IMPROVEMENT OF COMFORT OF FRICTION BRAKES

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SUMMARY
Brake noise is generated during car braking at low speeds and low pressures. Stick-slip between brake linings and the rotor occurs because of the difference between static and dynamic friction. New additives have been developed which reduce the discontinuity of friction and thereby improve comfort of braking.

Keywords: Judder, stick slip, friction brake, polarised graphite

1 INTRODUCTION
A friction brake is a converter of velocity into heat by friction. In this design organic brake linings and a metal rotor or drum are in sliding contact. A high performance friction brake has to fulfill a number of tribological requirements; safety issues are the most important ones [1]. However, comfort of braking has become an important topic since brake noise is regarded as pollution.

Since the cast iron alloy of the metal rotor basically never changed all requirements for improved braking performance had to be accomplished by upgrading the brake lining formulation.

It is assumed that by a discontinuity of friction a difference between static and dynamic friction is generated. In recent years there was a trend towards weight saving of car components and also brake pads were downsized. In order to maintain the same braking performance the friction coefficient of the brake increased from µ = 0.25 to 0.45. This lead to greater discontinuity of friction and brake noise increased dramatically.

Discomfort of braking is primarily brake squeal at a frequency of about 5000 to 8000 Hertz [2]; brake judder may be below 100 Hertz. Brake noise primarily occurs during braking at low speeds and low pressures [3] and is assumed to be caused by micro stick slip which is basically a difference between adhesive and dynamic friction.

It was found empirically that brake noise is reduced when a certain amount of lead sulphide or molybdenum disulphide powder is added to the brake lining formulation. Lead sulphide will not be used anymore for environmental concerns. MoS2 was found to reduce friction level by about 20%, which was an undesired side effect in brakes. Both metal sulphides have been used in brake linings for improvement of brake comfort for several decades. The challenge was to develop an environmentally friendly comfort additive which does not reduce friction.

2 TESTING OF BRAKE COMFORT
For development of a "green" antinoise additive a test method for detecting brake noise was required. In a friction lining test machine the specimen consist of three composite segments and a brake rotor. Recorded is disc temperature and friction force (figure 1). Since the rotor is stationary vibrations being generated during sliding friction can be detected by attaching a piezo sensor to the disc. Acceleration is amplified and recorded. The signal is analysed further in a frequency analyser ranging from 0 to 20.000 Hertz.

For detection of vibration various tests were performed during continuous braking at different speeds, different pressures and different disc temperatures.

After screening the test parameters were selected to be: Speed 500 RPM at constant disc temperature of 200°C by heating the rotor. Over a 6 hour test program the pressure was changed from 40 N/cm² to 5 N/cm². During the test the acceleration signal, the analysis of frequency and friction force were recorded. Testing a number of brake linings with known comfort level it was found that good correlation existed between the vibrational signal in the test machine and brake noise in the field. A typical recording of vibration during continuous braking of a noisy brake pad is given in figure 2.

During the first hour of braking the vibrational signal is very low indicating no brake noise. According to the experience new brake pad components do not generate brake noise. During running-in surfaces of friction components change. At the composite surface a friction layer is formed which has a different composition than the matrix and the rotor surface is covered by a transfer layer [4,5]. Both layers in sliding contact may generate stick slip. After a smooth running-in of a noisy brake pad the vibrational signal suddenly increases and stays high for the rest of the run [6].
It has been confirmed that the addition of lead sulphide and molybdenum disulphide reduces the vibrational signal substantially for the entire test, which is in good correlation with field results.

![Figure 2: Recording of vibration during continuous braking of a noisy brake pad.](image)

3 DEVELOPMENT OF NEW ADDITIVE TECHNOLOGY

One of the key materials in friction linings is graphite. However, this material can only be used in brake lining formulations in limited quantities, since the friction coefficient changes with humidity. In a humid environment or in case of brake pads at lower temperatures friction is comparably low. At higher temperatures water is evaporating and dry graphite presents a very high friction coefficient. Dry graphite also has poor adhesion to substrates and poor film formation. Molybdenum disulphide, however, has good adhesive properties on metal surfaces and good filming ability. These features can be explained by the polar surface of MoS2 lamellae, which is caused by small molybdenum atoms of high polarity. Since graphite is an element the lamella surfaces have no polarity. By special surface treatment the graphite particles have been coated with inorganic compounds. Such treatment with metal molybdates, - phosphates, - sulfates, and - sulphides change the tribological properties of graphite entirely. Friction coefficient is no longer dependent on humidity, load carrying capacity is increased and wear reduced [7]. Dry lubricating ability is greatly improved since polarised graphite has under pressure very good adhesion to substrates and good film forming ability (figure 3).

When polarised graphite was added to a brake lining matrix it was found during continuous braking in the friction lining tester that vibration was greatly reduced also after the running-in procedure. The frequency analysis also showed much lower peaks in comparison to the matrix (figure 4).

Brake linings containing polarised graphite as an additive showed a substantial reduction of squeal during braking. Frictional level was not reduced by the addition of the additive. Brake roughness and judder could not be detected by the vibrational signal since the frequency is comparably low. Friction force recording was analysed during continuous braking and low speeds and low pressures. It was noted that the brake pads with a high roughness level showed a high fluctuation of friction force. Polarised graphite was added to a matrix with high roughness level and tested during continuous braking at various pressures (figure 5).

![Figure 3: Molybdenum disulfide (left) and polarised graphite (right) on a metal surface.](image)
From figure 5 it can be seen that the matrix has a rather non-uniform friction and a high fluctuation. The addition of polarised graphite stabilises friction and reduces friction fluctuation drastically.

4 CONCLUSION

Using a friction test machine a vibration test method was developed, which showed a good correlation between vibration generated during dry friction of composite surfaces against a cast iron rotor and noise and judder occurring in a friction brake. By the help of this test facility antinoise additives were tested which reduce micro stick slip by reducing the difference between static- and dynamic friction. Field tests revealed that polarised graphite as additive in brake linings improve braking comfort by reducing high frequency - and low frequency vibrations. Brake squeal and roughness was reduced substantially. The new additive is environmentally friendly and does not reduce friction level. It is in use as a comfort additive in place of presently used metal sulphides in brake lining formulations.

5 REFERENCES