INSTITUTE OF AERONAUTICAL ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING

PRESENTATION ON

DESIGN OF MACHINE MEMBERS-II

B.TECH III-II R-15

Prepared by:

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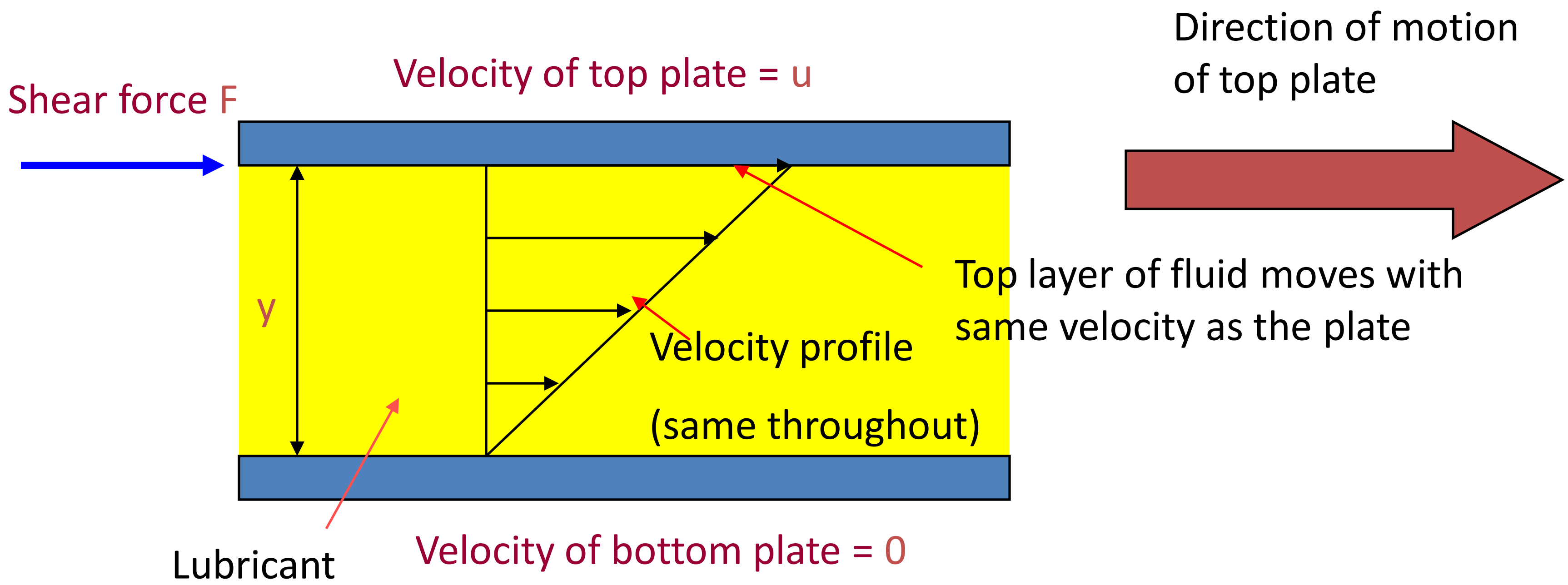
UNIT-1 : Hydrodynamic lubrication

- Also called fluid-film, thick-film, or flooded lubrication
- A thick film of lubricant is interposed between the surfaces of bodies in relative motion
- There has to be pressure buildup in the film due to relative motion of the surfaces
- Fluid friction is substituted for sliding friction
- Coefficient of friction is decreased
- Prevalent in journal and thrust bearings

