Published paper
Lewis, R. (2009) *Friction in a hydraulic motor piston/cam roller contact lined with PTFE impregnated.* Wear, 266 (7-8). pp. 888-892.
http://dx.doi.org/10.1016/j.wear.2008.12.009

FRICTION IN A HYDRAULIC MOTOR PISTION/CAM ROLLER CONTACT LINED WITH PTFE IMPREGNATED CLOTH

R. LEWIS*

Department of Mechanical Engineering, The University of Sheffield, Mappin Street, Sheffield, S1 3JD

Tel. +44 (0) 114 2227838; Fax. +44 (0) 114 2227890

roger.lewis@sheffield.ac.uk

ABSTRACT

The aim of this work was to test a new PTFE impregnated cloth material for use as a surface layer on the pistons of a hydraulic motor at the interface with the cam roller. Tests were carried out using a standard Bowden & Leben sliding friction tester which indicated that the cloth material gave similar results to the current material (PTFE impregnated sintered bronze) in both dry and lubricated conditions. Actual component tests run on a modified twin-disc test machine showed that the cloth performed better in conditions of reduced lubrication. Wear testing would be required to fully assess the feasibility of using the material in a hydraulic motor.

Keywords: Hydraulic motor, piston, roller, friction

1 INTRODUCTION

Hydraulic motors convert hydraulic energy into mechanical energy. They are used as part of a hydraulic system with fluid reservoir and pumps to supply the fluid. The fluid, supplied via a pump from the reservoir, forces the movable components of the motor into motion, which in turn rotate the attached output shaft.

There are three types of hydraulic motor; gear, vane and piston. Each of these types can be either unidirectional or reversible. The type of motor considered in this work was a piston type. These can be either axial or radial and are generally the most expensive of the hydraulic motors. They have advantages over the other motors, however, in that they are far more adaptable to high torque, low speed operation and higher system pressure applications. Hydraulic motors are used in a wide range of industries. In the aerospace industry they are employed to actuate wing flaps; in the food processing industry they power automated manufacturing machinery and they are also used in construction equipment and industrial processing.

The components tested in this work were from a radial motor configuration design as shown in Figure 1. The cam rollers slide against the pistons as they rotate and against the cam ring, which is profiled to move the piston in and out as it rotates. The surface of the piston, where the cam roller is making contact, is usually coated to help reduce friction and wear. The aim of this work was to investigate the possibility of using a PTFE impregnated cloth material instead of the current PTFE impregnated sintered bronze coating used, which would create a cost benefit. In normal operation the parts are all submerged in oil. The major concern with using the cloth was that problems may exist under dry conditions due to lubricant loss during operation or at start-up.

Some work has been carried out previously on the tribology of hydraulic motor components. This has either focused on the piston ring/flank contact [1] or on wear of the cam roller [2], rather than friction.

2 SPECIMEN FRICTION TESTS

Initial tests were carried out using simple flat specimens with the current and proposed surface layers attached to thin strips of steel. Tests were carried out with a flat-on-flat and then a ball-on-flat geometry.

2.1 Test Procedure

A Bowden & Leben type friction tester was used for the testing, as shown in Figure 2. Tests were carried out in dry and lubricated conditions. A standard 15W40 automotive lubricant was used. Flat-on-flat tests were carried out at a contact pressure of 2.7MPa and ball-on-flat at 2000MPa. These were dictated by the limitations on specimen sizes and loads on the rig rather than representing what actually happens in the hydraulic motor. The actual operating contact pressure is around 100MPa. The sliding speed in the tests was 5mm/s, again dictated by the rig. Actual sliding speeds are several orders of magnitude higher.

2.2 Results

Results of the specimen sliding friction tests are shown in Figures 3a and 3b (sintered bronze and cloth respectively). As can be seen there is little difference between the two materials. Flat-on-flat friction was higher, but it was seen that the flat specimens cut into the cloth/bronze, which would have increased the lateral force measured. While these results gave a good indication of relative performance, the tests were at different contact pressures, using different contact geometries and at sliding speeds well below those in the actual component contact. It was clear that a more realistic test utilizing the actual specimens and running at higher sliding speeds was required.

