Influence of surface texture on grease lubrication

Abstract

This paper presents theoretical and experimental research on the behavior of laser textured bearings lubricated with grease. Textured surfaces can improve the reliability of this type of bearings in boundary and mixed lubricated regime by providing reservoirs for grease, [1]-[5].

1. Theoretical model

In order to find the optimal textured area of the dimples, it is considered that after a worn height *dh*, the grease from the dimple reservoirs should be enough to completely fill the cavities of the rough surface. This condition translates into the following equation:

$$dh \cdot A_t \cdot \rho_t = dh \cdot (1-\rho_t) \cdot A_t \cdot \rho_c \tag{1}$$

where A_t is the total area of the textured surface, ρ_t is the area density of dimples (Area of dimples/A_t) and ρ_c is the fraction volume of the cavities of the rough surface (Figure 1).

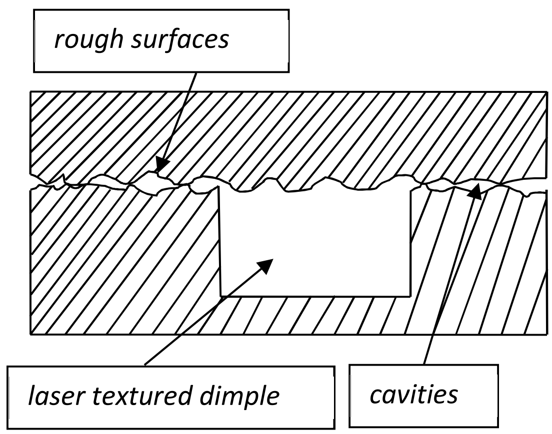


Fig. 1 Schematic of a laser textured dimple

From equation (1) we obtain:

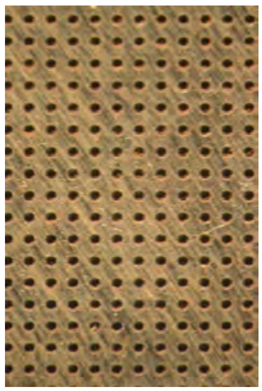
$$\rho_t = \frac{\rho_c}{1+\rho_c} \tag{2}$$

2. Computation using nonlinear finite element program

In order to determine the fraction volume of the cavities, a simulation using the nonlinear finite element program MARC was accomplished. A two dimensional of untextured surface topography was measured with a stylus profilometer Ambios XP2. A rigid surface was created for the contact simulation. The applied force on the rigid surface was 12.4N in order to be compatible with the pressure applied on the real system. For the deformable surface a case hardened steel was used with an elastic-perfectly plastic behaviour. The elastic limit is considered to be 1GPa. The nodes of the lower surface were constrained to have zero displacement. The fraction volume of the cavities was computed using a Python subroutine. The z coordinate of the nodes after the deformation was extracted. For the present case the fraction volume of the cavities was 54%. Using formula (2) the resulted area density of the dimples is 35%.

3. Laser texturing technology

The laser used has a $Nd:YVO_4$ active medium (Lumera model P50) and can be operated on 4 wavelengths. A Nutfield technologies model XLR8 2 axis galvanometer scanning system was also used to ensures rapid processing of the piece. The textured surfaces of a plain bearing realized by laser ablation is presented in Figure 2. The dimples have a diameter of 200 µm and they are arranged in three concentric areas with the density of 10, 20 and 30 %. The depths of the holes are 20, 30 and 40 µm.



a)

b)

Fig. 2 Microscope view of a part of the textured plain bearing sample, (a) before the tests, (b) after the tests

4. The experiment

The experiments were performed on the universal tester UMT-2 from Bruker, on a pin-on-disc configuration, Figure 3.

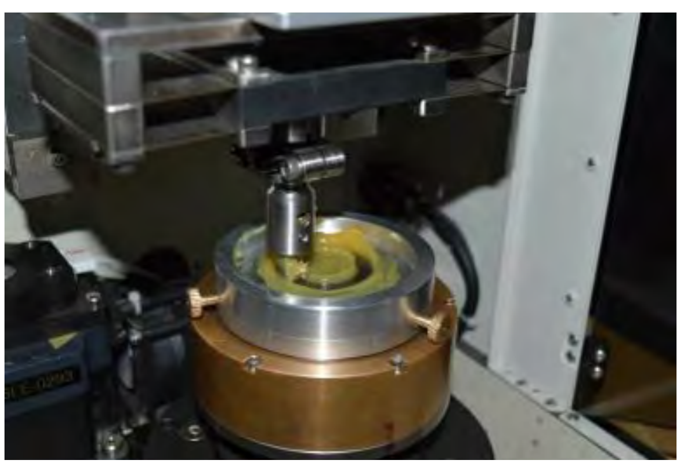


Fig. 3 The test rig

The grease used for testing is called Divinol Mehrzweckfett 2, produced by Zeller+Gmelin Gmbh & Co. KG. The rheological parameters were determined at 20°C using a Brookfield viscosimeter.

5. Results and conclusions

Stribeck curves are used to determine the optimal parameters for the textured surfaces in specified working conditions. One of these is presented in Figure 4.

