PRINCIPLES OF TRIBOLOGY: LUBRICATION, FRICTION AND WEAR

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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,)

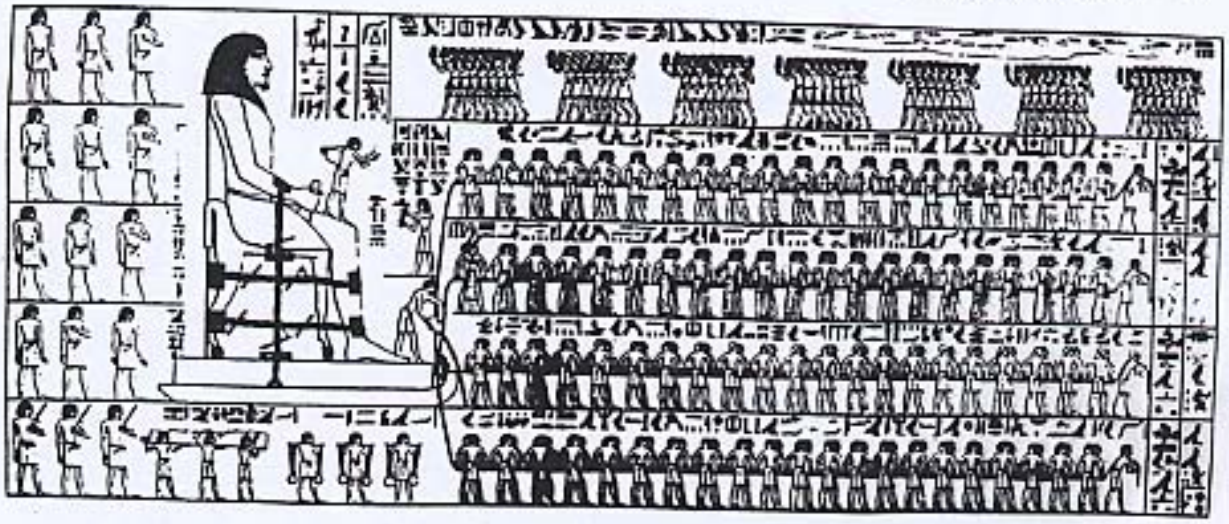
- **Interdisciplinary Science**
    - **Contact Mechanics and Elasticity**
    - **Fluid Mechanics**
    - **Heat Transfer**
    - **Rheology**
    - **Finite Element Methods**
    - **Computer Graphics**

