International Conference
“UNIVERSITARIA ROPET 2002”,
Mechanical Engineering, Petroşani, 17-19
October 2002, Vol.2, pp.117-121

LUBRICATION OF TEXTURED SURFACES

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ABSTRACT

Textured surfaces create a lubrication film, which produces a load carrying capacity when there is no condition for the wedge effect. This phenomenon can have a large variety of industrial applications: it improves the functioning of mechanical seals, it can be used to manufacture partial textured thrust bearings, also it leads to an improvement of fuel consumption in the case of internal combustion engines by texturing the rings or the liner and by texturing the cage of cylindrical roller bearings their durability increases. The article presents all these applications and also a finite difference model for calculating the pressure distribution for a textured surface.

1. NOMENCLATURE

ℓ dimension of the square dimple
L dimension of the textured cell
h film thickness
s depth of the dimples
η oil viscosity
U speed of the runner
$\overline{p} = \dfrac{p \cdot h^2}{6 \cdot \eta \cdot U \cdot L_{tot}}$ dimensionless pressure
L_{tot} total length of the slider
p fluid film pressure
N number of cells on one row

2. INTRODUCTION

The role of textured surfaces in lubrication

Textured surfaces create a lubrication film, which produces a load carrying capacity when there is no condition for the wedge effect.

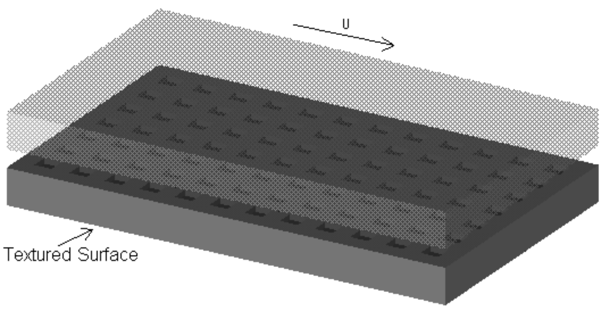

Fig.1

The origins of texturing

The idea appeared by observing an optimal roughness, which leads to local load carrying capacity effects.

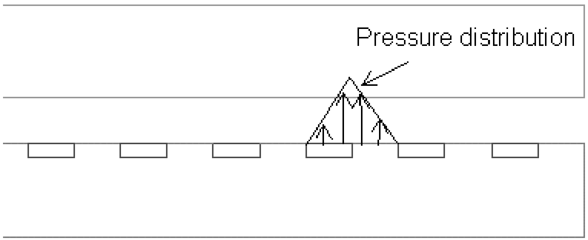

Fig.2

For increasing efficiency (trying not to have a random character of the micro geometry), after the 50-60s people began the texturing of surfaces. The texture has a regular shape of “valleys”. A reference article vas wrote in 1965 [11]. It studies an application of the textured surfaces in the case of mechanical seals.

The existence of a large variety of pore shapes

The pores of the textured surface can have different shapes as in Fig.3.

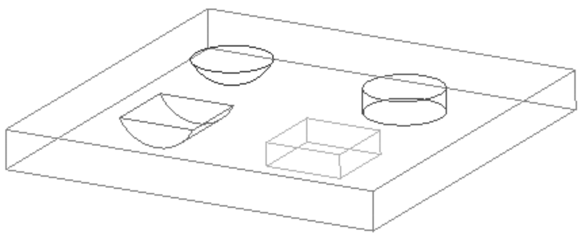

Fig.3

These shapes can be obtained by various technologies:

- Chemical etching [1,10,11]
- Laser texturing [2-9,12,13,15,16]
- Grit blasting with photoresist [14]

Secondary effects

Due to laser texturing, for example, asperities can appear near the holes, which can present porosities (zones thermally affected) (Fig.4). These asperities can have a negative effect on lubrication, creating contact zones between the surfaces. To prevent this, the surfaces can be ground after texturing.

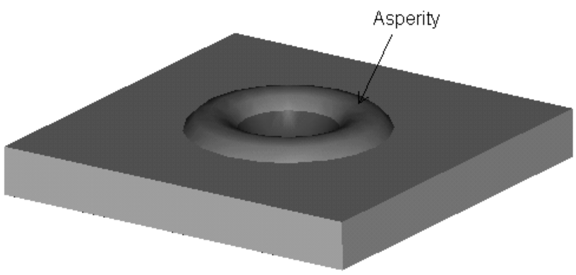

Fig.4

Modeling Possibilities

Some ancient ideas would be the modeling of the step bearing and the pocket bearing. The actual models are based on the cavitation phenomenon [2-7,12]. We can observe in Fig.5 the variation of the pressure on the cell.

