MKT 1821
Chapter-4

Mechatronics Technology:

Mechanics

Motto of the Lecture

In mechatronic system design,

If the mechanics of the system is not solved correctly, you may not fix the problem using the electronics, controls and/or software.

A balanced design head start is a must.

Outline: Machine Elements

1) Motors (ACTUATORS)
2) Power transmission devices (gears, belt, pulley, chain, friction drive)
3) Miscellaneous:Bearings(types, selection issues), springs, pins, retaining rings…
4) Other motion generation devices (linkage mechanisms, cams)
5) Joining methods (welding, brazing, soldering, bolts, screws, rivet, …)

Machine Elements

- Gear
- Belt, pulley
- Chain, sprocket
- Universal joint
- Friction drive
- Cam-follower
- Mechanisms (linkages)
- Bearings
- Joining methods (welding, brazing, rivets, bolts, screws, etc)

Mechanical systems

- Devices which can be considered to be motion converters in that they transform motion from one form to some other required form.

  Eg: Transform linear motion into rotational motion and vice versa.

- Mechanical elements can include the use of linkages, cams, gears, rack-and-pinion, chains, belt drives, etc.

  Eg: Rack-and-pinion can be used to convert rotational motion to linear motion.

- Many of the actions which previously were obtained by the use of mechanism are, however, often nowadays being obtained, as a result of a mechatronics approach by the use of microprocessor systems.

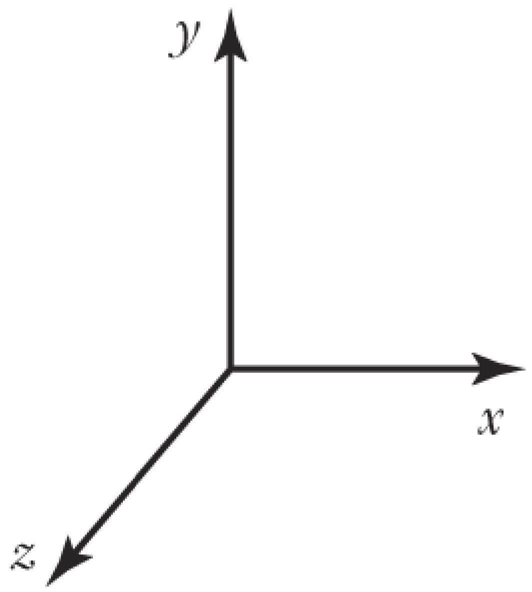
Mechanical systems

- Mechanisms have a role in mechatronics systems. For example, the mechatronics system in use in an automatic camera for adjusting the aperture for correct exposures involves a mechanism for adjusting the size of diaphragm.

- Others function:
  - Force amplification – given by levers.
  - Change of speed – given by gears.
  - Transfer of rotation about one axis to rotation about another – timing belt.

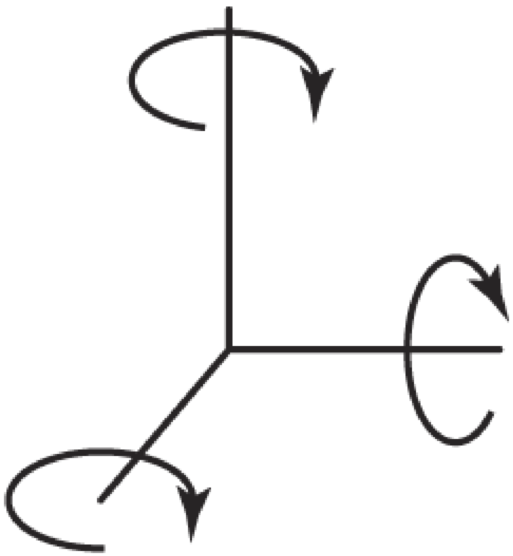
Mechanical systems

- Types of Motion



Translation motion

Movement which can be resolved into components along one or more of the 3 axes.

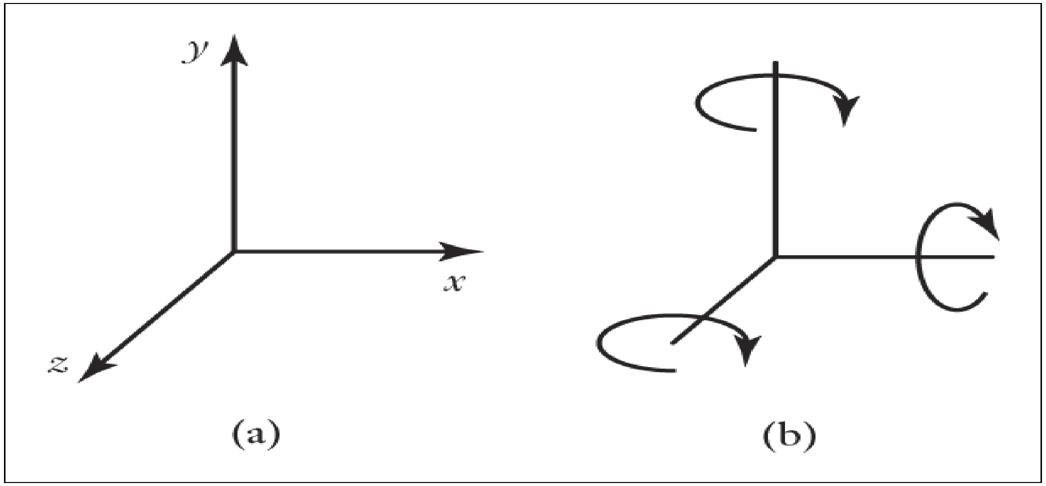


Rotational motion

Rotation which has components rotating about one or more of the axes.

