SMOOTH SLIDING

Consulting company providing engineering
services on issues related to sliding bearings

Development of Sliding Bearings

Dr. Dmitri Kopeliovich
Smooth Sliding (Owner)
King Engine Bearings (VP R&D)

1. Design and Geometry of Sliding Bearings

Geometry of a sliding bearing should provide optimal hydrodynamic conditions of the bearing friction, distribution of the load over the bearing surface and firm tightening in the housing.
The geometry parameters such as clearance, eccentricity, press fit, oil groove and oil hole dimensions are analyzed and optimized.

1.1. Hydrodynamic Lubrication

Most sliding bearings work in the hydrodynamic regime of lubrication, in which the bearing surface is separated from the journal surface by the pressurized lubricant film generated by the journal.

The minimum value of the lubricant film thickness may reach down to 0.5 µm/0.00002" (~1/100 of a human hair diameter). Such a minor gap between the bearing and the journal surfaces explains the importance of keeping the dimensions, shapes and the surface quality of the parts at very tight tolerances.

The bearing design and working conditions should provide stable hydrodynamic lubrication which guarantees reliable operation during a long time.

The software based on Reynolds equation is used for calculating hydrodynamic conditions of bearing operation: minimum oil film thickness, oil temperature rise, coefficient of friction, power friction loss, oil flow rate.

The software has been validated in many cases of calculations of various hydrodynamic bearings and proved its reliability for optimization of the bearing design.

When a bearing is being designed, theoretical simulation of hydrodynamic lubrication is performed to optimize the bearing dimensions and lubrication conditions.

Optimal values of the lubricant clearance, lubricant viscosity and temperature, lubricant feed rate are calculated in the bearing design.

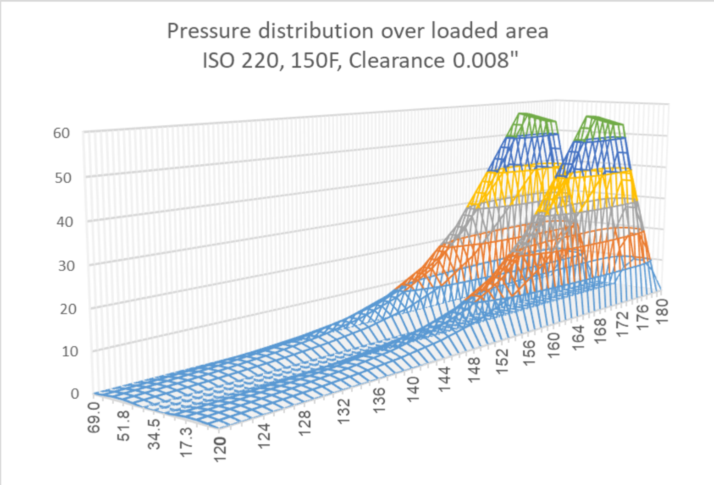


Fig.1 Distribution of Lubricant Pressure over bearing Surface (example)

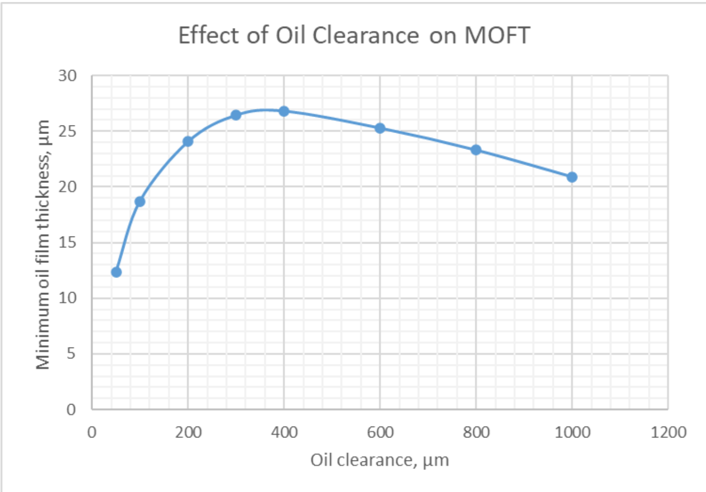


Fig.2 Effect of Oil Clearance on Minimum Oil Film Thickness (example)

1.2. Lubrication Arrangements

Sliding bearing is an open system. The lubricant is flowing out of the clearance.
The lubricant feeding to a bearing must compensate for the leakage out of the bearing.
Correct design of lubrication grooves, pockets, holes of the bearing guarantees continuous and sufficient feeding of the lubricant which is crucial for maintaining stable hydrodynamic lubrication.
Configuration and dimensions of the lubricant passages as well as the inlet lubricant pressure and flow rates are calculated. The lubricant pressure drops in oil passages are calculated with the Darcy–Weisbach equation.

