

A Study of Low-Frequency and High-Frequency Disc Brake Squeal

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ABSTRACT

When two identical brakes are simultaneously tested on a vehicle chassis dynamometer, very often the left hand brake is found to squeal more or less than the right hand brake, all at different frequencies. This study was performed to develop some understanding of this puzzling phenomenon. It is found that as the wear rate difference between the inner pad and the outer pad increases, low frequency (caliper and knuckle) squeals occur more and more, and as the differential wear becomes larger and larger, high frequency (disc) squeals occur less and less, finally disappearing all together. Discs and calipers are found to affect the differential pad wear, in turn affecting brake squeal generation.

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INTRODUCTION

When two identical brakes are tested simultaneously on a chassis dynamometer for noise, very often the left hand (LH) brake is found to squeal more or less than the right hand (RH) brake although the two brakes are supposed to be the same [1]. Also, very often, repeatability is less than satisfactory. This research was undertaken to develop some understanding of this puzzling phenomenon.

MATERIALS, HARDWARE, EQUIPMENT AND EXPERIMENTAL

A number of combinations of different NAO pad formulations and different sizes of single piston floating calipers along with various required sizes of gray cast iron discs were tested on Link Chassis Noise Dynamometer 4900 with environmental control and also on Link Corner Noise Dynamometer 3900 with environmental control to measure squeal occurrences.



Fig.1. Equipment and Hardware

RESULTS AND DISCUSSION

Figure 2 is a summary of a combination of 2 caliper A's and 2 sets of NAO formula 1 pads, simultaneously tested on the Link Chassis Noise Dynamometer according to an OEM procedure. The procedure involves some 1400 stops and snubs. The pads had no slots, no chamfers and no noise shims. The left hand (LH) brake squeals only at 3.6 kHz and the right hand (RH) brake only at 12.3 kHz although the two brakes are supposed to be "the same"; low frequency squeals only and high frequency squeals only, respectively [2]. It is interesting to note that the pad wear rate difference between the inner pad and the outer pad is 0.117 mm (large) for the LH while the difference is only 0.023 mm (small) for the RH. Figure 3 is a summary of caliper A and disc pad formula 2 with respective pad wear rate differences of 0.161 mm (large) for the LH and 0.035 mm (small) for the RH, being similar to the case of disc pad formula 1; low frequency squeals only for the LH and high frequency squeals only for the RH. Figure 4 is a summary of NAO disc pad formula 3 tested with caliper A according to the same test procedure. In this case, the LH brake squeals at 3.5 kHz and the right hand brake at 3.5 kHz in addition to 6.5 kHz. The difference in pad wear rates for the LH is 0.103 mm vs. 0.088 mm for the RH, 0.088 mm being

substantially greater than 0.023 mm for the RH in Figure 2 or 0.035 mm for the RH in Figure 3. It appears that as the pad wear rate differences between the inner and outer pads become larger and larger, the low frequency squeal occurrence increases, thus resulting in low frequency squeals and high frequency squeals at the same time. In other words, when the differential pad wear is small, only high frequency squeals occur and as the differential wear becomes large, only low frequency squeals occur. When the differential pad wear is in between, low frequency and high frequency squeals occur at the same time.

In order to find out if the trend observed on the chassis noise dynamometer is a general trend, the B caliper - disc pad formula 4 combination was tested on Link Corner Noise Dynamometer 3900 (Figure 5) and compared with the B caliper - disc pad formula 5 combination (Figure 6). Here again, when the differential pad wear is 0.040 mm, only high frequency squeals occur while the difference in inner and outer pad wear rates increases from 0.040 mm to 0.073 mm, the low frequency squeals appear along with high frequency squeals, similar to the chassis noise dynamometer results shown above. If the differential pad wear increases much beyond 0.073 mm, high frequency squeals are expected to disappear entirely.