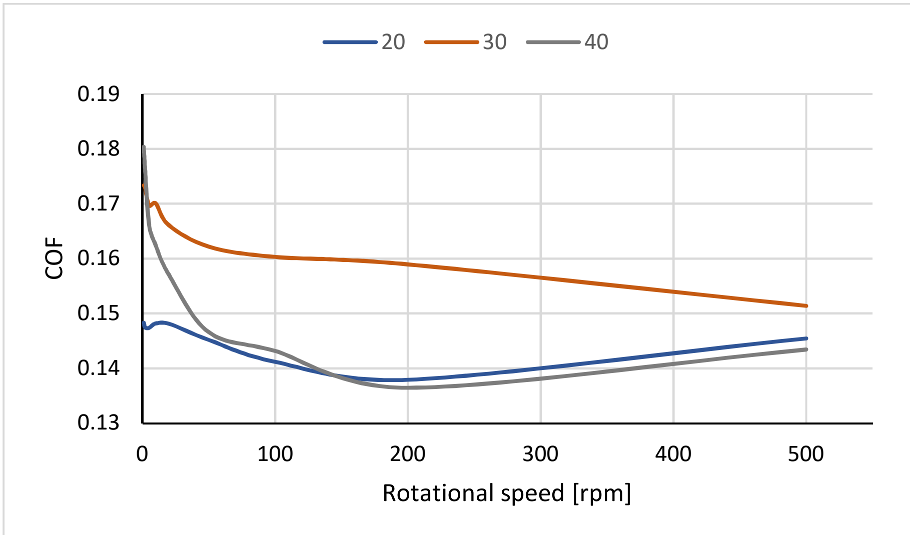


Fig. 4 Stribeck curves for density of 30 % and for the three holes depths (20,30,40 μm).

It can be seen that the COF have maximum values for the depth of 30 μm.

Acknowledgement

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6. References

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Influence of Surface Texture on Grease Lubrication

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Objectives

Theoretical and experimental analysis of a textured laser bearing, lubricated with grease

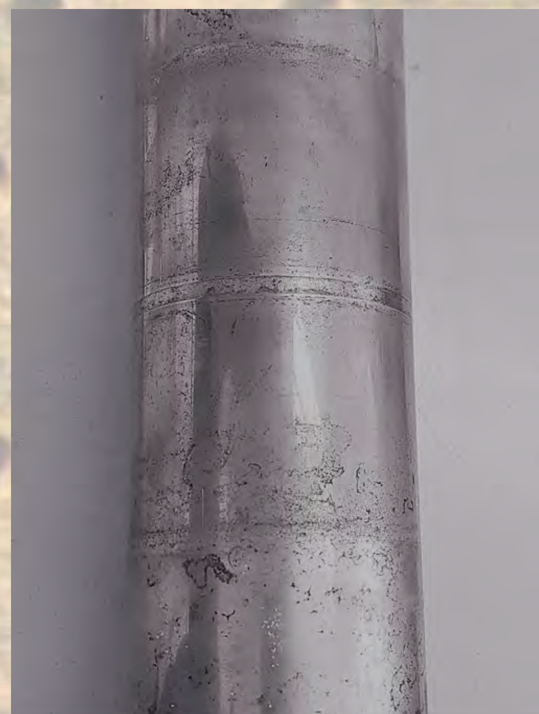
Determination of the optimal geometry of the textured surface using the finite element method

Using the laser texturing technology to optimize the functional parameters of the bearing

Repair and maintenance industry requirements

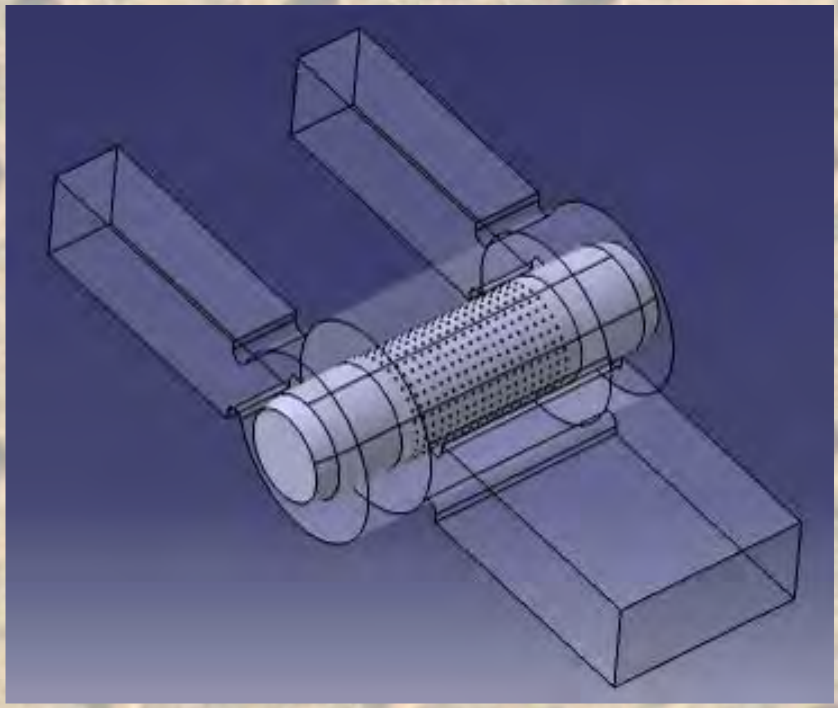
This mechanical articulation is wears quickly due to the harsh functioning conditions of a backhoe loader before