3 COMPONENT FRICTION TESTS

Tests using actual rollers and pistons with both surface layers were carried out on a modified twin disc test machine. A number of lubrication scenarios were tested.

3.1 Apparatus

The twin disc test machine used to carry out the testing is shown schematically in Figure 4. More details on the use of the machine are given in Lewis et al. [3]. In its usual operation the test discs are hydraulically loaded together and driven at controlled rotational speed by independent electric motors. Shaft encoders monitor the speeds continuously. A torque transducer is assembled on one of the drive shafts and a load cell is mounted beneath the hydraulic jack. Different slip ratios can be achieved by adjustment of the rotational speeds. All data is acquired on a PC, which is also used for load and speed control.

For the purposes of this testing the pivoted drive shaft was disconnected and a plate and bracket were attached to the bearing housing to support the piston (as shown in Figure 5). The roller had a hole and recess accurately machined through it so that it could be bolted to the disc mounting on the left hand shaft. The rig was set up so that the roller was in position in the piston before load was applied (see Figure 5). The hydraulic jack could now be used to load the piston up against the roller.

3.2 Specimens

The roller and piston specimens used are shown in Figure 6. The roller has a diameter of 22mm and a length of 35mm. The piston has an outer diameter of 31mm. The PTFE cloth material was initially attached to a thin strip of steel that was then mounted on the piston. The cloth was approximately 0.3mm thick and had an initial roughness (R_A) of 9μm. The roller roughness was 0.46μm.

3.3 Test Procedure

Tests were run in a number of different ways to simulate the start-up conditions, actual running conditions (with parts continuously supplied with lubricant) and dry conditions. Details are given in Table 1, including the load and rotational speeds used. The load of 6.8kN was chosen to represent the actual load in the motor (this gave a contact pressure of 100MPa), the actual rotational speeds could not be achieved in this rig. For most tests the rotation was started and then the load was applied. For the dry conditions a test was also run where the load was applied first and then rotation started.

The same piston had to be used for the tests with the original PTFE impregnated sintered bronze coating. The piston was cleaned thoroughly between tests with ethanol to remove any remaining oil. The lubricated tests were run first and then the dry tests, just in case the dry tests damaged the surface. A new piston was used for each test on the proposed PTFE impregnated cloth material.

3.4 Results

Figure 7 shows the friction results for both materials and all test conditions. For the initial lubricated tests it was intended to supply lubricant constantly, but for the test using the sintered bronze material the flow was interrupted. This caused the friction to rise, as the lubricant that was present was removed from the contact, until reaching a peak and then becoming quite variable. When lubricant was supplied continuously the friction dropped and levelled off. With a constant supply of lubricant, the cloth friction rose initially before levelling off at a value just below that of the sintered bronze. The cloth material showed signs of polishing and the thread pattern was less prominent (see Figure 8a).

The lubricant run off test for the sintered bronze material gave a similar result to that seen in the first lubricant test where supply was interrupted, confirming the original response was repeatable. Slight damage was seen to the material surface as shown in Figure 9a. The friction for the cloth rose, but at a much slower rate. This may be because it absorbed lubricant when it was applied at the start of the test. The post test roughness (R_A) of the cloth was 2.84μm. Clearly the surface has been smoothed. This may have been due to wear or deformation of the surface.

For the dry tests where the load was applied and then the rotation was started, the friction dropped sharply for both materials, the cloth finally reaching a slightly lower value.

For the dry tests where rotation was applied first the friction climbed sharply for the sintered bronze material (the test was eventually stopped as the components were showing evidence of overheating), but remained more stable for the cloth around the level reached in the first dry test. The sintered bronze material sustained damage during the dry testing, as is shown in Figure 9b, where severe scuffing is evident, as did the cloth material (see Figure 8b).