Mechanical systems

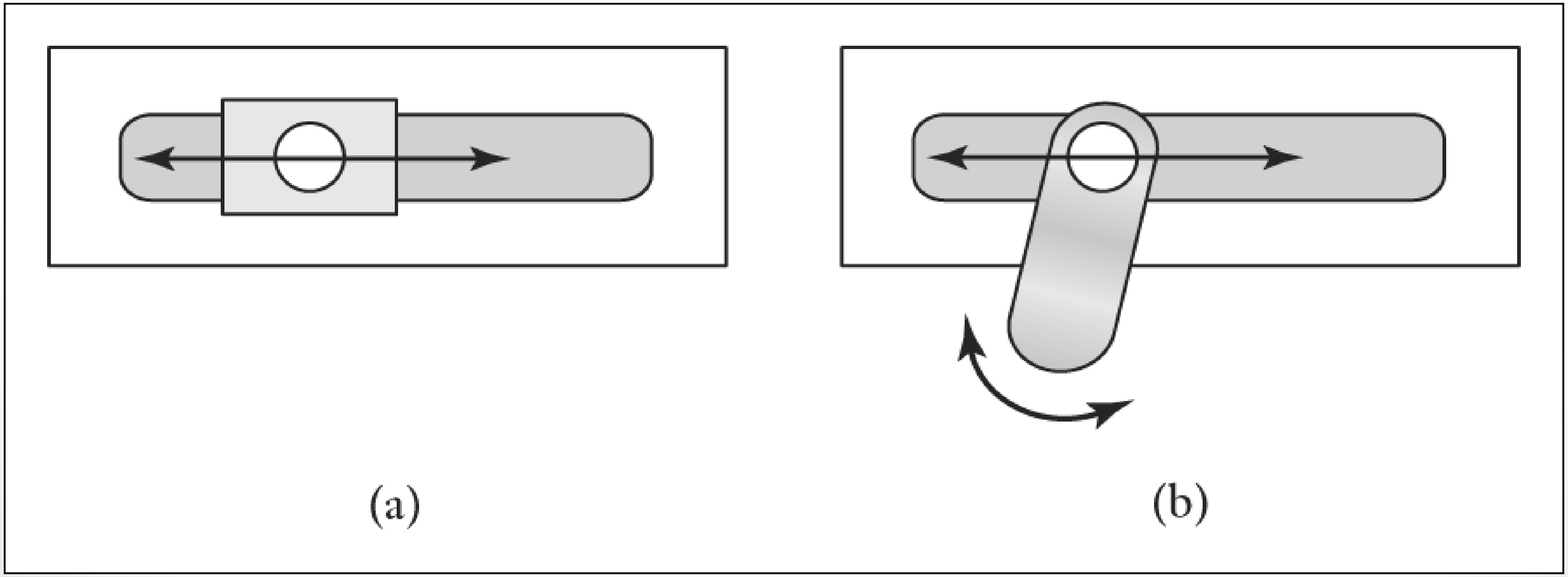
- <u>Freedom and Constraints</u>
  - An importance aspect in the design of mechanical elements is the orientation and arrangement of the elements and parts.
  - A body that is free in space can move in three, independent, mutually perpendicular directions and rotate in three ways about those directions.



  - It is said to have six degree of freedom. The number of degree of freedom is the number of components of motion that are required in order to generate the motion.

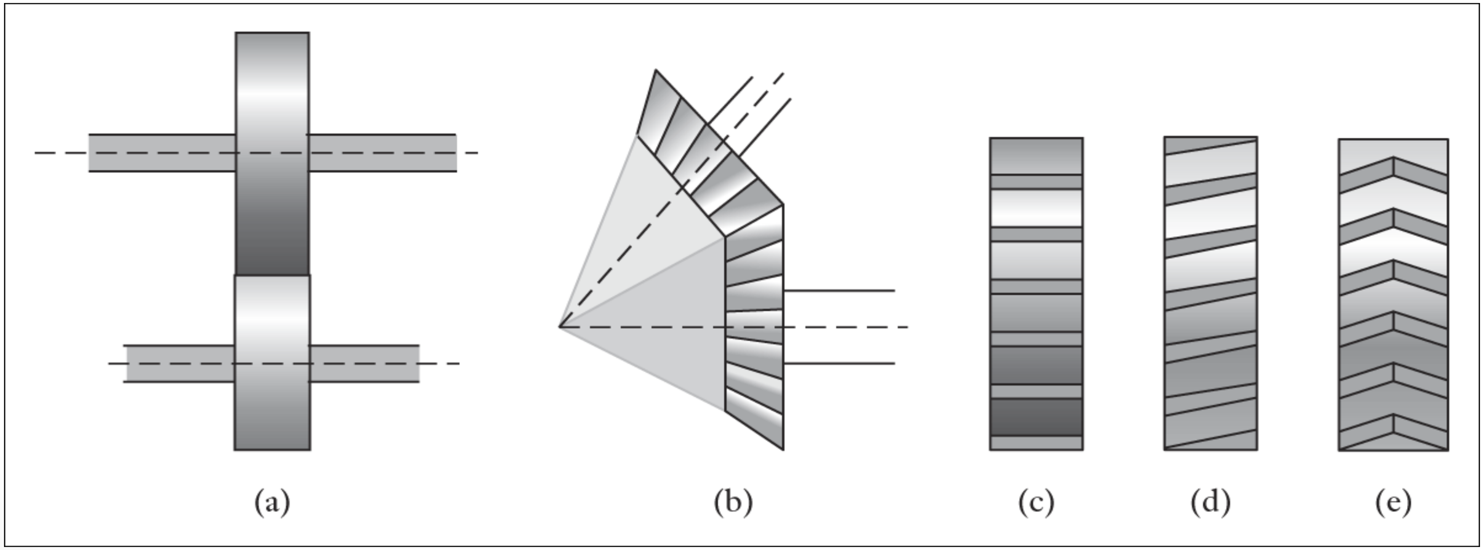
Mechanical systems

- <u>Freedom and Constraints</u>
  - Figure (a) shows a joint with just this one translational degree of freedom.
  - Figure (b) shows a joint which has one translational degree of freedom one rotational degree of freedom.



