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A pin-on-disc tribometer study of friction at low contact pressures and sliding speeds for a disc brake material combination

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ABSTRACT

Disc brake creep groan is a stick-slip phenomenon which results in a low frequency noise in road vehicles that could occur at low vehicle speeds and brake torques. Simulation approaches are used predict the stick-slip phenomena for disc brakes. These approaches depend on the friction model used. Tribometers can be used to map how the local coefficient of friction (CoF) depends on the contact pressure (*p*) and sliding speed (*v*). A CoF *pv*-map can be used as friction model in simulation approaches. There is a lack of CoF maps at low contact pressures and sliding speeds are reported in the literature. The aim of the presented study is to map the CoF for a disc brake material combination at low contact pressures (0.03–0.28 MPa) and sliding speeds (0–3.8 mm/s). The result shows that the friction decreases with increased contact pressure and sliding speed for the specific material combination tested and the test conditions used. More studies are needed to further investigate the validity of the results.

Introduction

Disc brake creep groan is a stick-slip phenomenon which results in a low frequency noise [1]. The creep groan occurs at low vehicle speeds and brake torques, that is, at low contact pressures and sliding speeds between the pads and disc. Creep groan typically occurs when a road vehicle with automatic transmission drive starts from zero velocity [2].

Brake creep groan has been experimentally studied with tribometers [3], brake benches [4], and chassis dynamometers [5]. Furthermore, simulation approaches have been used to study stick-slip phenomena for disc brakes [6]. The output of the simulation approaches strongly depends on the friction models used. One way of defining a friction model is to use experimental data for the brake system studied. Tribometers can be used to map how the local CoF depends on contact pressure and sliding speed [7]. The idea with CoF *pv*-maps is to use them to model the local friction in simulation tools on the system level to predict creep groan. To the author known, there is a lack of CoF maps at low contact pressures and sliding speeds reported in the literature.

The aim of the present study is therefore to map the CoF for a disc brake material combination at low contact pressures and sliding speeds.

Pin-on-disc tribometer

An illustration of the pin-on-disc tribometer used in the present study can be seen in Fig. 1. Detailed information about the tribometer can be found in Ref. [8]. In this setup, a stationary pin is pressed against a rotation disc. A normal load is applied on the pin by a dead weight and a load cell (HBM® Z6FC3/10 kg) measures the tangential force exerted on the pin. The CoF is obtained by dividing the measured tangential force by the applied normal load.

A pin and a disc were cut-out from a low-metallic pad and a grey cast iron rotor used in a typical disc brake for a medium-sized car. The pin is cylindrical with a diameter of 10 mm and a height of 20 mm. The disc has an outer diameter of 60 mm and a thickness of 6 mm. The mid.

The load conditions is presented in see Table 1. The dead weighs used varied between 0.25 and 1 kg which corresponds to nominal contact pressures between 0.03 and 0.28 MPa. The wear track on the disc had a diameter (midpoint of track to midpoint of disc) of 12 mm. The rotational velocity varied between 1 and 3 rpm which corresponds to sliding speeds between 1.3 and 3.8 mm/s. Each combination was run three times for one hour. In the static CoF tests (v = 0 mm/s), a force applied to the disc was slowly increased until it started to rotate thereafter the test was stopped. The same pin and disc samples were used in all tests. The test specimens were run-in

