

ROCO222: Intro to sensors and actuators

Lecture 6

Mechanical power transmission

Mechanical power transmission

Transmission of power in mechanisms can be used to realize:

- Changes in torque
 - Changes in rotational speeds
 - Provide drive at the appropriate location
-
- It can be achieved my means of:
 - Shafts and levers
 - Gears
 - Pulleys and timing belts
 - Chains
 - Ball screws



Shafts and levers

- Shafts can be used to transmit torque to other components

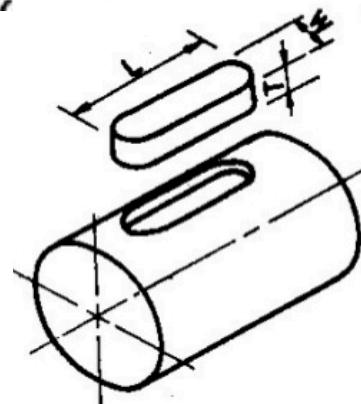


- Torque transmission implied must deal with torsional strain
- May also need to resist longitudinal strain

Attaching shafts to other components

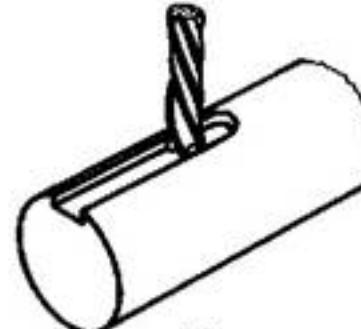
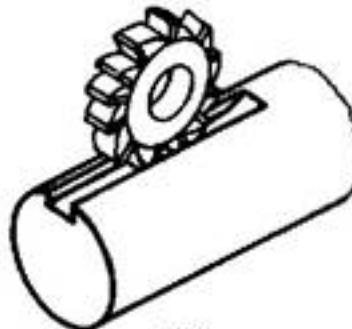
Grub screws

- Very basic approach
- May be OK if torques very low
- Better if flat end on grub and flat on shaft



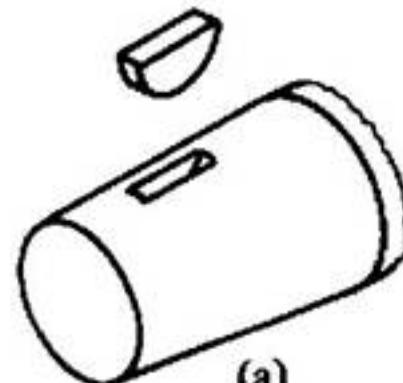
Parallel sunk

- Key
- Much better than grub



Woodruff key

- Like parallel key



Attaching shafts to other components

Splines

- Can be very effective and deal with high torques
- E.g. Used to connect car engines to their gearboxes



Expanding bushes

- Bush expands and provides good connection between shaft and attachment
- Put strain on attachment
- Can be expensive!



Joining and retaining shafts

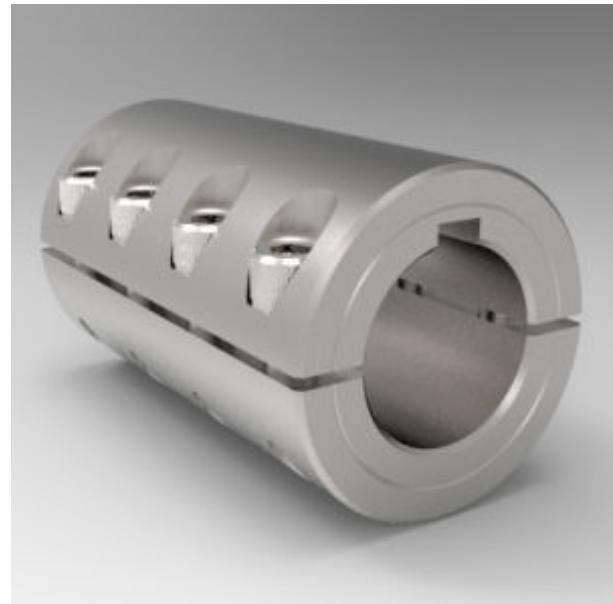
Grub screw retaining collar

- Useful to provide end-stop on shaft
- e.g. to provide shaft retention against bearing



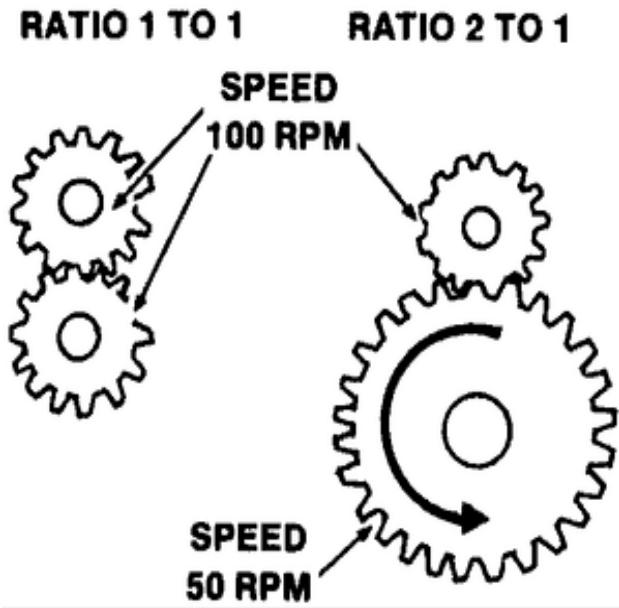
Grub screw clamp extension

- Useful to provide connection between different shafts
- Here also uses keyway



Spur gears

- Directly meshing cogs
- Simplest kind of gears
- Very common
- Can be noisy
- Exhibit backlash

