19. Plain Surface Bearings

Objectives

- Understand the three modes of operation of plain surface bearing: boundary, mixed-film and full-film, or hydrodynamic operation.
- Gain an understanding of which materials are appropriate for different bearing applications.
- Understand how to use the pressure-velocity relationship in selection and sizing of bearings.
- Use the principles of operation and selection criteria to specify appropriate bearings for individual applications.
- Understand basic principles of lubrication and how they apply to design process.

1

Introduction

- Bearing is a member designed to support a load while permitting relative motion between two elements of a machine
- Where do you find them?
  - Hinges, door locks, latches, wheels,etc.

2

Introduction

- As a designer what will you be doing for a bearing design?
  - Decide type of bearings
  - Type of lubrication depending on the bearing selected
  - Bearing materials
  - Lubricants to be used

3

Introduction

- Moving parts – Friction
- Friction – loss of power

4

Introduction

- Journal Bearings – sliding friction
  Antifriction Bearings – rolling resistance
- To reduce sliding friction lubrication is used in Journal Bearings

5

Journal Bearings

- Journal bearing is a cylindrical bushing made of a suitable material.
- Journal is the part of a shaft that rotates inside the bearing.

6

Sleeve Bearing

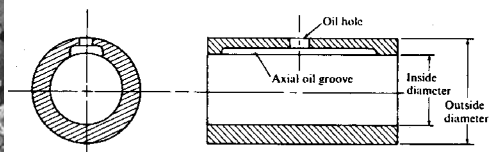


FIGURE 3.1 Sleeve bearing with provisions for lubrication

7

Conformal Surfaces

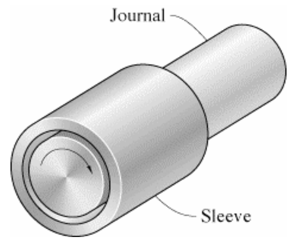


Figure 8.1 Conformal Surfaces

Text Reference: Figure 8.1, page 309

8

Plain Surface Bearings

- Boundary Lubrication
  - Direct contact between the materials. May have some lubricating film in between
- Mixed film lubrication
  - It may be boundary or full film lubrication. It is a transition
- Full film lubrication or Hydrodynamic lubrication
  - Full film of lubrication supports the load
- Hydrostatic bearing lubrication
  - Pressurized lubricant

9

LUBRICATION—BOST-BRONZ

All standard BOST-BRONZ bearings, bars and plates are impregnated with a high grade, oxidation-resistant mineral oil of SAE30 (ISO 100) viscosity. If properly stored, BOST-BRONZ parts retain their oil supply indefinitely. To prevent loss of lubricant, BOST-BRONZ should be stored in non-absorbent materials (metal, plastic, or suitably lined containers, etc.) The bearings should be covered to keep out dirt and dust.

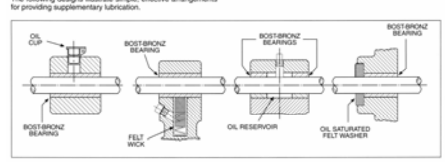
REMOVING LUBRICANT: If it becomes necessary to remove the oil from BOST-BRONZ, for example to replace with another type or viscosity of lubricant, the following procedure may be used.:

Immerse parts in a good grade of oil solvent, such as lead-free gasoline, naptha, carbon tetrachloride or alcohol. Change solvent often, until solvent appears clear. Agitation will hasten the process.

RE-OILING: BOST-BRONZ parts may be re-impregnated by submerging in oil (pre-heated to about 150°F) for approximately 30 minutes. More time should be allowed for larger parts.

SUPPLEMENTARY LUBRICATION

The following designs illustrate simple, effective arrangements for providing supplementary lubrication.



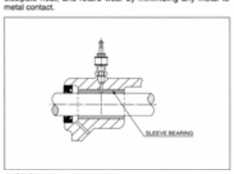
10

LUBRICATION—BEAR-N-BRONZ

The maintenance of an oil film between the shaft and bearing surfaces is extremely important, serving to reduce friction, dissipate heat, and retard wear by minimizing any metal to metal contact.

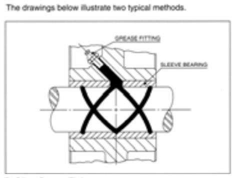
Lubricant is usually supplied into the bearing from an oil cup or fitting through an oil hole.

The drawings below illustrate two typical methods.