after

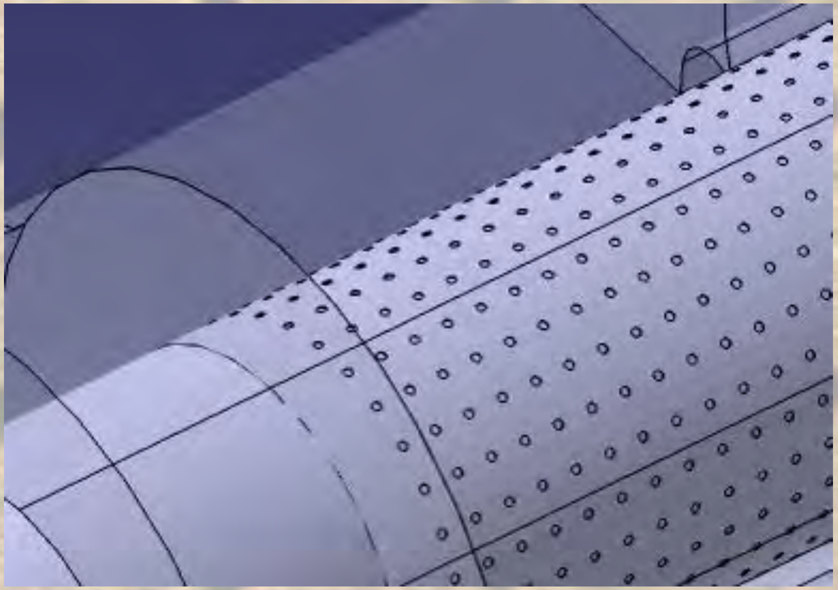


Bolt before and after use

The idea

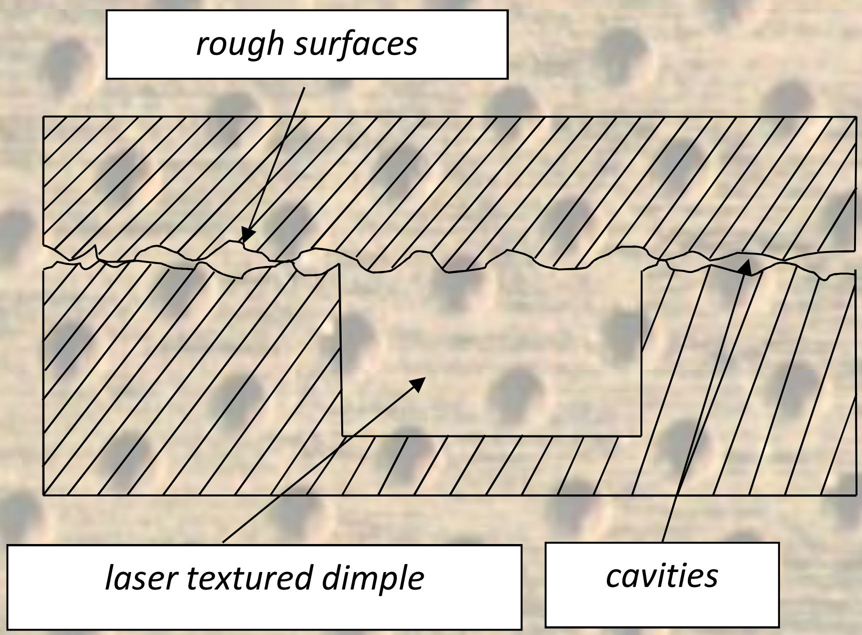


For technological simplicity was chosen for texturing the surface of the bolt



3D design

Theoretical model for determining the optimal texture density



Schematic of a laser textured dimple

$$dh \cdot A_t \cdot \rho_t = dh \cdot (1 - \rho_t) \cdot A_t \cdot \rho_c \quad (1)$$

$$\rho_t = \frac{\rho_c}{1 + \rho_c} \quad (2)$$

Where:

A_t is the total area of the textured surface

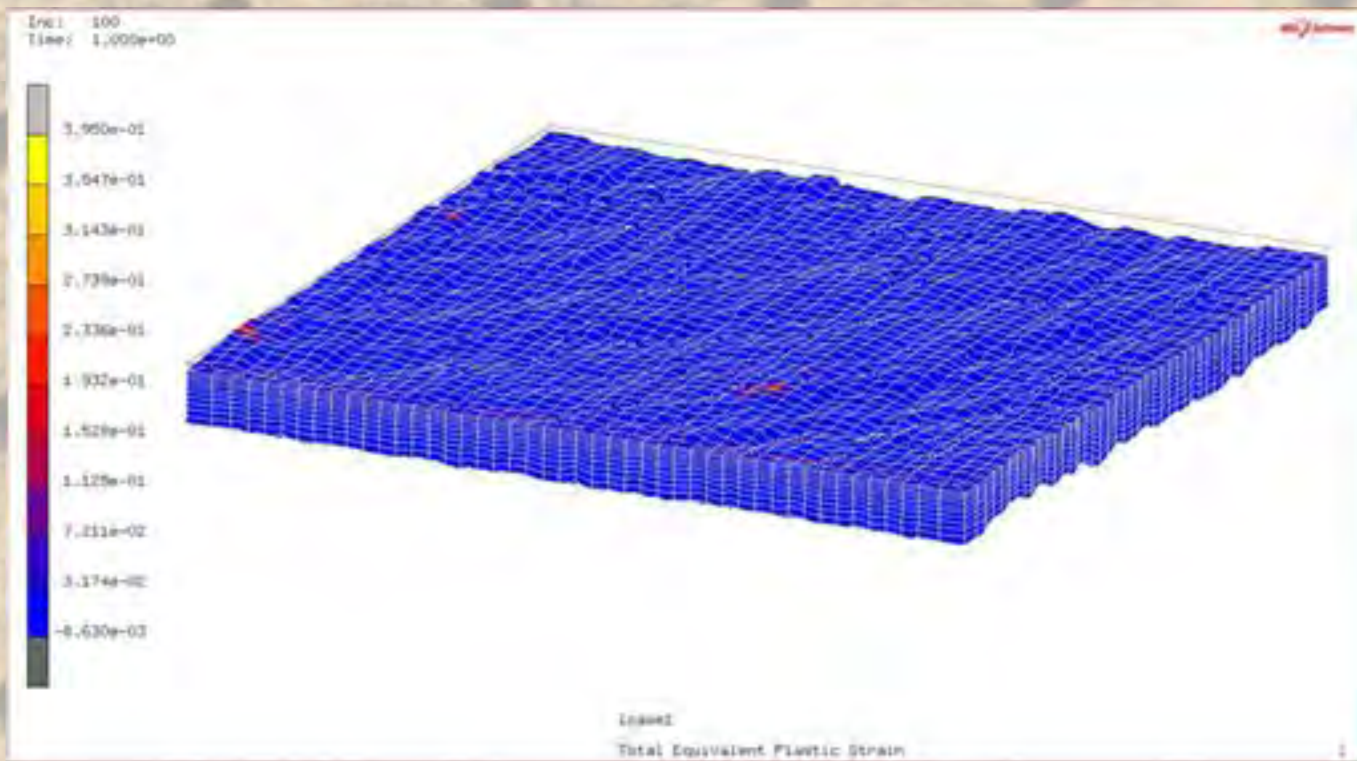
ρ_t is the area density of dimples (Area of dimples/A_t)