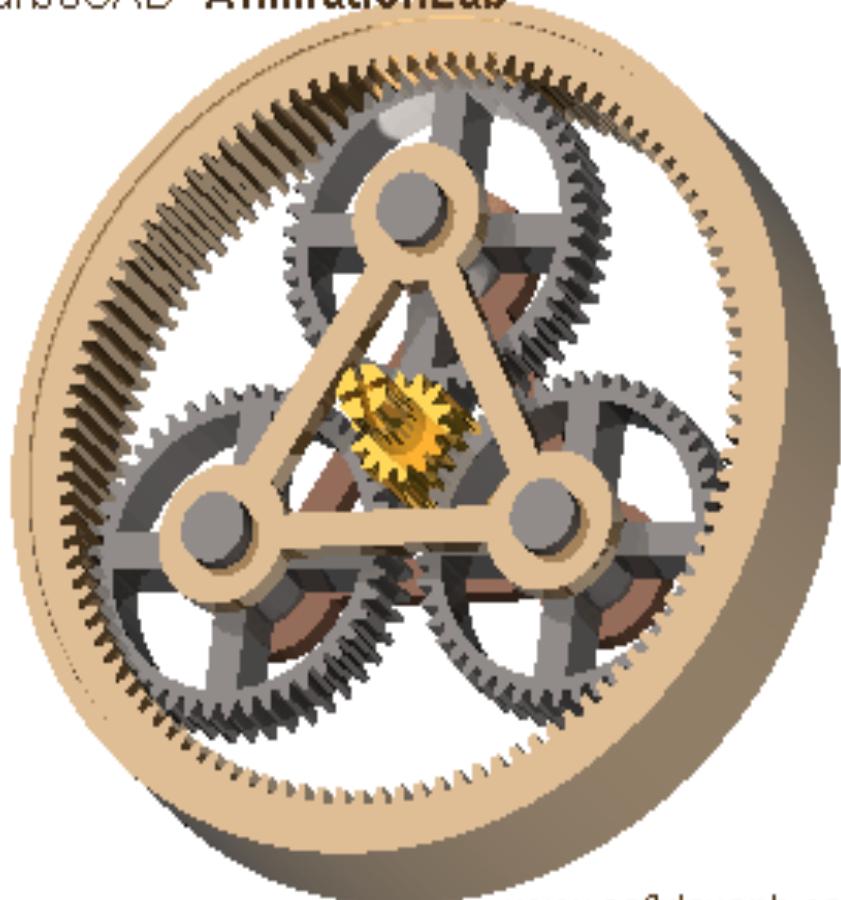


Planetary gears

- Center of one gear revolves around the center of the other
- Load shared among planets
- High the torque density
- High power density
- But higher design complexity compares to spur gearbox!

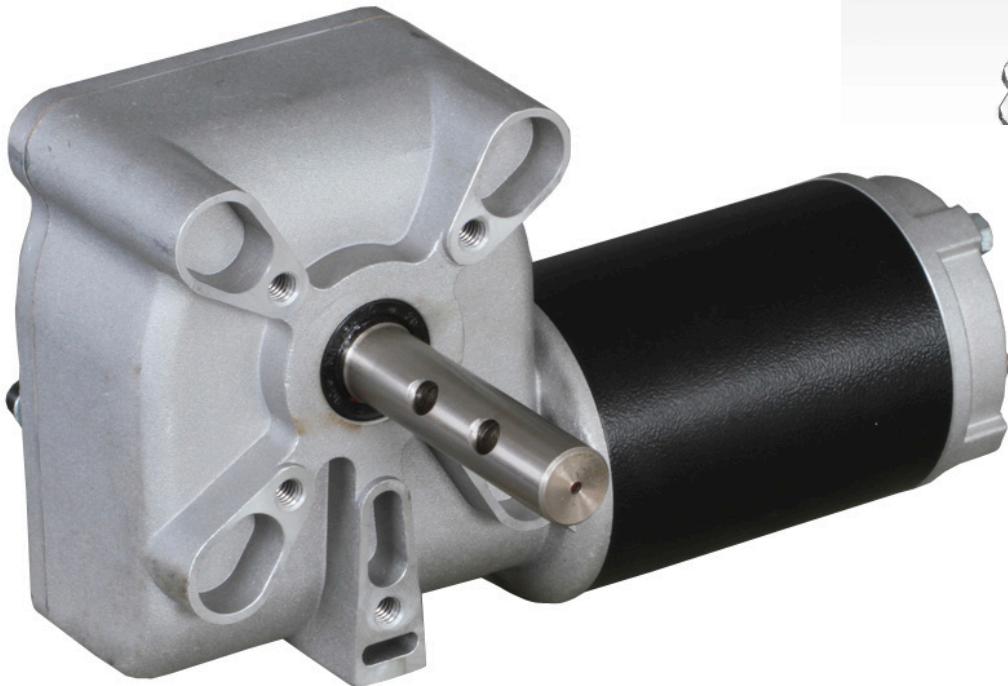
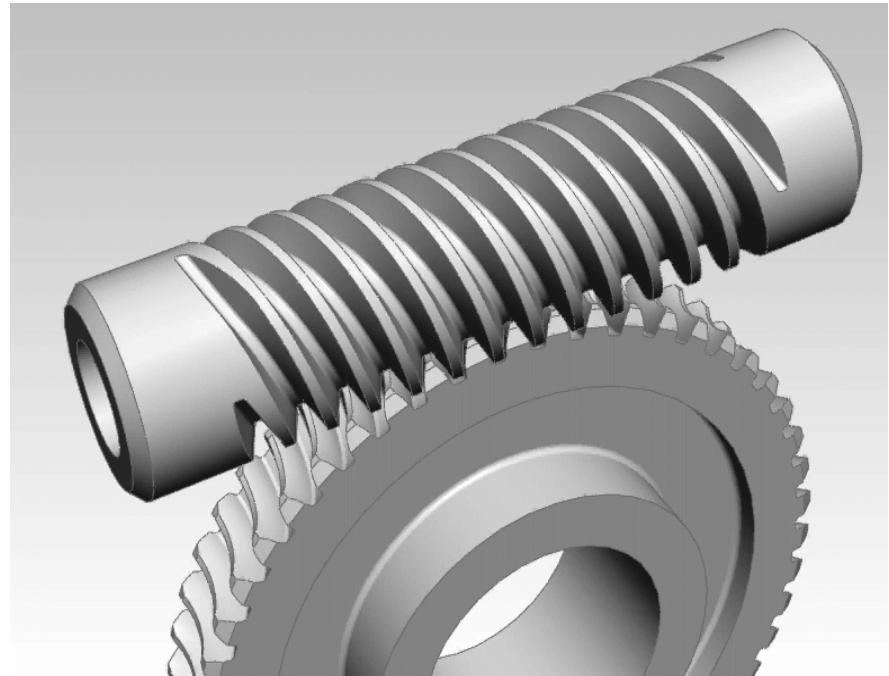


