# 6.1.Classification of Bearings

## 1) What is a bearing? State the functions of a bearing.

A bearing is a machine element that constrains relative motion and reduces friction between moving parts . Bearing is a mechanical element which permits relative motion between two parts, such as the shaft and the housing, with minimum friction. The functions of the bearing are as follows:

1. The bearing facilitates free **rotation** of the shaft with minimum **friction.**

2. The bearing **supports** the shaft and holds it in **correct position.**

3. The bearing takes up the forces that act on the shaft and transmits them to the frame .

## 2) Classify Bearings.

Bearings are classified on different basis,

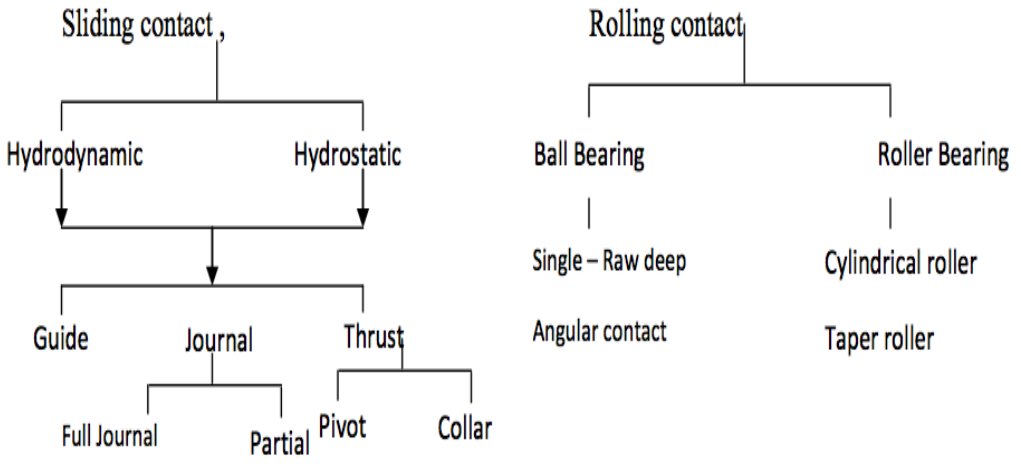
A) Classification based on TYPE OF CONTACT

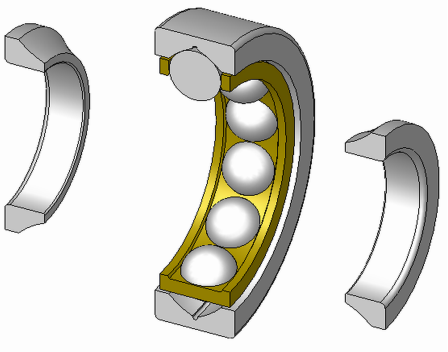
1) Sliding contact bearing

2) Rolling contact bearing.

B) Classification based on DIRECTION OF LOAD

1) Radial bearing 2) Thrust bearing.