ρ_c is the fraction volume of the cavities of the rough surface

Results

Imported measured surface in MENTAT

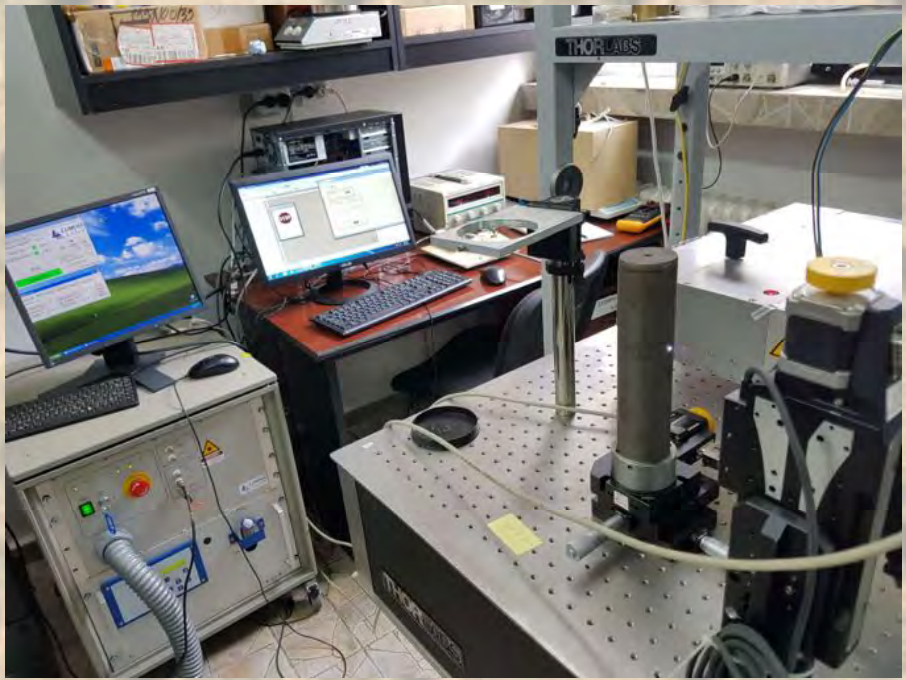
Finite element model



Total equivalent plastic strain

Using formula (2) the area density of the dimples is 30%.

