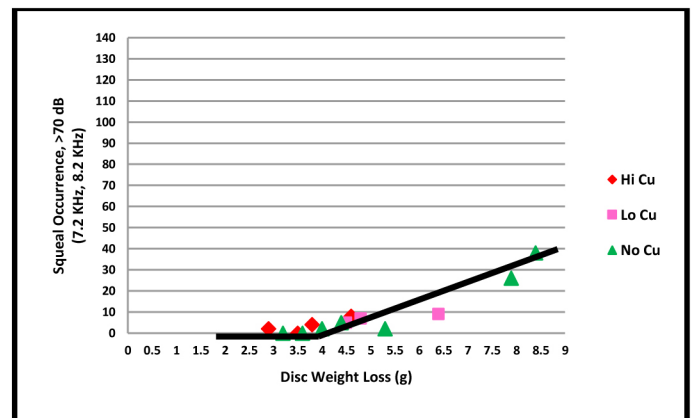


Figure 3. Brake squeal occurrences vs. disc weight loss; SAE J2522 after-burnish

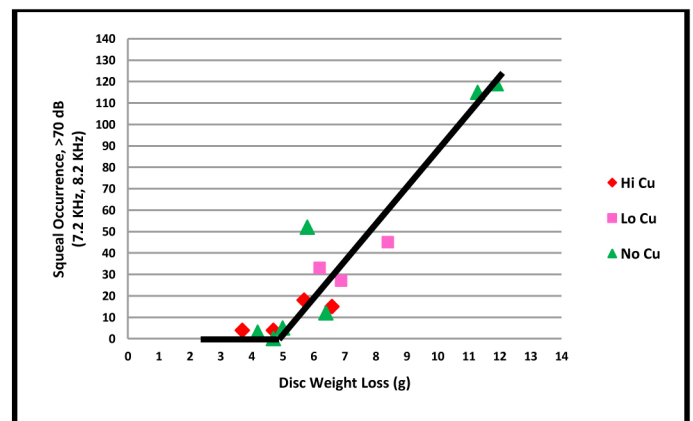


Figure 4. Brake squeal occurrence vs. total disc weight loss; SAE J2522