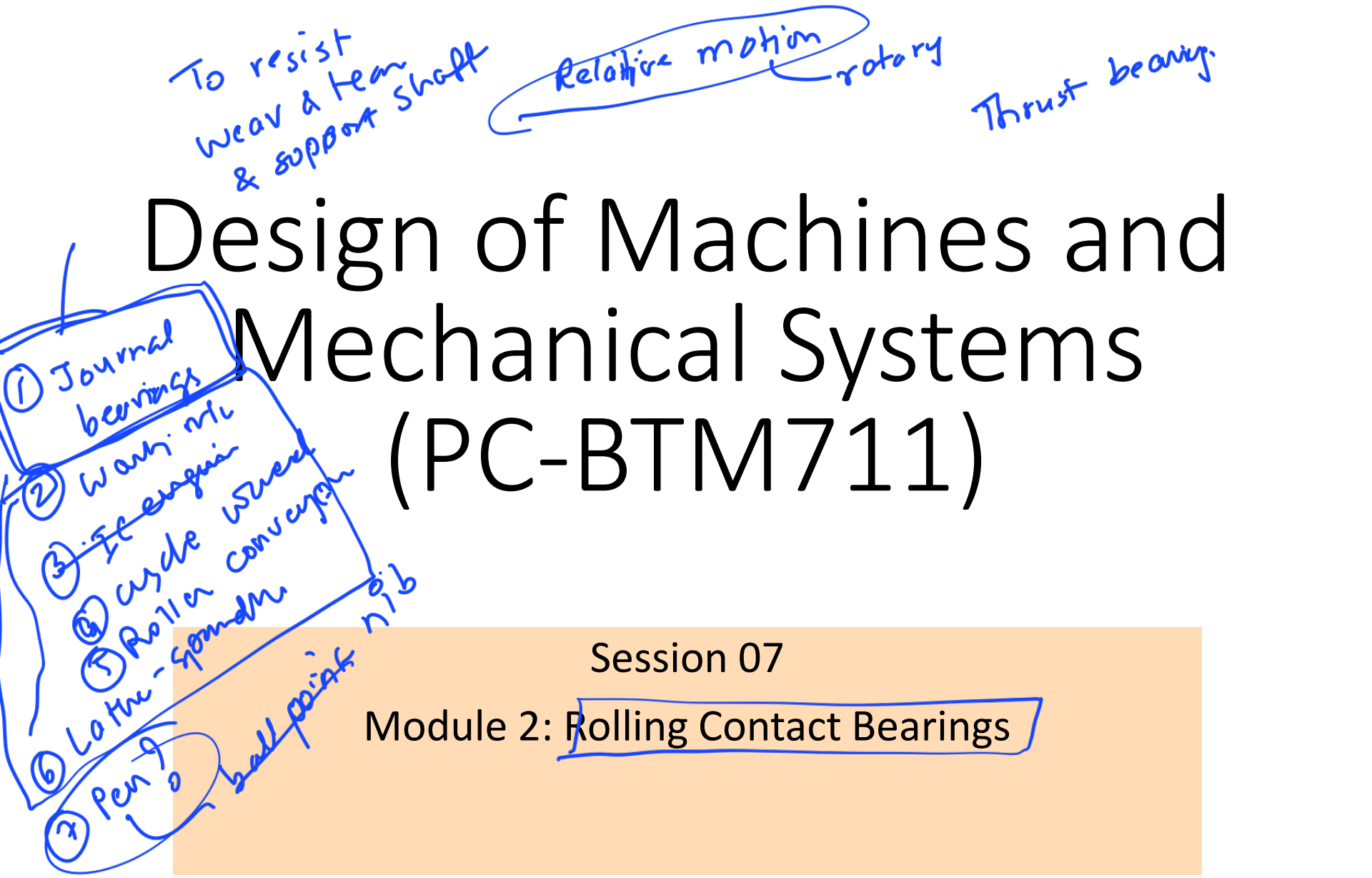


Design of Machines and Mechanical Systems (PC-BTM711)