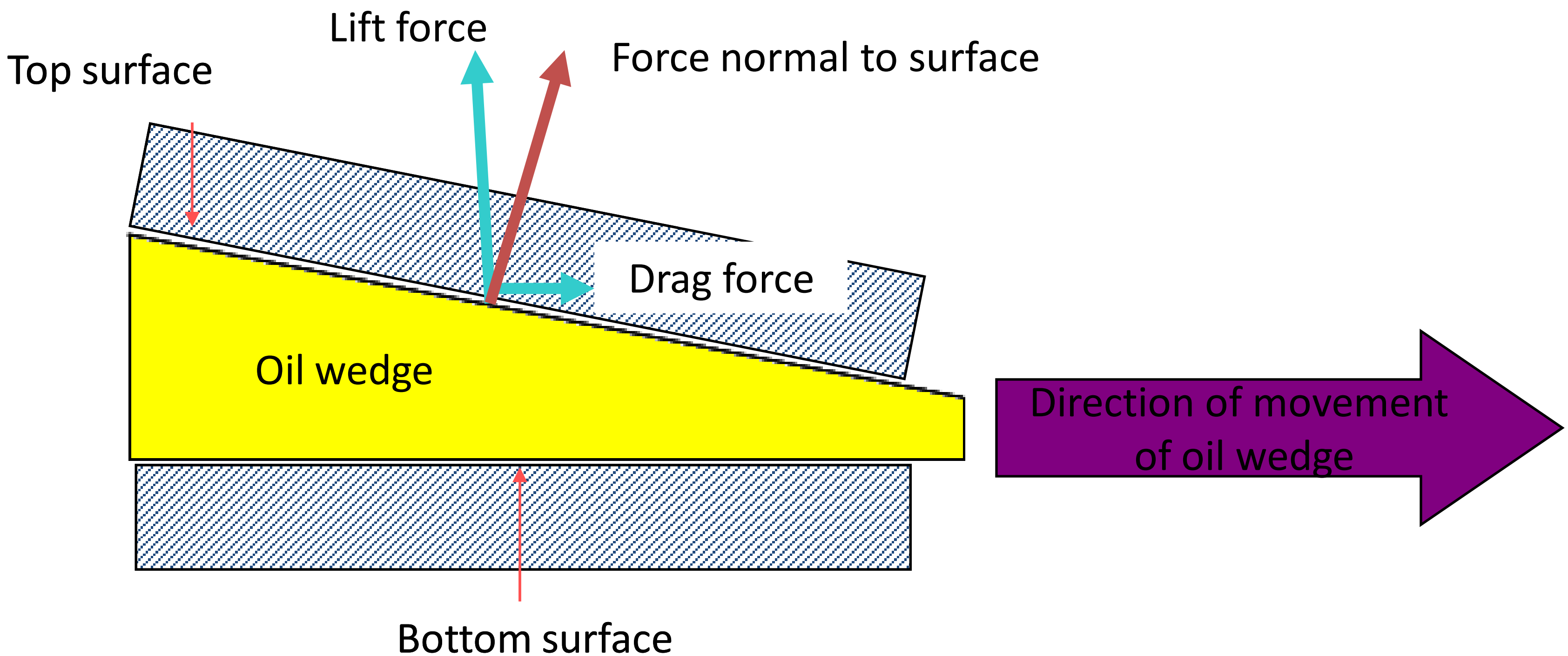
Parallel surfaces



A is area of the plate

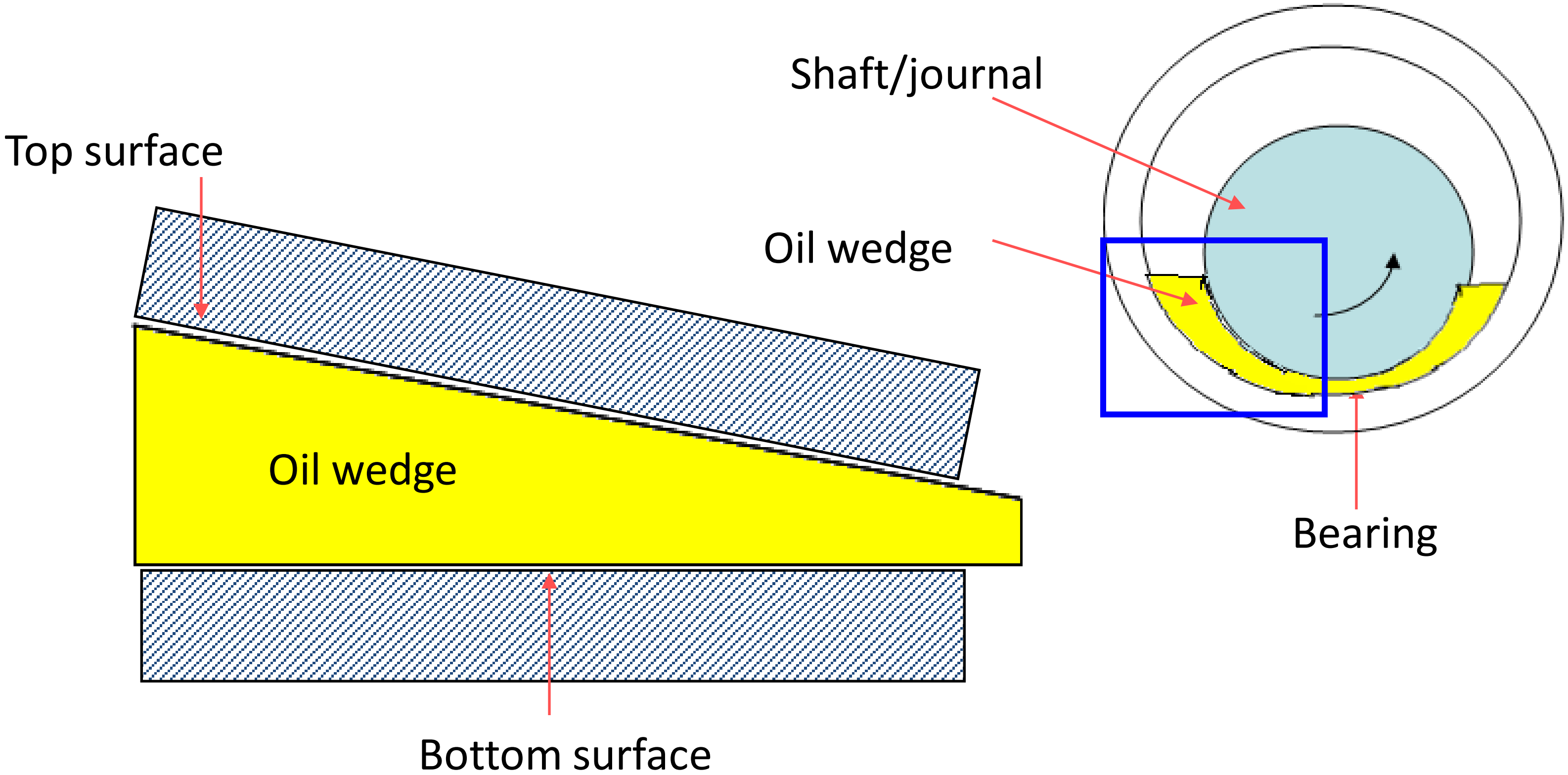
- **There is no pressure buildup in the fluid due to relative motion**
- **It remains constant throughout influenced only by the load**
- **As load increases the surfaces are pushed towards each other until they are likely to touch**

Hydrodynamic lubrication



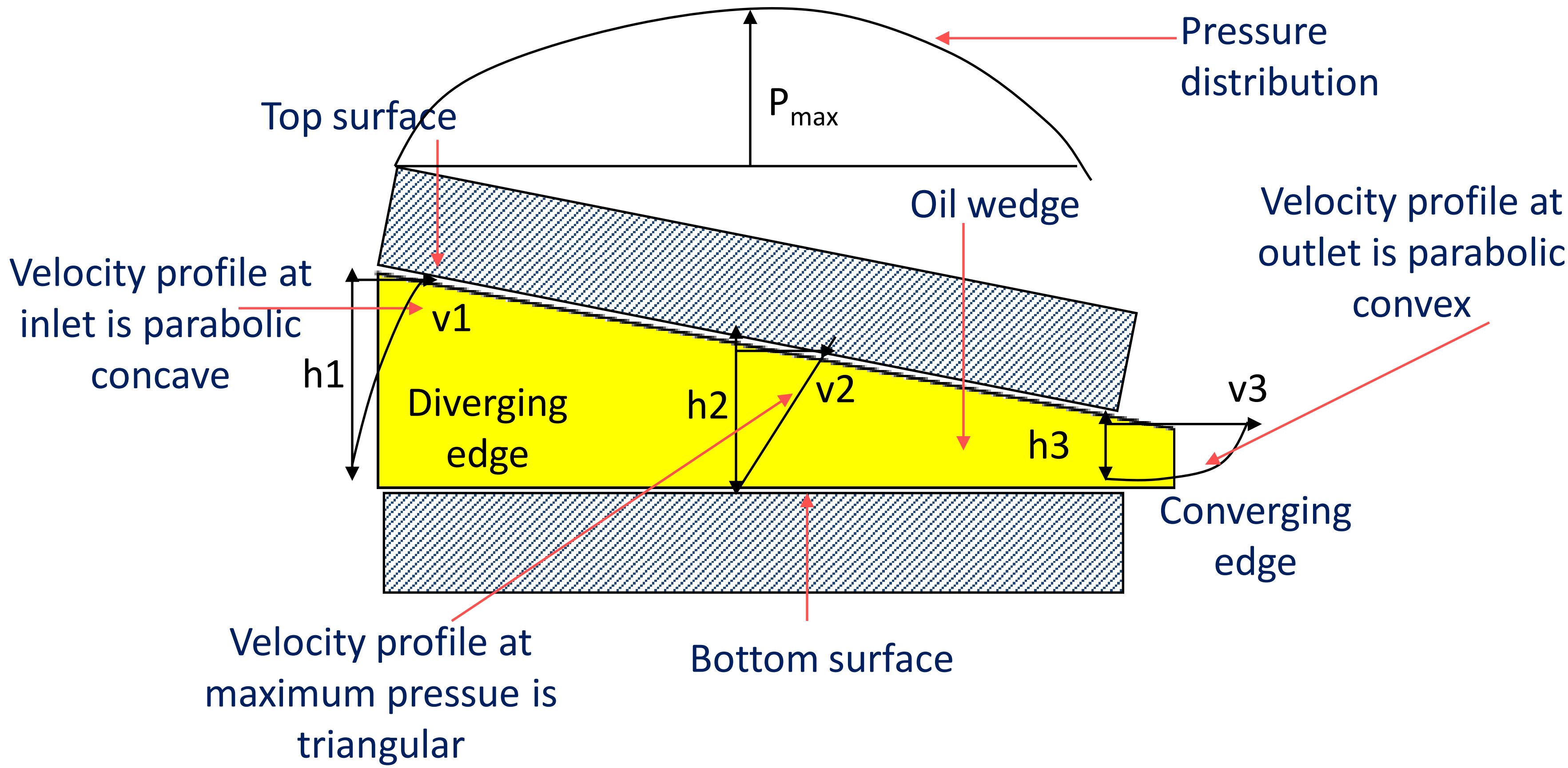
- Surfaces are inclined to each other thereby compressing the fluid as it flows.
- This leads to a pressure buildup that tends to force the surfaces apart
- Larger loads can be carried

Hydrodynamic theory- journal bearings



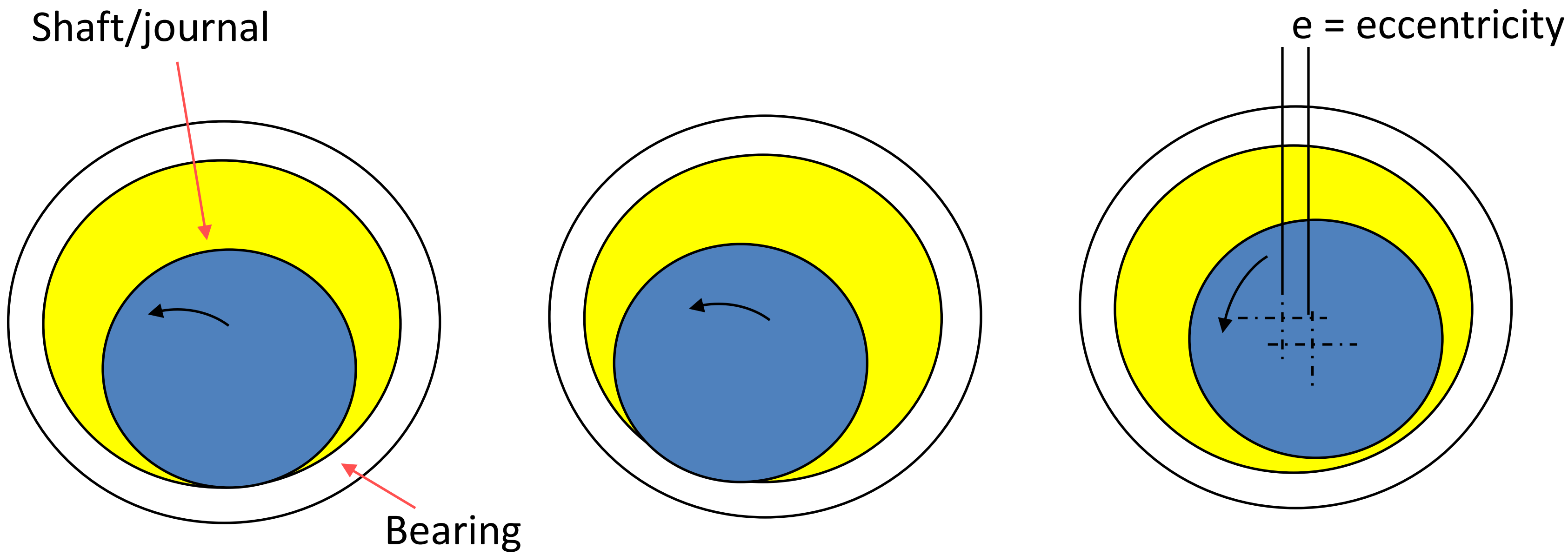
Oil wedge forms between shaft/journal and bearing due to them not being concentric