4 CONCLUSIONS

In terms of friction the cloth material performed better in the lubrication run-off test and in dry tests than the sintered bronze material. It gave slightly higher friction in the lubricated tests. Clearly the cloth would cope adequately with any problems due to lubricant starvation in the actual motor.

However, wear may be an issue so further testing for extended running times would be required before deciding whether this material could be used.

REFERENCES

1. U.I. Sjödin, U. Olofsson, Experimental study of wear interaction between piston ring and piston groove in a radial piston hydraulic motor, Wear 257 (2004), 1281-1287.
2. R. Gåhlin, R.Larker, S. Jacobson, Wear volume and wear distribution of hydraulic motor cam rollers studied by a novel atomic force microscope technique, Wear 220 (1993), 1-8.
3. R. Lewis, R.S. Dwyer-Joyce, Wear mechanisms and transitions in railway wheel steels, Journal of Engineering Tribology, Proceedings of the IMechE Part J, 218 (2004), 467-478

Figure Titles

Table Title

Figure 1

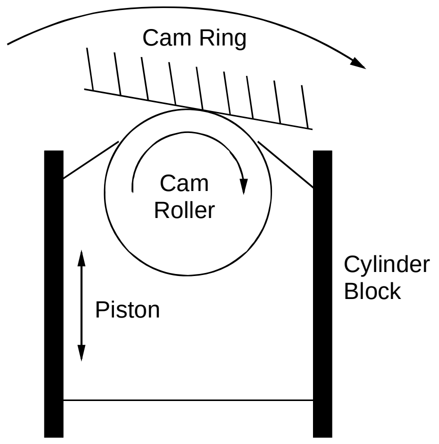


Figure 2

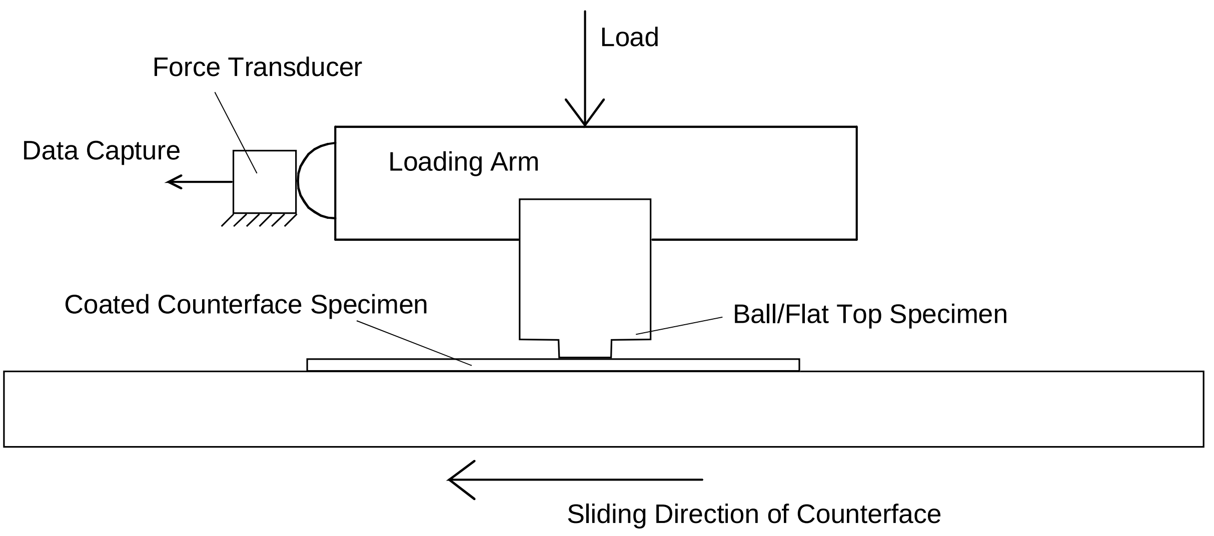
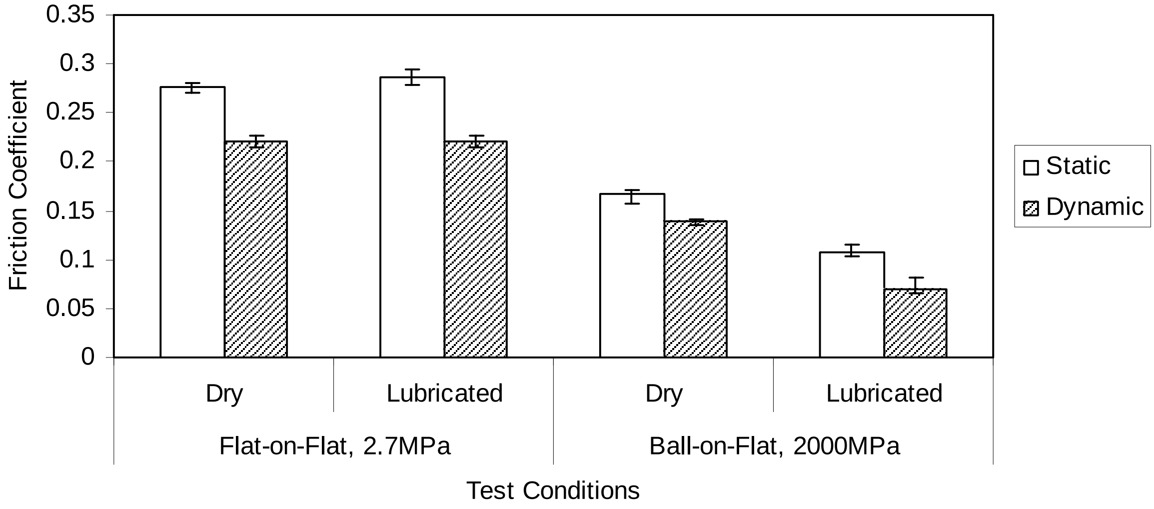