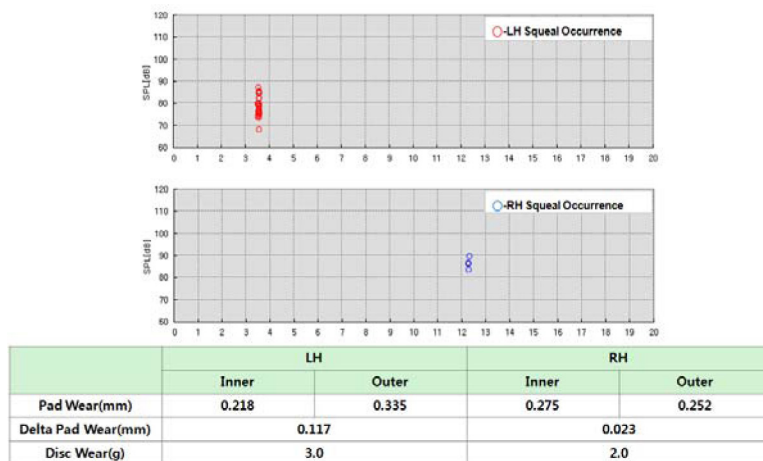


Fig.2. Chassis Noise Dyno: Caliper A/ NAO Formula 1; No Slots, No Chamfers and No Noise Shims; OEM Procedure.

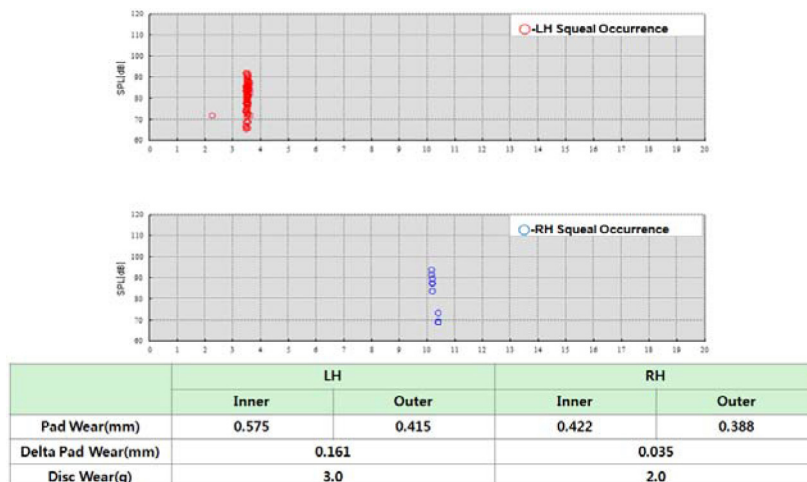


Fig.3. Chassis Noise Dyno: Caliper A/ NAO Formula 2; No Slots, No Chamfers and No Noise Shims; OEM Procedure.

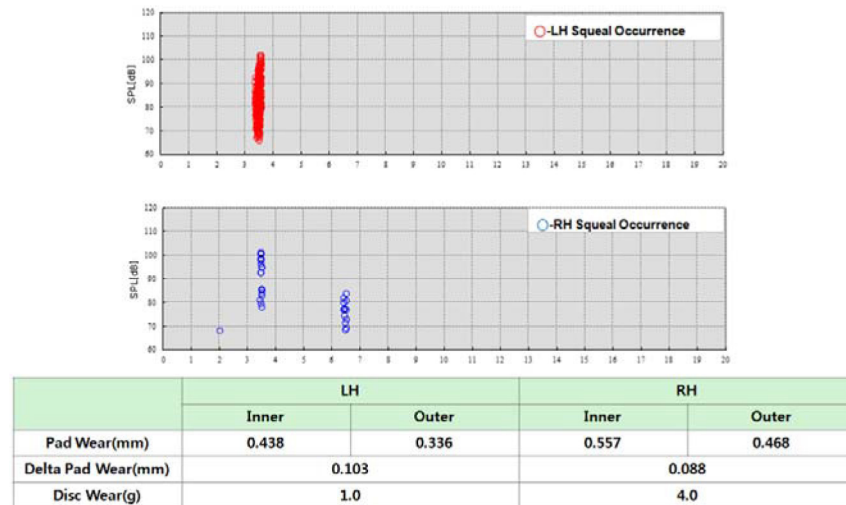


Fig 4. Chassis Noise Dyno: Caliper A/ NAO Formula 3; No Slots, No Chamfers and No Noise Shims; OEM Procedure.