Velocity, pressure distribution



Volume rate of flow is same throughout the path, therefore as height of film decreases, the velocity has to increase (v3>v2>v1)

Journal bearing- process at startup



Stationary journal

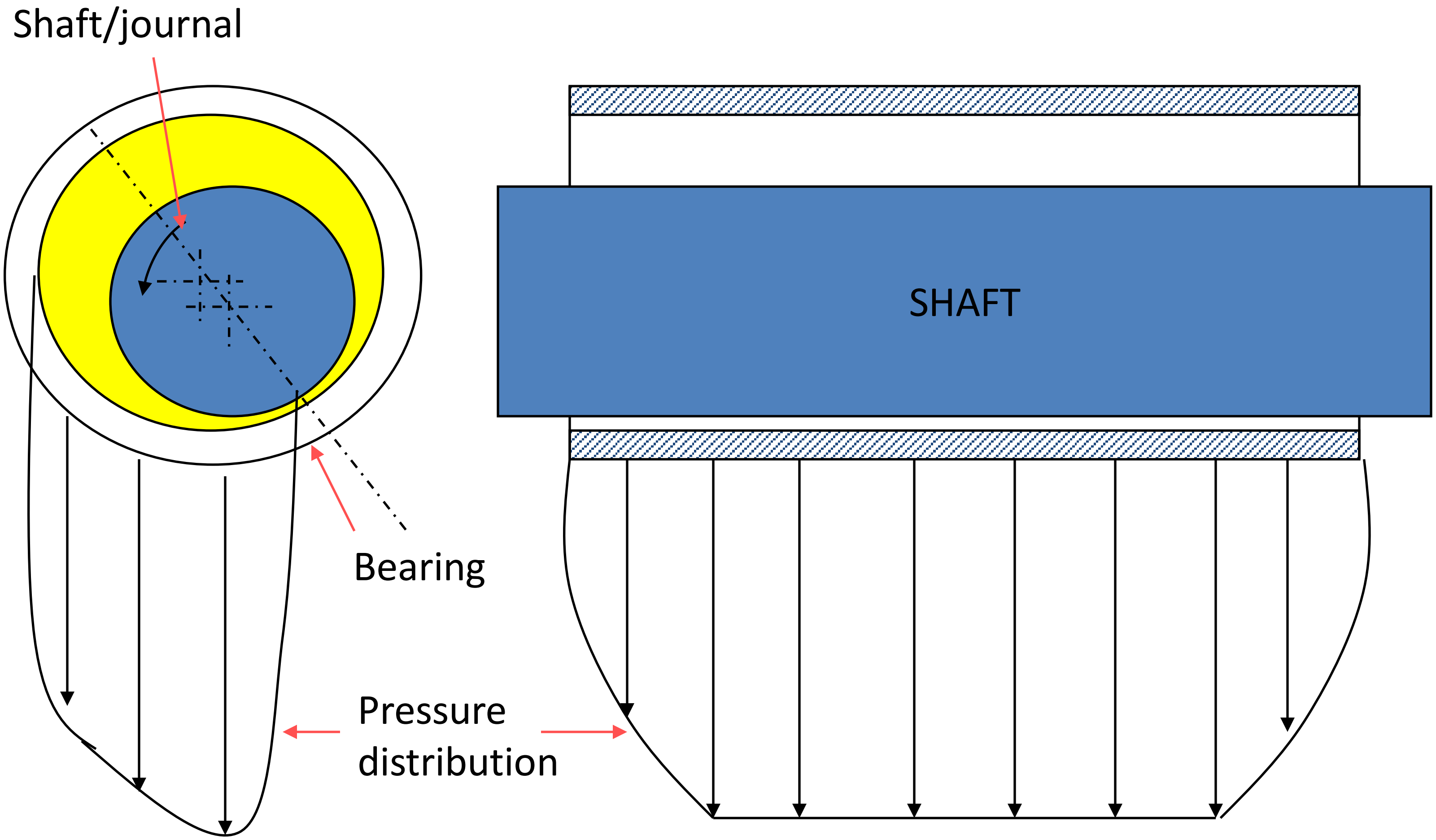
Instant of starting (tends to climb up the bearing)

While running (slips due to loss of traction and settles eccentric to bearing)

Because of the eccentricity, the wedge is maintained

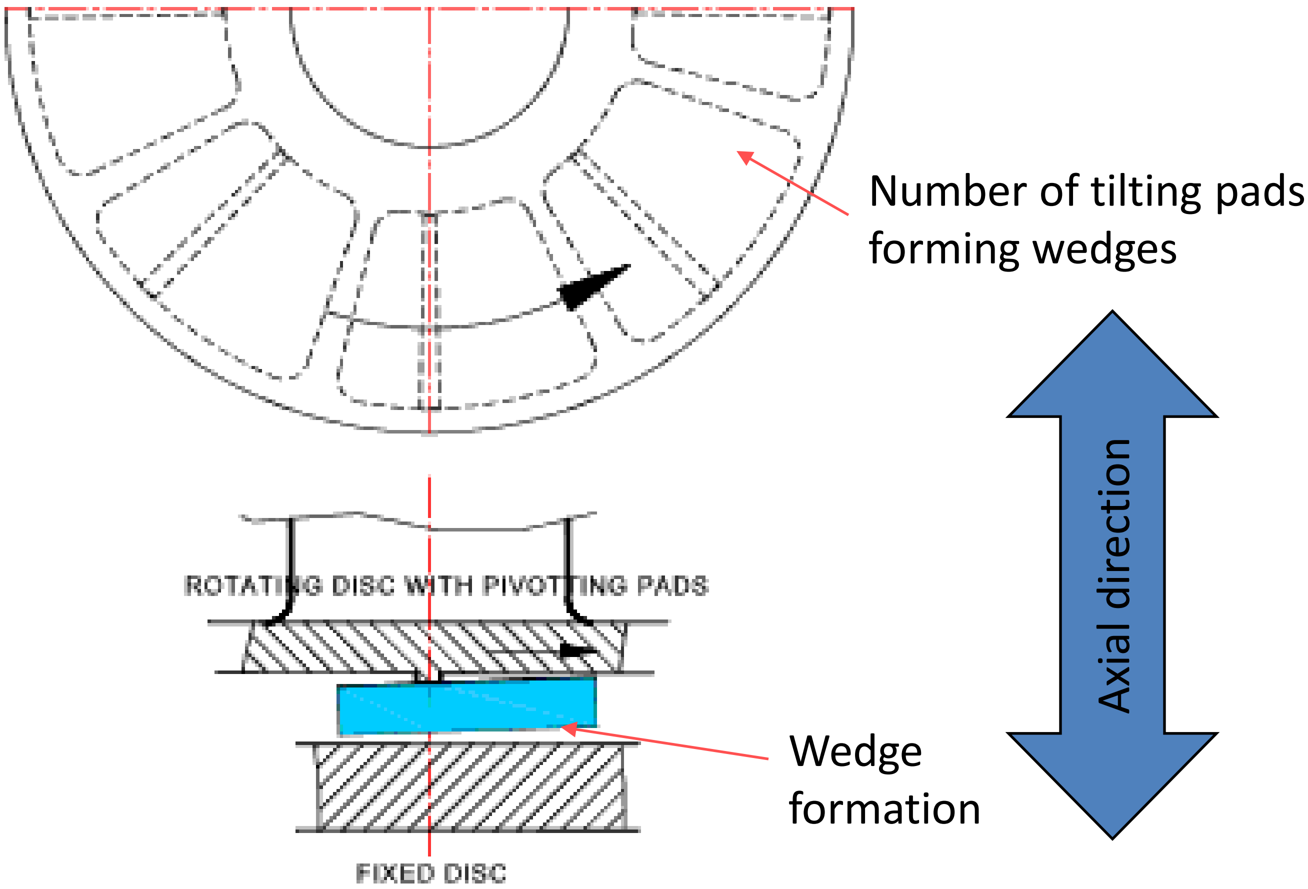
(lack of concentricity)