Science of Tribology

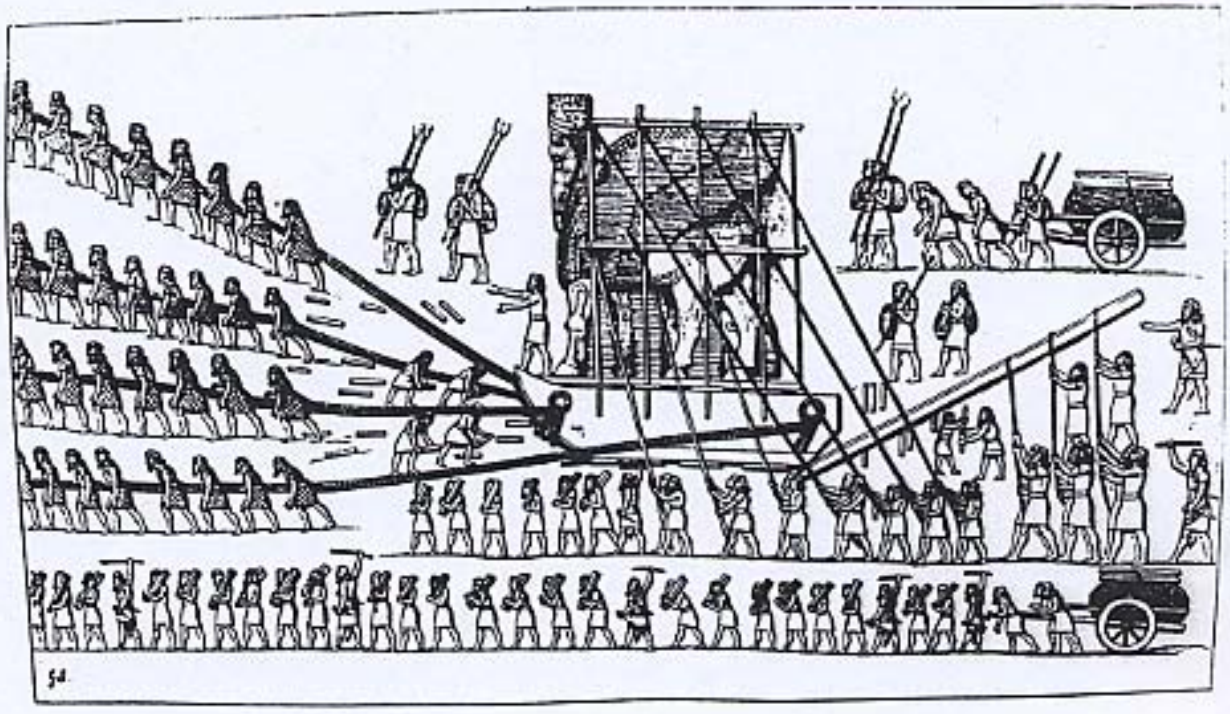
- Tribology is derived from the Greek work meaning "rubbing."
- Tribology literally means the science of rubbing surfaces.
- Tribology is the science of lubrication, friction and wear of bodies in relative motions.

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.)

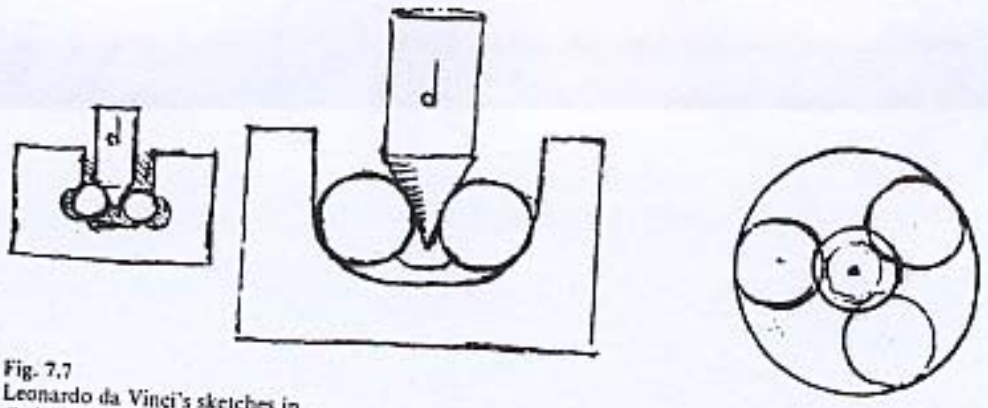
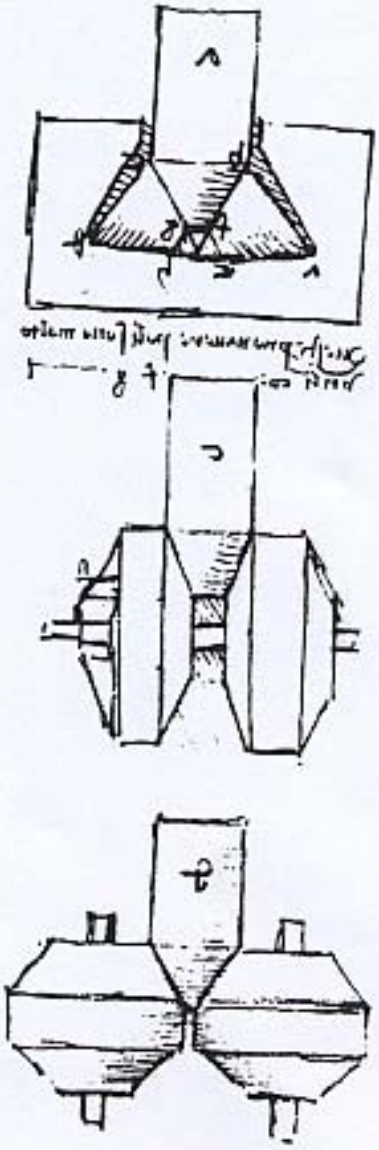