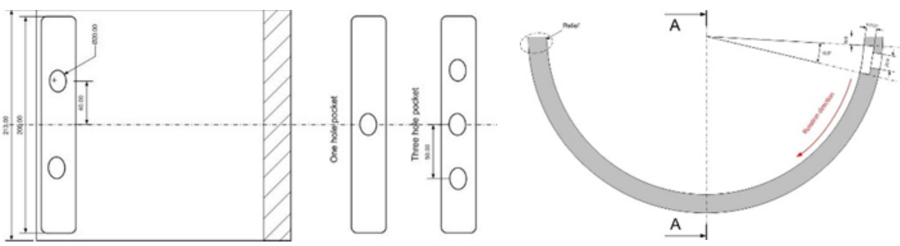


Fig.3 Arrangement of Lubricant Pocket and Holes (example)

1.3. Bearing Press Fit

The bearing outside diameter (OD) is greater than the bore diameter. Therefore, a bearing mounted in the housing is mechanically stressed and elastically compressed.

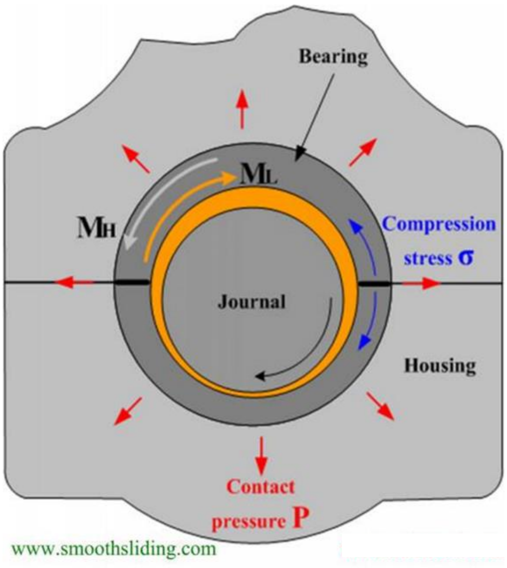


Fig.4 Condition of Press Fitted Bearing

The difference between the bearing OD and bore diameter is called interference. Its value determines parameters of the bearing press fit.
A properly fitted bearing has uniform firm contact with the housing surface, which fulfills the following functions:

- Creates friction torque at the bearing back surface;
- Provides maximum heat transfer out of the bearing;
- Increases the rigidity of the housing.

The optimal interference of the bearing and housing is determined by their dimensions, materials and work temperature. Its value as well as the effect of the interference on the lubricant clearance are calculated in the bearing design.

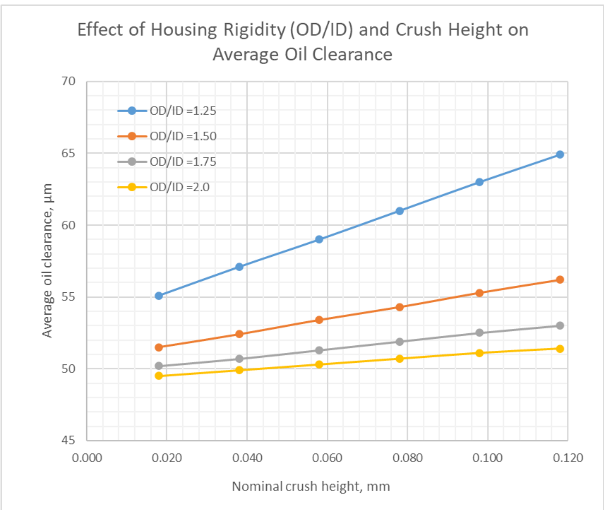


Fig.5 Effect of Interference and Housing Rigidity on Oil Clearance (example)

2. Development of Materials for Sliding Bearings

The wide variety of applications and work conditions of sliding bearings requires the variety of bearing materials.
Real hydrodynamic bearings work in the lubrication regime combining hydrodynamic lubrication with direct friction.
Therefore, the developed bearing materials combine strength and wear resistance with surface anti-friction properties.
Depending on the work conditions and stability of hydrodynamic lubrication the bearing materials are developed with different structures:

- Monometallic
- Two-layer structure
- Three-layer structure having one thin coating
- Four-layer structure having two different thin coatings

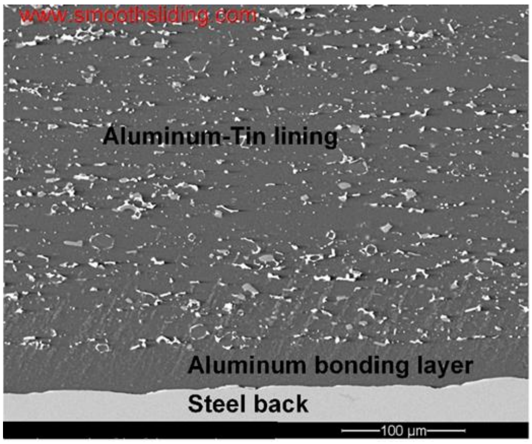
The bearing materials have composite microstructures providing the optimal combination of strength and anti-friction properties.
The material range is as follows:

- Steel;
- Copper alloys (cast or sintered);
- Aluminum alloys (cast or PVD);
- Leaded alloys;
- Silver alloys;
- Tin;
- Polymer nano-composites;
- Graphite.