Pressure distribution in a journal bearing



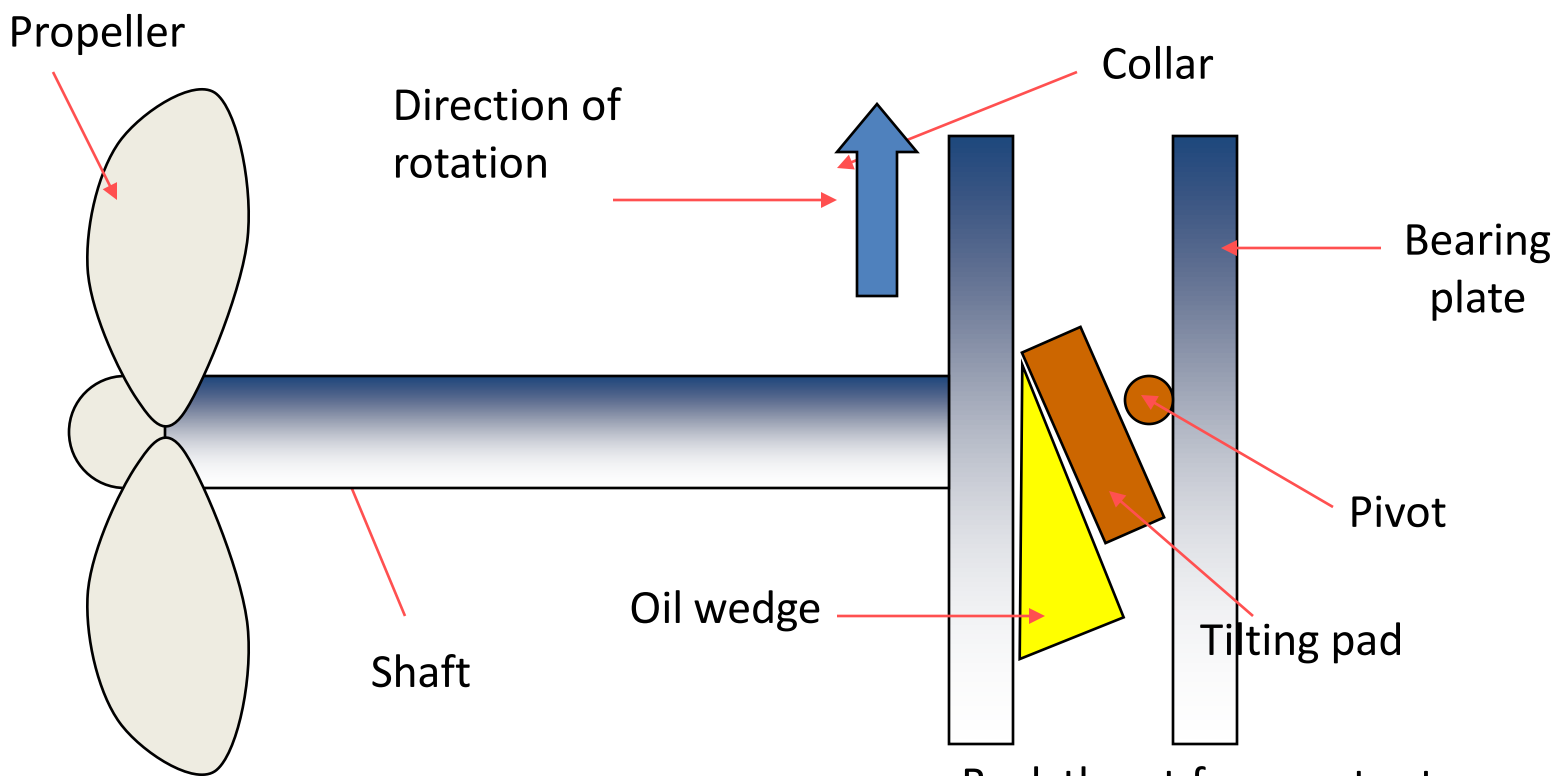
Max. pressure is reached somewhere in between the inlet and outlet
(close to outlet)

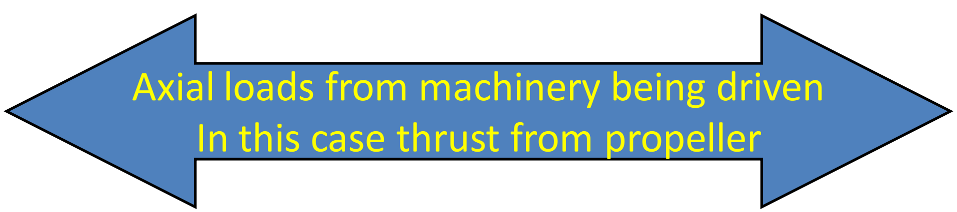
Tilting pad thrust bearings



Ref: http://www.roymech.co.uk/images3/lub_6.gif

Tilting pad thrust bearing





- Back thrust from water to propeller causes axial loading on the shaft
- Axial loads are opposed by pressure buildup in the wedge
- Gives a damping effect

Hydrodynamic lubrication- characteristics

- Fluid film at the point of minimum thickness decreases in thickness as the load increases
- Pressure within the fluid mass increases as the film thickness decreases due to load
- Pressure within the fluid mass is greatest at some point approaching minimum clearance and lowest at the point of maximum clearance (due to divergence)
- Viscosity increases as pressure increases (more resistance to shear)

Hydrodynamic lubrication- characteristics

- Film thickness at the point of minimum clearance increases with the use of more viscous fluids
- With same load, the pressure increases as the viscosity of fluid increases
- With a given load and fluid, the thickness of the film will increase as speed is increased
- Fluid friction increases as the viscosity of the lubricant becomes greater

Hydrodynamic condition- Fluid velocity

- Fluid velocity depends on velocity of the journal or rider
- Increase in relative velocity tends towards a decrease in eccentricity of journal bearing centers
- This is accompanied by greater minimum film thickness

Hydrodynamic condition- Load

- Increase in load decreases minimum film thickness
- Also increases pressure within the film mass to provide a counteracting force
- Pressure acts in all directions, hence it tends to squeeze the oil out of the ends of the bearing
- Increase in pressure increases fluid viscosity

Bearing characteristic number

Since viscosity, velocity, and load determine the characteristics of a hydrodynamic condition, a bearing characteristic number was developed based on the effects of these on film thickness.

- Increase in velocity increases min. film thickness
- Increase in viscosity increases min. film thickness
- Increase in load decreases min. film thickness

- **Therefore**

Viscosity x velocity/unit load = a dimensionless number = C

C is known as the Bearing Characteristic Number

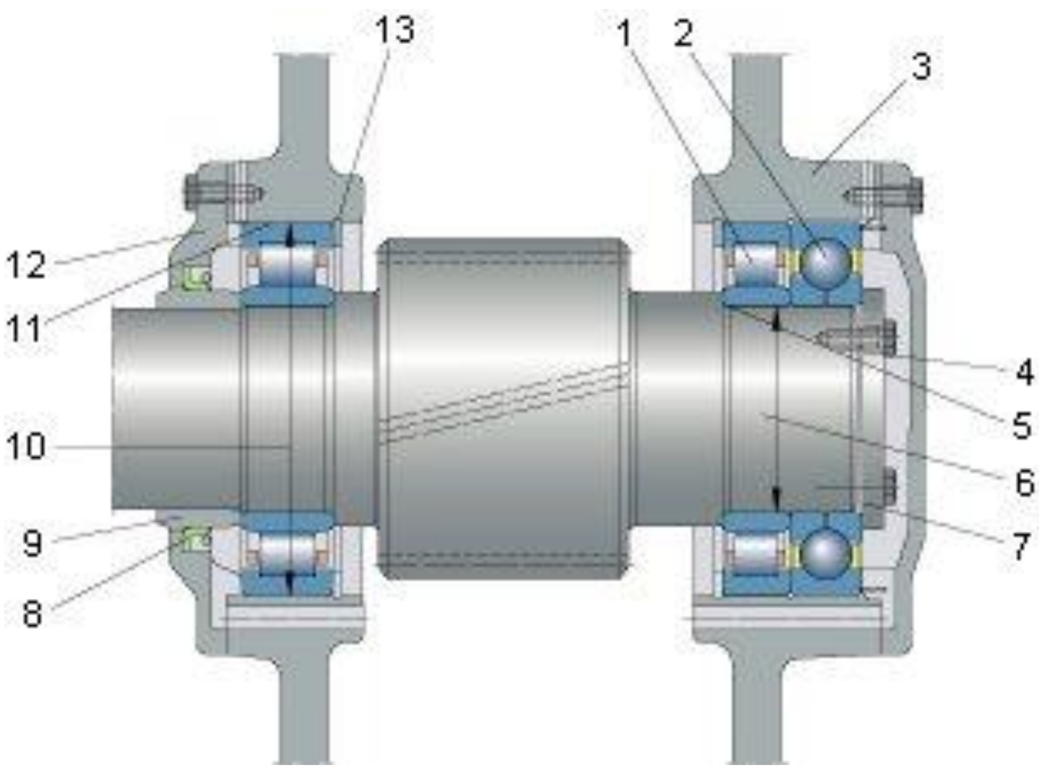
The value of C, to some extent, gives an indication of whether there will be hydrodynamic lubrication or not

