ABSTRACT
The paper describes a study of the operation of a wide inlet textured bearing pad, pivoted at the load centre. Scatter in experimental results recently obtained might be interpreted to indicate the existence two modes of operation.

This possibility of this phenomenon occurring is established theoretically. Further, the findings are discussed in relation to the results of the experimental scatter. The latter appears to support the theory.

INTRODUCTION
The very promising concept of inlet texturing [1] has mainly been suggested for fixed geometries running parallel to the counterface. Because of the very limited amount of experimental evidence, more extensive testing of the concept is called for. However, unless the test equipment is of high quality, the counterface may not be sufficiently plane for the desirable features – high damping and stiffness; low coefficient of friction and low flow rate – to be fully detectable. A tempting remedy to this problem is the use of a pivoted device. An example may be a pad bearing. A wide step pad running parallel has a load centre that is independent of the load as well as of the inlet-to-outlet film thickness ratio. The load centre of a pivoted pad, however, is directly dependent on that ratio. It is therefore feasible that a tilted inlet textured pad may have two operational points – one corresponding to the parallel operation and one to an inclined configuration. The two modes would have different characteristics. This is the topic of this paper.

EARLY EXPERIMENTS
A pin-on-disc arrangement, in which the pin was replaced by a rectangular pad rigidly fixed to the supporting arm, was used to test the inlet texture effect. The results were unrealistic for plain and textured pads alike and vibrations were sometimes encountered. The fixed pad was then replaced by a similar pivoted one to allow the pad to adjust itself to possible waviness and/or wobbling. The pivot location was that of an infinitely wide pad running parallel to the disc. However, the experimental results were very scattered, particularly for textured pads. It was thought that the cause was essentially one of poor equipment, but the existence of two modes of operation in pivoted textured bearings might also be a cause. Theory shows that if infinitely wide, such bearings have only the stable parallel-running mode. In the experiments the adopted width-to-length ratio of 3.5 was thought to be large enough. The possibility of two modes was not considered.

MODEL AND RESULTS
To study the possibility of a double mode, the validity of the Reynolds equation and the version modified for roughness is assumed. The profile of the pad studied is shown in figure 1, sinusoidal grooves running across the direction of motion being indicated by the dark field. To compare with the experimental results the width-to-length ratio is \( \nu = 3.5 \)

\[
\frac{\partial}{\partial x} \left( \frac{\partial p}{\partial x} H \right) + \frac{\partial}{\partial y} \left( \frac{\partial p}{\partial y} H \right) = 6 \rho U \frac{\partial}{\partial x} \left( \frac{H^2}{H} \right)
\]

(1)

The ratio \( \lambda = L_2/L_1 \) has been assigned the value 0.4. \( H \) is local film thickness, \( \eta \) viscosity and \( U \) effective relative velocity. The tilt, \( S \), expressed as a fraction of \( C \) (the amplitude of in the inlet grooves), is a change in the inlet gap, the minimum thickness, \( h \), being constant. It is positive when the inlet is wider than the outlet. The ratio \( k = C/h \) is similar to \( k \)-values of smooth pads. Equation (1) is solved for three values of the load, \( W \). The pivot point is at the load centre of a non-tilted pad. The location of the load centre, \( X_W \), is plotted against \( S \). There are indeed two \( S \)-values that will correspond to the same pivot point. The first mode is one of zero inclination; the second has a tilt similar to that of a smooth bearing. Only the latter mode is stable. This can be seen from the following:

![Fig. 1 Model, non-tilted position](image)

![Fig. 2 Load centre pos., W = 0.01462](image)
An accidental increase in tilt forces the load centre backwards thus creating a restoring moment. Similarly, a decrease in the tilt places the load vector in front of the pivot, thus again creating a restoring moment. For non-tilted operation, an increase in tilt shifts the load centre closer to the inlet, which results in a moment that increases the inclination. It is readily seen that a decrease in tilt will make the pad collapse.

The effect on the minimum film thickness, \( h \), essentially the inverse of \( k \), is shown in figures 5 to 7.

![Fig. 3 Load centre pos., W = 0.02828](image1)

![Fig. 4 Load centre pos., W = 0.03464](image2)

An accidental increase in tilt forces the load centre backwards thus creating a restoring moment. Similarly, a decrease in the tilt places the load vector in front of the pivot, thus again creating a restoring moment. For non-tilted operation, an increase in tilt shifts the load centre closer to the inlet, which results in a moment that increases the inclination. It is readily seen that a decrease in tilt will make the pad collapse.

From the tables we note that in the stable mode, the performance of the textured pads is very good. For high loads, the coefficient of friction, \( \mu \), is lower than that of the step bearing. The non-dimensional stiffness, \( C_k \) is higher but the damping coefficient, \( C_d \) is lower. The parallel textured pad has by far the highest damping and the highest friction coefficient.

**DISCUSSION**

The performance of parallel devices has been described elsewhere [2] The present study is made for moderate \( k \)-values, i.e., for fairly thick films. The reason for the choice is the desired comparison with experiment. These conditions are the least favourable ones for very wide textured devices in the parallel mode. Attempts to increase the load to very high values failed since an increase in the \( k \)-value above a certain level reduced the load capacity. Hence a \( v \)-value of 3.5 is too small to yield the performance of infinitely wide pads.

In the introduction it was hypothesised that the scatter in the experimental results might be caused by the pivoted pad switching between two different modes. Since one mode is unstable, this may seem incorrect. However, for the lowest load (and thickest film) the restoring moment is very small, fig. 2. The tendency is clear: the lighter the load, the weaker the restoring moment. The experiments referred to were partly run with non-dimensional loads considerably lower than 0.01462.

**Table 1. Performance, low load**

<table>
<thead>
<tr>
<th>( W ) = 0.01462</th>
<th>Parallel, textured</th>
<th>Parallel, smooth</th>
<th>Tilted, textured</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \mu )</td>
<td>10.842</td>
<td>6.946</td>
<td>7.229</td>
</tr>
<tr>
<td>( C_k )</td>
<td>0.0230</td>
<td>0.0226</td>
<td>0.0224</td>
</tr>
<tr>
<td>( C_d )</td>
<td>0.01834</td>
<td>0.00880</td>
<td>0.00868</td>
</tr>
</tbody>
</table>

**CONCLUSION**

1. Pivoted inlet textured pads may have two operational modes
   - Only the tilted mode is stable, even for rather large pads.
2. Lightly loaded pivoted inlet texturing may generate unsteady friction coefficients.
3. Inlet texture finite parallel pads have limited load capacity
4. Partial texturing may be beneficial under general non-parallel operation conditions.

**REFERENCES**