Gears

- Gear trains are mechanisms which are very widely used to transfer and transform rotational motion. They are used when a change in speed or torque of a rotating device is needed. For example, the car gearbox enables the driver to match the speed and torque requirements of the terrain with the engine power available.



(a) Parallel gear axes, (b) axes inclined to one another, (c) axial teeth, (d) helical teeth, (e) double helical teeth

Gear Types

Worm Gear

- Right angle crossing shafts
- Self locking
- High friction and wear
- High speed reduction

Bevel Gear

- Right angle I/O torque
- Smooth tooth interaction
- Low noise

Rack and pinion

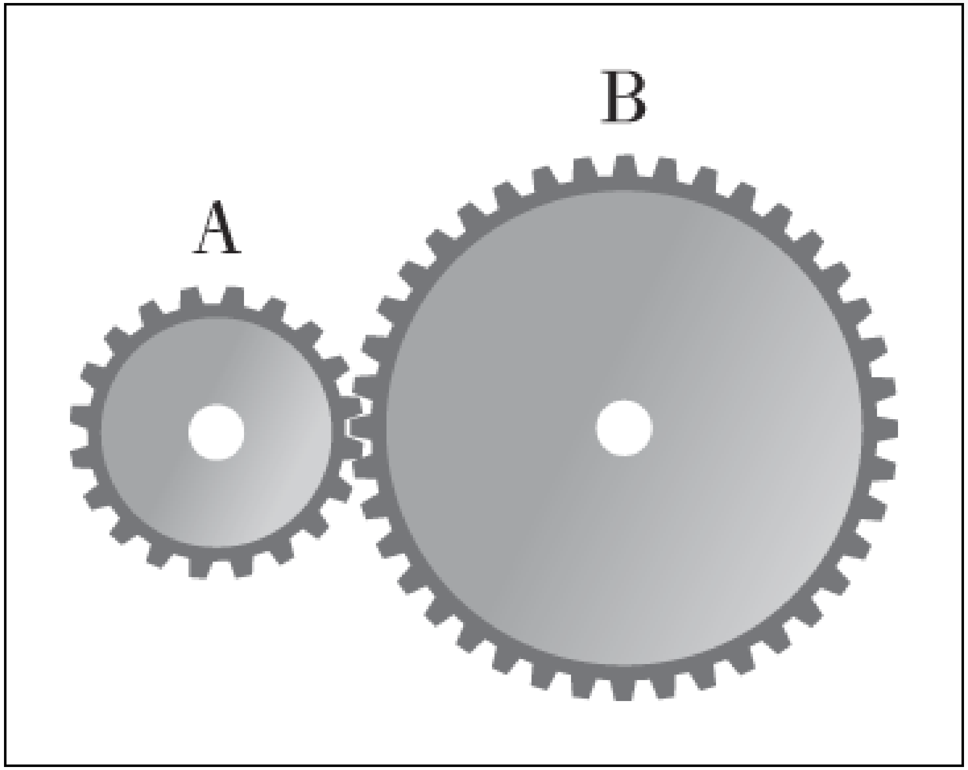
- Rotary-Linear power transmission

Different kinds of power transmission or motion control capability of gears:

a) Changing rotational speed.
b) Changing rotational direction.
c) Multiplying or dividing torque.
d) Converting rotational to linear motion.
e) Offsetting or changing the location of rotating motion.

Gears

- Two meshed gears.



- Gear ratio,

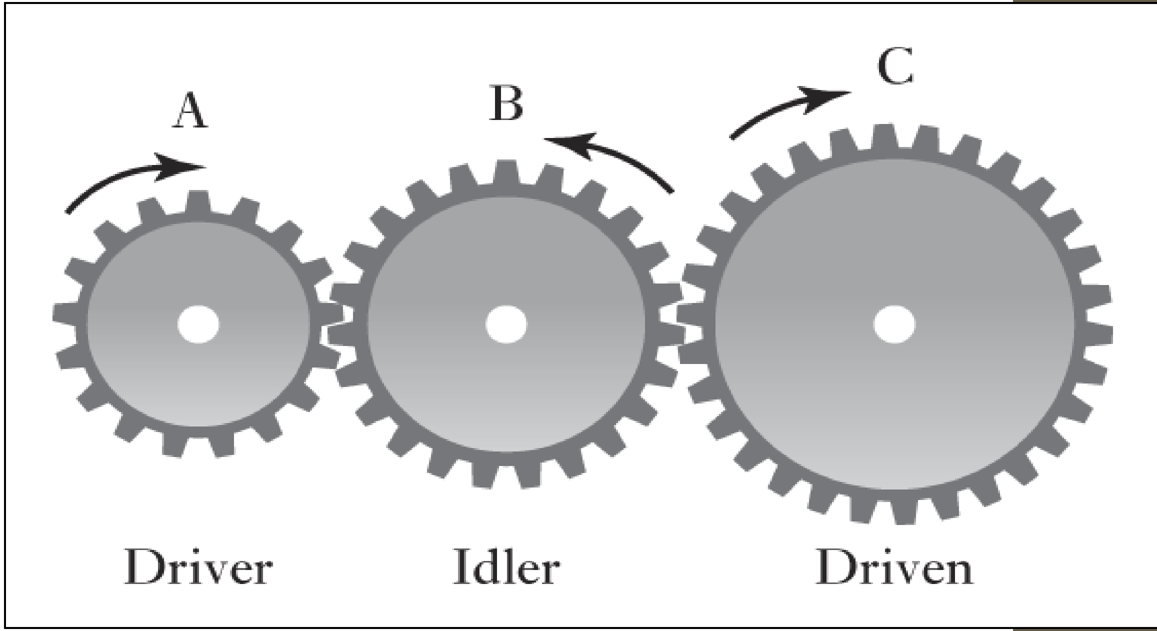
$$\frac{\omega A}{\omega B} = \frac{\text{number of teeth on B}}{\text{number of teeth on A}} = \frac{dB}{dA}$$