TurboCAD AnimationLab



Worm gears

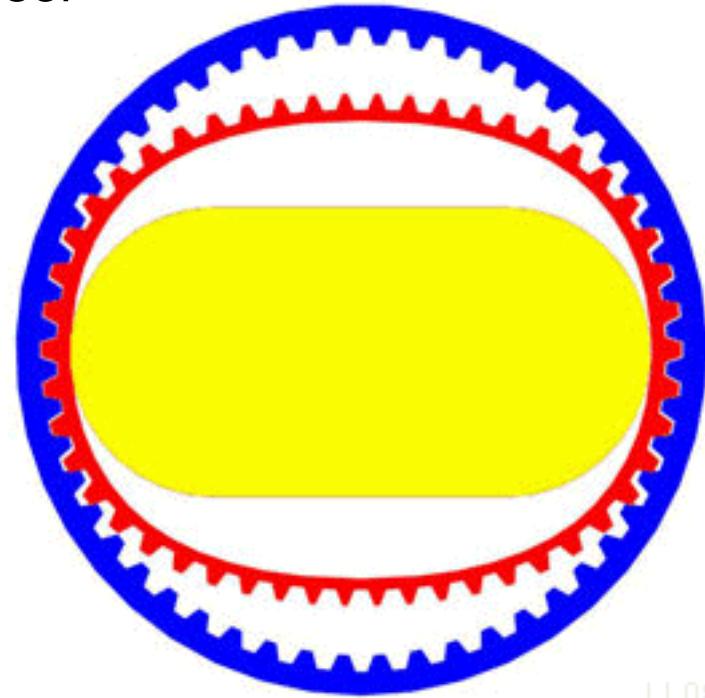
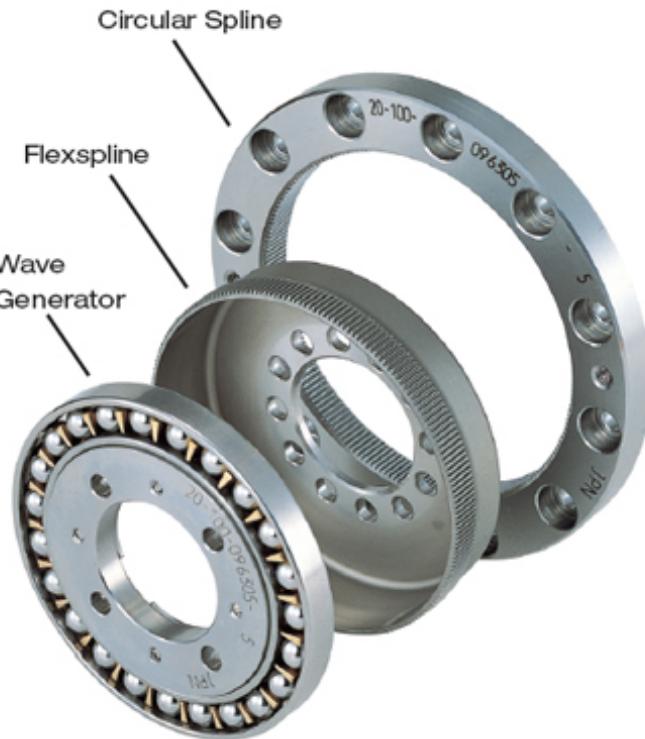
- Use a screw action
- Need bearing to deal with thrust load on screw
- Large reduction in single stage
- Not back-drivable
- Used in mobility vehicles, lifts, elevators, rotary tables etc.



Harmonic drive

Strain wave gear invented in 1957 by C.W. Musser

- Outer ring has 2 teeth more than inner
- three basic components:
- a wave generator
- a flex spline
- a circular spline

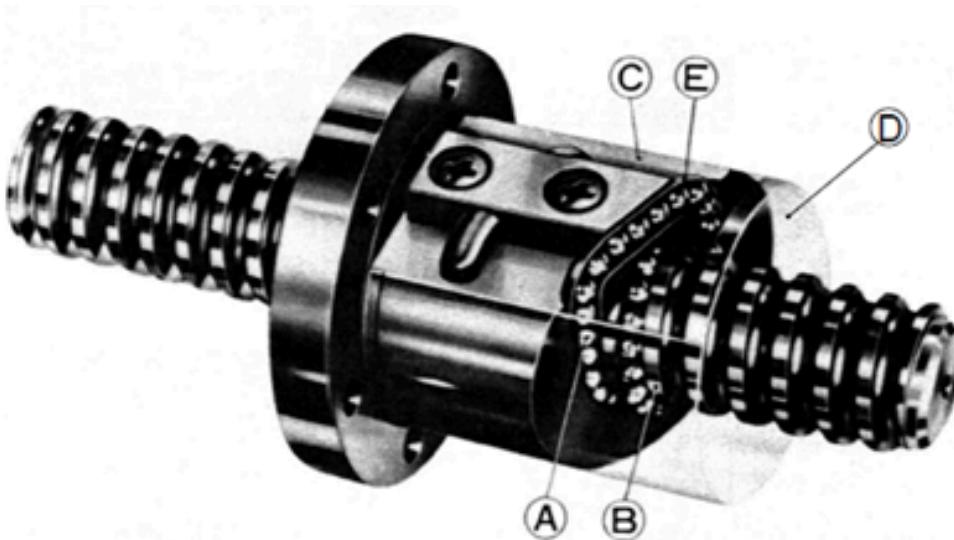


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- Properties:
- Lack of backlash
- High compactness
- High reduction ratio
- High torque capacity
- But can be expensive
- Used in higher end robots

Ball screw

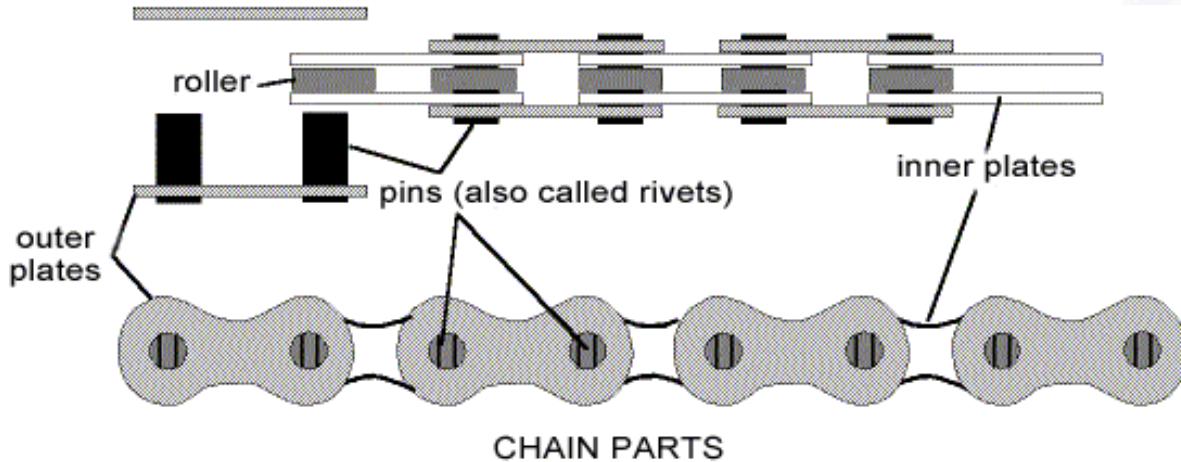
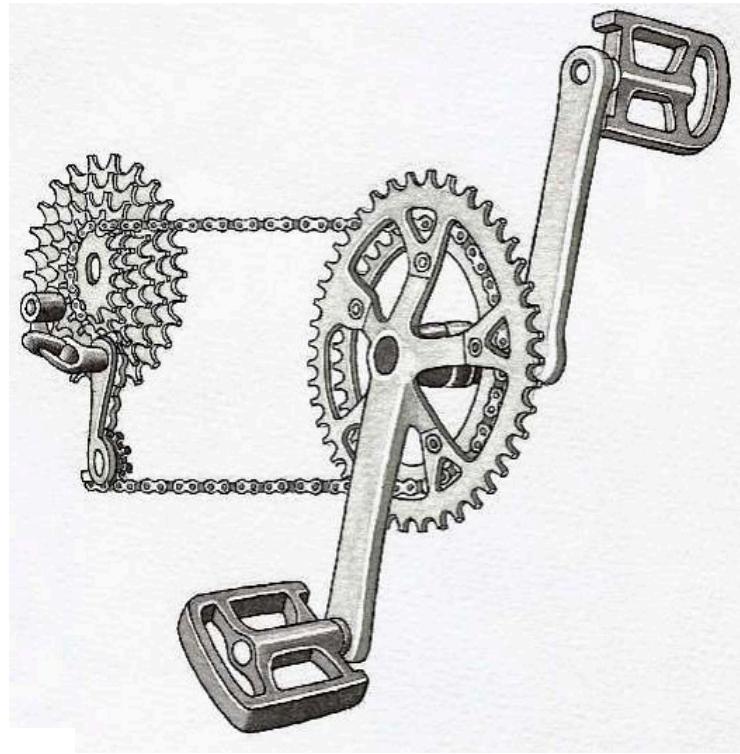
- Translates rotational motion to linear motion
- Mechanism to re-circulate the balls
- Low friction
- High precision
- Linear drive
- Used in machine tools & robots to move components



