Acoustic Quality Control of Drum Brake Shoes

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Introduction

Recent investigations of brake noise phenomena show that natural frequencies and damping of brake components play an important role regarding the propensity of noise excitation. While works are on-going to include requirements of those parameters into international standardization of disc brakes, there is lack of knowledge regarding drum brake noise. Vibrational modes of drum brake shoes are a main contributor to squeal phenomena [1]. Natural frequencies, damping and variability of physical properties of the shoes are main influencing parameters. Vehicle tests have shown that in various cases a strong increase of the torsional stiffness of drum brake shoes can eliminate squeal phenomena. Here, the term *acoustic quality* stands for optimised vibrational properties in order to avoid brake squeal. Similar tests, however, are suitable to determine non-acoustical quality, e.g. variability of material properties, while those parameters also have an influence on vibrational modes.

Investigated Squeal Phenomenon

Under specific conditions, a drum brake squeal was detected at 3.2 and 4.8 kHz. It is well known that brake drum, brake shoes and backing plate (fig. 1) critically influence the squeal propensity of the system [2], [3], [4]. Resonance tests

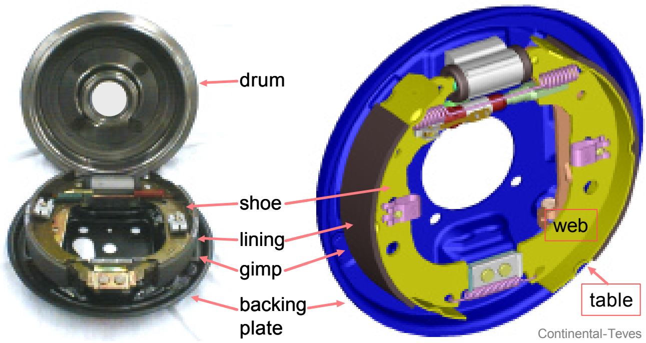

Figure 2: Simplex Drum Brake Assembly

of the brake assembly under artificial excitation (shaker) showed an axial "hat-shape" mode and its first harmonic at the squeal frequencies (fig. 2). Corresponding bending modes have been found at the backing plate. Main excitation forces, however, occur during brake operation in tangential direction in-between friction surface of the shoes and inner surface of the drum. If this leads to excitation of mode shapes with maximum deflection in axial direction, it can be assumed that a specific process is involved, transforming tangential excitation into axial movement. Therefore an operational deflection shape analysis was done on a brake noise dyno at Continental-Teves, Frankfurt. Results indeed

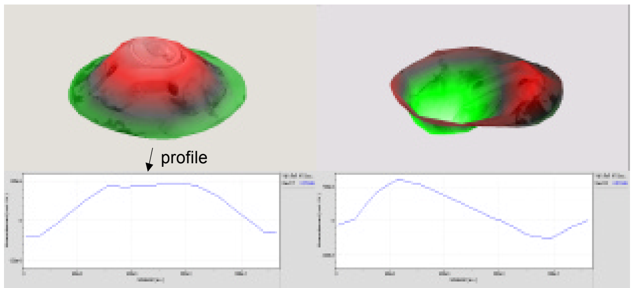

Figure 1: drum "hat shape" mode and 1st harmonic at 3.219 and 4.813 kHz (brake assembly, shaker excitation)

clearly showed torsional vibration of the brake shoes during squeal excitation.

Component Behaviour

Brake drum and backing plate show various vibrational modes in the frequency range where squeal phenomena occur. Beside bending modes shown in fig. 2, various "circumferential modes" exist, causing symmetric bending pattern of the rim. The brake shoes act as link between both vibration systems and therefore are capable to either boost or suppress coupling. In the case described here, it was found that torsional modes enable system instability and self excitation of noise. Those modes can be studied under free-free conditions (fig. 3), but Eigenfrequencies naturally differ from those observed within the assembled system, and with brake pressure applied. While the interaction of modal

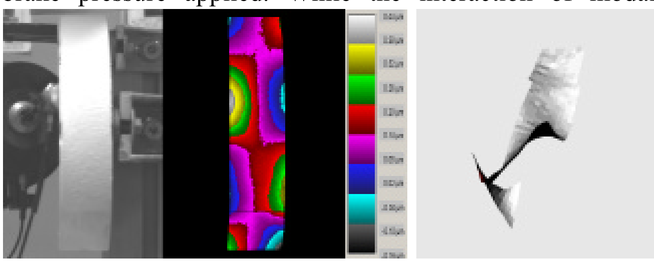

Figure 3: torsional mode of drum brake shoes at 3.1 kHz, measured with Laser ESPI and shaker excitation

behaviour of drum, brake shoes and backing plate causes instability of the system, modifications of one of these parts can in principle eliminate noise generation. In example, increase of drum mass or weights fixed upon the backing plate can both reduce modal alignment. Alternatively, a modification of the stiffness of brake shoes can strongly change the coupling in-between drum and backing plate and therefore eliminate squeal without adding weight to the system.