Figure 3

(a) Sintered Bronze



(b) Cloth

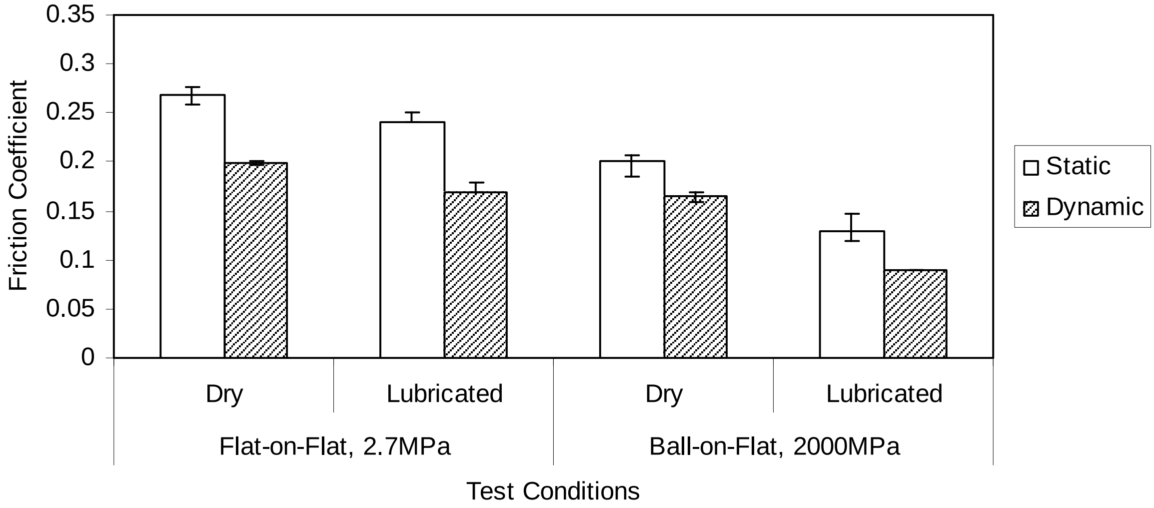


Figure 4

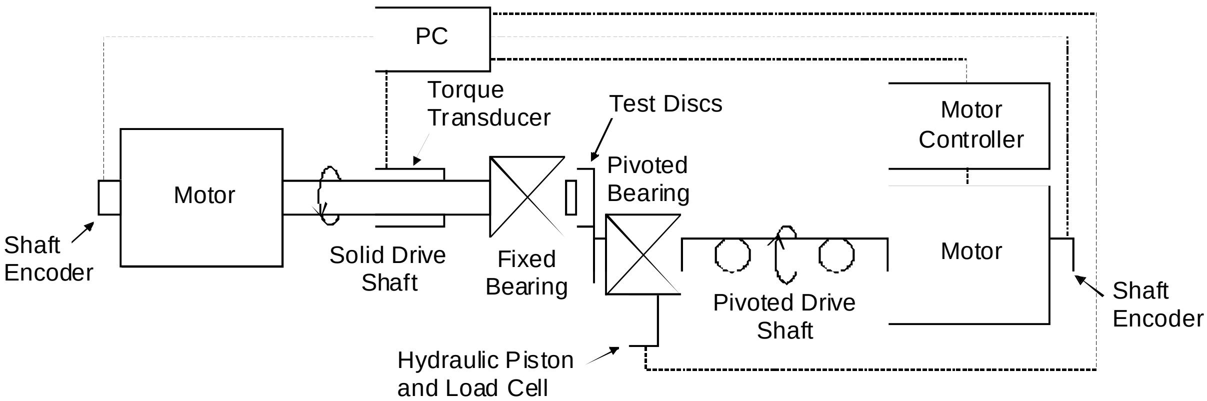
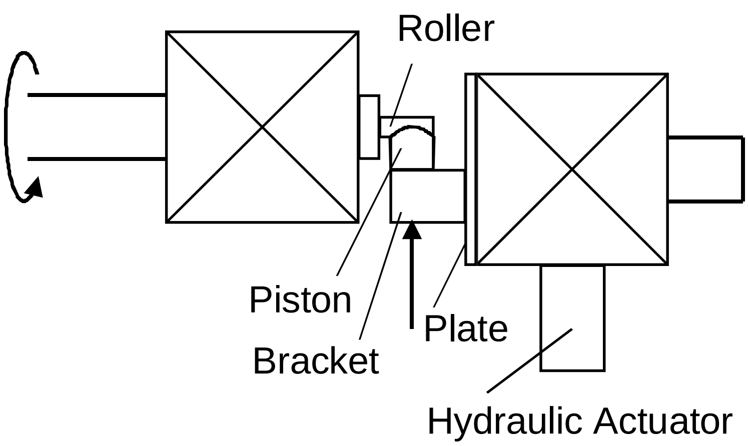