- A: Steel ball
- B: Screw shaft
- C: Ball nut
- D: Seal (both sides of ball nut)
- E: Recirculation parts (return tube, etc.)

Chain drive

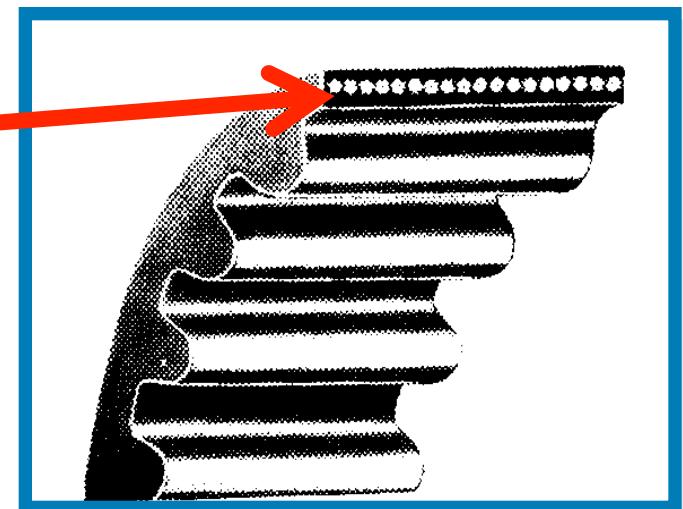
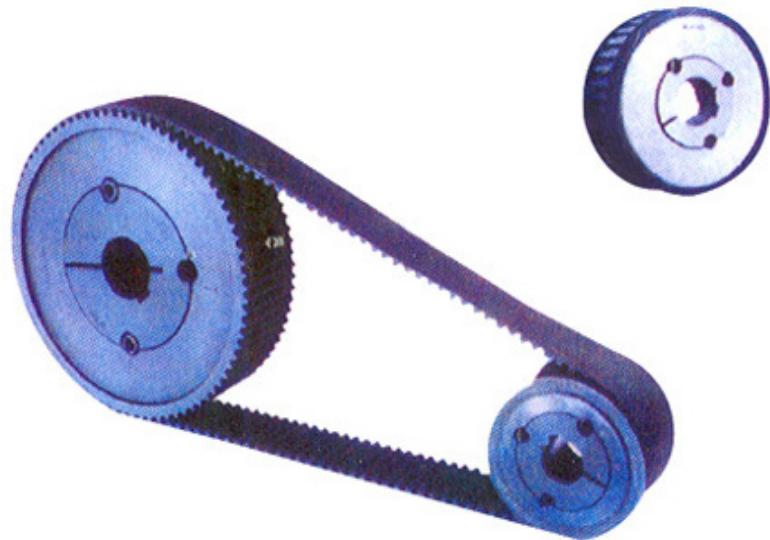
- Roller chain can transmit mechanical power from one place to another
- Very efficient, low friction and cheap
- Can also generate MA
- Problems with vibration can occur
- used to convey power to the wheels of a vehicle, particularly bicycles and motorcycles
- Also used in a wide variety of machines besides vehicles
- Timing belts taking over more applications now though



- Uses pin connected links
- Teeth mesh into chain gaps to avoid slipping

Belt drive

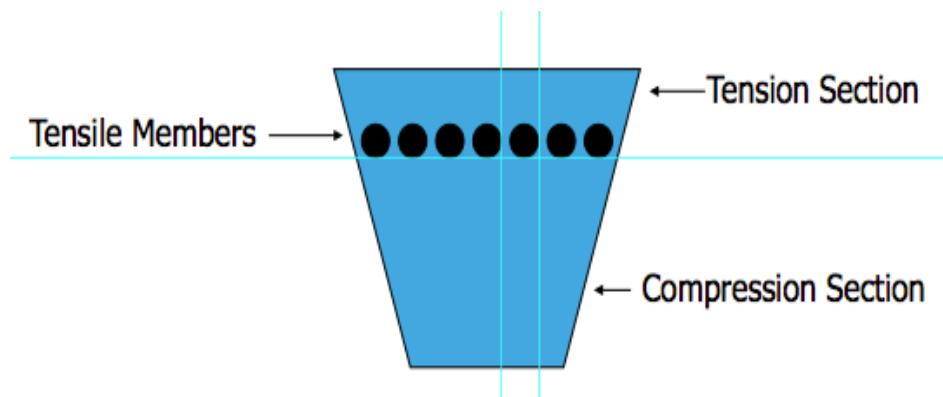
- Transfer power (torque) from one location to another
 - Belts used with pulleys
 - Simple and inexpensive
 - Often used to generate MA
-
- Toothed belts needed to avoid slip
 - Low or zero backlash
 - Kevlar or steel tension wires sometimes employed in design
 - Back drivable
 - Fixed length complicates adjustment
 - Can have vibration problems



