PRINCIPLES OF TRIBOLOGY:
LUBRICATION, FRICTION AND WEAR

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July 1998
OUTLINE

- Introduction and History of Tribology
- Definition of conformal and non-Conformal Contacts
- Regimes of Lubrication
- Lubricants, Newtonian, non-Newtonian, Units, Grades, Pressure and Temperature Dependence, Mineral or Synthetic Lubricants, Greases, Viscometry
- Types of Bearings, Journal, Thrust, Rolling Element, etc., Bearing Materials
- Fundamentals of Lubrication (Reynolds Equation)
- Hydrodynamic Lubrication Analysis & Sample Problems
  - Journal Bearing
  - Thrust Bearing
  - Hydrostatic Bearing
- Hertz Stress Theory & Sample Problems
  - Line and Point Contacts
- Elastohydrodynamic Lubrication Analysis and Sample Problems
  - Line and Point Contacts
  - Film Thickness Equations
  - Surface Roughness Effects
• Internal Stresses and Fatigue Damage (Contaminant Effects)
• Surface Profilometry
  – Measurement Techniques (Contacting & non-Contacting)
  – Surface Parameters of Interest
• Brief Review of Wear Measurement Techniques
  – Wear Equations
TRIBOLOGY

Is the science that deals with the design, friction, wear and lubrication of interacting surfaces in relative motion (e.g. bearings, gears, cam/follower mechanisms, manufacturing processes etc.)

• Interdisciplinary Science

  • Contact Mechanics and Elasticity

  • Fluid Mechanics

  • Heat Transfer

  • Rheology

  • Finite Element Methods

  • Computer Graphics
Science of Tribology

- Tribology is derived from the Greek work meaning "rubbing."

- Tribology literally means the science of rubbing surfaces.

- Tribology is the science of lubrication, friction and wear of bodies in relative motions.
History of Tribology

- Dates back to the time of Pharoahs (1880 B.C.) and Assyrians.
- Leonardo da Vinci (1452-1519)
- Sir Isaac Newton (1642-1727)
- Guillaume Amontons (1663-1705)
- Charles Coulomb (1736-1806)
- Nikolai Petrov (1836-1920)
- Sir Osborn Reynolds (1842-1912)
- Heinrich Hertz (1856-1894)
- Grubin and Vinogradova (1949)
- Dowson (1961)
Transporting an Egyptian Colossus (1880 B.C.)
Assyrians Positioning a Human Headed Bull (700 B.C.)
Fig. 7.7
Leonardo da Vinci's sketches in
Codex Madrid I of ball, cone and
roller pivot bearings.
what is a Bearing:

is a device that supports load while allowing relative motion inherent in the mechanism to take place.

Bearing(s) ≤ Conformal. non Conformal.
BEARING TYPES

- Bearings are used to support, load while allowing the relative motion inherent in the mechanism to take place.

- There are many different types of bearings. Some examples include:

  - Journal bearing
    - dry rubbing
    - impregnated
    - lubricated

  - Rolling element bearing
    - ball
    - roller (tapered, spherical, etc.)

  - Thrust bearing

- However, bearings can be classified in general in two categories:
  - conformal
  - non-conformal
CONFORMAL AND NON-COMFORMAL

- Conformal contacts fit into each other with a high degree of geometrical conformity so that the load is carried over a large area.

- In the above example the clearance between the bearing and the journal is usually 1/1000 of journal diameter.
CONFORMAL AND NON-COMFORMAL
(Continued)

- Non-conformal contacts have surfaces that do not conform to each other. In these contacts the load is carried by a small area.

- The lubrication area for non-conformal bodies is typically three orders of magnitude less than that of conformal contacts.
LUBRICATION REGIME

1: Hydrodynamic Lubrication
   Conformal. Film thickness: 1 μm -- 100 μm. MPa
   Journal & Thrust Bearings

2: Elasto-Hydrodynamic Lubrication (EHL)
   Non-conformal. Film thickness: 0.1 μm -- 1 μm. GPa
   Gears, Cam and Followers, Rolling-Element Bearings

3: Partial Lubrication (Mixed Lubrication)
   Film thickness: 0.01 μm -- 1 μm

4: Boundary Lubrication
   Film thickness: 0.001 μm -- 0.01 μm
FRICTION COEFFICIENT IN DIFFERENT LUBRICATION REGIMES

![Graph showing friction coefficient in different lubrication regimes]

- Boundary: \( h \approx 0.0025 \mu m \)
- Mixed: \( h \approx 0.0025 \mu m \)
- EHD: \( h \approx 0.025 \) to \( 2.5 \mu m \)
- Hydrodynamic: \( h > 25 \mu m \)

Coefficient of friction vs. viscosity\(*velocity / load\)
WEAR RATE IN DIFFERENT LUBRICATION REGIME

- Wear Rate
- Load
- Hydrodynamic
- EHD
- Boundary
- Unlubricated