Session 07

Module 2: Rolling Contact Bearings

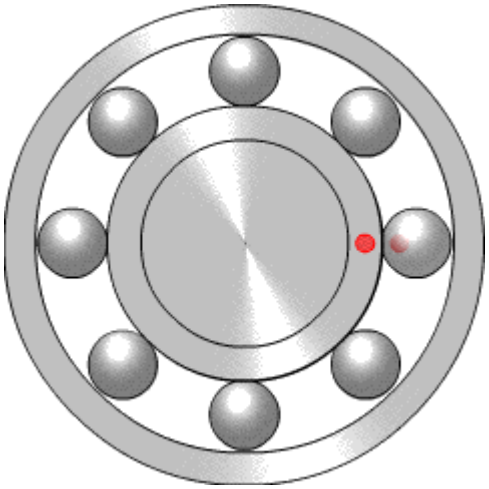
Session Outcomes

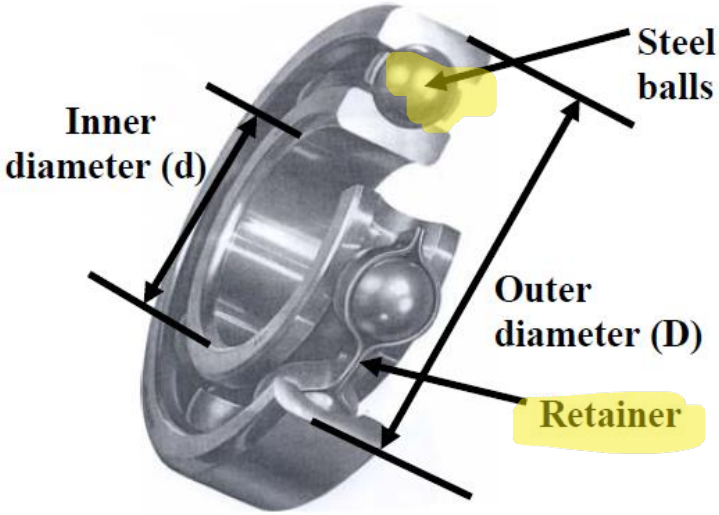
- Discuss types of rolling contact bearings and guidelines for its selection
- Calculate static, dynamic and equivalent load

Types of Bearings

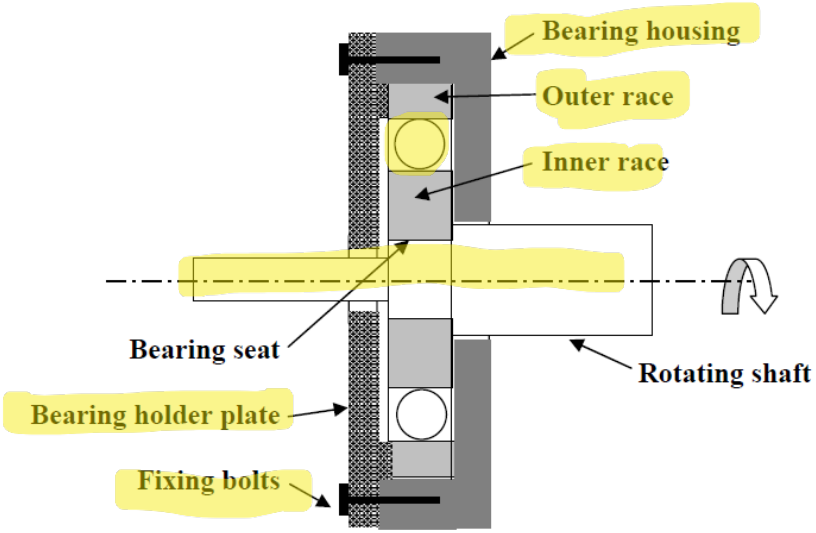
- Rolling contact bearings
  - Anti-friction bearings
  - Ball-, Roller-, Pin- bearing
- Sliding contact bearings
  - Bush bearings
  - Journal bearings