The torsional stiffness of the shoes is influenced by the connection of its metal parts: web and table. Vehicle tests showed that squeal could be eliminated by stiffening web and table with an additional welded reinforcement. This finding was confirmed by CAE calculations. Component tests also showed that properties of a welded connection differ from properties of clenched parts. Material properties of friction material and glue used for fixing linings upon the table have additional influence. The variability of vibrational properties of assembled shoes depends on the well-known high variability of friction material, but in this case even web and table showed pronounced variability. The limited process capability of brake shoe production pushes the drum brake system far away from a status of sufficient control, which would enable robust design of acoustical properties.

Quality Test Methods

The described component investigations clearly remind the urgent importance of variability control of brake shoes. The first step is measurement of the vibrational properties of large samples, continuously applied to on-going production. An appropriate assessment of Eigenfrequencies can be done by measurement of frequency-response functions (FRF) with one excitation point and one location of response measurement. The excitation can be done either mechanical (hammer, shaker), acoustical (loudspeaker) or magnetic. The time function of excitation signals can be continuously or impulsive. The sensor can be mechanical (accelerometer), optical (Laser interferometer), magnetic or acoustical (microphone). In case of torsional movement, measurement of table vibration in out-of-plane direction gains sufficient data. While a great variety of equipment can be used, it can be chosen regarding costs, measurement time and personnel resources. Under production conditions, an automated device will provide an optimum solution.

Quick Quality Check

A measurement system for quick quality check of drum brake shoes was developed in the laboratory. The main task was to demonstrate that an automated setup with low cost components can provide accurate results.

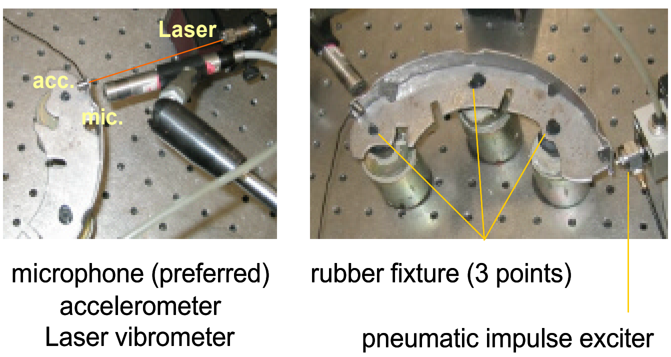

Figure 4: Setup for quick quality test

The brake shoes are fixed upon 3 rubber bearings (fig. 4), providing free-free-conditions within the relevant frequency range. The design of bearings enables automated feeding of parts. Tests were done with assembled web and table, without friction material. The test, however, can also be done with complete shoes. A pneumatic impulse exciter was equipped with a force transducer. Three measurement pick-ups were installed in parallel to enable comparison of results: *light-weight accelerometer*, *single-point Laser interferometer* and *electret microphone*. Sensors were positioned 7 mm from the edges of a table corner. Excitation of the diagonally opposite corner generated torsional vibration. Use of a microphone provides the cheapest method of measurement. Results show very good compliance of Eigenfrequencies (fig. 5). Damping values slightly differ in case of microphone measurement, while it covers radiation of a larger table area.

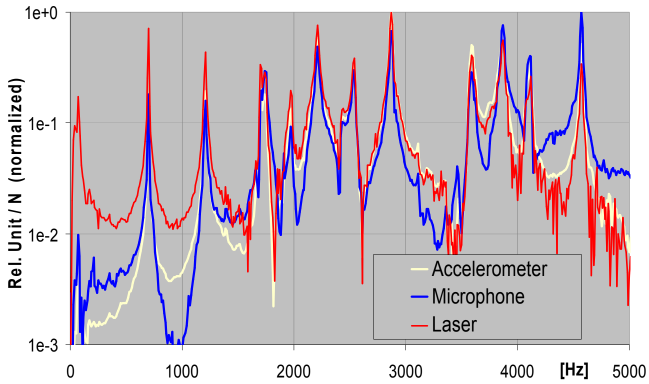

Figure 5: Results of the quick test:
FRFs related to input force, normalized to max. values

Conclusion

While torsional modes of drum brake shoes play an important role for squeal generation, the standardisation of a robust measurement procedure to determine Eigenfrequencies and damping must be accelerated. It is necessary to base the standard on low cost measurement units which can easily be installed at brake suppliers, friction material manufacturers and OEMs. Methods used for development shall be similar to those used for production control. An automated test setup is suitable for quick tests of large samples, thus providing excellent statistical significance. As demonstrated within this paper, it is possible to build-up an efficient, accurate and cheap measurement system with good chances of broad acceptance. Further steps must clearly define variability of test results and best choice of measurement/excitation units.

References

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