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.

**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, \( \eta \), for fluids is analogous to shear modulus, \( G \), for solids
- Units
  - English—lbf-s/in² (reyn) generally micro-reyn
  - Metric—N-s/m² (Pascal-second) generally cP (centipoise), mPa-s (milli-Pascal-second)
- Kinematic Viscosity \( (\nu)=\eta/\rho \) \( \rho \): density
- See Figure 10-1 (pp. 625)

**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
    - $f=0.002-0.010$

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
  - $f=0.002-0.010$
- 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 indentation softness—embedding of particles
- Low shear strength—material flow
- Sufficient Compressive and fatigue strength—support load and endure repeated flexing
- High heat conductivity—conduc heat away
- Coefficient of thermal expansion similar to journal and housing
- Corrosion resistance—avoid oxidation

Common materials: babbitts (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
- Eccentricity of journal "e" is the distance between resting cg and floating cg.

Basic Concepts of Hydrodynamic Lubrication

Design of hydrodynamic 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

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

\[
T_s = \frac{d}{2} \left( \frac{d}{2} \frac{U}{h} \right) \eta \tau = \frac{d}{2} \eta (\delta l) (l m) \left( \frac{\pi}{h} \right)
\]

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