Rolling Element Bearings





Ball Bearing



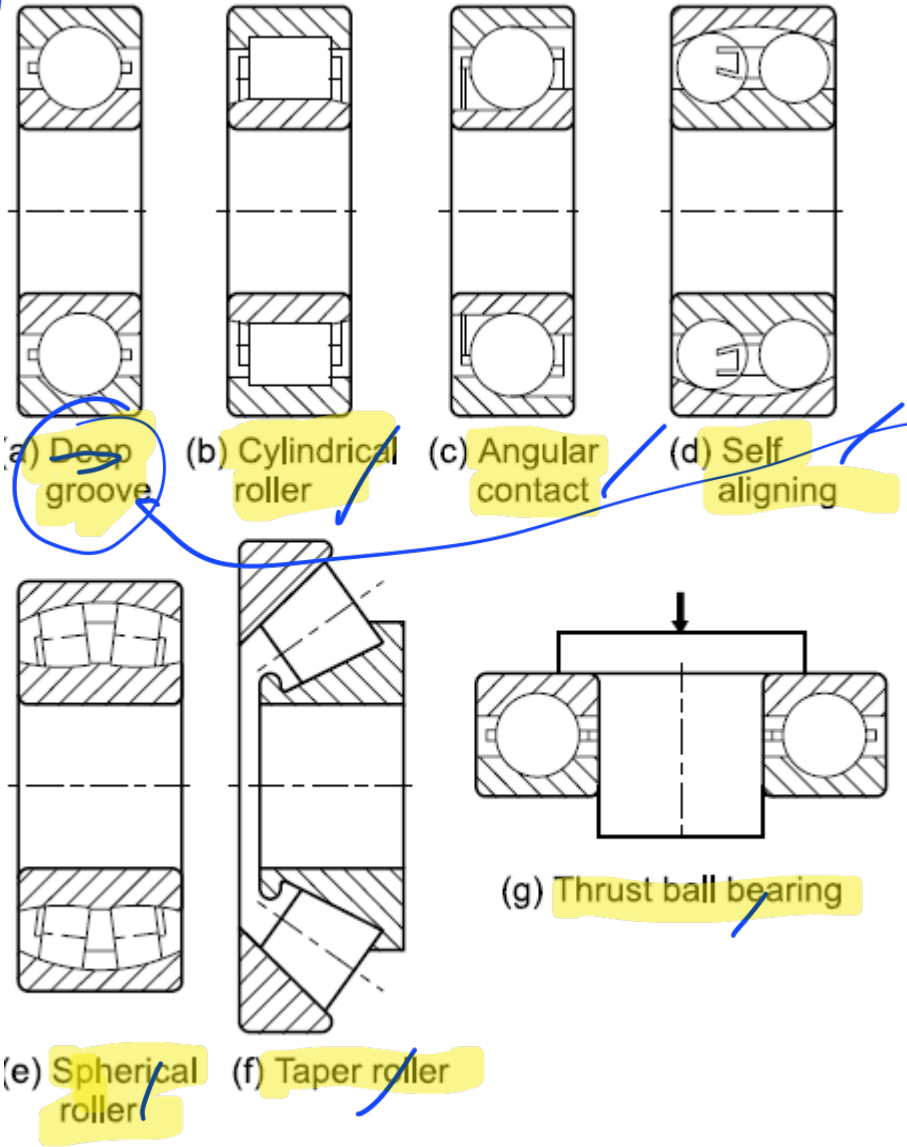
Cylindrical Roller Bearing

Ref: https://en.wikipedia.org/wiki/Ball_bearing

Credits: NPTEL course by IIT Kharagpur

Types of Roller Element Bearings

SELF-STUDY



Discuss advantages and disadvantages of different types of roller element bearings