The next set of experiments involved the B caliper and pad formula 6 but two different discs, one coming from A foundry from one country (A disc) and another coming from B foundry in another country (B disc). The combinations were tested on the Link Corner Noise Dynamometer 3900. The test results are summarized in Figures 7 and 8, respectively. Here again, at a differential pad wear of 0.101 mm, low frequency and high frequency squeals occur at the same time while at a low differential pad wear rate of 0.038 mm, only high frequency squeals occur, being consistent with all the trends shown above. The two surfaces of the inner and outer pads run against the A disc and the two surfaces of the inner and outer pads run against the B disc were analyzed for iron concentrations by SEM. The analytical results are summarized in Figures 9, 10 and 11, respectively. As can be seen, the differential pad wear rate of 0.101 mm of the A disc corresponds to a

differential iron concentration of 0.75 wt% relative while the differential pad wear rate of 0.038 mm of the B disc corresponds to a differential iron concentration of 0.42 wt% relative. The data implies that the differential μ between the inner pad and the outer pad in the case of A disc probably was greater than the case of B disc. In other word, when the μ differential is small (more synchronized between the inner pad and the outer pad), high frequency squeals occur while the μ differential becomes larger and larger, low frequency squeals begin to appear, eventually resulting in all low frequency squeals. It is also interesting to note that lower pad wear is associated with higher transferred iron concentration on the surface. In other words, friction material formulation changes and disc variability both can affect the generation of low frequency and high frequency squeals.

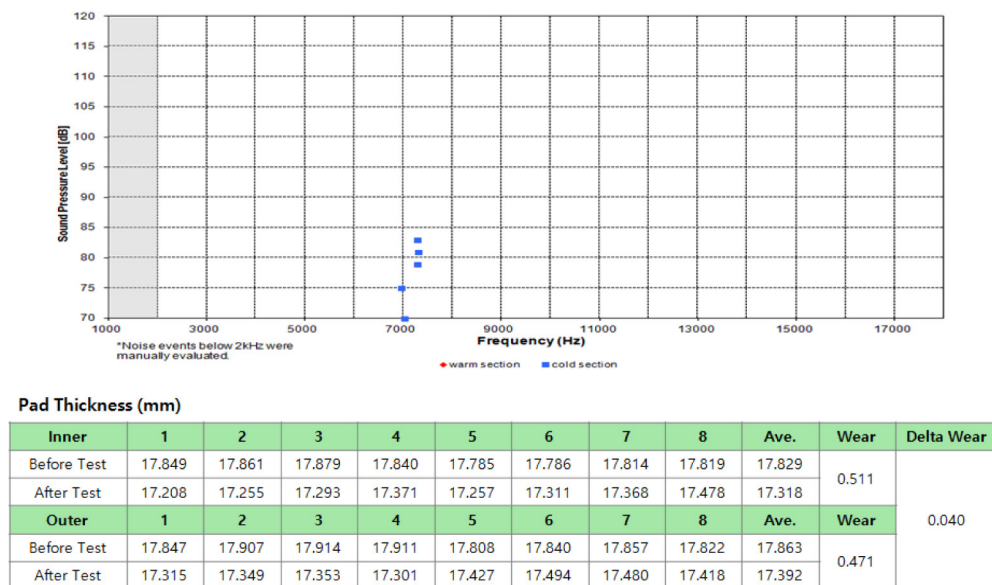


Fig.5. Corner Noise Dyno: Caliper B/ NAO Formula 4; No Slots, No Chamfers and No Noise Shims; OEM Procedure; 2500 Stops and Snubs.