Fig. 7.7
Leonardo da Vinci's sketches in *Codex Madrid I* of ball, cone and roller pivot bearings.



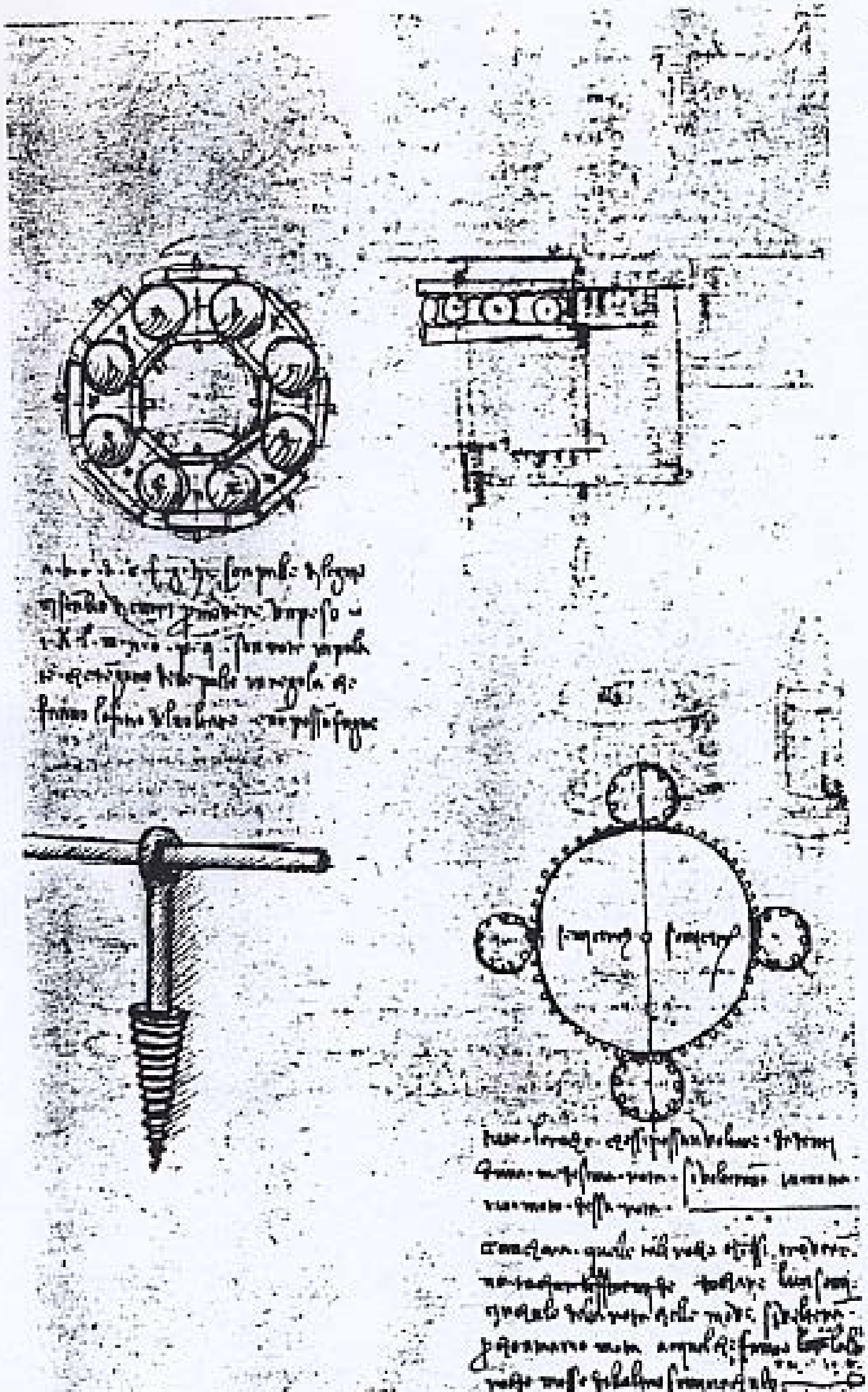
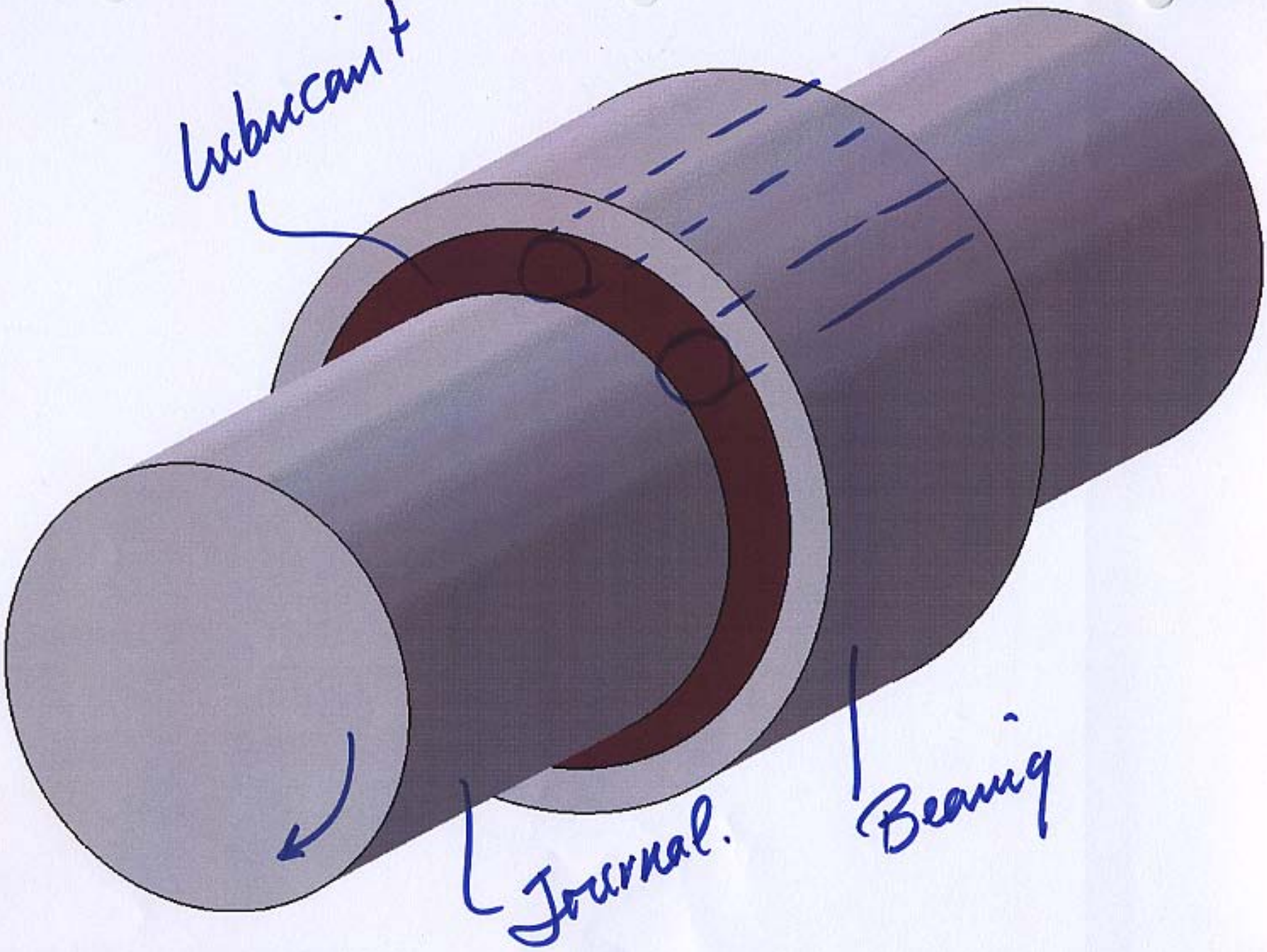