The texturing

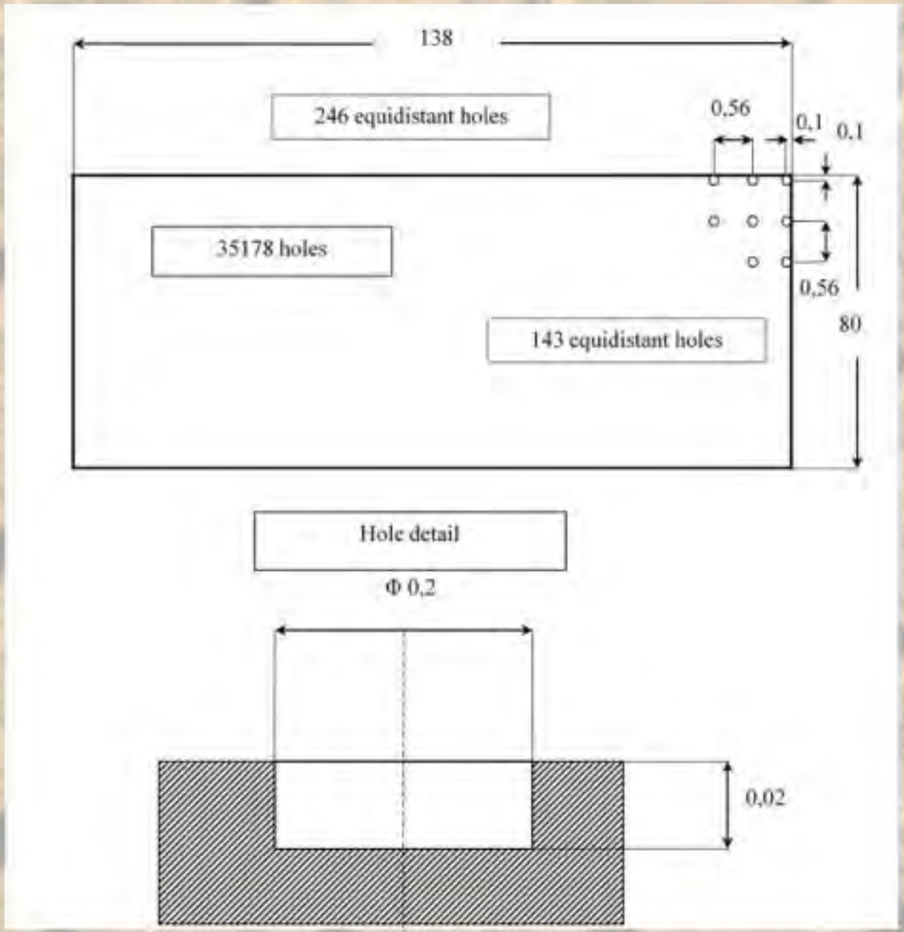


Assembly scheme for texturing the cylindrical surfaces

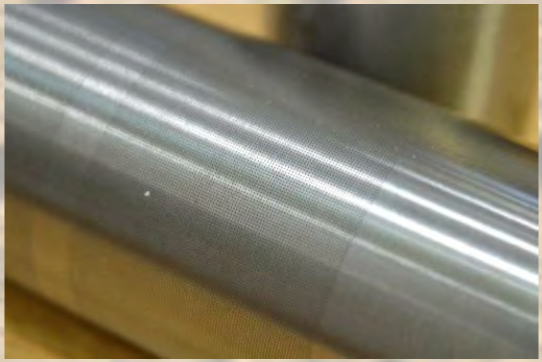
The laser used has a Nd:YVO4 active medium

A Nutfield technologies model XLR8 2 axis galvanometer scanning system was used.