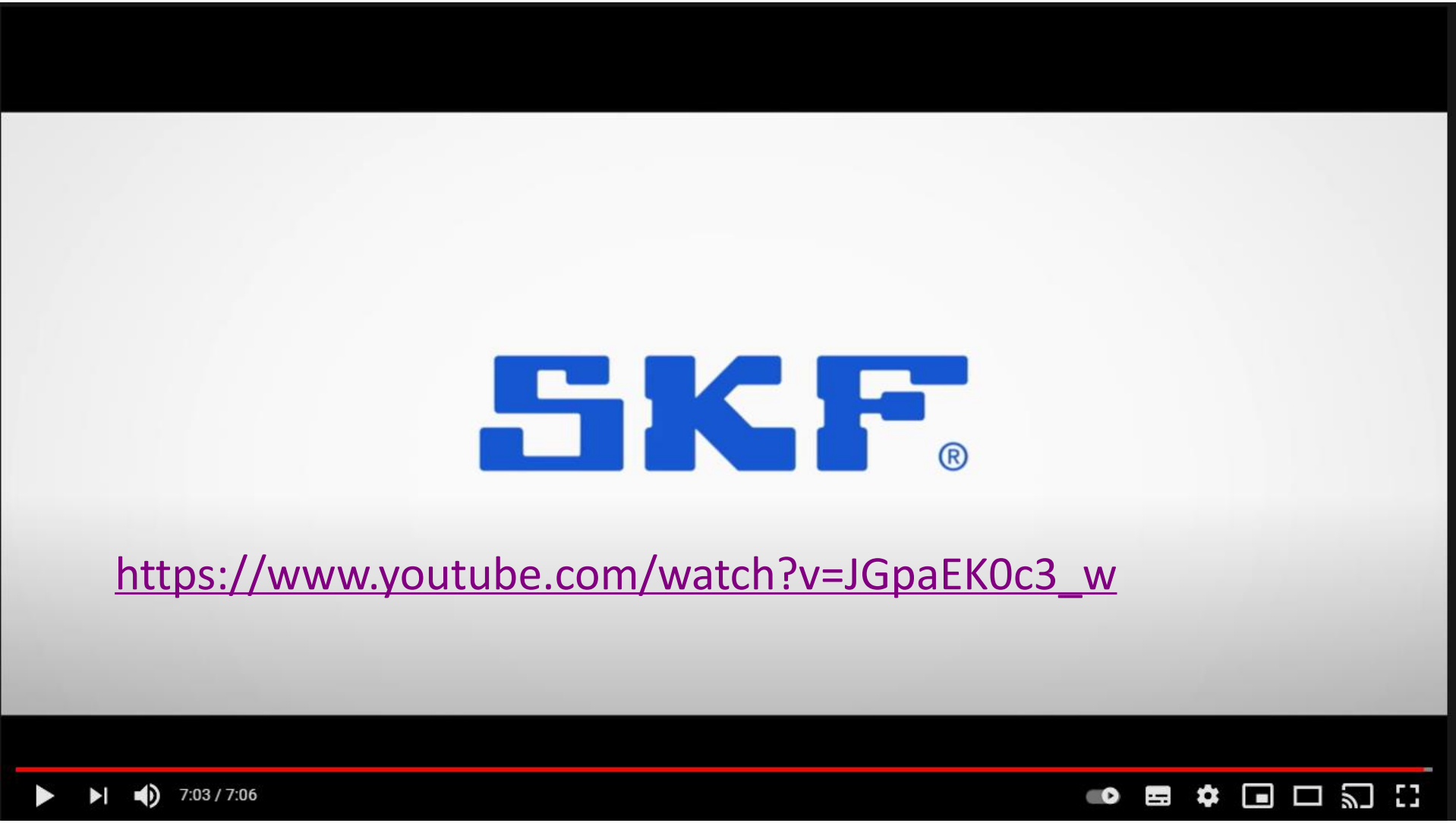
DGBB

Adv
- High loads @ high speeds
- Minimum noise

Disadvantage
- Not self aligning
- less rigid

Ref: Bhandari V.B., Design of Machine Elements (2017)

Recent Trends in Rolling Element Bearing Technology



https://www.youtube.com/watch?v=JGpaEK0c3_w

QUIZ

Features of DGBB

Which of the following is NOT an advantage of a deep groove ball bearing?

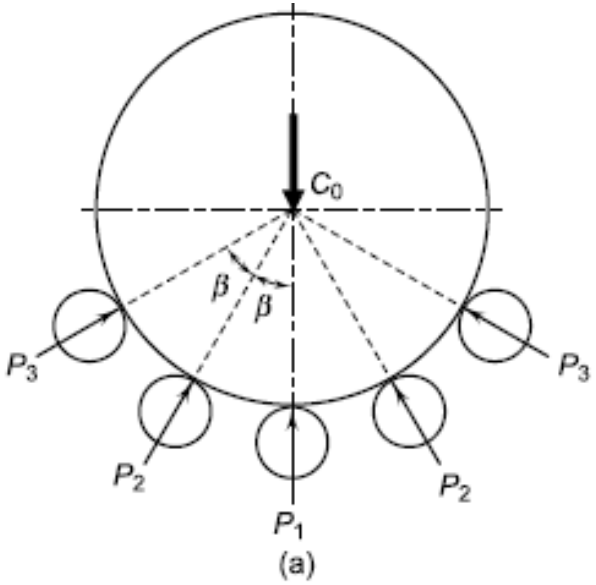
1. Can operate under high loads and high speeds
2. Has high rigidity
3. Generates less noise

Static Load Capacity

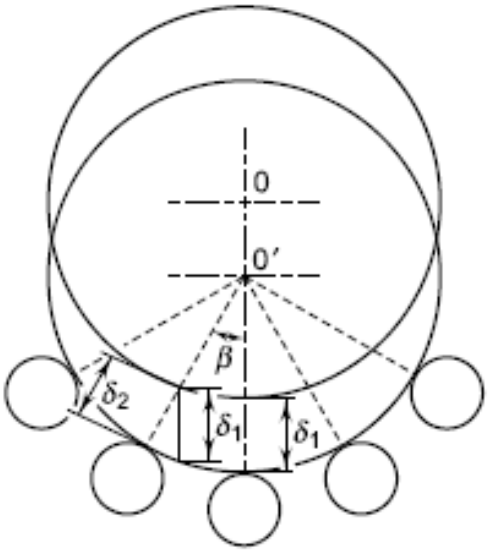
- **Static load capacity (C_0)**: Static load corresponding to maximum total permanent deformation of balls and races equal to 0.0001 of ball diameter.
- **Stribeck's eqn.**