A. Oil Cup

Oil is fed from the oil cup to the bearing by gravity.

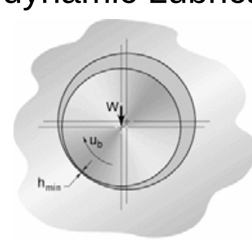


B. Oil or Grease Fitting

Lubricant is fed through the fitting under pressure and distributed through grooves by the rotation of the shaft.

11

Hydrodynamic Lubrication



Conformal surfaces
$p_{max} \approx 5$ MPa
$h_{min} = f(W, u_b, \eta_0, R_x, R_y) > 1\ \mu m$
No elastic effect

Text Reference: Figure 8.3, page 310

12

Lubricant Characteristics

- Lubricant forms a film between mating bearing surfaces. (Fig. 3.16)
- Reduces abrasive action that causes wear and surface damage.

13

Lubricant Characteristics

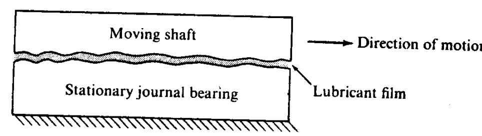


FIGURE 3.16 Separating action of lubricant film

14

Hydrodynamic action

- Radial clearance is one half of diametral clearance
- As clearance increases it decreases the coefficient of friction but reduces the load carrying capacity.
- A very thin film is likely to cause the rubbing of high spots in the shaft and journal.

15

Hydrodynamic action of Journal Bearings

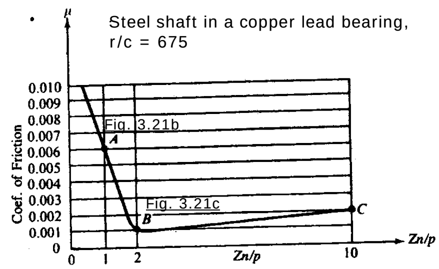


FIGURE 3.20 μ-Zn/p curve

16

Hydrodynamic action of Journal Bearings

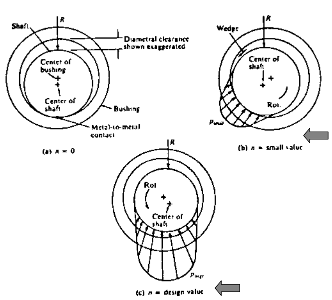


FIGURE 3.21 Hydrodynamic action of journal bearings

17

Hydrodynamic action of Journal Bearings

- High value of μ left of A is because of the surface irregularities since lubricant film is very small.
- Point B is where μ is lowest. However any drop in speed or temperature raises it to a very high value and thus likely to cause bearing seizure.
- Left of B is called boundary, thin-film or imperfect lubrication. Right of B is thick film or perfect lubrication.
- From B to C there is a gradual increase in μ .

18

- Perfect lubrication is enhanced by
  - Low temperature (high viscosity)
  - Low loads (sudden acceleration from standstill is undesirable because of the out-of-round journal)
  - Adequate supply of oil
  - High speed

19

Bearing Selection

- Suitability of a bearing is selected by
  - Rotational velocity
  - Materials used for bearing and shaft
  - Clearances between the journal and the bearing
  - Temperature of operation
  - Type of lubrication
  - Surface finish

20

Journal Bearings

- Length of bearing should be at least equal to the diameter, but preferable to have it two times the diameter.

21

Shaft considerations

- Shaft end in the bearing should be hardened and smooth (4 to 12 μin rms)

$$PV = \frac{F}{L\,d}\,\frac{\pi\, d\, n}{12} = \frac{\pi\, F\, n}{12\, L}$$

- P = pressure (psi)
- V = Bearing velocity (ft/min)
- L = bearing length (in)
- d = shaft diameter (in)
- F = load on shaft (lb)
- n = speed (rpm)

22

TABLE 19.1

RECOMMENDED VALUES FOR BEARING PRODUCTS

Material	Max. PV	Max. P	Max. V
Bear-N-Bronz	75,000	3,000	750
Bost-Bronz	50,000	2,000	1,200
Bost-Bronz (Thrust washers)	10,000	2,000	1,200
F-1—Glass-filled Teflon	20,000	1,000	400
TN—Teflon-filled nylon	10,000	800	300
AF—Teflon-filled acetal	8,000	750	300
GS—Nylatron	4,000	500	300
D—Delrin or Celcon	3,000	480	300
N—Nylon	3,000	480	300
UHMW-PE	2,300	1,400	100
Nyloil	16,000	2,000	400
UHMW-PE with internal wear strip	4,000	1,400	100
Nyloil with internal wear strip	16,000	2,000	400