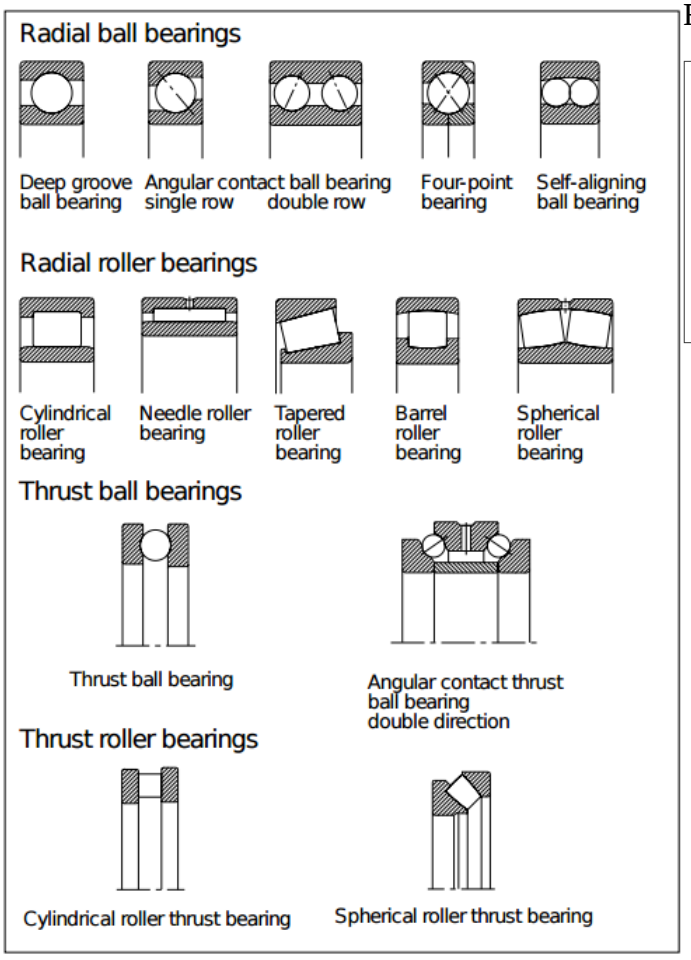




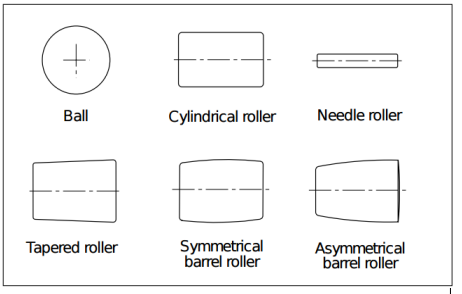
SLIDING CONTACT BEARING

ROLLING CONTACT BEARING

TYPES OF ROLLING CONTACT BEARINGS




Roller elements



## 3) State the applications of rolling contact and sliding contact bearings?

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Rolling contact bearings are commonly used where there is relatively less load but very high speed. Following are the practical applications of rolling contact bearings.

1) Automobile front and rear axle
2) Electric motors of small size.
3) Gear boxes
4) Machine tool spindles and shafts
5) Load hoisting mechanisms
6) Bicycles and motorcycles.

Sliding contact bearing are commonly used where there is relatively high load but relatively less speed. Following are the some of the practical applications.

1) Steam and gas turbines
2) Crankshaft bearing of diesel engines.
3) Electric motors of large size.
4) Centrifugal and axial pumps
5) Material handling equipments like rope conveyors.

## 4) Compare Sliding contact bearing with rolling contact bearing.

| Point | Sliding contact bearing | Rolling contact bearing |
|---|---|---|
| Load carrying capacity | Increases with speed. | Fixed load carrying capacity, does not depends on speed |
| Load directions | Sliding contact bearing can take load in one direction only | Rolling contact bearing can take radial as well as axial loads. |
| Shock load | Can absorb shock load, due to dampening of the oil film. | Can not absorb shock loads. |
| Starting torque | Require large starting torque. | Require lower starting torque. |
| Radial space required | less radial space required. | more radial space required. |
| Noise | Less noise | More noise |
| Service life | Service life is not fixed, hence can take remain in service for longer time. | Service life is fixed , hence it should be replaced after certain time. |
| Initial Cost | Higher | Lower |

{Same table can be used to write advantages and disadvantages of each type of bearing}

**5) Select the appropriate type of type of rolling contact bearing under the following conditions of loading 1) Light radial load with high rotational speed. 2)Heavy axial load with high rotational speed 3) Axial thrust only with medium speed. 4) Combined radial and axial load with medium speed.**

Ans:

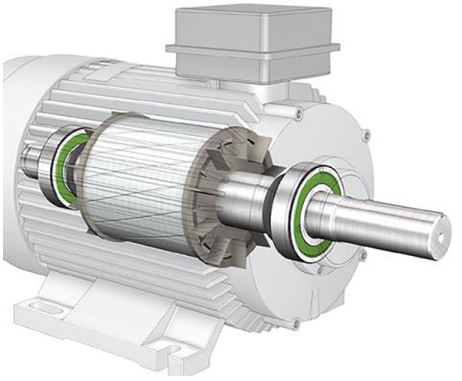
| Application Requirement | Type of Bearing |
|---|---|
| Light radial load with high rotational speed | Single row Deep-Groove ball bearing |
| Heavy axial load with high rotational speed | Angular contact bearing. |
| Axial thrust only with medium speed. | Thrust ball bearing |
| Combined radial and axial load with medium speed. | Taper roller bearing |

## 6) State the applications of the following bearings

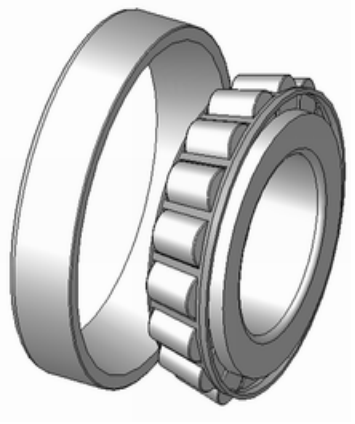
## 1) Deep groove ball bearing 2) Taper roller bearing 3) Thrust roller bearing 4) Needle roller bearing

Applications of the following bearings

**1. Deep groove ball bearing:** - It is used to take radial as well as thrust load. Because they have high radial load carrying capacity and moderate thrust load carrying capacity. It is used in electric motors, machine tool spindles and small types of centrifugal pump.