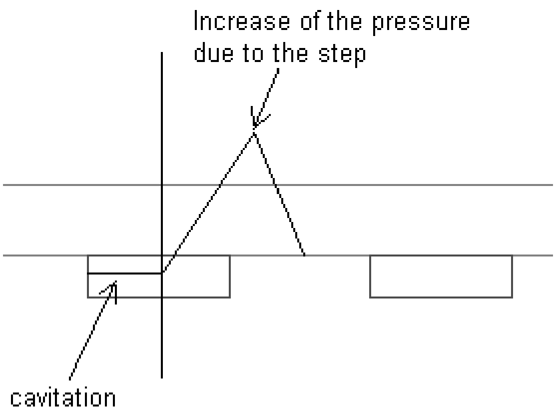

Fig.5

We can observe that the pressure sum on the cell is positive due to the cavitation phenomenon.

3. INDUSTRIAL APPLICATIONS OF TEXTURED SURFACES

Textured Surfaces present a large variety of industrial applications.

Mechanical seals

A large number of studies show the improvement in functioning of mechanical seals due to textured surfaces [3-7,14-16]. Formation of fluid film is essential to avoid dry friction of the surfaces. An example of a textured seal ring is presented in Fig. 6.

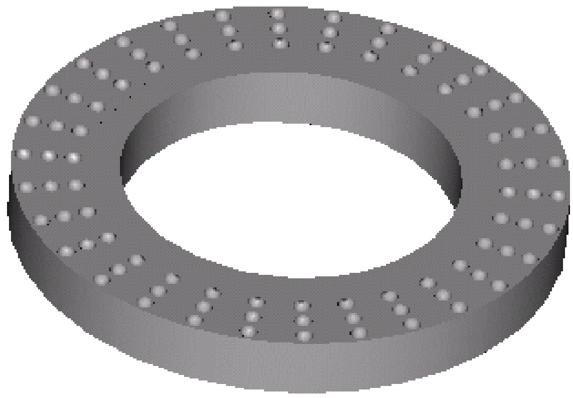

Fig.6

Surface texturing is a cheaper method to produce load carrying capacity at the surface of the seal, comparing to other methods (i.e. spiral grooves, waviness).

Thrust bearings

Surface texturing can be used in the case of thrust bearings, where by texturing a portion of the slider we can obtain the collective effect of the dimples, similar to the effect of the stepped bearing [2]. A sketch of the bearing is presented in Fig.7.

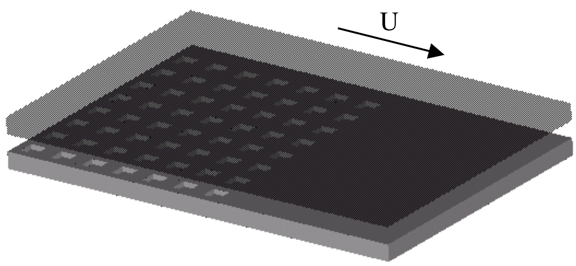

Fig.7

The bearing presents lower load carrying capacity than a stepped slider, but can be more easily manufactured by various techniques (i.e. photolithography).

Internal combustion engine piston rings

It is well known that friction forces present an essential factor in fuel consumption and performance of the engine.

It was established that about 40 percent of the friction losses of the engine are due to the contact of the piston ring and liner, so a reduction of this force is crucial.

The texturing of the rings has two positive effects:

- the reduction of friction between the piston and the rings

- the good functioning in conditions of “starvation”, because of the properties of oil retention of the dimples.

By surface texturing, the friction coefficient decreases by 20 to 30 percent [8,12,13].

In the figure bellow a textured piston ring is presented.

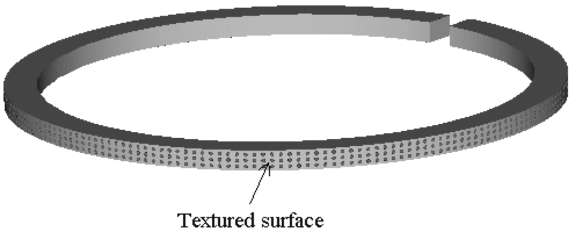

Fig.8

Roller bearings

In the case of cylindrical roller bearings with large diameters, an important factor for the good functioning of the bearing represents the precise centering of the cage. In the case of important clearances, the vibrations of the cage could lead to the total failure of the bearing. That is why the cage is centered on the outer ring and a lubricant film assures the lubrication. A textured outer ring determines a better functioning.