Angular velocity

Diameter

Gears

- **Gear trains** – a series of intermeshed gear wheels.
  - Simple gear train – used for a system where each shaft carries only one gear wheel.

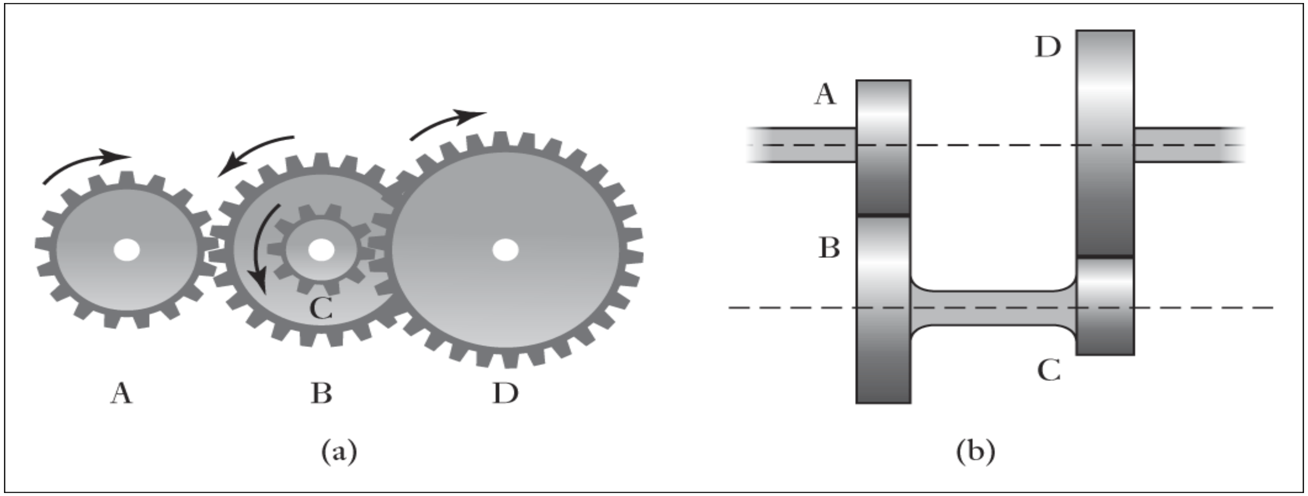


  - Ratio of the angular velocities

$$G = \frac{\omega A}{\omega C} = \frac{\omega A}{\omega B} \times \frac{\omega B}{\omega C}$$

Gears

- Compound gears trains – two wheels are mounted on a common shaft.



- Ratio of the angular velocities,

$$G = \frac{\omega A}{\omega D} = \frac{\omega A}{\omega B} \times \frac{\omega B}{\omega C} \times \frac{\omega C}{\omega D} = \frac{\omega A}{\omega B} \times \frac{\omega C}{\omega D}$$

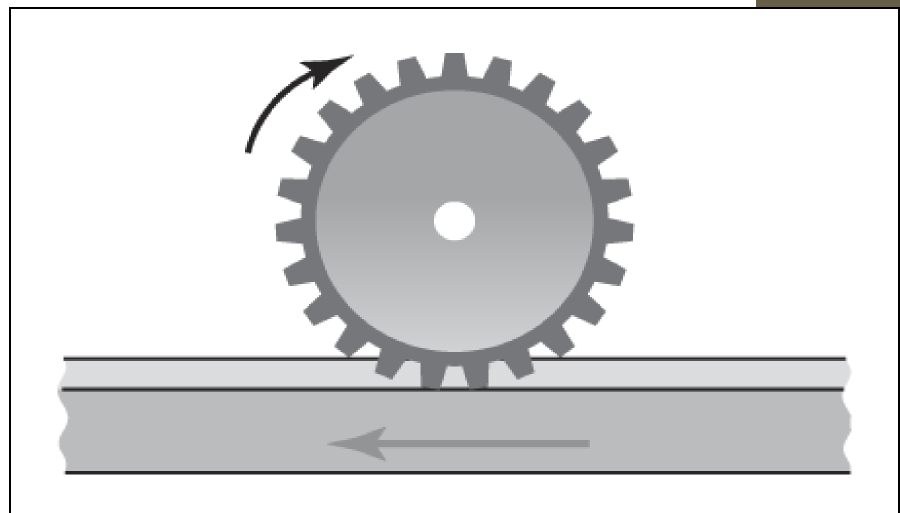
- For the input and output shafts to be in line, we must also have for the radii of the gears.

$$rA + rB = rD + rC$$

Gears

<u>**Rotational to translational motion**</u> – two intermeshed gears with one having a base circle of infinite radius. Such gear can be used to transform either linear motion to rotational motion or rotational motion to linear motion.