Courtesy of Boston Gear Company

23

Example Problem 19-1: Bearing Sizing

- Determine the length required for a nylon sleeve bearing under the following conditions:
  - ¾-inch shaft diameter
  - n = 500 rpm
  - load on the bearing of 20 pounds

24

Example Problem 19-1: Bearing Sizing

- Determine the length required for a nylon sleeve bearing under the following conditions:
  - ¾-inch shaft diameter
  - *n* = 500 rpm
  - load on the bearing of 20 pounds

– If:

$$(PV) = \frac{\pi F n}{12 L} \qquad \text{(19-1)}$$

– Then:

$$L = \frac{\pi F n}{12 (PV)}$$

$$PV = 3000 \qquad \text{(from Table 19-1)}$$

$$L = \frac{\pi\, 20 (500)}{12 (3000)}$$

$$L = .872 \text{ inch}$$

– Use a 7/8-inch or longer bearing.

Example Problem 19-1: Bearing Sizing (cont'd.)

- Check maximum pressure and maximum velocity:

– Maximum pressure:

$$P = \frac{F}{A} = \frac{20 \text{ lb}}{3/4 \times 7/8}$$

$$P = 30.5 \qquad \text{(OK)}$$

– Maximum velocity:

$$V = \frac{\pi D n}{12}$$

$$V = \frac{\pi\ (3/4)\ 500}{12}$$

$$V = 98 \qquad \text{(OK)}$$

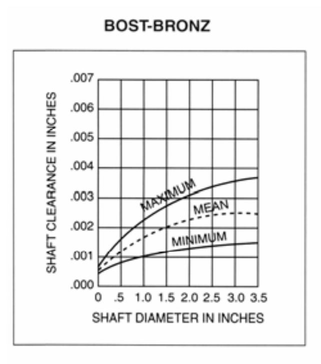
– 7/8-inch-long nylon bearing will suffice.

26

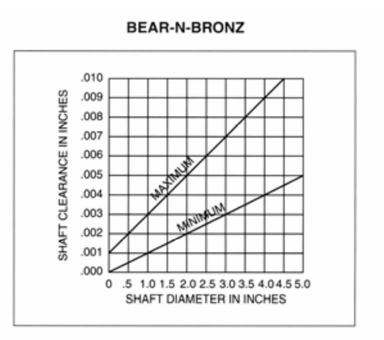
Shaft clearances

- Clearances vary depending upon the size and lubrication

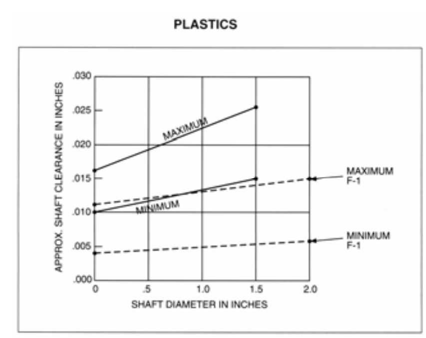
27



28



29



30

Wear

- Wear of the bearings can be calculated as
- K Wear factor (in^3 min / lb ft hr) $K = \frac{W}{F\ V\ T}$
- Expected life time, T is $T = \frac{t}{K\ P\ V}$
- W = volume of material lost, in^3
- T = hours of running time
- F = load in pounds
- K wear factor from Table 19.2
- t = thickness of wear

31

TABLE 19.2

WEAR RATE FACTORS

Typical Materials	K
Delrin or Celcon (D)	50×10^{-10}
Nylatron GS (GS)	35×10^{-10}
Teflon-filled acetal (AF)	17×10^{-10}
Teflon-filled nylon (TN)	13×10^{-10}
Glass-filled Teflon (F-1)	12×10^{-10}
Nylon	12×10^{-10}

32

Example Problem 19-2: Wear

- If, in the bearing from Example Problem 19-1, a wear of .010 inch is acceptable, what is the estimated life in hours of operation?
  - *K* is found from Table 19-2.