Texturing results



Cylinder lateral area plan

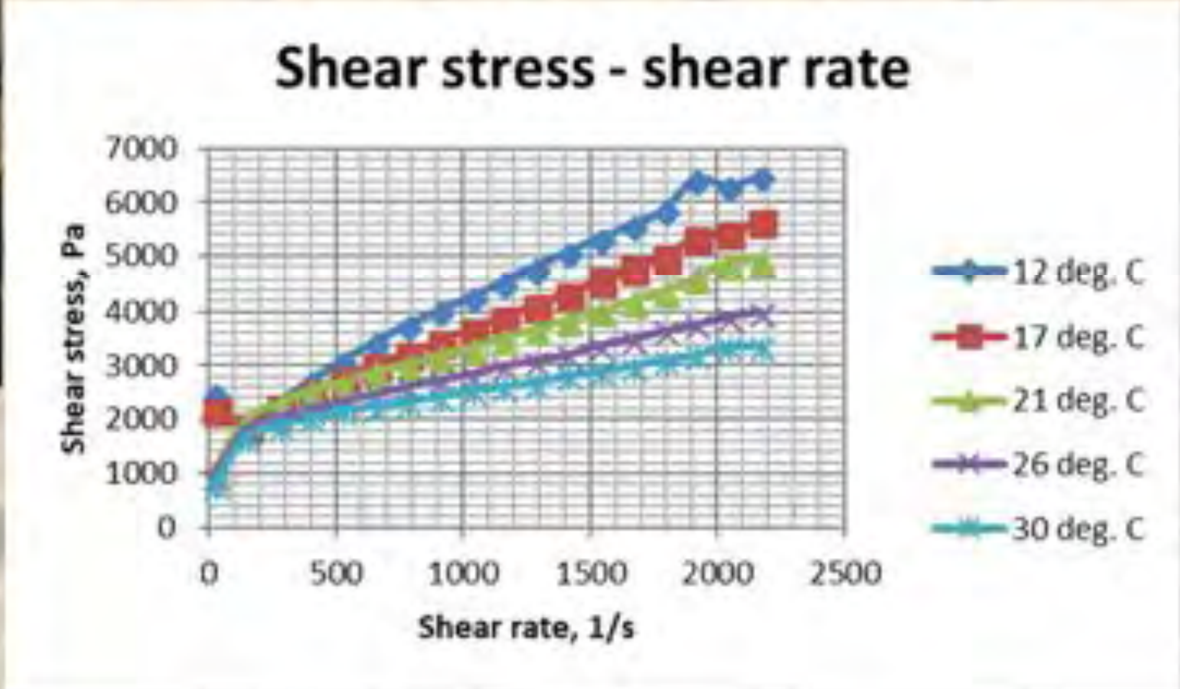


Textured circular bearing

Textured plain bearing

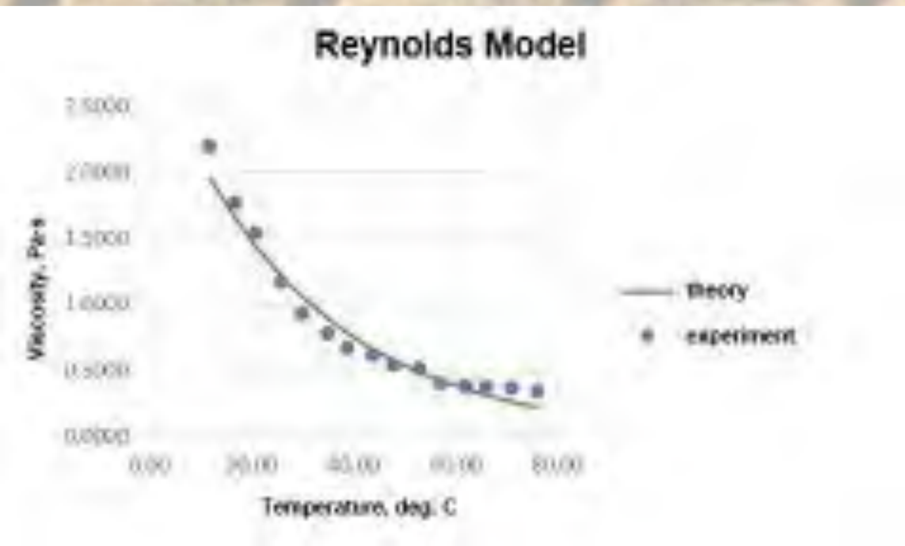
The grease

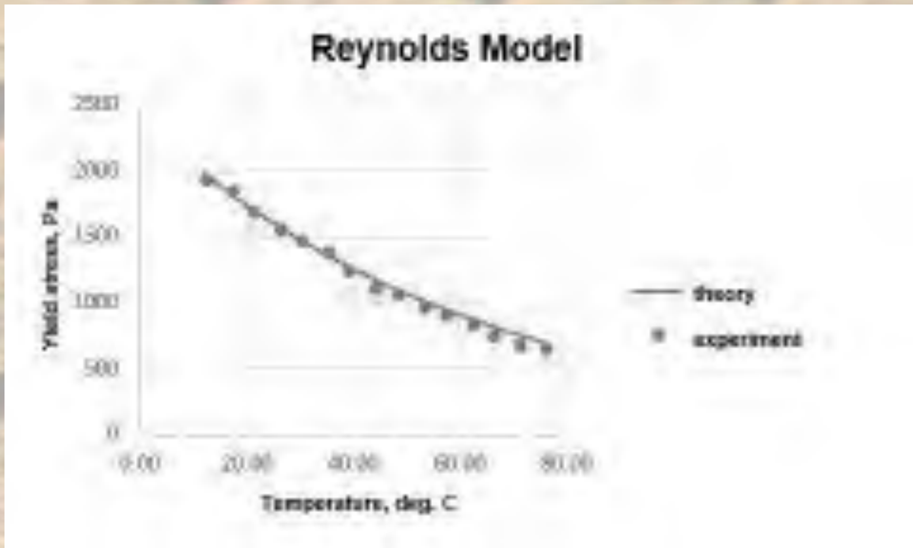
Brookfield viscosimeter



Shear stress vs. Shear rate

Physical properties





Viscosity vs. Temperature

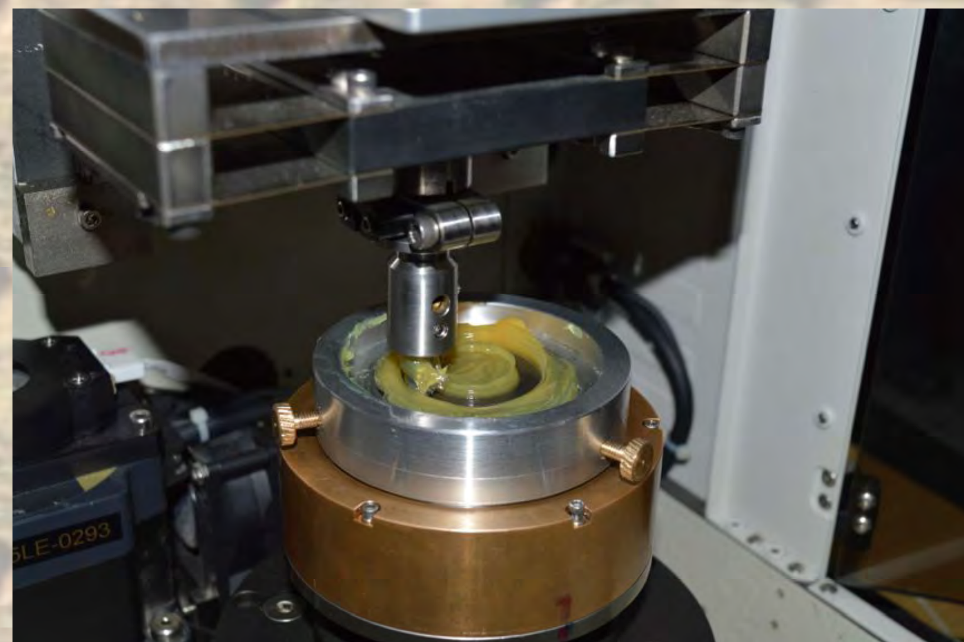
Yield stress vs. Temperature

at 20°C:

- Yield stress = 1573 Pa
- Dynamic viscosity = 1.2721 Pa·s.