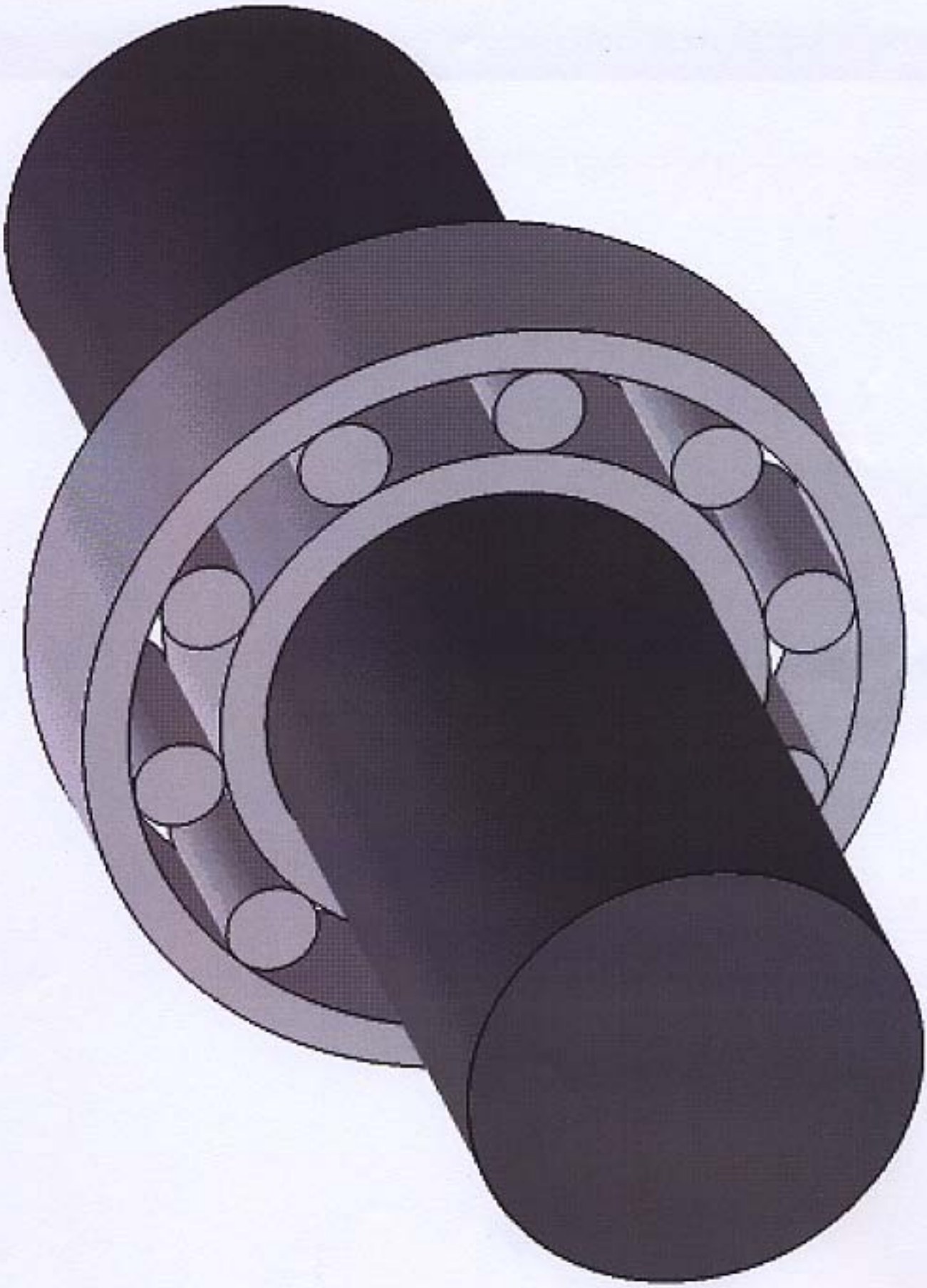
Fig. 7.6
Early form of 'cage' proposed by Leonardo da Vinci in Codex *Madrid I* for a ball-bearing to prevent contact between the balls.