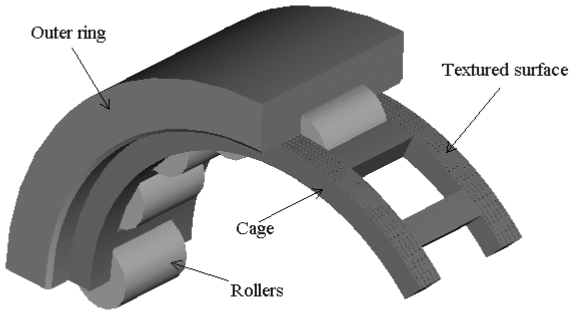

Fig.9

4. PRESSURE DISTRIBUTION FOR AN INFINITE WIDTH TEXTURED SLIDER

The finite difference method was used to determine the pressure distribution for a textured slider of infinite width. The textured slider is presented in the Fig.1.

For the sake of simplification we consider that the slider has an infinite width. So we can calculate the pressure distribution considering only one row and assuming zero flow on the sides (Fig.10).

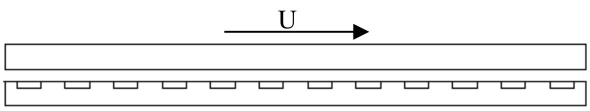

Fig.10 a.

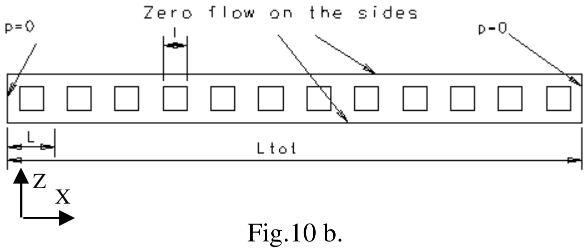

Fig.10 b.

The pressure distribution was calculated using the finite difference method. The system of numerical equations was solved iteratively using the Gauss-Seidel method. The cavitation pressure was set to zero. This cavitation condition was integrated in the Gauss-Seidel iterative method so the Reynolds condition results by numerical diffusion.

The results of a numerical simulation are presented in Fig.11. The configuration has the following parameters:

- L=200µm
- ℓ=100µm
- N=10 (number of cells in one row)
- The depth of the cell is equal to the fluid film thickness

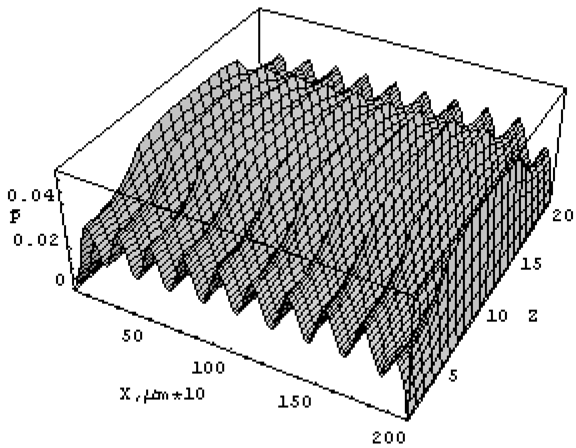

Fig.11

The pressure presented in the figure is the dimensionless pressure $\overline{p}$.

The pressure distribution along the symmetry axis of the row is presented in Figure 12.

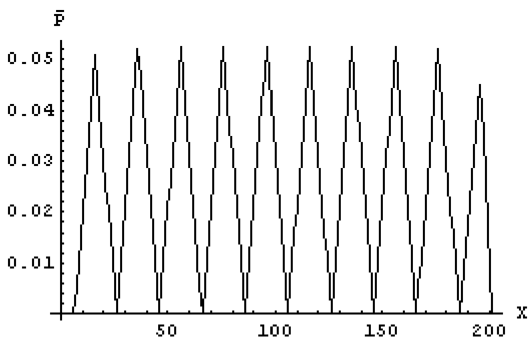

Fig.12

We can observe that the overall pressure distribution is positive, due to the cavitation phenomenon. So the textured slider creates a positive lift force.

5. CONCLUSIONS

Textured surfaces generate a load carrying capacity even between two parallel surfaces.

Surface texturing can have a wide variety of industrial applications. It can be used to manufacture partially textured thrust bearings. It can also improve the functioning of mechanical seals. The friction forces can be reduced in the case of the piston – liner contact and consequently the fuel consumption. Surface texturing can also improve the functioning of large diameter roller bearings.

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