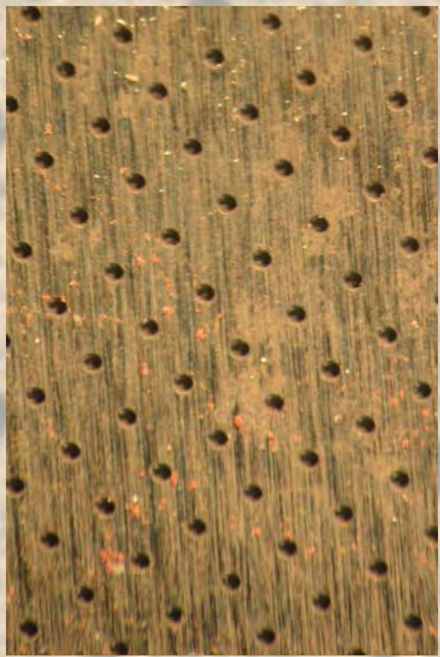
The experiments

The UMT-Bruker test rig



Pin-on-disk testing arrangement

Specimens before UMT tests



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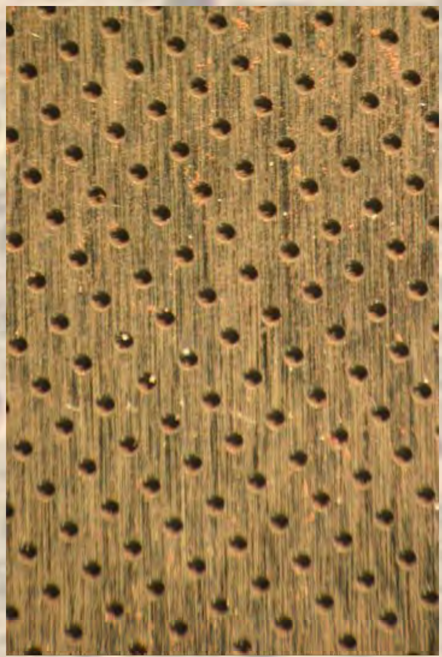

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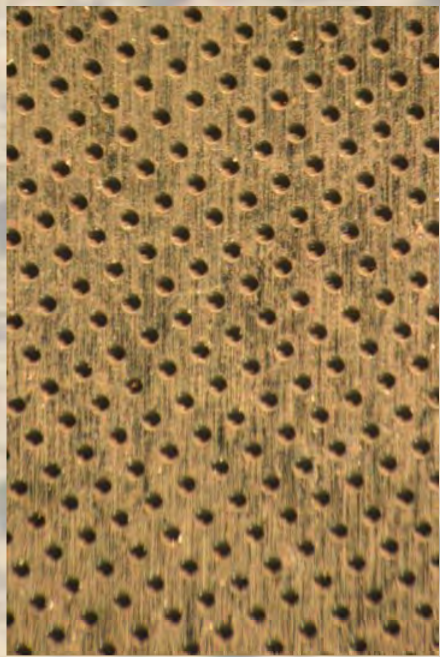

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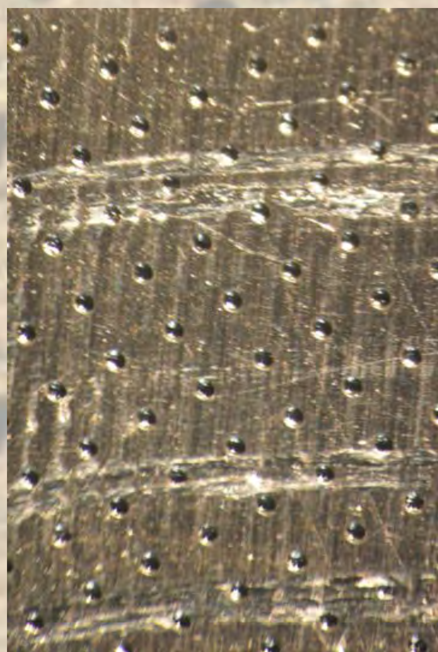
Specimens after UMT tests



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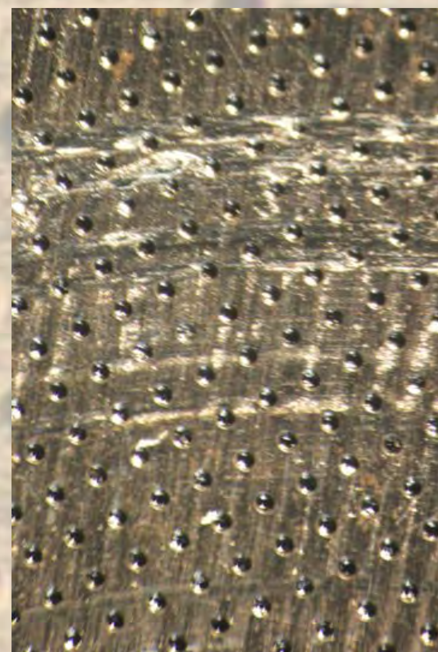

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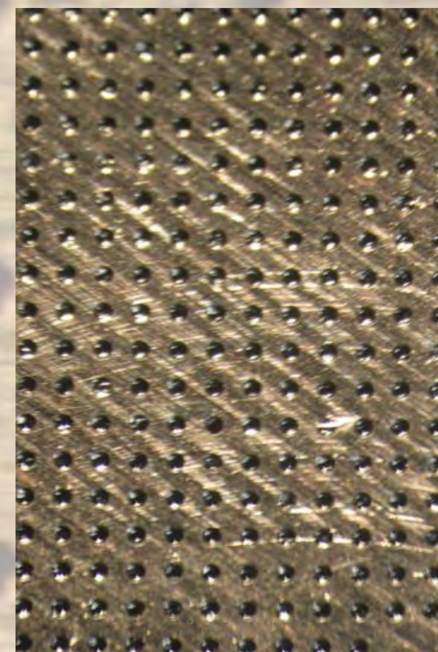