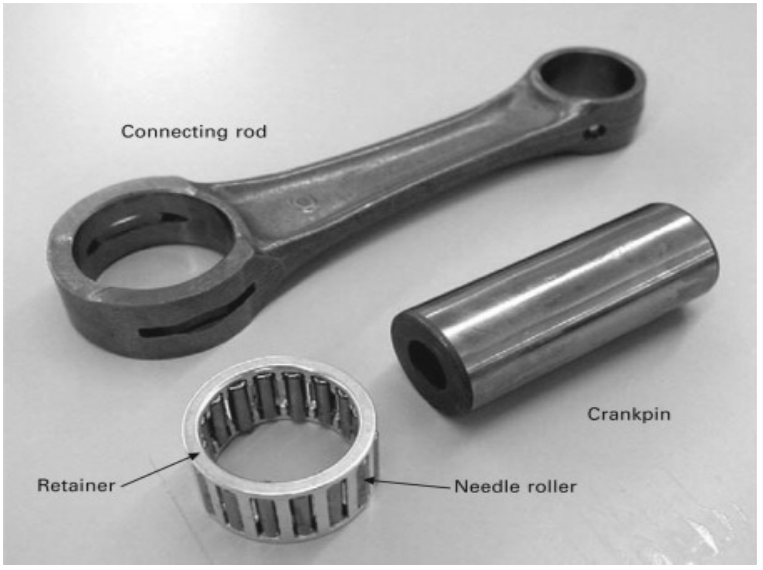


**2. Taper Roller bearing:-** It is used to take radial as well as thrust load. Because such type of bearing can carry both radial thrust loads, It consists of rolling elements that is in the form of cone. It is used in Industrial and automotive gear boxes and automobile front and rear axle.



**3. Thrust Roller Bearing:** - These are used to take pure thrust loads, hence they are called thrust roller bearings. It is used in power plant and mine pumps.

**4. Needle Roller Bearing:** - These are useful where radial space is limited. They have high radial load carrying capacity. These bearings are used when heavy load are to be carried with an oscillatory motion. It is used in piston pin bearings in I.C.engines.



## 7) What are the required properties of the sliding contact bearing material?

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**1) Compressive strength –** The bearing material should have high compressive strength to withstand the maximum bearing pressure so as to prevent extrusion or permanent deformation of bearing. The material with less compressive strength will easily fail by crushing.

**2) Fatigue strength –** The bearing material should have sufficient fatigue strength so that can with stand repeated loads without developing surface fatigue cracks. Fatigue strength is the ability of the material to withstand the repeated reversed stressed. It is expressed in terms of Endurance limit for that material.

**3) Embed-ability –** It is ability of the bearing material to accommodate or embed small particles of dust, grit etc, without scoring the material of bearing. This property enables the bearing to accepts the mico-imputities to get them embedded in the material. Without this property there will be faster wear and tear of the material.

**4) Bond-ability–** Many high capacity bearings are made by bonding one or more thin layers of a bearing material to high strength steel shell. Hence strength of bond is important consideration while selecting bearing material. It is never economical to have whole bearing made up of costly material, it is always economical to have bearing body made up of steel and a thin layer of bearing metal bonded where there is contact.

# 6.2 Bearing Terminology

## 8) What is load rating of a bearing ? How it is calculated ?

Answer : Following are the two load ratings used for the bearings.

**i) Basic static load rating:-**

*Definition : "Basic static load rating is defined as the radial or axial load which corresponds to a total permenant deformation of the ball and race, at the most heavily stressed contact, equals to 0.001 times the ball diameter "*

Staticl load means the load acting on the bearing when the shaft is stationary. The basic static load rating is the static radial load or axis load which corresponds to a total permanent deformation of ball (or roller) and race, at the most heavily stressed contact, equal to 0.0001 times the ball (or roller) diameter.

As per IS 3823 – 1988, for radial ball bearings basic static load rating is given by

$$C_o = f_o \times I \times z \times D^2 \times \cos\alpha$$

i = no. of rows of balls

z = no. of balls per row

D = dia. of balls in mm

$\alpha$ = nominal angle of contact

fo = a factor depending on type of bearing.

These formulas are given in the IS 3823 -1988 , but while selecting the bearing from the manufacturers catalog, the designer need not to use this formula because the catalog provides the already calculated tables.