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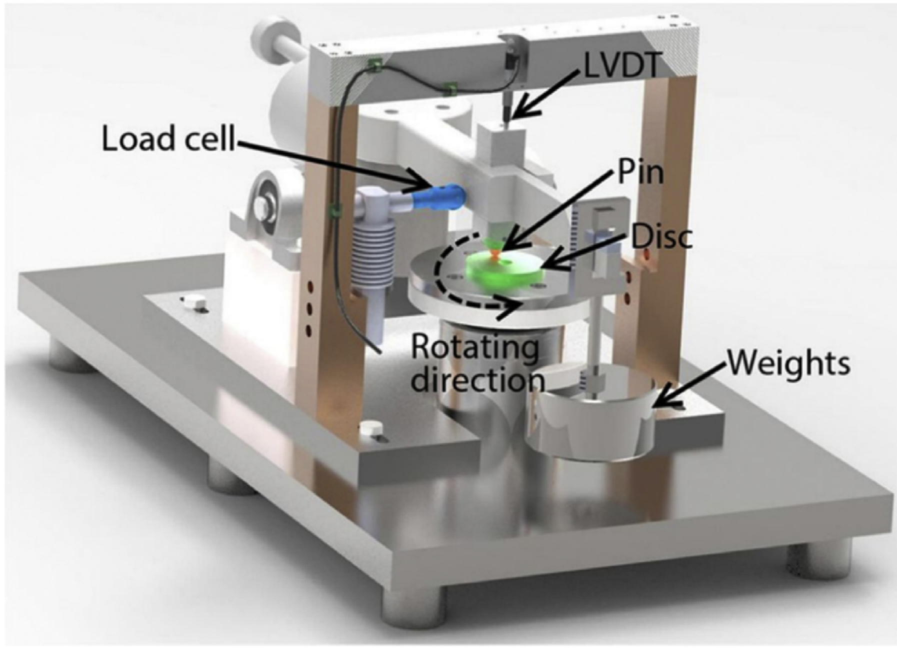

Fig. 1. Pin-on-disc tribometer equipment [8].

Table 1
Test conditions and resulting mean values and standard deviations of the calculated CoF's.

Condition [#]	*p* [MPa]	*v* [mm/s]	*μ* [−]
1	0.03	0	0.58 ± 0.02
2	0.06	0	0.56 ± 0.01
3	0.14	0	0.55 ± 0.01
4	0.28	0	0.51 ± 0.01
5	0.07	1.3	0.49 ± 0.04
6	0.14	1.3	0.46 ± 0.04
7	0.21	1.3	0.48 ± 0.05
8	0.28	1.3	0.49 ± 0.01
9	0.03	1.3	0.61 ± 0.08
10	0.06	1.3	0.56 ± 0.01
11	0.09	1.3	0.55 ± 0.02
12	0.18	1.3	0.52 ± 0.07
13	0.07	2.5	0.34 ± 0.05
14	0.14	2.5	0.33 ± 0.02
15	0.21	2.5	0.38 ± 0.07
16	0.28	2.5	0.39 ± 0.08
17	0.07	3.8	0.38 ± 0.08
18	0.14	3.8	0.41 ± 0.08
19	0.21	3.8	0.39 ± 0.06
20	0.28	3.8	0.38 ± 0.04

at a higher load, a contact pressure of 0.6 MPa and a sliding speed of 2 m/s, for two hours before the tests started to minimise run-in effects. This was also done to expose the test samples to temperatures and contact pressures which represent urban driving before the tests starts [8]. The ambient temperature was about 22 °C and the relative humidity about 30%.

Results and discussion

The mean CoF values and standard deviations of all repetitions are presented in Table 1. Note that the mean CoF values of each individual test are calculated for the last 10 minutes of the tests when the CoF is more stable. Also note that the highest peaks measured during the static tests is used to estimate the static CoF. Typical coefficient of friction curves as a function time can be seen in Fig. 2. The variation in CoF presented in Fig. 2 could be directly related to the rotational speed of the disc and not stick-slip. The time between the peak values, is the time it takes for the disc to rotate one round which indicates the variation is due to that the disc is not perfectly horizontal mounted in the tribometer. This results in that the component of the measured tangential force will vary during one round. Shims could be placed under the disc to minimise this effect in the future. The corresponding CoF *pv*-map in Fig. 3. Overall the trend is that the friction increases with decreasing sliding speed if the pressure is kept constant (Fig. 3). This is in line with results reported in the literature [7] at higher contact pressures and sliding speeds. It can also be seen in Fig. 2 that the friction increases with decreasing contact pressure.