Eg: The rack-and-pinion.



- Linear velocity

Revolution

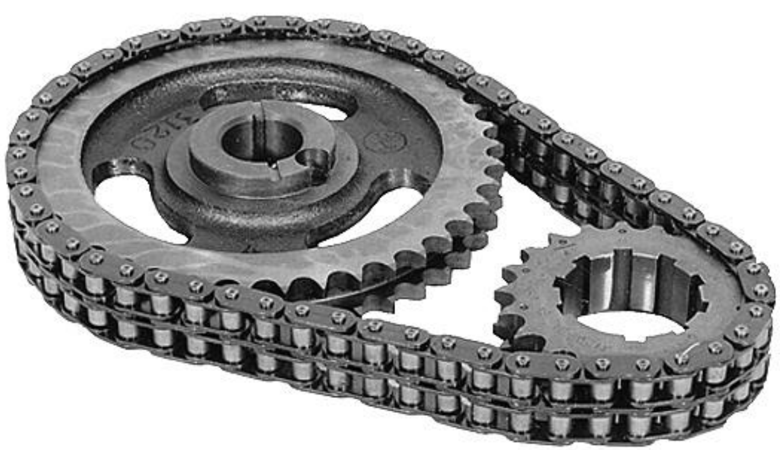
Time

$$v = nL / t = fL$$

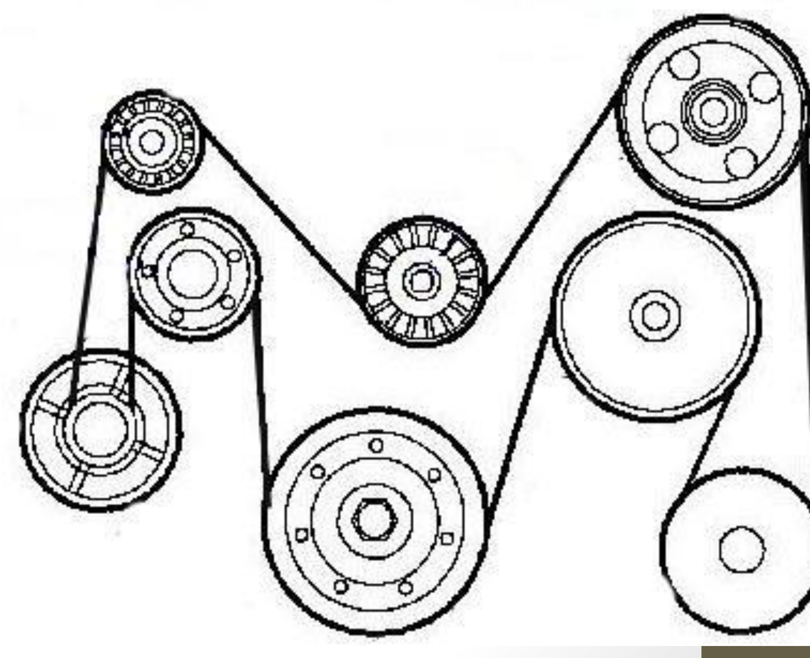
Distance moved parallel to the screw axis

Flexible Transmission

Chain-sprocket

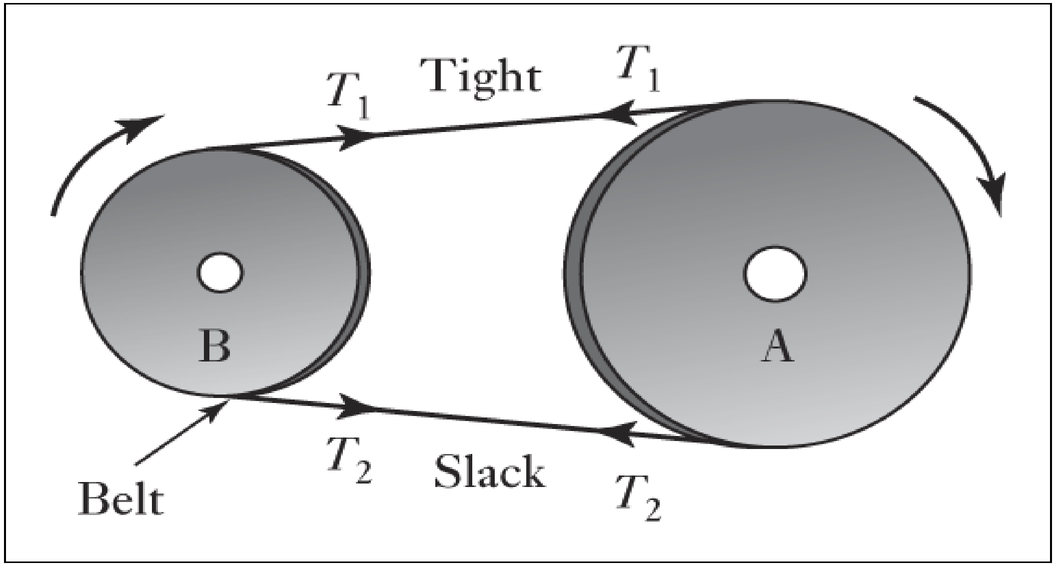


Belt-pulley



Belt and Chain Drives

- Pair of rolling cylinders with the motion of one cylinder being transferred to the other by a belt.



- Belt drives use the friction that develops between the pulleys attached to the shaft and the belt around the arc of contact in order to transmit a torque.
- The transmitted torque is due to the differences in tension that occur in the belt during operation. This difference results in a tight side and a slack side for the belt.

