Bearings and Lubrication

Chapter 10

Bearings

• In general, whenever two parts have relative motion, they constitute a bearing by definition.
• Usually lubrication is needed in any bearing to reduce friction and remove heat.
• Bearings may roll or slide or do both simultaneously.

Bearings → Sliding Bearings → Journal (no thrust resistance) / Thrust (supports axial loads)
Bearings → Rolling Bearings

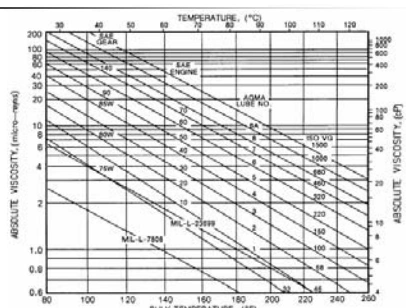
Types of Lubricants

- Oils
  - Flow easily (relatively low viscosity)
  - Easy to add additives to
- Greases
  - Thicker
  - Cannot be cycled through system
- Solid Films
  - Low coefficient of friction
  - High temperature resistance

Viscosity

- Viscosity is a measure of fluid's resistance to shear.
- Viscosity, η, for fluids is analagous to shear modulus, G, for solids
- Units
  - English—lbf-s/in^2 (reyn) generally micro-reyn
  - Metric—N-s/m^2 (Pascal-second)
    generally cP (centipoise): milli-Pascal-second
- Kinematic Viscosity (ν)=η/ρ ρ: density
- See Figure 10-1 (pp. 625)

Viscosity



Temperature and Pressure Effects on Viscosity

- Temperature increases, viscosity decreases
- Pressure increases, viscosity increases

Types of Sliding Bearings

- Journal or sleeve
  - No thrust resistance
- Thrust
  - Capable of supporting end loads

Types of Lubrication

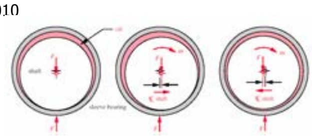
- Full Film: bearing surfaces are fully separated by a film of lubricant, eliminating any contact.
  - Hydrostatic
    - continuous flow of lubricant to the sliding interface
    - e.g air hockey, hovercraft
    - f=0.002-0.010

air hockey

hovercraft

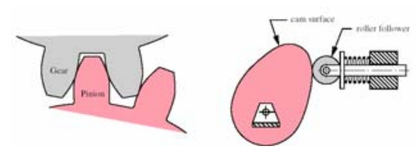
Type of Lubrication

- Hydrodynamic:
  - The most effective technique in journal bearings.
  - The relative velocity of the mating surfaces pumps the lubricant to the gap.
  - Surface wear does not occur
  - Film thicknesses 0.008-0.020 mm
  - f=0.002-0.010



Type of Lubrication

- Elastohydrodynamic: occurs if the contacting surfaces nonconforming as with the gear teeth or cam and follower. Small contact patch allows a full hydrodynamic film to form.
  - Depends on elastic deformation of parts.
  - Generally on noncircular parts
  - Full-film lubrication occurs if the surface roughness is no more than ½ of the oil-film thickness.



Types of Lubrication

- Mixed Film
  - Combination of partial lubricant film plus some asperity contact between the surfaces.
  - f=0.004-0.10
- Boundary
  - Continuous surface contact
  - Lubricant smeared over surface
  - f=0.05-0.20

Desired Properties of Bearing Materials

- Embeddability or indention softness--embedding of particles
- Low shear strength—material flow
- Sufficient Compressive and fatigue strength—support load and endure repeated flexing
- High heat conductivity—conduct heat away
- Coefficient of thermal expansion similar to journal and housing
- Corrosion resistance—avoid oxidation

Common materials :Babbits (alloys based on lead and tin), copper alloys, aluminum, silver

Basic Concepts of Hydrodynamic Lubrication

- See figure 10-3 (pp. 627)
- Journal tries to climb bearing wall
- Simultaneously, it forces fluid down into crevice
- Pressure increases at interface and "floats" journal
- <u>Eccentricity of journal "e"</u> is the distance between resting cg and floating cg.

Hydrodynamic Lubrication

MACHINE DESIGN - An Integrated Approach, 2ed by Robert L. Norton, Prentice-Hall 2000

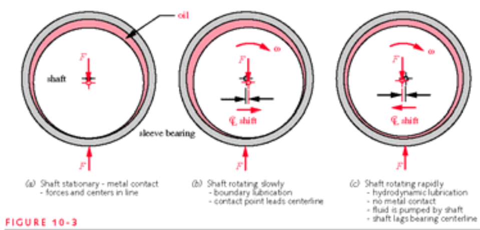


FIGURE 10-3
Boundary and Hydrodynamic Lubrication Conditions in a Sleeve Bearing—Clearance and Motions Exaggerated

Basic Concepts of Hydrodynamic Lubrication

Design of hydrodyanmic bearing involves finding a suitable combination of bearing diameter and/or length that will operate with a suitable viscosity and reasonable clearance.

- Higher viscosity
  - Journal floats at lower velocity
  - Friction increases
- Higher rotating speed
  - Lower viscosity is needed to float
  - Once floating, increasing speed increases friction

Basic Concepts of Hydrodynamic Lubrication

- Bearing Unit Load
  - W/dL
  - Smaller bearing unit load
    - lower viscosity and speed are needed to float bearing
    - lowering bearing load beyond floating does not lower bearing friction

Petroff's Equation

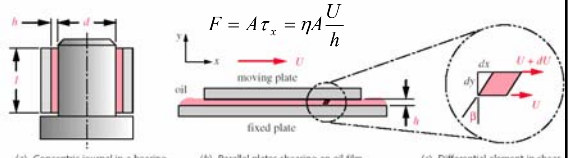
- Assumes ideal case:

Petroff's equation for no-load torque

  - No eccentricity (concentric journal and bearing)
  - No transverse load
  - No axial lubricant flow

Petroff's Equation

$$F = A\tau_x = \eta A \frac{U}{h}$$



$$T_o = \frac{d}{2}F = \frac{d}{2}\eta A \frac{U}{h} = \frac{d}{2}\eta(\pi d l)\frac{(\pi d m)}{h}$$

$$T_o = \eta \frac{\pi^2 d^3 l m}{c_d}$$

- c_d : Diametral clearance
- T_o : Torque to shear oil film
- F : Force to shear oil film
- m: rotational speed of journal (rev/sec)