What is a Bearing:

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

Bearings — Conformal.
— non Conformal.


Lubricant
Journal.
Bearing



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**

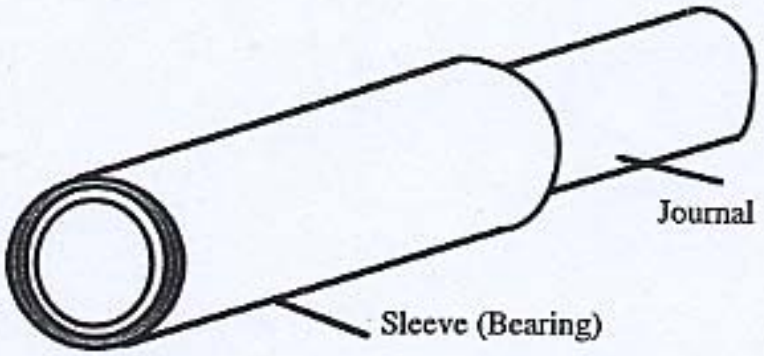
- **Rolling element bearing**
  - **ball**
  - **roller (tapered, spherical, etc.)**

- **Thrust bearing**

- **However, bearings can be classified in general in two catagories:**
  - **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.**

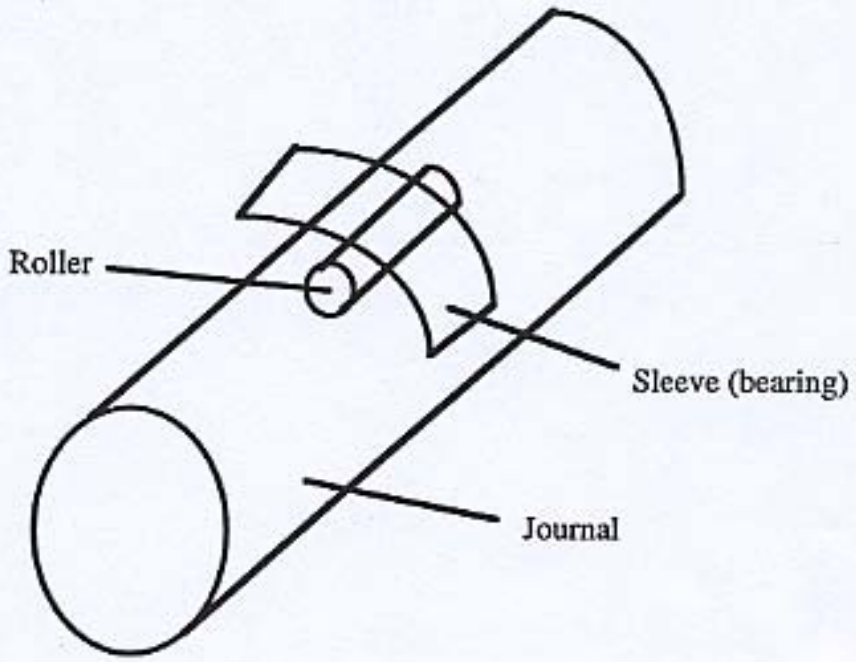


- **In the above example the clearance between the bearing and the journal is usually 1/1000 of journal diameter.**