Belt and Chain Drives

- If the tension on the tight side is T1, and a slack side is T2, then with pulley A as a driver,

Torque on A = (T1 – T2) rA

- Pulley B as a driver,

Torque on B = (T1 – T2) rB

- Since the power transmitted is the produce of the torque and the angular velocity, and since the angular velocity is v/rA for pulley A and v/rB for pulley B, then for either pulley we have

Power = (T1 – T2) v

Belt and Chain Drives

- As a method of transmitting power between two shafts, belt drives have the advantage that the length of the belt can easily be adjusted to suit a wide range of shaft to shaft distance. The system is automatically protected against overload because slipping occurs if the loading exceeds the maximum tension that can be sustained by frictional forces.
- If the distance between shafts is large, a belt drive is more suitable than gears, but over small distances gears are to be preferred.

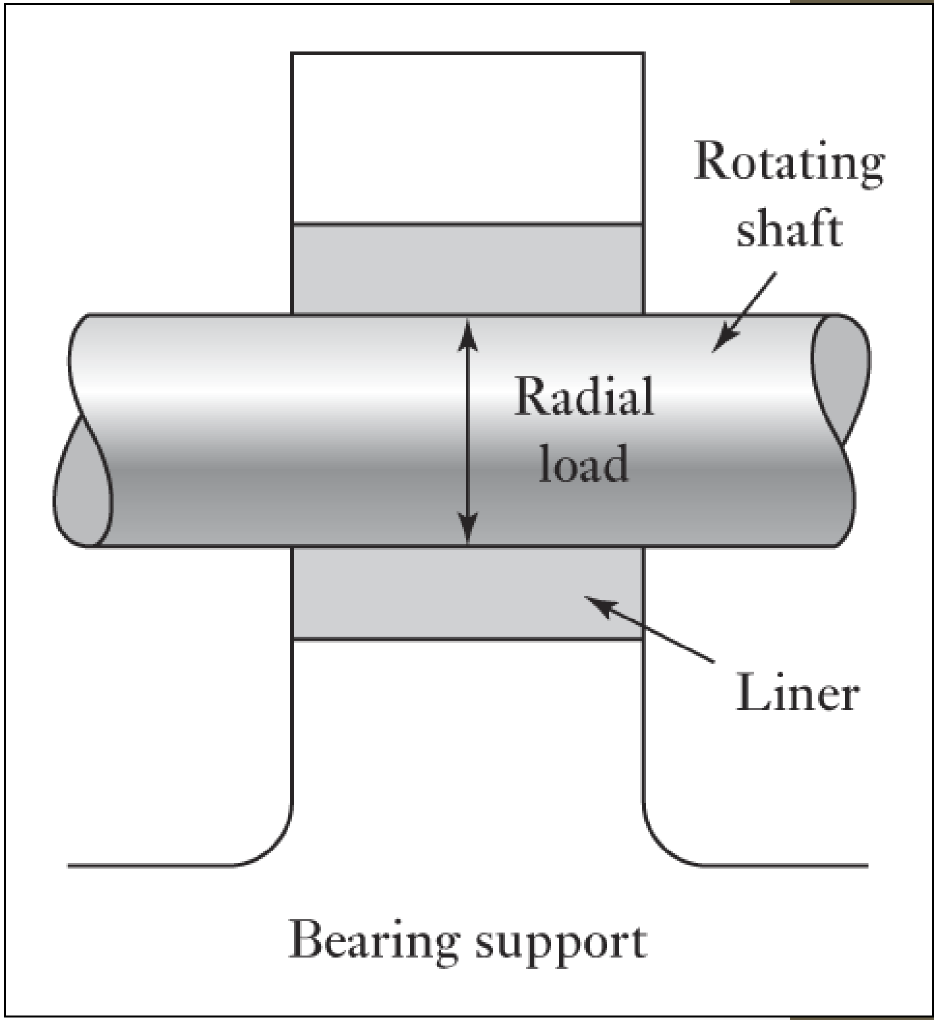
Bearings

- Whenever there is relative motion of one surface in contact with another, either by rotating or sliding, the resulting frictional forces generate heat which wastes energy and results in wear.
- The function of bearing is to guide with minimum friction and maximum accuracy the movement of one part relative to another.
- Give suitable support to rotating shaft.

Bearings

<u>Journal bearings</u>

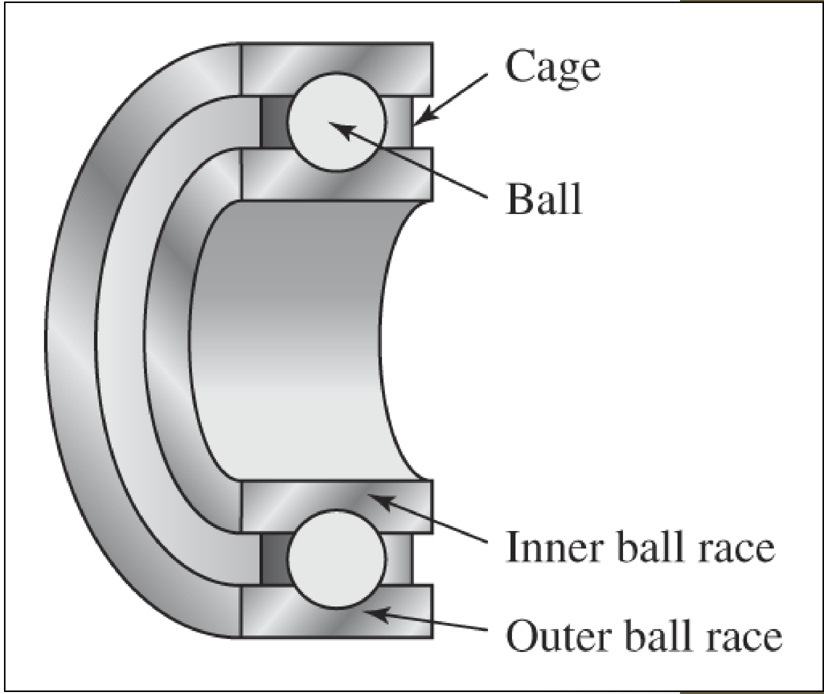
- Used to support rotating shafts which are loaded in a radial direction (journal – shaft).
- Consists of an insert of some suitable material which is fitted between the shaft and the support.
- Rotation of the shaft results in its surface sliding over that of the bearing surface.
- The bearing may be a dry rubbing bearing or lubrication.