Example belts: V-belt

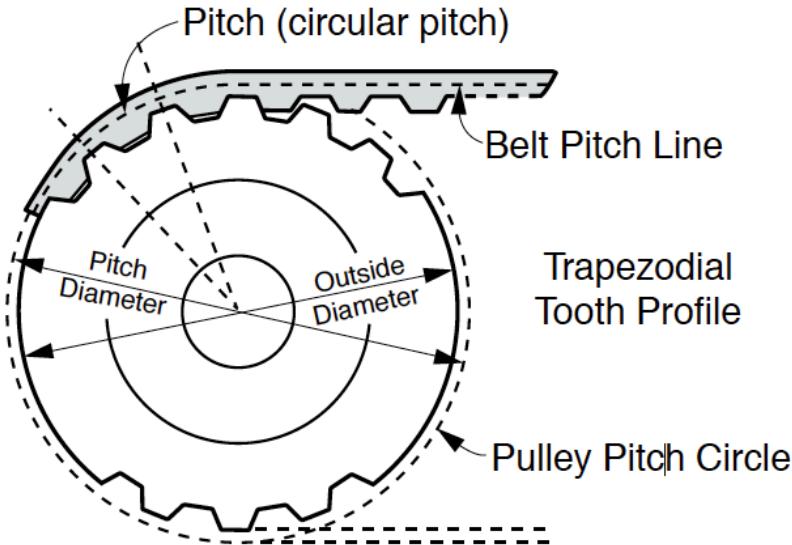
V-Belts

- Operate using the principle of the "wedge"
- Less expensive than other forms of power transmission
- Operate noiselessly and without lubrication
- Absorb objectionable and harmful vibrations
- Rugged and long lasting
- Used for air compressors, in cars for water pump, etc

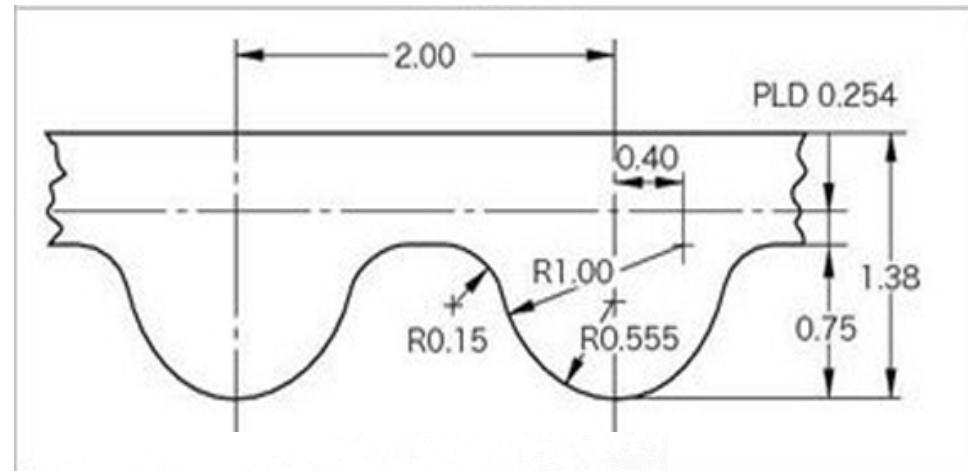


Example belts: Timing belt

- Trapezoidal pulley geometry
- Used in many timing belts



- GT2
- Curvilinear pulley geometry
- Design for linear motion drive
- Rounded profile avoids backlash
- Used a lot in 3D printers

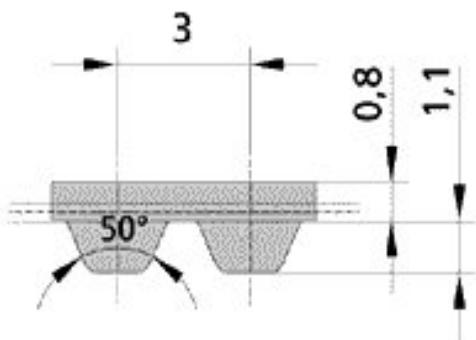


Select a timing belt drive

Compile together all the relevant design parameters

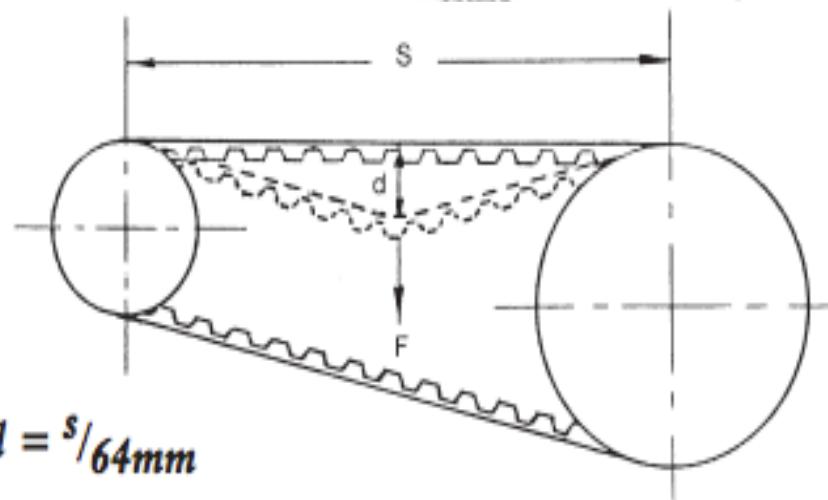
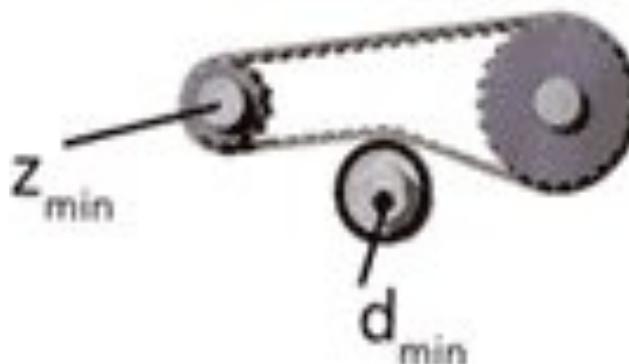
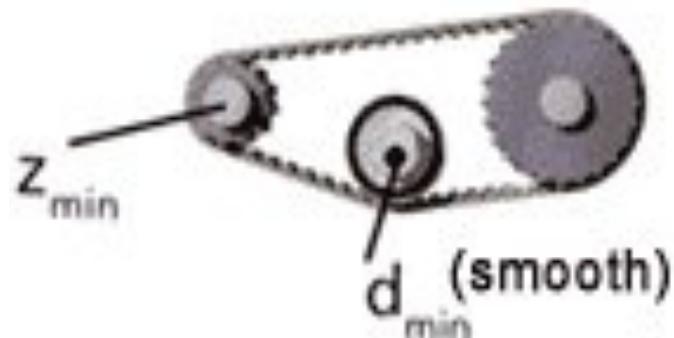
- Type of application
- E.g. linear drive or power drive
- Shaft speed
- Power to be transmitted
- Approximate shaft center distance
- Operation duration