Bearing Use in Design

Bearing Terminology

Bearing = Raceway Rolling Elements Cage Lubricant Seal

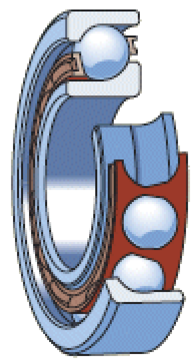
Bearing Arrangement Terminology



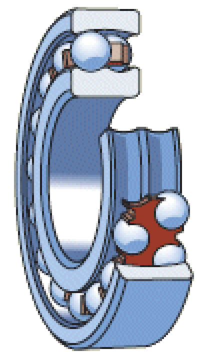
1. Cylindrical roller bearing
2. Four-point contact ball bearing
3. Housing
4. Shaft
5. Shaft abutment shoulder
6. Shaft diameter
7. Locking plate
8. Radial shaft seal
9. Distance ring
10. Housing bore diameter
11. Housing bore
12. Housing cover
13. Snap ring

Radial Bearing Types

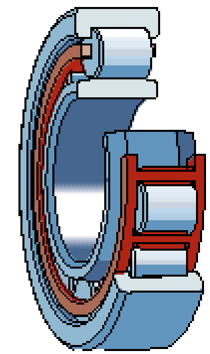
Deep Groove



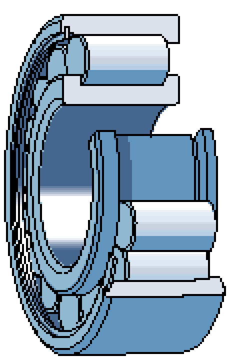
Angular Contact



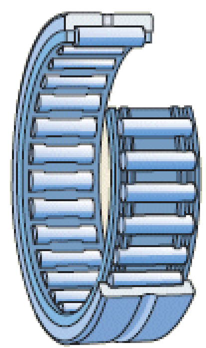
Self Aligning



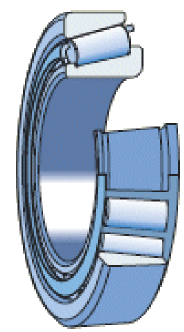
Cylindrical Roller



Full Complement
Cylindrical Roller

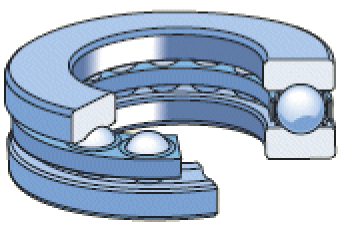


Needle Roller

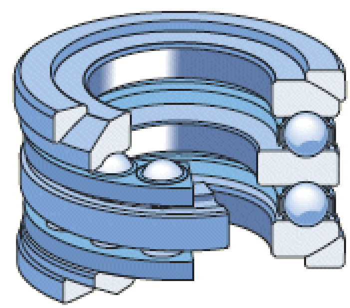


Tapered Roller

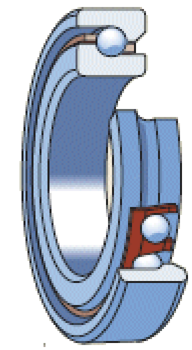
Thrust Bearing Types



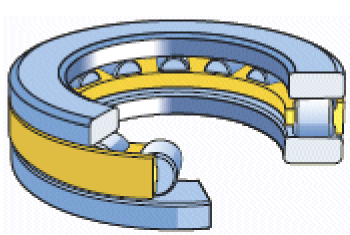
Thrust Ball
Bearing
Single Direction



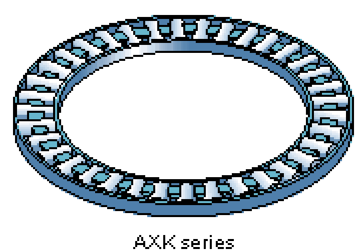
Thrust Ball
Bearing
Double Direction



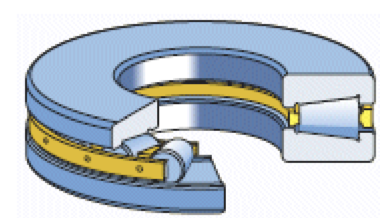
Angular Contact



Cylindrical Roller



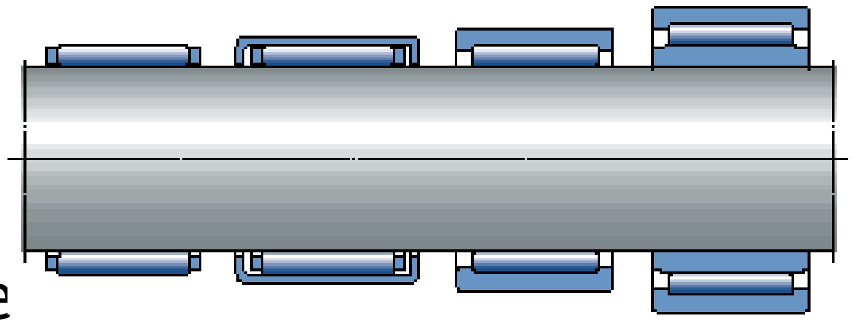
Needle Roller



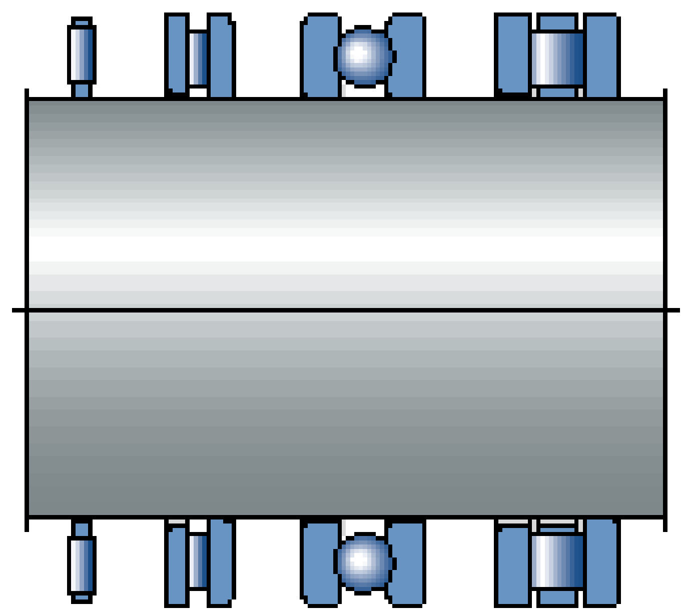
Tapered Roller

Bearing Selection – Space

- Limited Radial Space
  - Choose bearing with low cross-sectional height
  - EX. Needle roller and cage assemblies

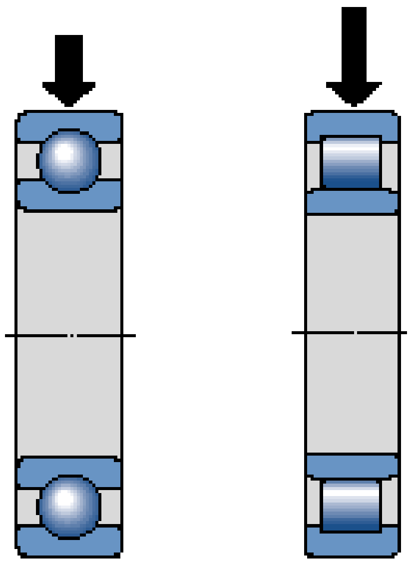


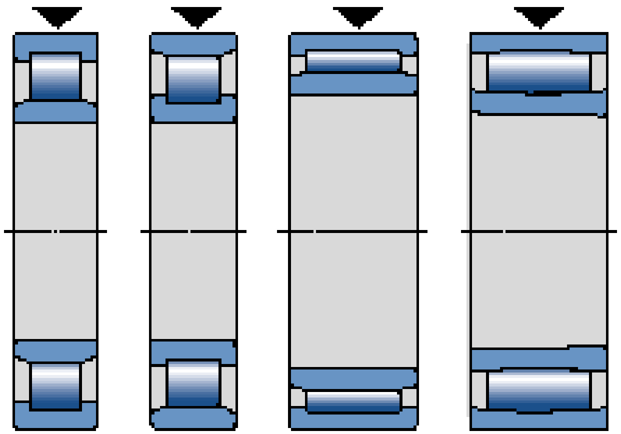
- Limited Axial Space
  - Choose bearings that can handle combined loads
  - EX. Cylindrical roller, deep groove, needle roller