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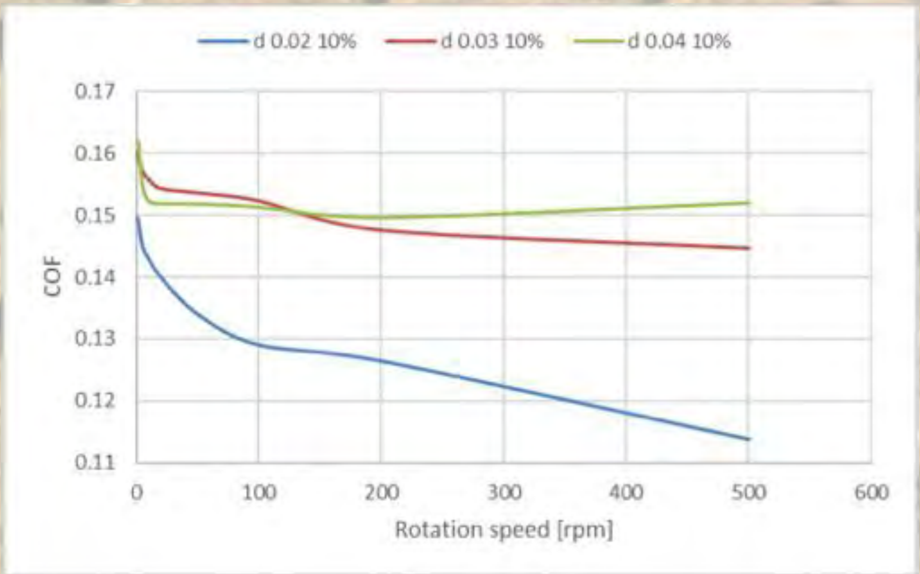
COF's values



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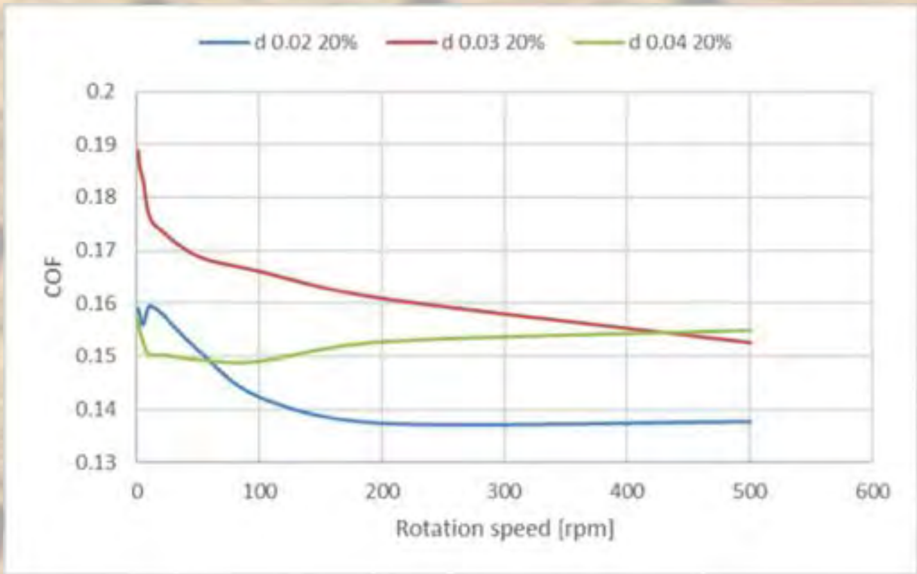

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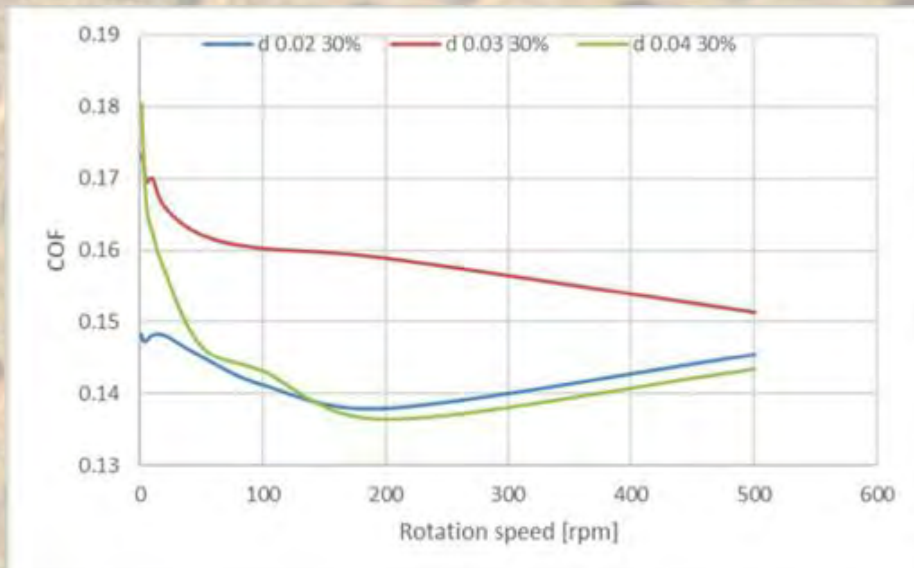
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Rotation speed [rpm]

The result of tests under real operating conditions

Conclusions

1. Original experimental setup for testing grease lubricated textured surfaces using a standard pin-on-disc machine specially instrumented.

2. The theoretical model presented can predict the textured area fraction of the textured surface in order to have optimal lubrication.

3. Laser surface texturing proves to be a fast and reliable method to texture plain and cylindrical surfaces.

4. The experimental tests showed that the friction coefficient is lower in the case of textured surface for the applied pressure.

5. Further tests are needed with an increased pressure and different materials in order to make a deeper investigation.

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Thank you, Minneapolis!