- Decide on type of belt
- Calculate required drive ratio
- Select belt pitch and width determined by loading force
- Pulley selection affected by shaft diameters and space restrictions
- Design must fit into space
- Want at least 6 teeth in contact with the pulley at any given time
- Determine belt length



Belt adjustments

- Do not violate belt minimum radii recommendations
- Adjust Belt Tension
- Tension should always exceed the maximum driving force on the belt



Pros and cons of belt drive

Advantages

- Some misalignment is tolerable so parallel shafts are not required
- Overload and jam protection provided
- Noise and vibration are damped out
- Machinery life prolonged because load fluctuations are cushioned (shock-absorbed)
- They are lubrication-free
- They require only low maintenance
- They are highly efficient (90–98%, usually 95%)
- Very economical when shafts are separated by large distances

Disadvantages

- Because of belt slip and stretch heat buildup can occur
- Speed is generally limited to 35 meters per second
- Power transmission is limited to hundreds of kilowatts (not a problem in small robots)
- Operating temperatures usually restricted between –35° to 85°C
- Wear and stretch compensation requires adjustment of center distance or use of idler pulley
- Disassembly is needed to install endless belts

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Lecture 6

Bearings

Types of bearings

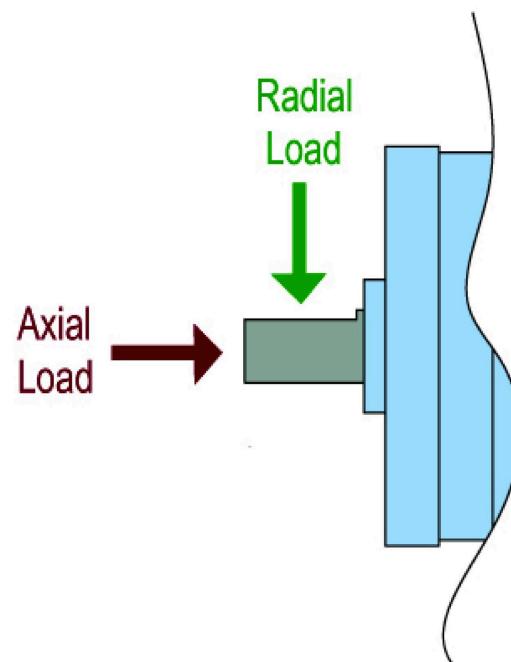
There are many types of bearings

- Plain
- Ball
- Roller



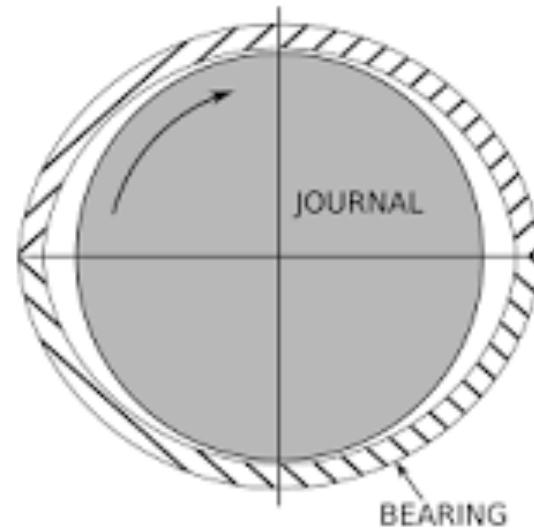
Simple bearing design principle

- Support of shaft at both ends
- Bearings must operate with axial and radial loads of task

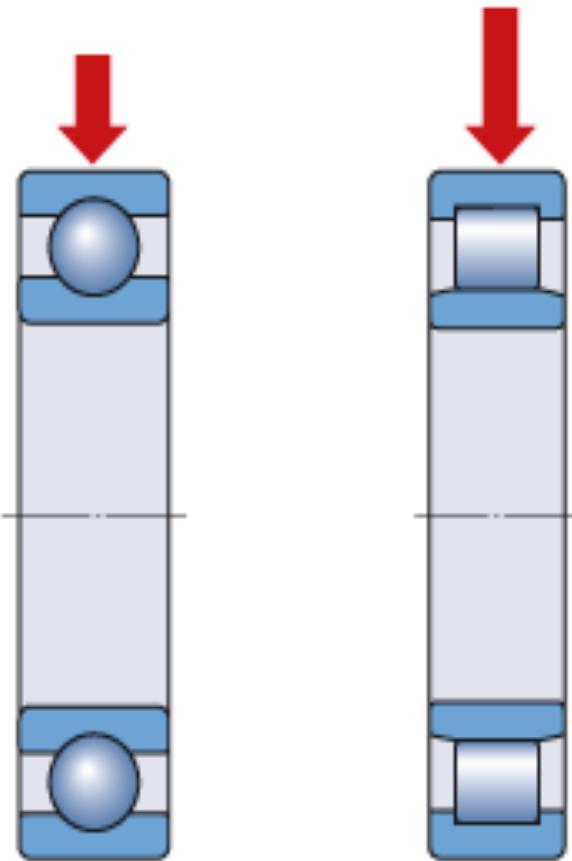


Plain bearings

- Plain surface
- Sliding contact not rolling contact
- Violates avoid friction guidelines
- Compact and lightweight
- High load
- Can be cheap
- Life depends on lubrication
- Phosphor bronze, nylon



Roller versus ball bearings



- Roller bearings are able to support heavier loads than similar-sized ball bearings

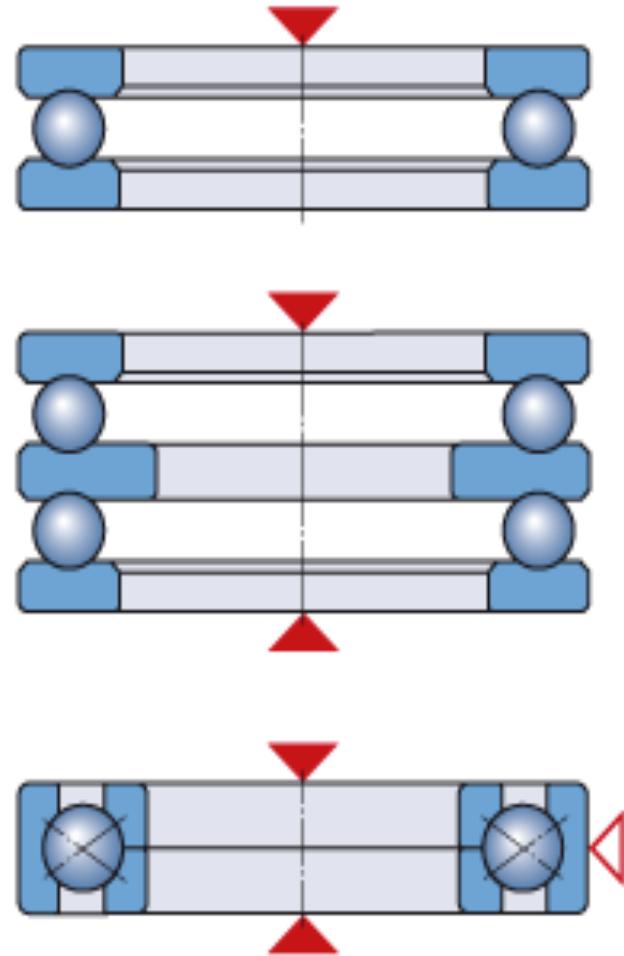
Single-row ball bearings

- Extremely common
- Stiff with some play
- Moderate life
- May be sealed
- Limited load capacity
- Use deep groove option for higher load
- Angular contact also permits thrust loading
- Bicycles use angular-contact bearings