Bearing Selection – Loads

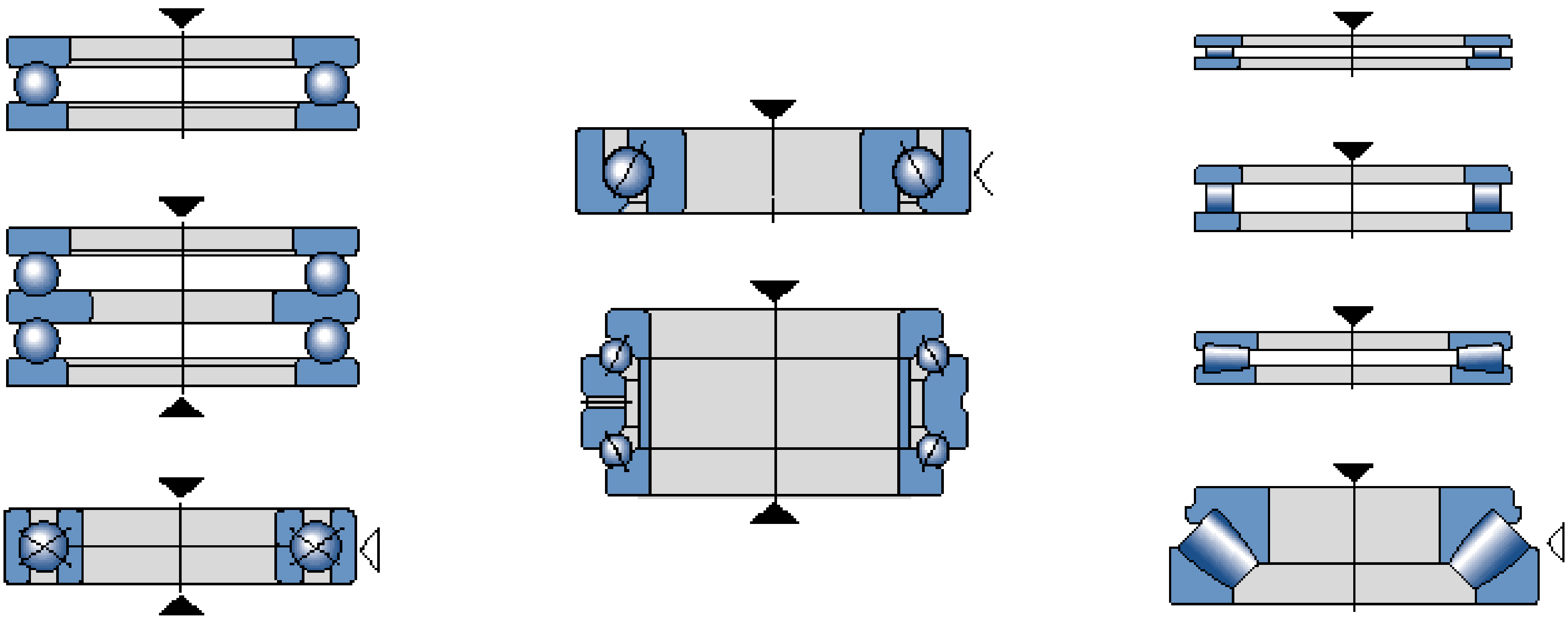
- Magnitude
  - Roller bearings support heavier loads than similar sized ball bearings
  - Full complement roller bearings support heavier loads than corresponding caged bearings
- Radial
  - Some cylindrical roller and all needle roller





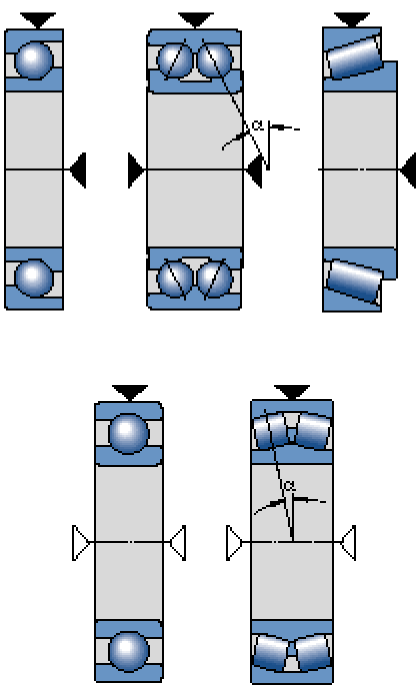
Bearing Selection – Loads

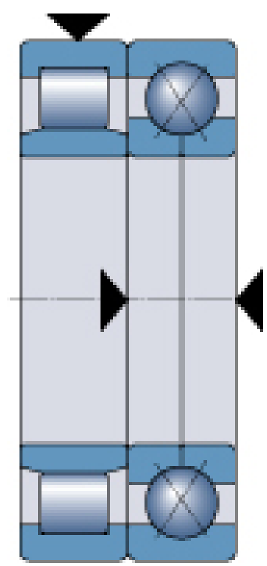
- Axial
  - Thrust ball bearing and four-point contact ball
  - Angular contact thrust ball bearings

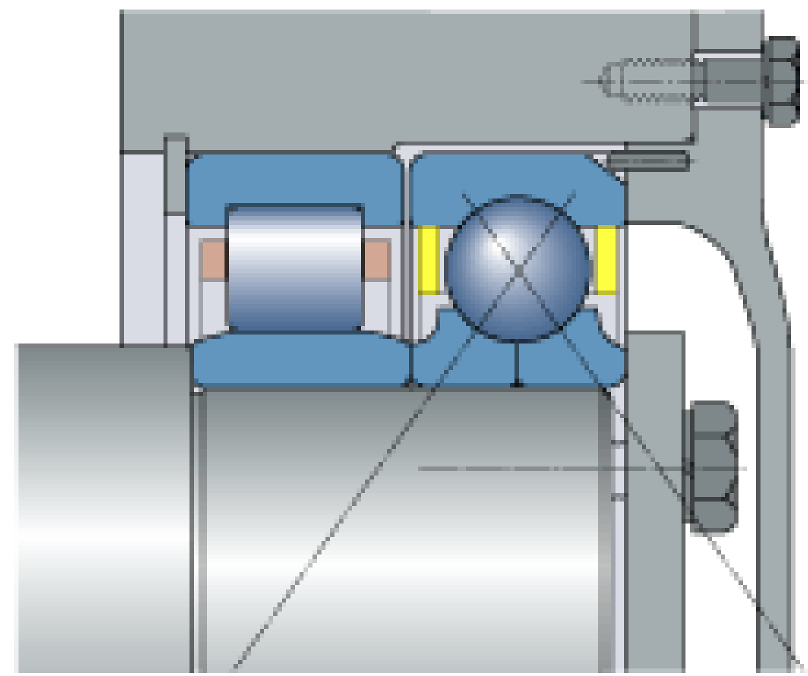


Bearing Selection – Loads

- Combined
  - Greater the angle of contact, greater ability to handle axial loads