Figure 5



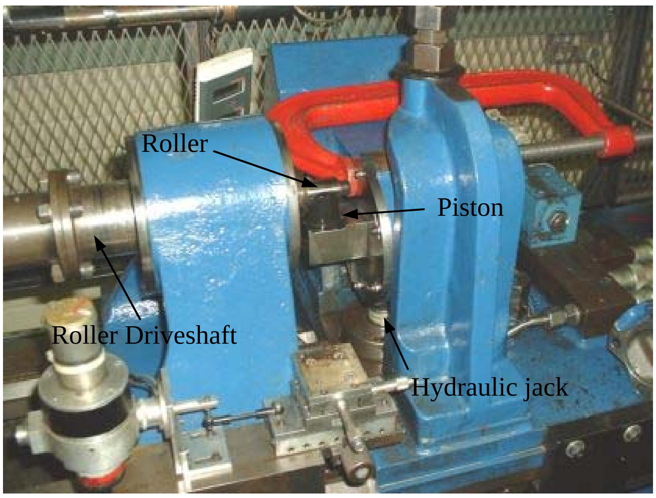


Figure 6

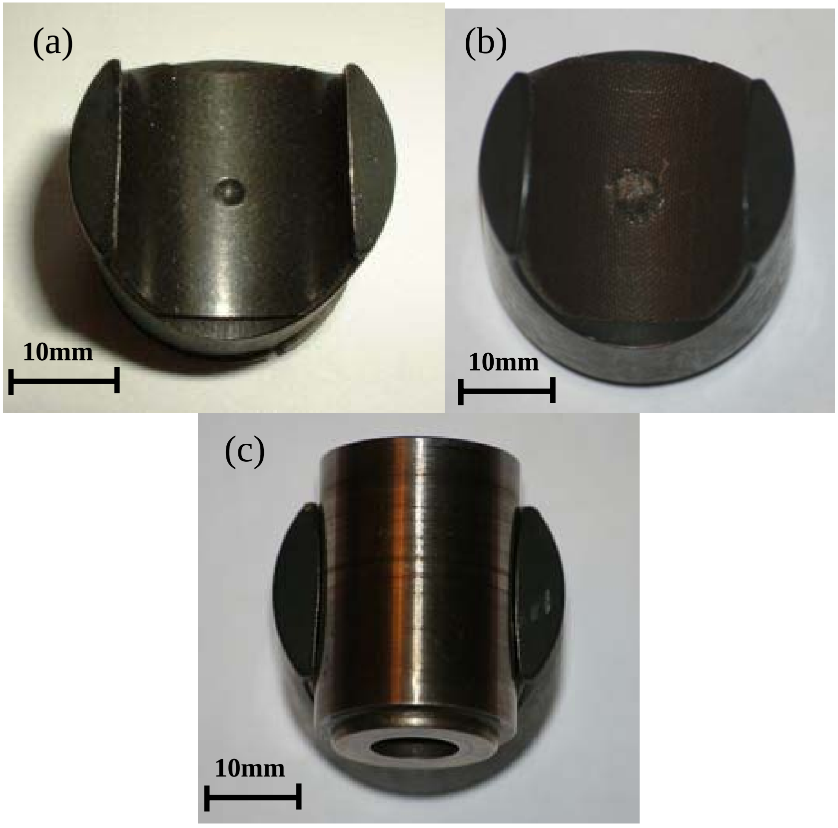
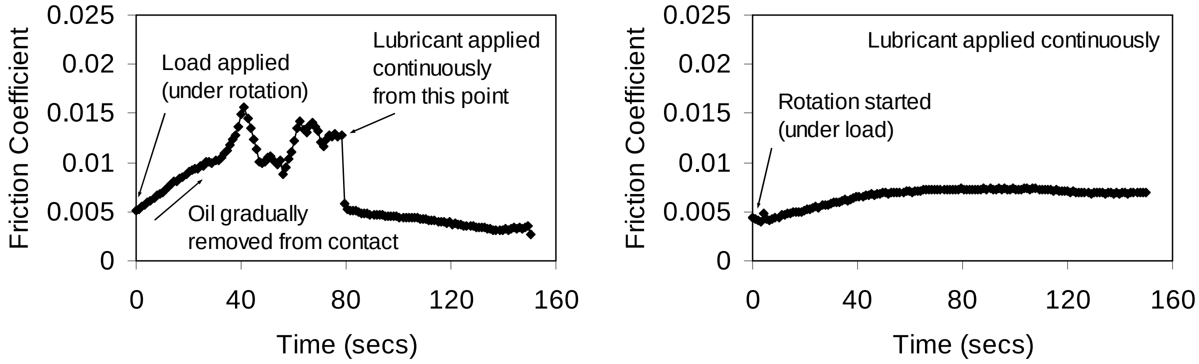