Anti-Friction Bearings

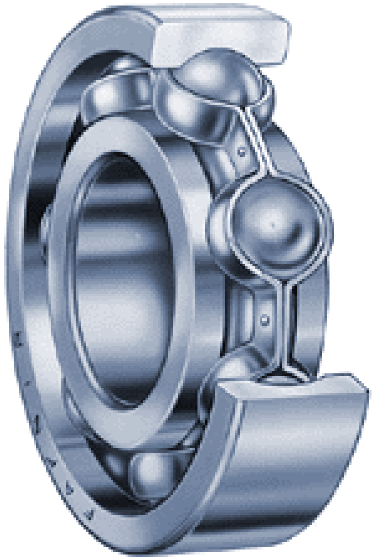
<u>Ball and roller bearing</u>

- With this type of bearing, the main load is transferred from the rotating shaft to its support by rolling contact rather than sliding contact.
- A rolling element bearing consists of 4 main elements : an inner race, an outer race, the rolling element either balls or rollers, and a cage to keep the rolling elements apart.
- The inner and outer races contain hardened tracks in which the rolling elements roll.



AF (rolling element) Bearing types

Ball bearing



Thrust bearing

Tapered roller bearing

Needle roller bearing

Important factors in bearing selection

- Loads (radial, axial)
- Operating speed
- Size and weight

Information sources:

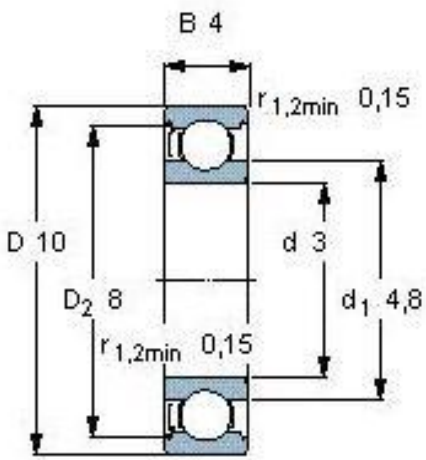
- Experts
- Manufacturer’s catalog (SKF, TIMKEN, FAG,…)
- Design handbook

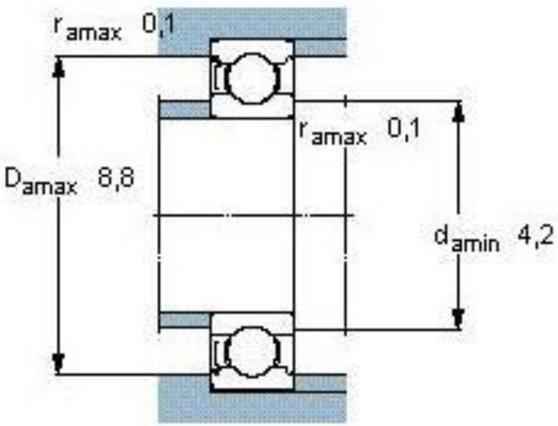
SKF interactive bearing selection example page

Deep groove ball bearings, single row

Tolerances , see also text
Radial internal clearance , see also text
Recommended fits
Shaft and housing tolerances

Principal dimensions			Basic load ratings dynamic	static	Fatigue load limit	Speed ratings Reference speed	Limiting speed	Mass	Designation
d	D	B	C	C_0	P_u				* - SKF Explorer bearing
mm			kN		kN	r/min		kg	-
3	10	4	0,54	0,18	0,007	130000	80000	0,0015	623-Z





Calculation factors

k_r 0,025
f_0 7,5

Joining methods

- Bolts/Nuts and screws
- Rivets
- Welding
- Brazing
- Soldering

Screws, Bolts - Nuts

- Hexagon head bolt
  - Usually uses nut
  - Heavy duty
- Hexagon head cap screw
  - Thinner head
  - Often used as screw (in threaded hole, without nut)
- Socket head cap screw
  - Usually more precision applications
  - Access from the top
- Machine screws
  - Usually smaller sizes
  - Slot or philips head common
  - Threaded all the way