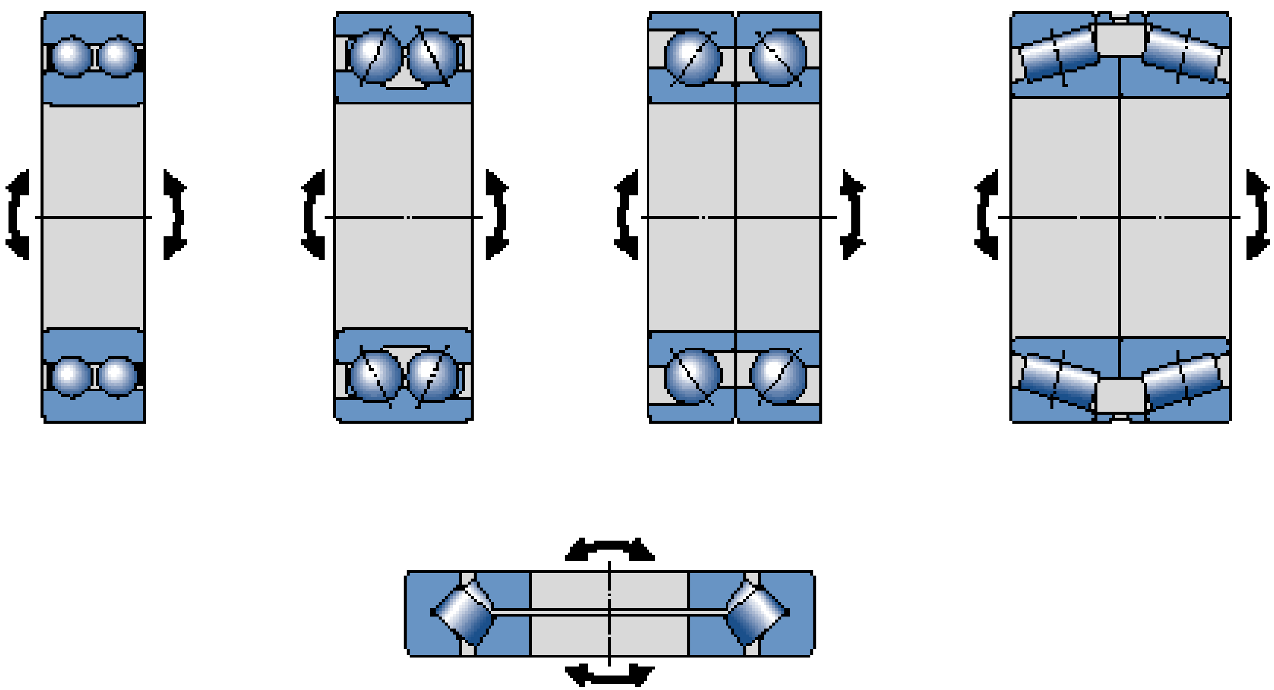






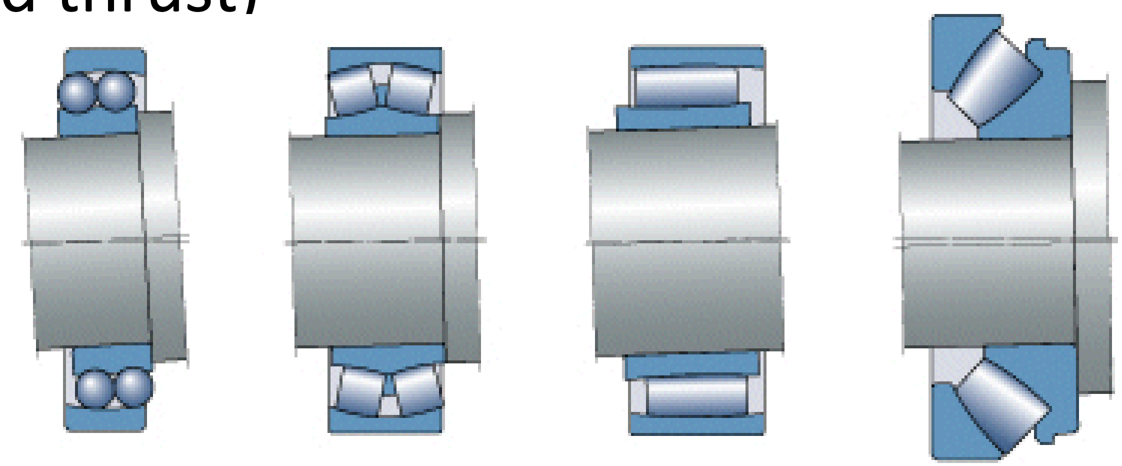
Bearing Selection – Loads

- Moment
  - Eccentric loads resulting in tilting moment
  - Best: paired single row angular contact bearings or tapered roller bearings



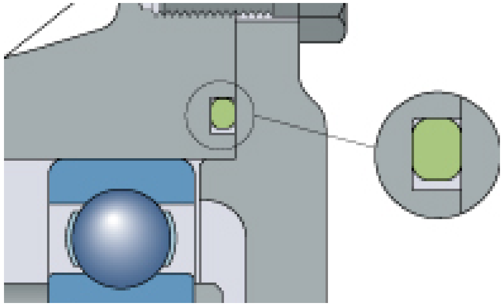
Bearing Selection – Misalignment

- Rigid Bearings
  - Deep groove and cylindrical roller
    - Cannot accommodate misalignments well
- Accommodating Bearings
  - Self-aligning ball bearings, spherical roller (radial and thrust)

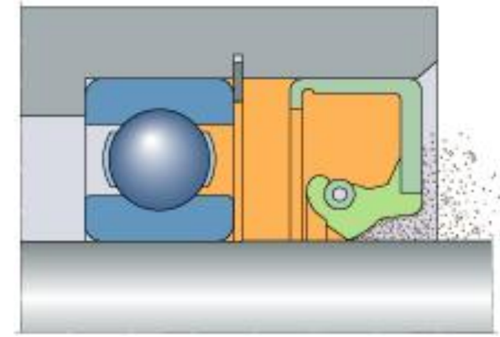


Bearing Selection – Speed

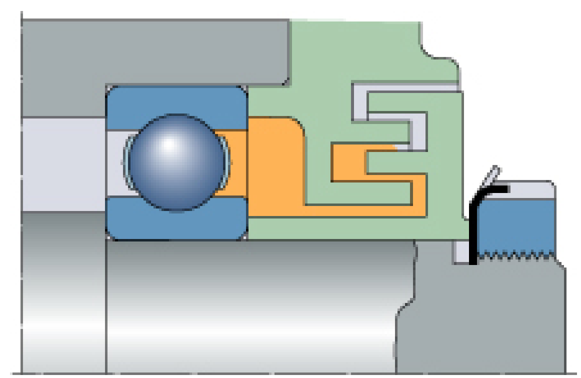
- Highest Speeds
  - Purely Radial Loads
    - Deep Groove Ball Bearings
    - Self Aligning Ball Bearings
  - Combined Loads
    - Angular Contact
- Thrust bearings cannot accommodate as high speeds as radial



Seals

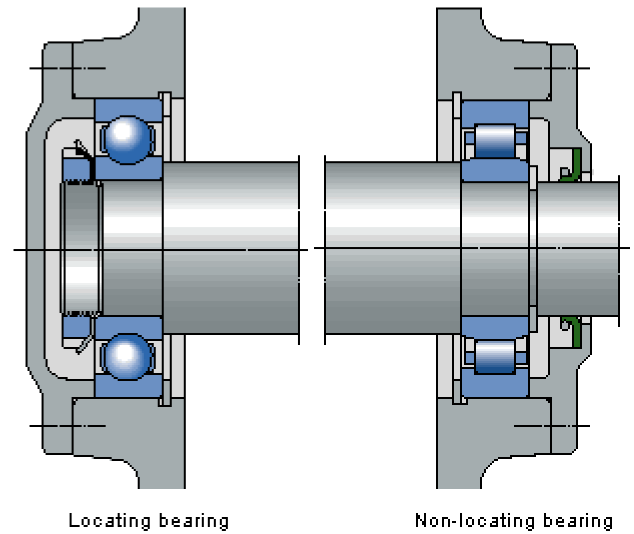


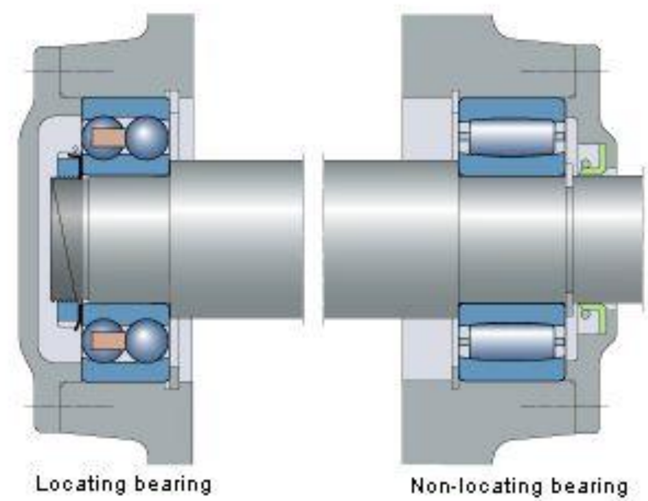
- Purpose
  - Keep contaminants out, and lubricant in the bearing cavity
- Types
  - Seals in contact with stationary surfaces (static) / sliding surfaces (dynamic)
  - Non-contact seals
  - Bellows and membranes



Bearing Arrangement

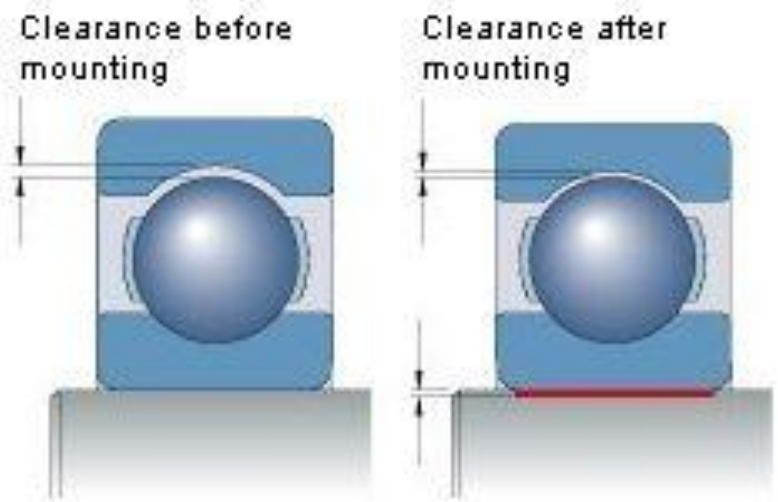
- Locating and Non-locating
  - Stiff
    - Deep groove ball bearing with cylindrical roller bearing
  - Self-Aligning
    - Self-aligning ball bearing with toroidal roller bearing