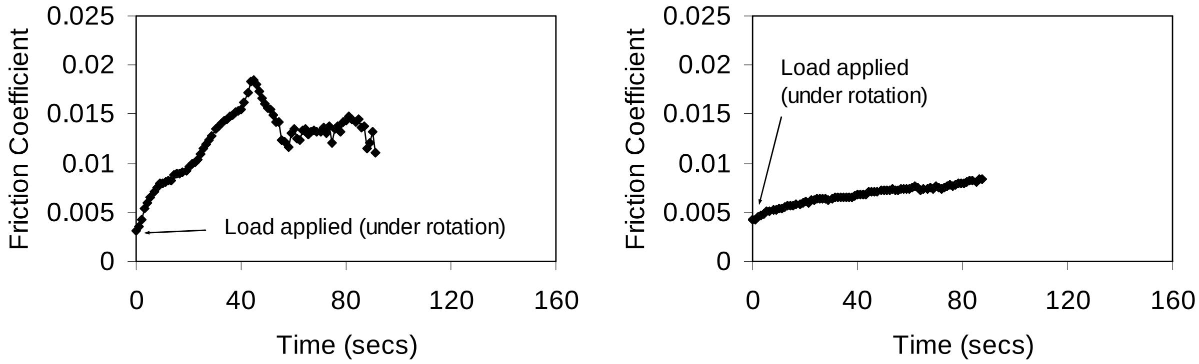
Figure 7

PTFE Impregnated Sintered Bronze — PTFE Impregnated Cloth Material

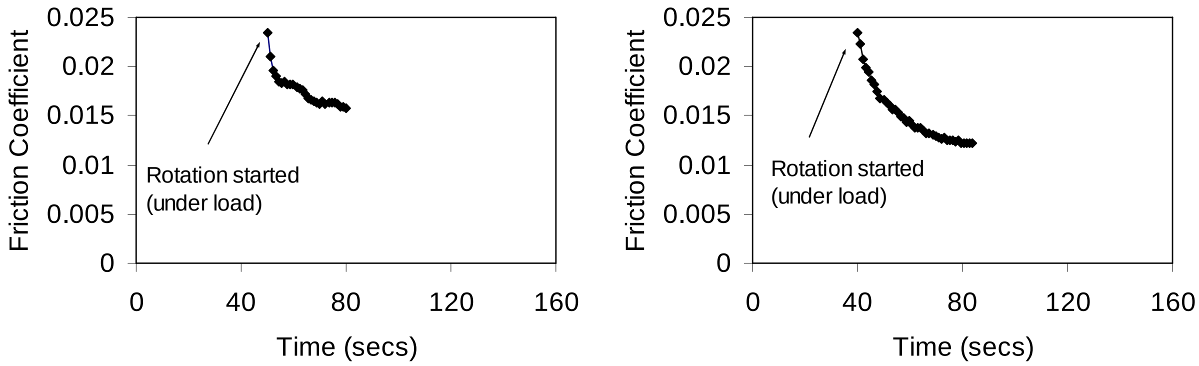
(a) Lubricant applied pre-test/continuously, rotation started, load applied