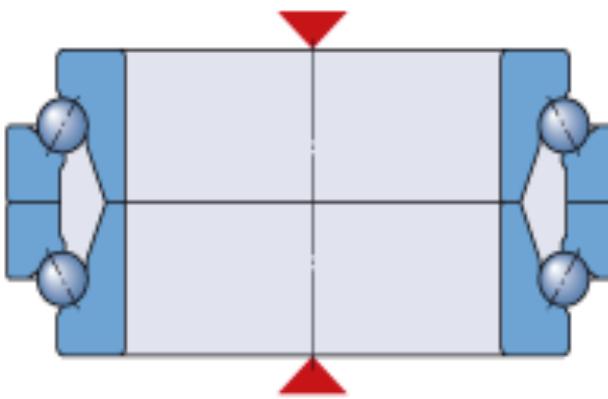
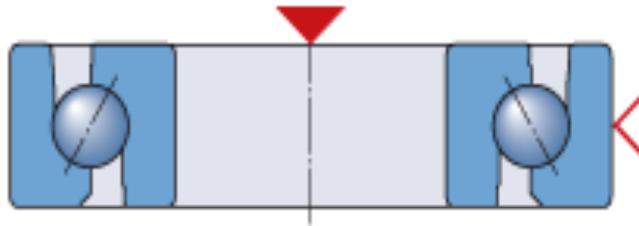
Thrust bearings

- Axial thrust loads
- E.g. bar stool, turntable



- Normal thrust ball bearings suitable for light or normal loads that are purely axial

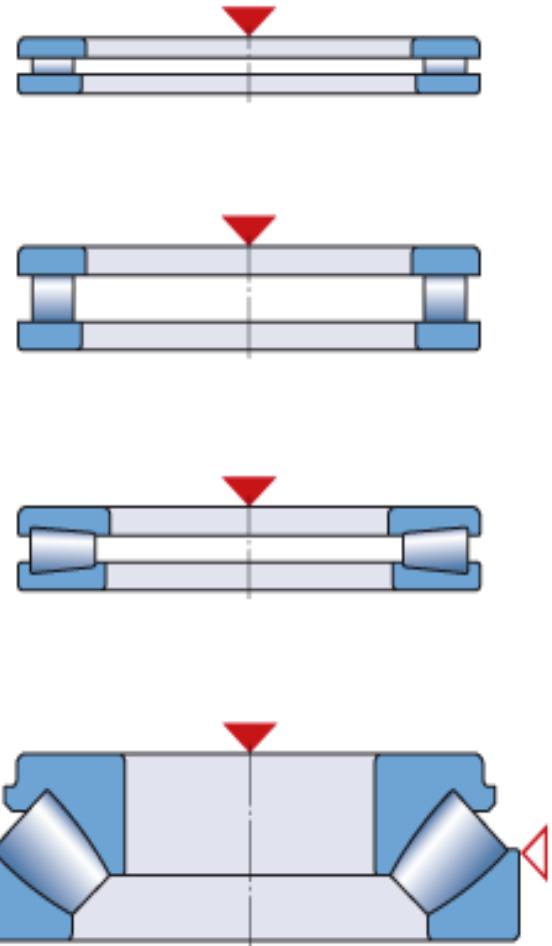
Angular contact thrust ball bearings



- Angular contact thrust ball bearings can support normal axial loads at high speeds

Roller thrust bearings

- Can handle large thrust loads
- Often used in gearboxes between gears



- Bearings for normal and heavy axial loads acting in one direction

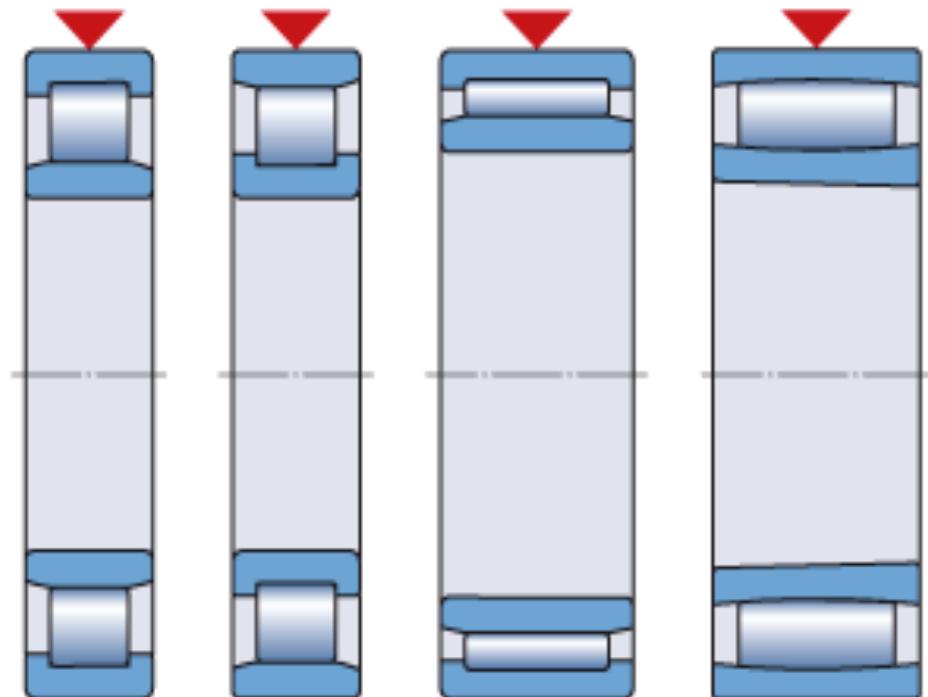
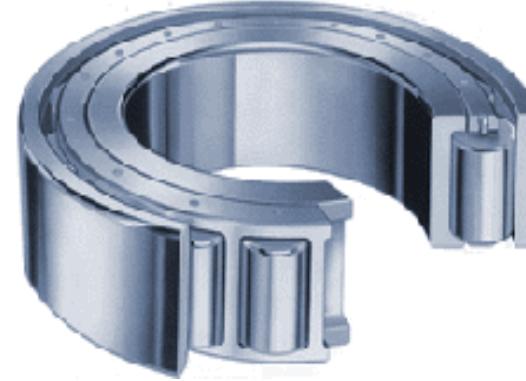
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Roller bearings for pure radial loads