$$C_0 = \frac{kd^2z}{5}$$

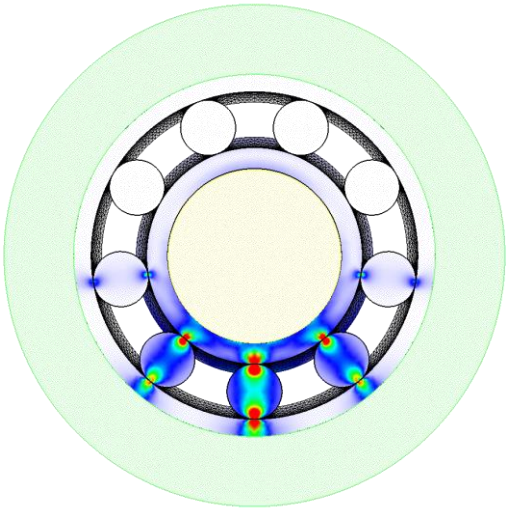
- Available in manufacturer's catalogue (DDB T15.10)



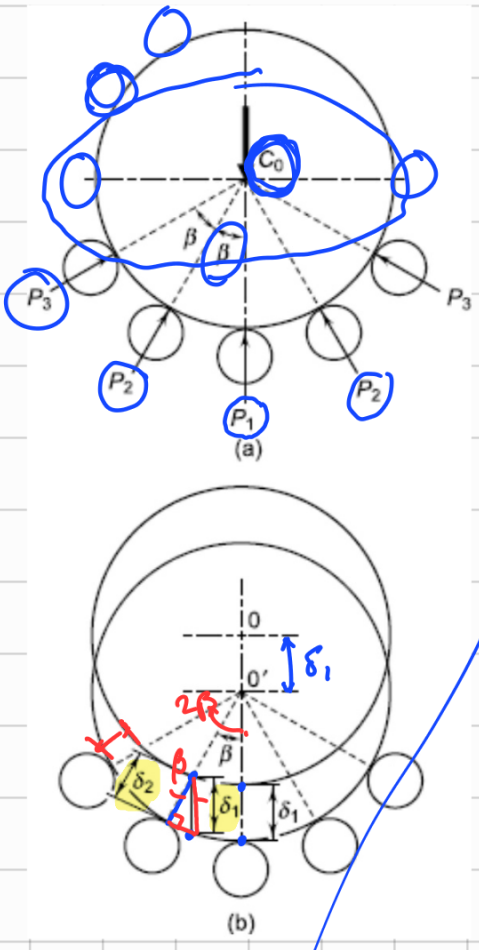
(a)



(b)



https://www.afdex.com/archive/miscellaneous/25
Ref: Bhandari V.B., Design of Machine Elements (2017)



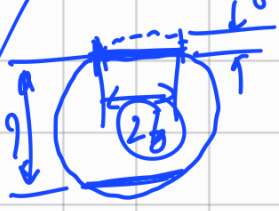
Assumption

(1) Balls are equally placed

→ (2) Races are rigid

(3) ~~Only~~ balls on upper side do not take load

$$C_0 = P_1 + 2P_2 \cdot \cos\beta + 2P_3 \cdot \cos(2\beta) + \dots$$



From Hertz theory

$$\delta \propto (P)^{2/3}$$

$$\therefore \delta_1 = k \cdot P_1^{2/3}, \quad \delta_2 = k \cdot P_2^{2/3} \dots$$

$\delta_2 = \delta_1 \cos\beta$

$\delta_3 = \delta_1 \cdot \cos 2\beta$

$$\Rightarrow \frac{\delta_2}{\delta_1} = \left(\frac{P_2}{P_1}\right)^{2/3}$$

$$\frac{\delta_2}{\delta_1} = \cos\beta \quad \therefore \quad P_2 = P_1 \cdot \left(\frac{\delta_2}{\delta_1}\right)^{3/2}$$

$$P_2 = P_1 (\cos\beta)^{3/2}$$

Similarly $P_3 = P_1 (\cos 2\beta)^{3/2}$

$$C_0 = P_1 + 2P_1(\cos\beta)^{3/2} \cdot \cos\beta + 2 \cdot P_1 (\cos 2\beta)^{3/2} \cdot \cos 2\beta + \dots$$

$$C_0 = P_1 \underbrace{\left[1 + 2(\cos\beta)^{5/2} + 2(\cos 2\beta)^{3/2} + \dots\right]}_{M}$$

$$= P_1 \cdot M \leftarrow$$

Z	8	10	12	15
Factor 'M'	1.84	2.28	2.75	3.47
Z/m	4.35	4.38	4.36	4.37

$\Rightarrow z/m \approx$ constant $= 5$

$\therefore C_o = \frac{P_1}{\uparrow} \cdot \frac{z}{5}$

$P_1 = K \cdot d^2$ ← 1) radii of curvature of two parts in contact
2) ~~Roof~~ Material

$$C_o = \frac{K d^2 \cdot z}{5}$$ ← Strbeck's eqns.