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.**

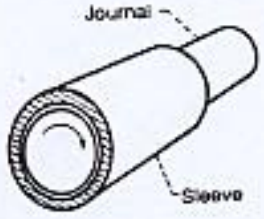


LUBRICATION REGIME

1: Hydrodynamic Lubrication

Conformal. Film thickness: 1 μm -- 100 μm. MPa

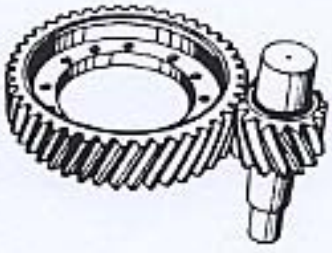
Journal & Thrust Bearings



2: Elasto-Hydrodynamic Lubrication (EHL)

Non-conformal. Film thickness: 0.1 μm -- 1 μm. GPa

Gears, Cam and Followers, Rolling-Element Bearings



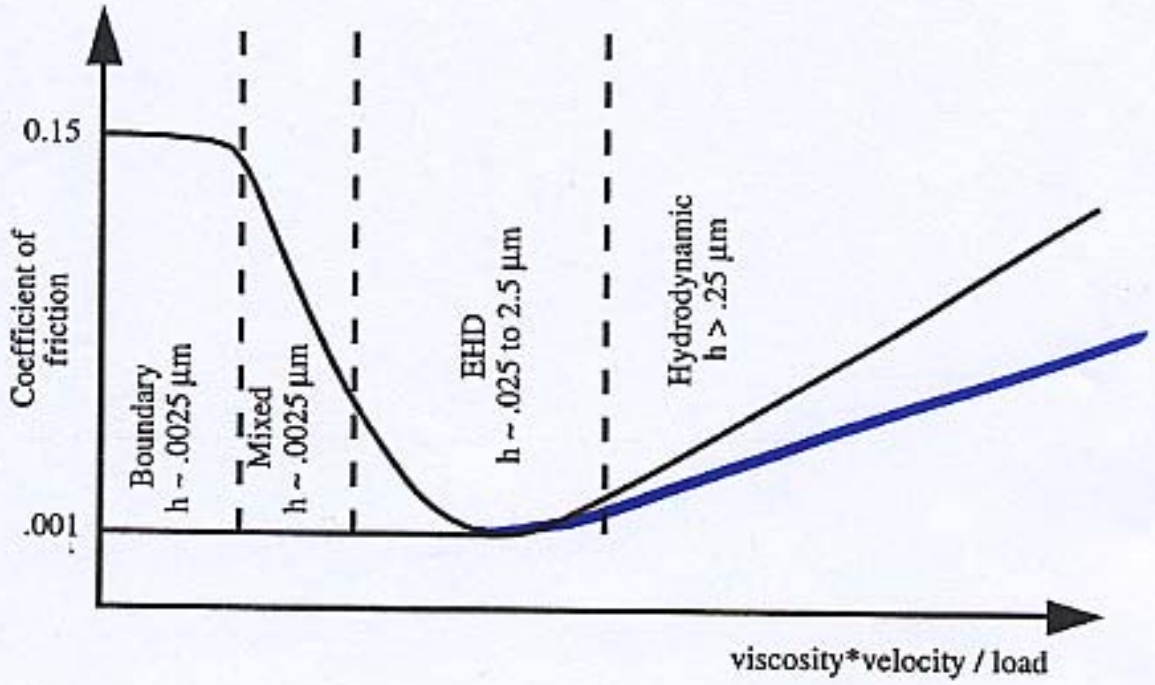
3: Partial Lubrication (Mixed Lubrication)

Film thickness: 0.01 μm --- 1 μm

4: Boundary Lubrication

Film thickness: 0.001 μm --- 0.01 μm

FRICTION COEFFICIENT IN DIFFERENT LUBRICATION REGIMES



WEAR RATE IN DIFFERENT LUBRICATION REGIME