- Roller spreads the load out over a larger area
- Can carry heavy radial loads
- Much greater loads than same sized ball bearing
- Not designed to handle much thrust loading
- So worse than ball bearings for thrust loading



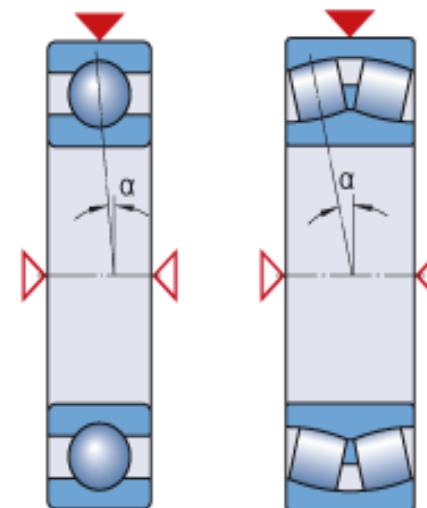
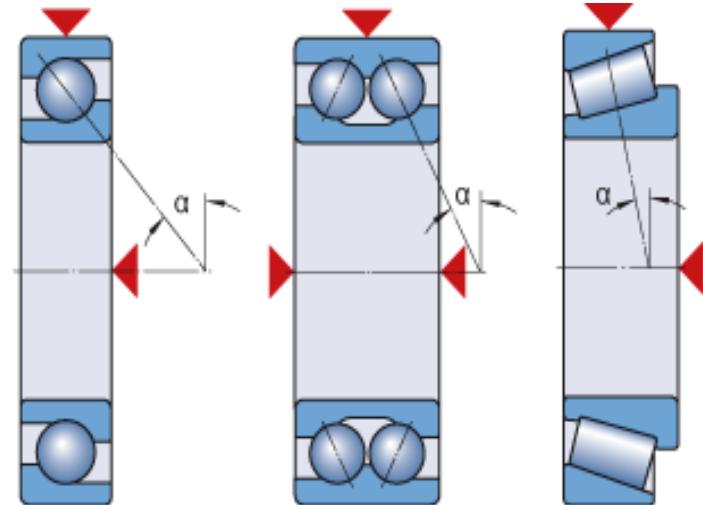
Needle bearings

- Type of roller bearings
- Designed to carry heavy loads
- Don't take up much space



Bearings for combined loads

- Support a combined load consists of a radial and axial load acting simultaneously
- Depending on orientation thrust load may only be supported in a single direction
- Deep groove ball bearings support radial and axial loads
- So do double row angular contact bearings



Taper roller bearings

- Support large radial and large thrust load in one direction
- Use two in opposite direction to support bidirectional thrust
- Used in car wheel hubs

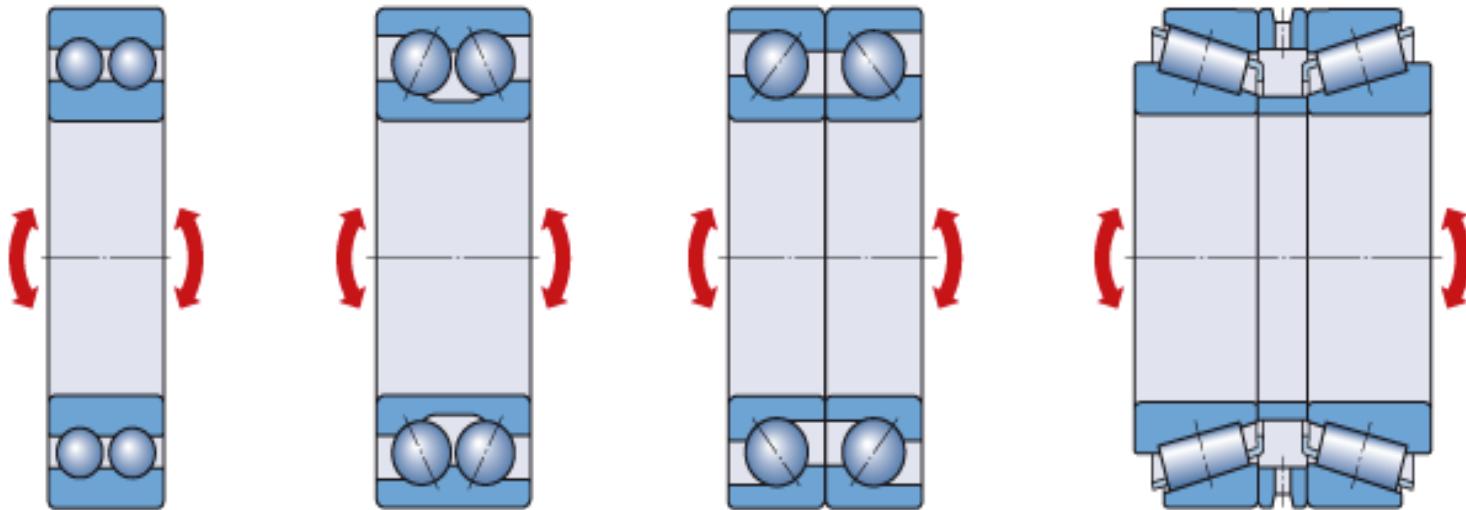


Double row ball bearings

- Can handle both radial and thrust loads
- Angular contact option gives high thrust
- Stiff with some play
- Moderate life
- May be sealed
- Larger load capacity



Bearings for moment loads



- Double row angular contact
- Needed when a load acts eccentrically on a bearing

Self-aligning bearings

- Useful if axial alignment cannot be guaranteed
- Avoids over constraining an assemble
- E.g. to support end of motor shaft



Spherical bearings

- Permits angular rotation about a central point in two orthogonal directions
- Consists of an outer ring and an inner ring
- Used in car suspensions, engines, drive shafts



Linear bearings

- Ball bearing slides
- Linear rack slides
- Used for machine tools
- 2D printers etc.



Bearing specification checklist

- Size – diameter and width of bearing an its shaft fit size
- Friction – high or low
- Loads – axial and radial
- Play – how much does is move
- Motions – axial rotation, linear, spherical
- Operating temperature
- Stiffness – rubber bearings are soft, roller very firm
- Service life – plane limited, ball/roller much better
- Lubrication – needed or not?
- Cost