(b) Lubricant allowed to run off for 5 minutes, rotation started, load applied



(c) Dry test, load applied, then rotation started



(d) Dry test, rotation started then load applied

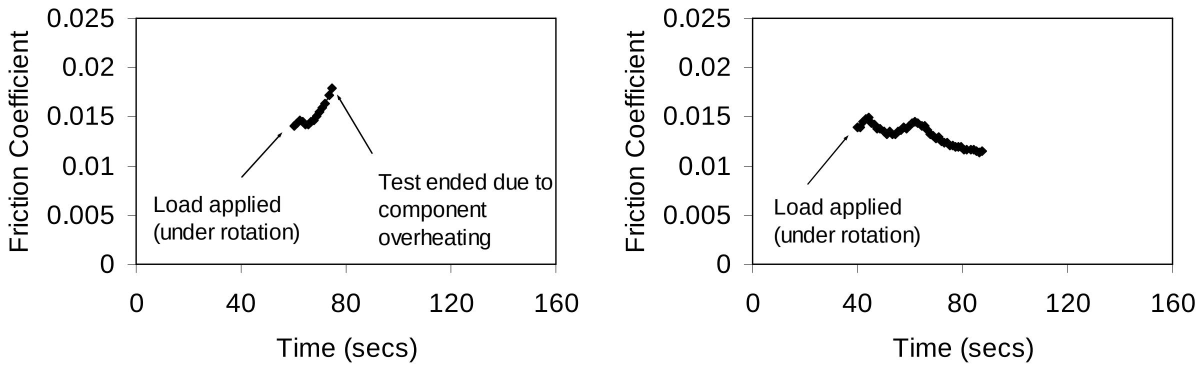


Figure 8

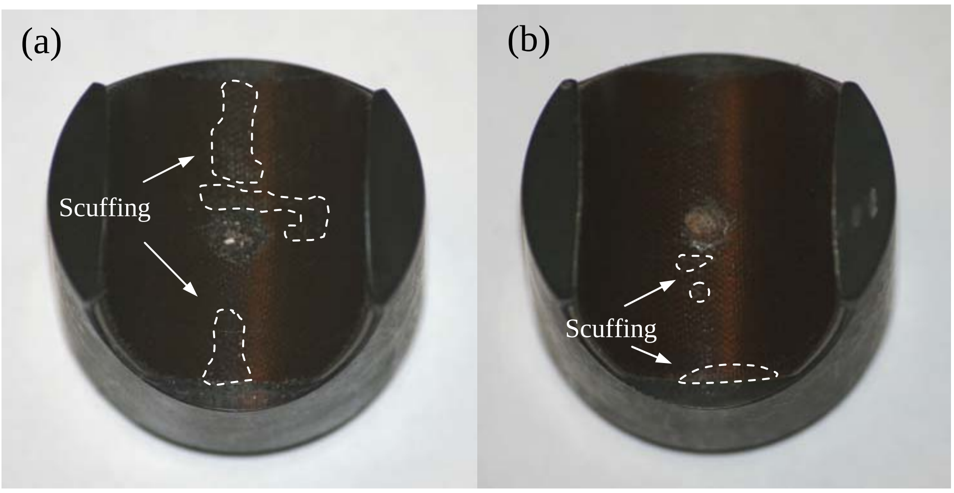


Figure 9

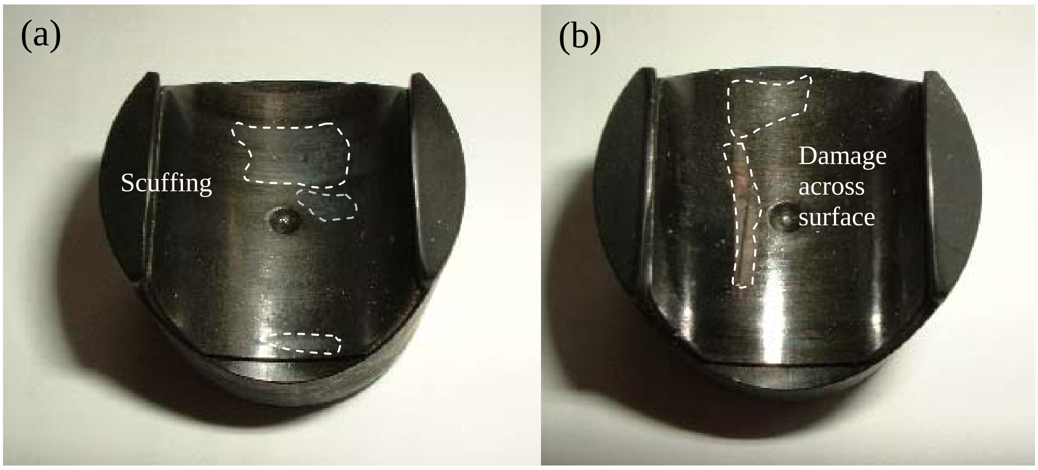


Table 1

Test	Description	Load (kN)	Rotational Speed (rpm)
Lubricated	Lubricant applied continuously during test	6.8	400
Lubricant run off	To simulate start-up, lubricant was applied and left to run off for 5 minutes as if the motor had just been stopped		
Dry	To simulate a lubricant supply problem (run two ways – rotation started and load applied and visa versa)		