$C_o \rightarrow$ limiting deformation

$\Rightarrow$ smooth (~~non~~ less vibration) operation
less noise

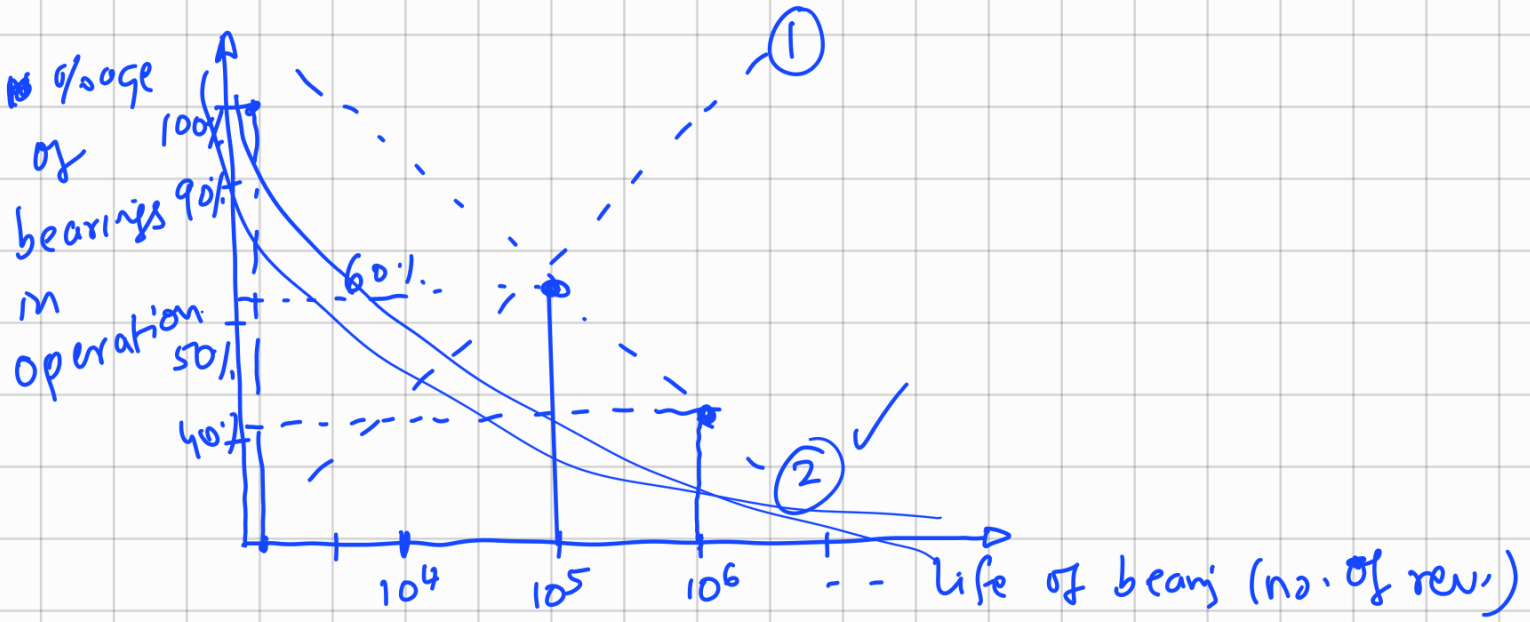
QUIZ

Static load capacity

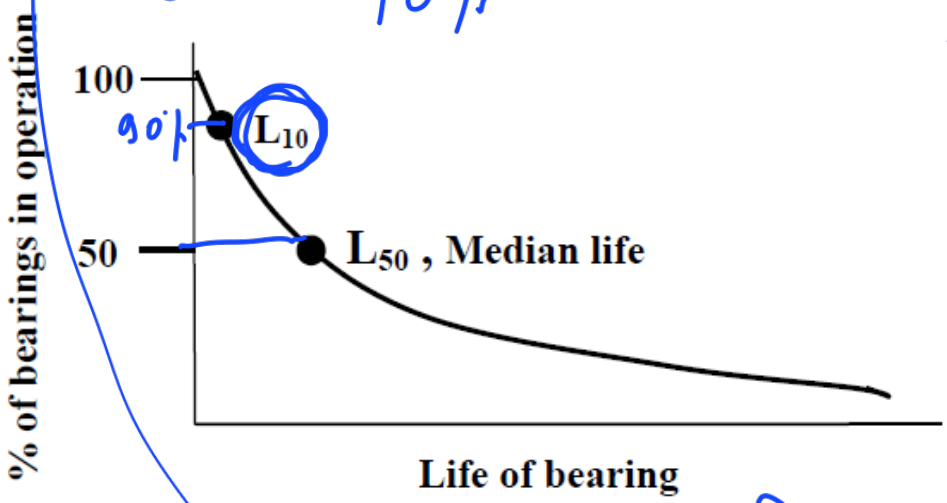
The static load capacity of bearing is related to _____