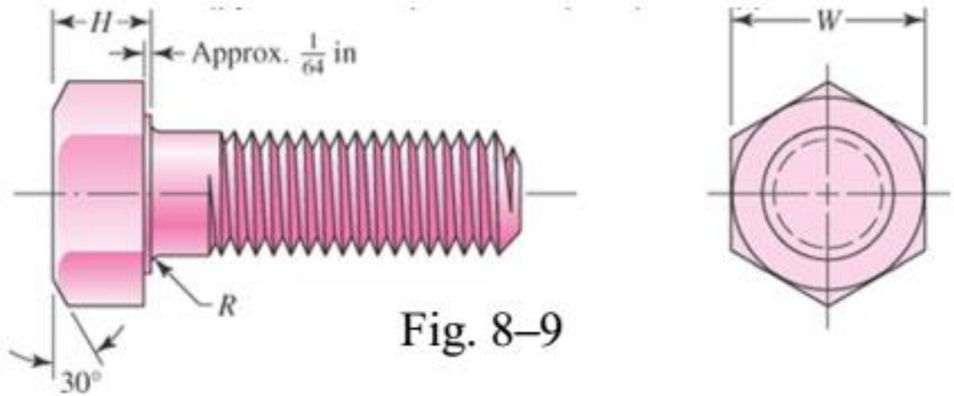


Fig. 8–9

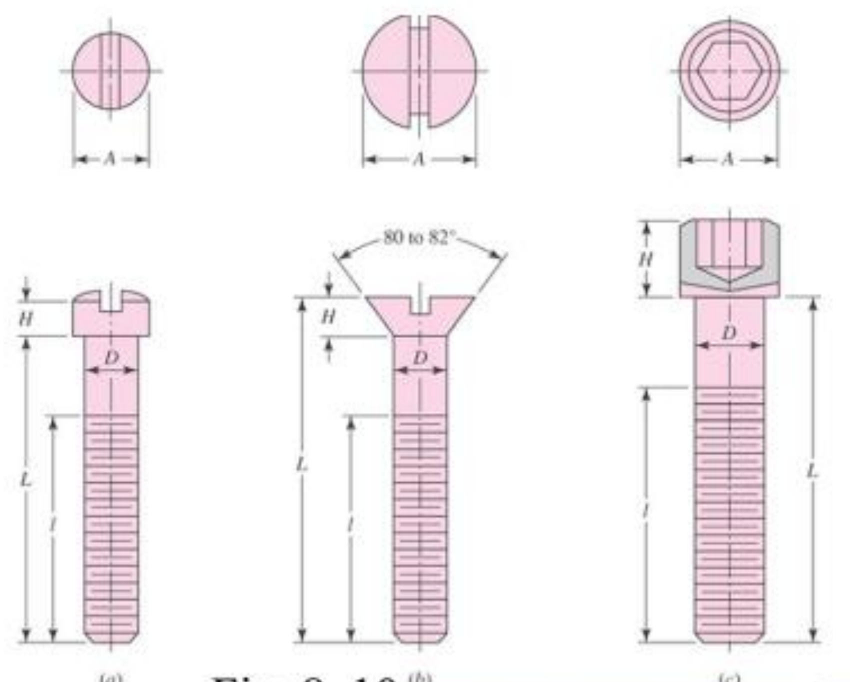
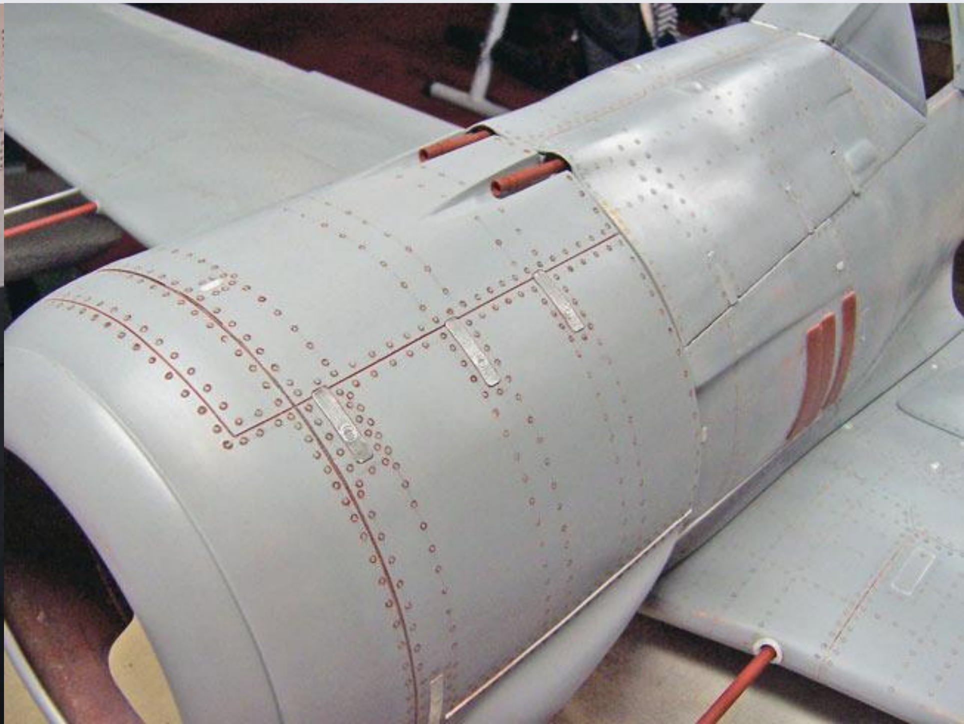


Fig. 8–10

Shigley's Mechanical Engineering Design

Screws

Rivets



Joining methods

- **Welding**: (melting both material and filler, generally used for welding ferrous materials)
- **Brazing**: (melting nonferrous metal, brass or bronze, as filler to join base materials by capillary action)
- **Soldering**: (same as brazing but at lower temperatures)

Joining method	Joint strength	temperature	Distortion	Aesthetics
Soldering	Poor	up to 400°C	None	Good
Brazing	Good	800-1000 °C	Minimal	Excellent
Welding	Excellent	above1500° C	Likely	Fair

e.g.
Brazing with Bronze alloy as filler with 870-980 °C for joining mild steel with melting temperature of 1600°C [1].

Welding types

Arc welding: An electric arc between material and filler melts them at the joining point.

Gas welding (oxyacetylene):

- Widely used for welding pipes and tubes and repair work

Resistance welding:

Generating heat by passing current through resistance caused by joining metals. (widely used in automotive industry)

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