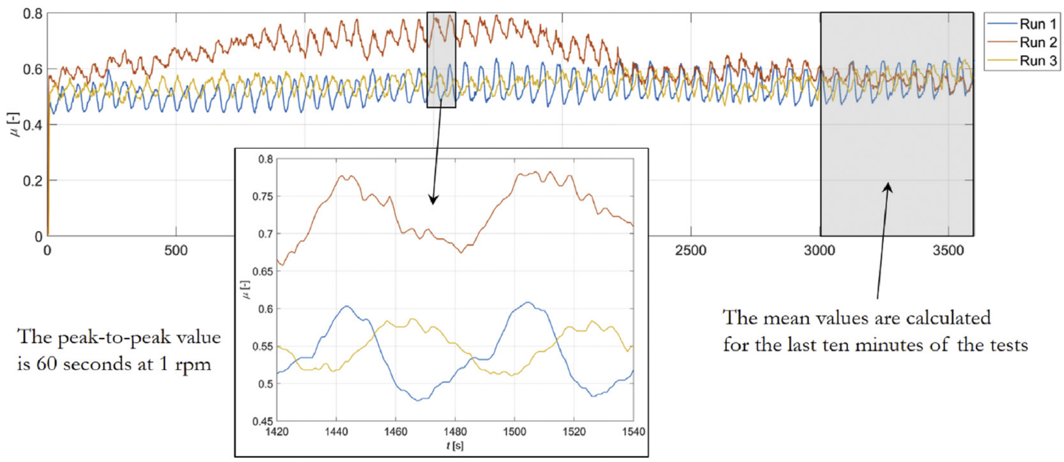

Fig. 2. CoF (μ) for the three receptions conducted at load condition 10.

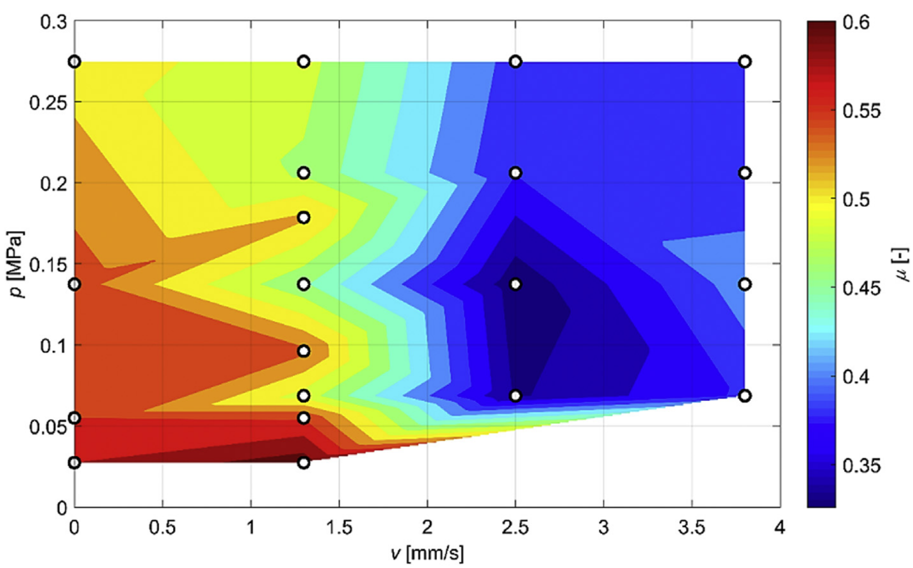

Fig. 3. Coefficient of friction pv-map.

Concluding remarks

A pin-on-disc tribometer study of a low-metallic pad and grey cast iron disc material combination has been done to map the CoF dependence of low contact pressures (0.03–0.28 MPa) and low sliding speeds (0–3.8 mm/s). It can be concluded from the results of the present study that the CoF increases both with decreasing contact pressure and sliding speed for this specific material combination and test conditions.

A drawback with this study is that only one pair of pin and disc was used. In the future this should be repeated with more pin and disc specimens. It would also be interesting to study how the influence of ambient conditions (temperature and relative humidity [9]) influence the friction. Also, it can be interesting to study how the initial temperature of the test specimens could affect the CoF. This could be done by pre-heating the test specimens before testing. Furthermore, it remains to implement the friction map in NVH simulation tools.

Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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