$$T = \frac{t}{K\,PV} \qquad (19\text{-}3)$$

$$T = \frac{.010}{(12 \times 10^{-10})\ (30.5)\ (98)}$$

$$T = 2800 \text{ hours}$$

33

Journal Bearing Materials

- Compatibility: with less or more friction
- Embedability: to embed foreign particles to reduce scratching of shaft material
- Conformability: to compensate small amounts of misalignment and shaft deflection. Low Young’s modulus

34

Journal Bearing Materials

- Corrosion resistance
- High thermal conductivity
- High fatigue strength

35

Bearing Materials

- Steel
- Bronze
- Babbitt
- Aluminum
- Porous materials
- Plastics

36

Journal Bearing Materials

- Lead bronze
- Tin base babbitt
  - 90% Tin + Antimony & Copper
- Lead base babbitt
  - 90% Lead + Antimony & Copper
- Aluminum
- Silver
- Plastics (Nylon, Teflon, Rubber)

Journal Bearing Materials

TABLE 3.1 Relative Quality of Bearing Materials

Bearing Material	Compatibility	Embedability	Conformability	Corrosion Resistance	High Thermal Conductivity	High Fatigue Strength
Lead bronze	3	2	2	4	3	3
Tin-base babbitt	5	5	4	5	2	2
Lead-base babbitt	5	4	5	4	2	2
Aluminum	3	1	2	5	3	4
Silver	3	2	1	5	5	5

5 = highest quality.
1 = lowest quality.

Journal Bearing Material selection

- Misalignment between the shaft center line and the center line of the bushing bore
- Shaft deflection due to shaft bending loads
- Type of shaft material
- Bearing loads and temperatures
- Shaft speed
- Characteristics of the lubricant

Journal Bearings

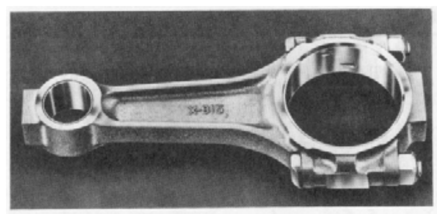


FIGURE 3.3 Automotive connecting rod showing crank-pin and wrist pin bearings *(Courtesy of Central Foundry, Division of General Motors Corporation)*

Journal Bearings

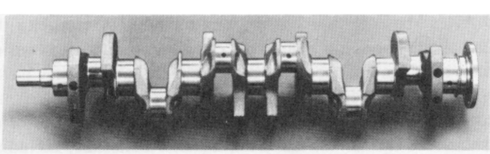


FIGURE 3.4 Six-cylinder automotive crankshaft *(Courtesy of Central Foundry, Division of General Motors Corporation)*

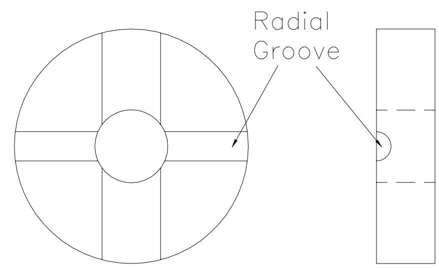
Thrust Bearings

- If the pressure is parallel to the axis of the shaft, the bearing is called Thrust Bearing.
- In a thrust bearing if the shaft terminates at the bearing, it is called a Pivot Bearing.
- If it continued beyond the bearing it is called a Collar Bearing.

Sliding-contact Thrust Bearing

- Thrust bearings are typically placed at the end of a shaft to absorb axial or thrust loads. (Fig. 3.23a)
- To transmit the axial force through collars attached to the shaft (Fig. 3.23b)

Washer type Thrust Bearing



Sliding Contact Thrust Bearings

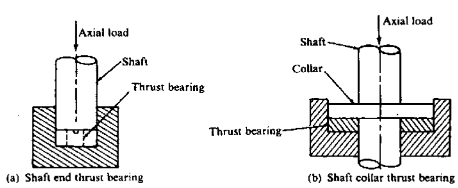


FIGURE 3.23 Two thrust bearing arrangements

Porous Bearings

- Self-lubricating (for life) bearings made by P/M process
- Advantages
  - They eliminate oil drip, which could contaminate the product (e.g. food and clothing)
  - They eliminate oil leakage, which could be a fire hazard in applications where heat or steam is nearby.

Summary

- Journal bearing is a sliding contact bearing.
- Friction is always present even with lubrication.
- Lubricant helps to reduce metal-to-metal contact in journal bearing.
- Viscosity is measured by viscometer.
- Thrust bearings absorb axial loads.
- Self-aligned bearings reduce shaft and bearing wear.