1. Maximum permanent deformation of rolling elements
2. Maximum load required for crushing of rolling elements

Life of bearing



Rating Life of Bearing



- **Rating life (L_{10})** : For a group of apparently identical bearings, it is the **number of revolutions** (inner ring rotating, outer ring stationary) that **90%** of bearing will complete or exceed before the first evidence of fatigue crack.
- L_{10}, L_{50} : Numbers 10, 50 represent percent of failures to achieve life of L_{10}, L_{50}

QUIZ

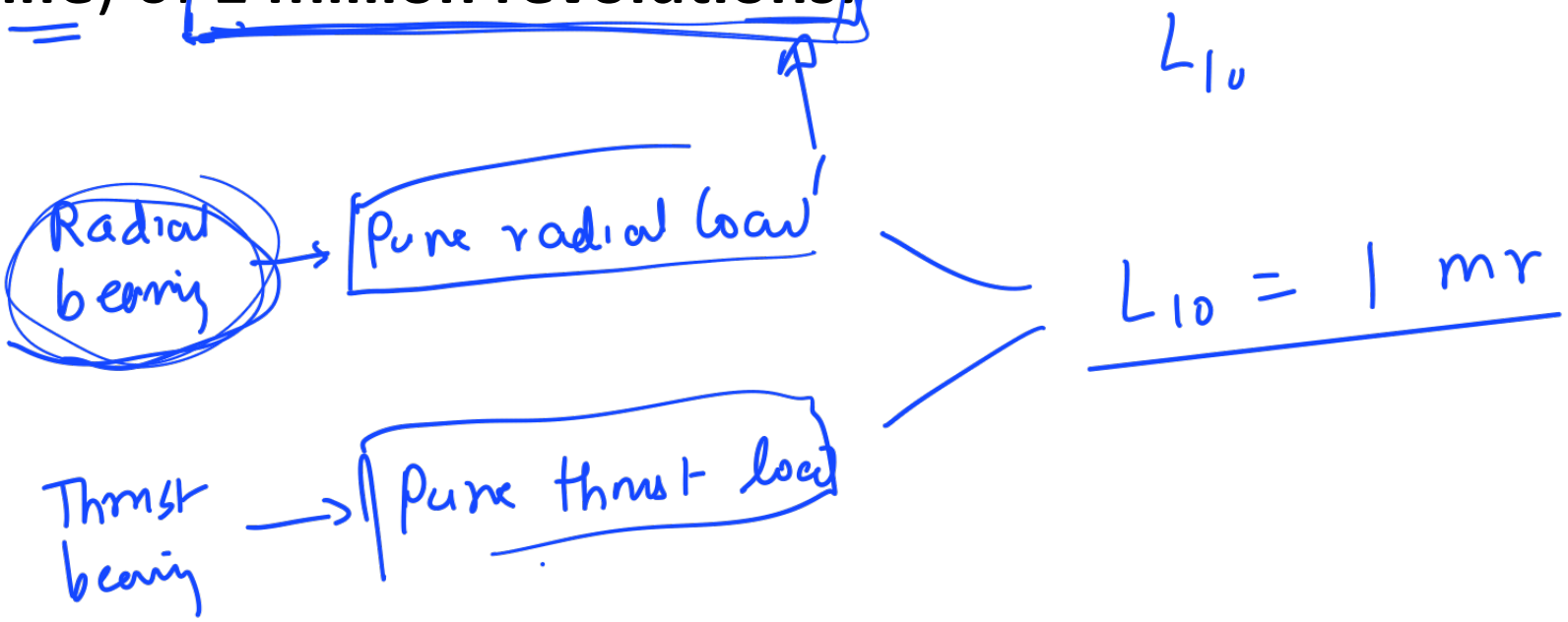
Rating Life of Bearing

Which of the following is TRUE regarding the rating life L_{10} ?

1. Rating life L_{10} will be achieved by 90% of bearings
2. Rating life L_{10} will correspond to a life of 10 million revolutions

Dynamic Load Capacity (C)

- The dynamic load capacity (C) of a bearing is **radial load** (for radial bearing) or thrust load (for thrust bearing) that can be carried for minimum life (**L_{10} life**) of **1 million revolutions**.