**ii) Basic dynamic load rating :**

***Definition :*** *"It is defined as constant stationary radial load or constant axial load which a group of apparently identical bearings with stationary outer ring can endure for rating life of one million revolutions (* $10^6$ *revolutions* *) with only 10% failure."*

The basic dynamic load rating, as per IS 3824 – 1983 is given by

$$C_r = b_m \times f_c \times (i \cos\alpha)^{0.7} \times Z^{\frac{2}{3}} \times D^{1.8}$$

Where,

bm = rating factor based on design of bearing (To be taken from table in IS3824)

fc= factor based on geometry of the bearing (To be taken from table in IS3824)

i=number of rows of balls or rollers

$\alpha$ = *nominal contact angle of bearing*

Z= number of balls/rollers in one row.

D = Diameter of ball or roller

The tables and formulas are provided in the IS, but while selecting the bearing from manufacturers catalog the designer is not required to use these formulas, because the catalog provides the detailed table giving the static and dynamic capacity values.

# 6.3 Selection of bearing

## 9) What the procedure for selecting the bearing from the manufacturers catalog ? {VV IMPORTANT}

The following procedure is followed in selecting the bearing from the manufacturer's catalog.

- Calculate the radial and axial loads i.e Fr and Fa acting on bearing.
- Determine the diameter of shaft on which the bearing is to be mounted.
- Select the proper type of bearing for the given application.
- The selection of bearing is done by trial and error. To begin with a bearing of extra

  light series is selected for the known shaft diameter.
- Find the value of basic static capacity $C_o$ of the selected bearing from the catalog.
- Calculate the ratios (Fa/V Fr) and (Fa/Co).
- Find the values of radial and thrust factors i.e. x and y from the catalog. The values

  depends upon two ratios (Fa/VFr) and (Fa/Co).
- For the given application, find value of load factor or app. factor Ka from catalog.
- Calculate the equivalent dynamic load by using relation
  Pe= (XVFr + YFa) Ka.
- Depending upon the application make the decision about the expected life of the bearing and express the life in million revolutions L10.
- Calculate the required basic dynamic capacity for the bearing by using relation

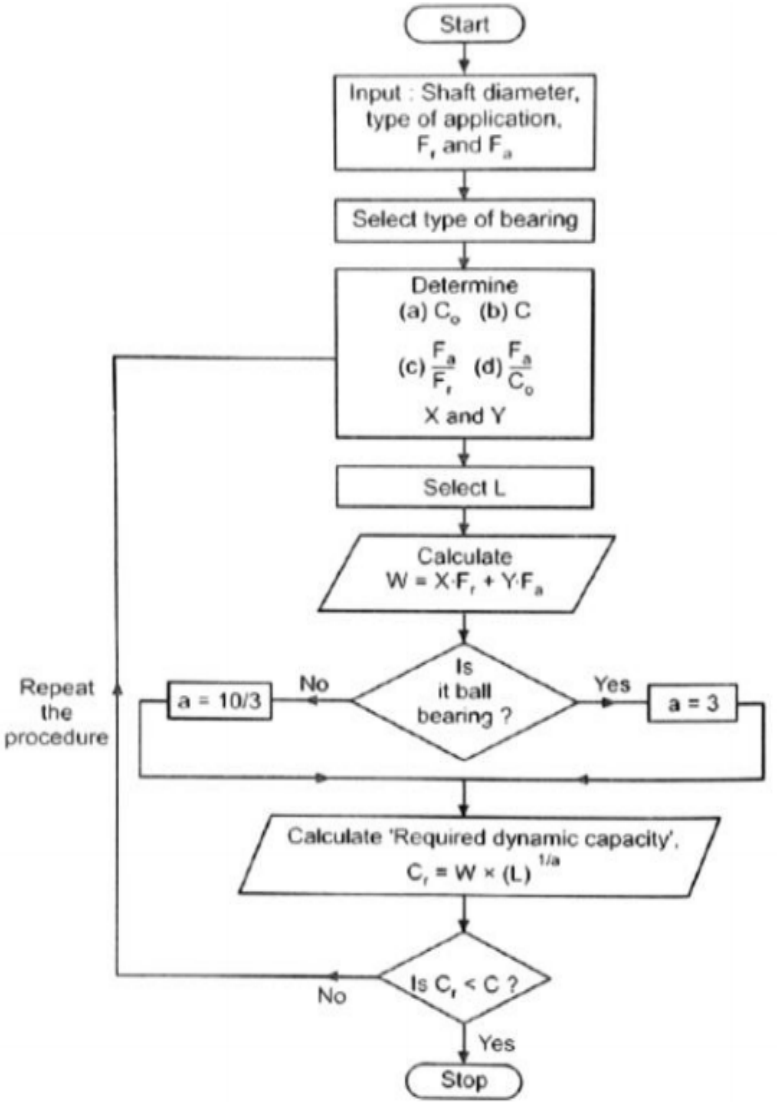
  L10 =(c/Pc)a.