A wide variety of metallurgical processes are used for manufacturing bearing materials:

- Continuous strip casting;
- Continuous strip sintering;
- Sintering of sound (no-pore) and porous parts;
- Cold rolling;
- Roll bonding of bi-metal strips
- Thermal treatments;
- Metal forming;
- Electroplating;
- Physical Vapor Deposition in deep vacuum (Sputtering);
- Coating with nano-composite polymer material;
- Polymer infiltration.

Examples of microstructures of some bearing materials are depicted in Fig.6 and 7.



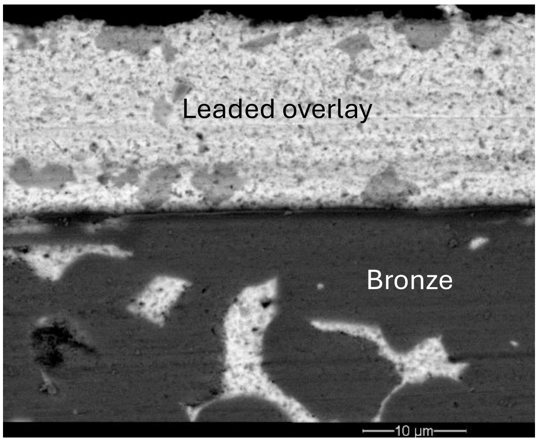


Fig.6 Typical Microstructures of Bi-metallic Bearings (left) and Bronze Lining Coated with Lead-Based Overlay (right)

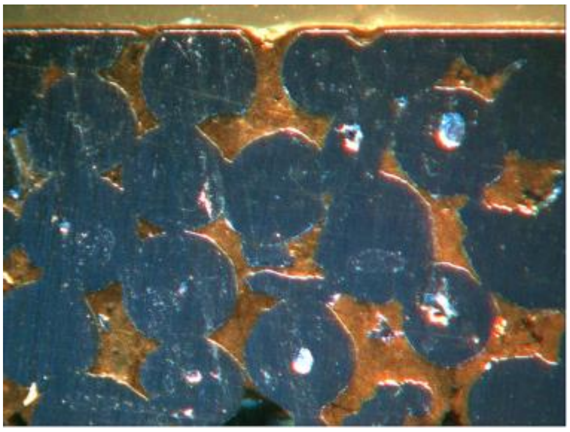
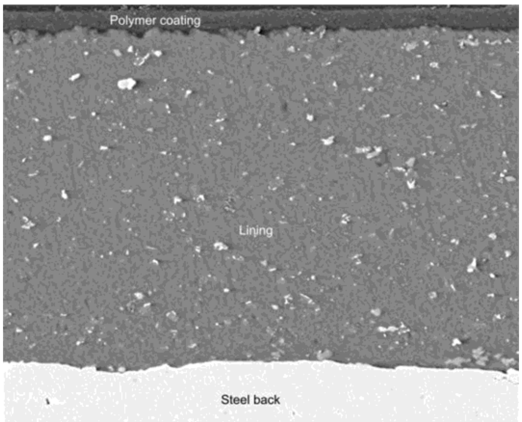



Fig.7 Porous Bronze Infiltrated with Antifriction Polymer (left) and Polymer Coated Bearing (right)

Multi-layer structures of materials for sliding bearings require particular attention to the adhesion strength and developing special methods enhancing the adherence of the layers.

3. Range of Developed Sliding Bearing

Smooth Sliding has accumulated extensive experience in developing sliding bearings for various applications:

- Internal combustion engines (automotive, aviation, diesel and gas generators);
- Pumps: oil pumps, fuel pumps, water pumps, crude oil pumps;
- Air compressors and air conditioning systems;
- Metal forming industrial equipment;
- Energy storage systems.

The range of the sliding bearings developed by Smooth Sliding:

- Bearing diameter: 4.5 mm – 590 mm (0.18" - 23.2")
- Rotation speed: 50 RPM – 20,000 RPM
- Radial load: 0.37 kN – 4000 kN
- Lubricants: oil, fuel, water, molten metal
- Construction: two-shell bearings, solid bushings, split bushings, partial bushing