QUIZ

Dynamic Load Capacity

The dynamic load capacity of bearing is

_____

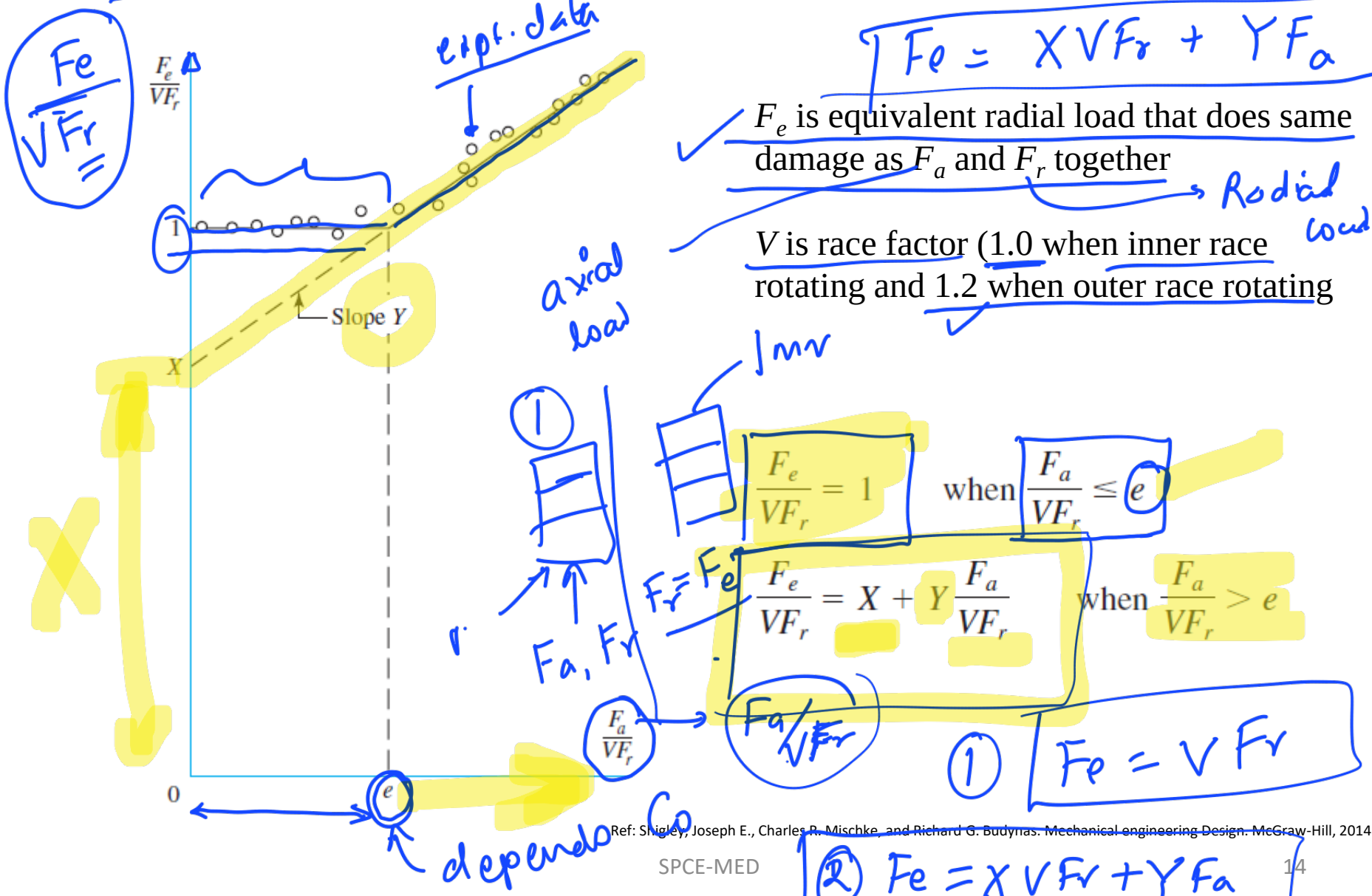
1. given in manufacturer's catalog
2. corresponding to minimum life of 1 mr
3. Both of above

Equivalent Dynamic Load (Fe)

$$F_e = XVF_r + YF_a$$

F_e is equivalent radial load that does same damage as F_a and F_r together → Radial load

V is race factor (1.0 when inner race rotating and 1.2 when outer race rotating



Ref: Shigley, Joseph E., Charles R. Mischke, and Richard G. Budynas. Mechanical engineering Design. McGraw-Hill, 2014