- Check whether the selected bearing has the required dynamic capacity. If not select the bearing of the next series and go back to step 5 and continue.

The above Steps can be expressed as a flow diagram as below

{In exam list either steps of flow diagram or both }

Flow chart for the selection of bearing from the manufacturers catalog



# 6.4 Design of Spur gears

## 10) State Design Consideration for the spur gears. (V V IMP)

Ans : In the design of a gear drive, the following data is usually given

1. The power to be transmitted

2. The speed of the driving gear

3. The speed of the driven gear or the velocity ratio and

4. The centre distance

The following requirements must be met in the design of a gear drive

a) The gear teeth should have sufficient strength so that they will not fail under static loading or dynamic loading during normal running conditions.

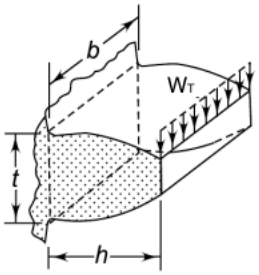
b) The gear teeth should have wear characteristics so that their life is satisfactory

c) The use of space and material should be economical

d) The alignment of gears should be perfect and

e) Proper lubrication must be done.

## 11) Write the Lewi's Equation for the strength of gear tooth. State meaning of each term in it. {V V IMP}



*Gear Tooth as Cantilever*

Solution :- Lewis equation considers that at a time only one tooth is in contact and considering the gear teeth as a cantilever,Using bending equation,

Maximum bending stress is given by,

$$\sigma_w = \frac{M.y}{I} \quad \text{.....(1)}$$

where M=bending moment

$$= W_t \times h$$

y= Half the thickness of tooth at critical section=$\frac{t}{2}$

I= Moment of inertia about centerline of tooth = $\frac{b.t^3}{12}$

Putting these values in equation 1,

$\sigma_w = \frac{M.y}{I} = \frac{W_t \times h \times \frac{t}{2}}{\frac{b.t^3}{12}}$ simplifying we get

$W_t = \sigma_w \times b \times \frac{t^2}{6h}$ here t and h are the functions of circular pitch $p_c$

$W_t = \sigma_w \times b \times P_c \times Y$ where Y= lewis form factor.

The equation in term of module becomes ($P_c = \pi.m$)

$W_t = \sigma_w \times b \times \pi.m \times Y$

This final equation is called the Lewis equation for the strength of spur gear.

## 12) State the different modes of failure of gear teeth and their possible remedies to avoid the failure.

Ans: The different modes of failure of gear teeth:

1. Bending failure. 2. Pitting. 3. Scoring. 4. Abrasive wear. 5. Corrosive wear

Remedies to avoid failure:

1. Bending failure. In order to avoid such failure, the module and face width of the gear is adjusted so that the beam strength is greater than the dynamic load.

2. Pitting- In order to avoid the pitting, the dynamic load between the gear tooth should be less than the wear strength of the gear tooth.

3. Scoring-This type of failure can be avoided by properly designing the parameters such as speed, pressure and proper flow of the lubricant, so that the temperature at the rubbing faces is within the permissible limits.

4. Abrasive wear- This failure can be avoided by providing filters for the lubricating oil or by using high viscosity lubricant oil which enables the formation of thicker oil film and hence permits easy passage of such particles without damaging the gear surface.

5. Corrosive wear- In order to avoid this type of wear, proper anti-corrosive additives should be used.

## 13) State and explain the Buckingham dynamic load equation.

Ans: According to Buckingham small machining error and deflection of teeth under load cause periods of acceleration, inertia forces, and impact loads on the teeth similar to variable load superimposed on a steady load. The total maximum instantaneous load on the teeth or dynamic load is Fd, which is given by,

Fd = Ft + Fi

where,

Ft= tangential load acting on gear

Fi= Additional load due to machining error and pitch line velocity

Buckingham provided the equation to calculate the additional load

$$F_i = [\frac{21v(Ceb + F_t)}{21v + \sqrt{ceb + F_t}}]$$

Where,

v = pitch line velocity in m/s

b = face width of gear in mm

C – deformation factor m/mm2

e = sum of errors between two meshing teeth (mm)