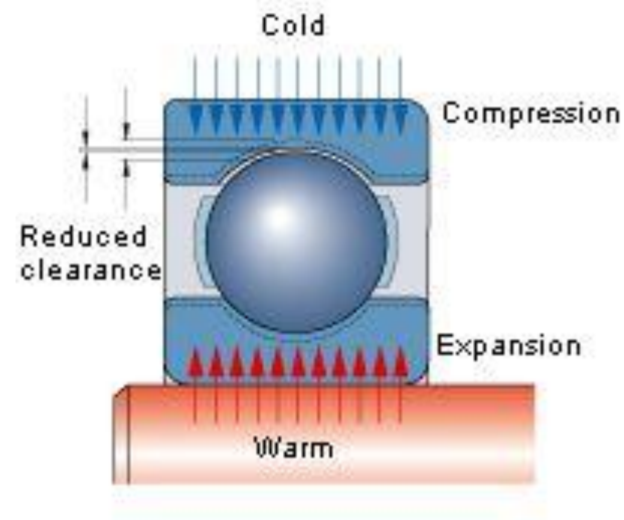




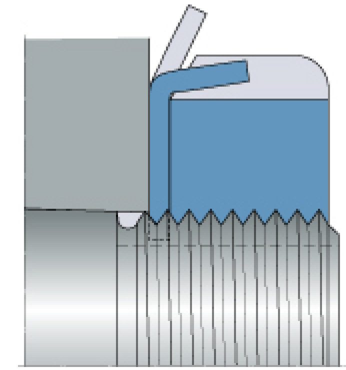
Selection of Fit

- The heavier the load, particularly if it is a shock load, the greater the interference fit
- Elements will heat up differently causing expansion
- Tolerances on shaft and housing
- http://www.skf.com/group/products/bearings-units-housings/ball-bearings/principles/application-of-bearings/radial-location-of-bearings/selection-of-fit/recommended-fits/index.html

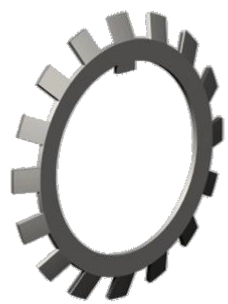




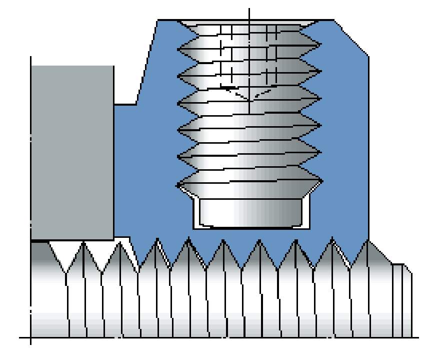
Methods of Location



- Locking Washer
  - Washer engages keyway in shaft
  - Tab is bent over into slot on circumference of nut


- Locking Screw
  - Prevents nut from turning



Bearing Load

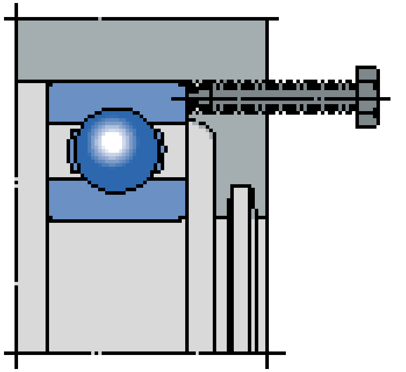
- Dynamic
  - Load to failure after 1,000,000 revolutions (ISO 281:1990)
  - Shows metal fatigue (flaking, spalling) on rings or rolling elements
- Static
  - Rotate at slow speeds (< 10 RPM)
  - Perform very slow oscillating movements
  - Stationary under load for certain extended periods

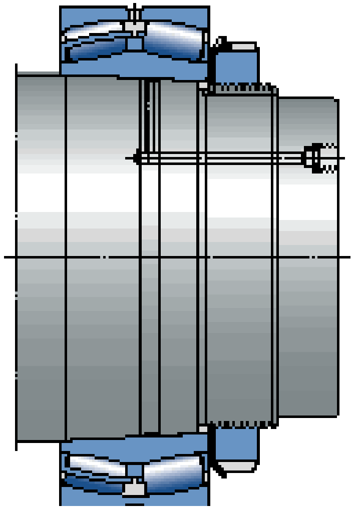
Service Life Factors

- Contamination
- Wear
- Misalignment
- Corrosion
- Cage Failure
- Lubrication
- Seal

Designing For Disassembly

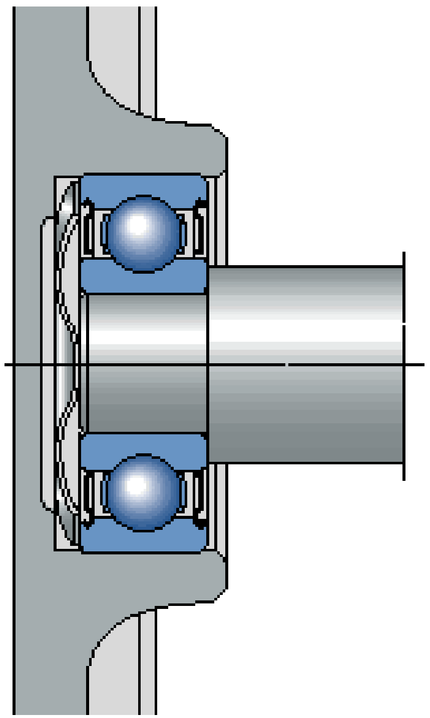
- Add threaded holes to use screws to ‘jack’ bearings out of housings
- Add porting and grooves to use high pressure oil to dismount bearings



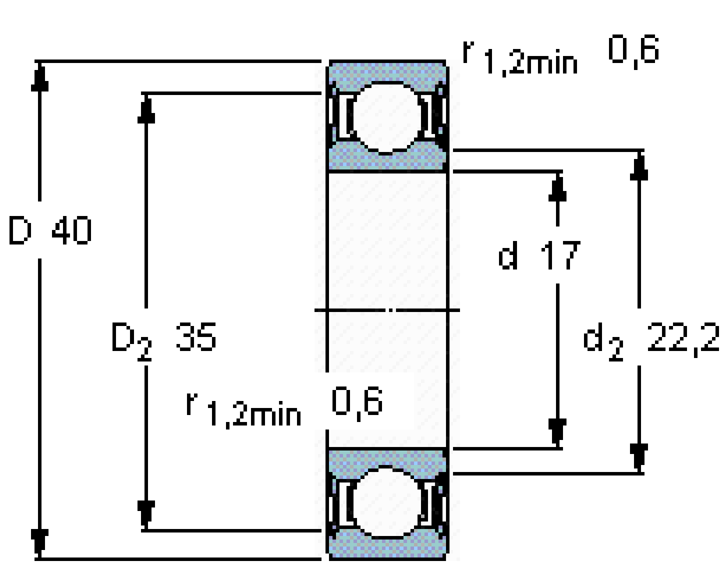


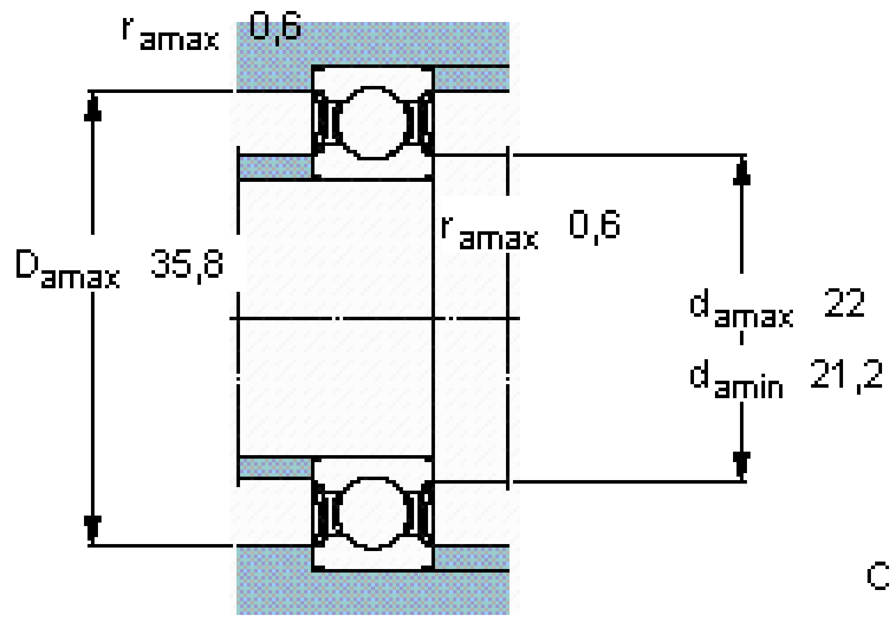
Introducing Pre-Load

- Enhance stiffness
- Quiet running
- Accurate shaft guidance
- Compensates for wear and settling
- Longer service life



Bearing Example





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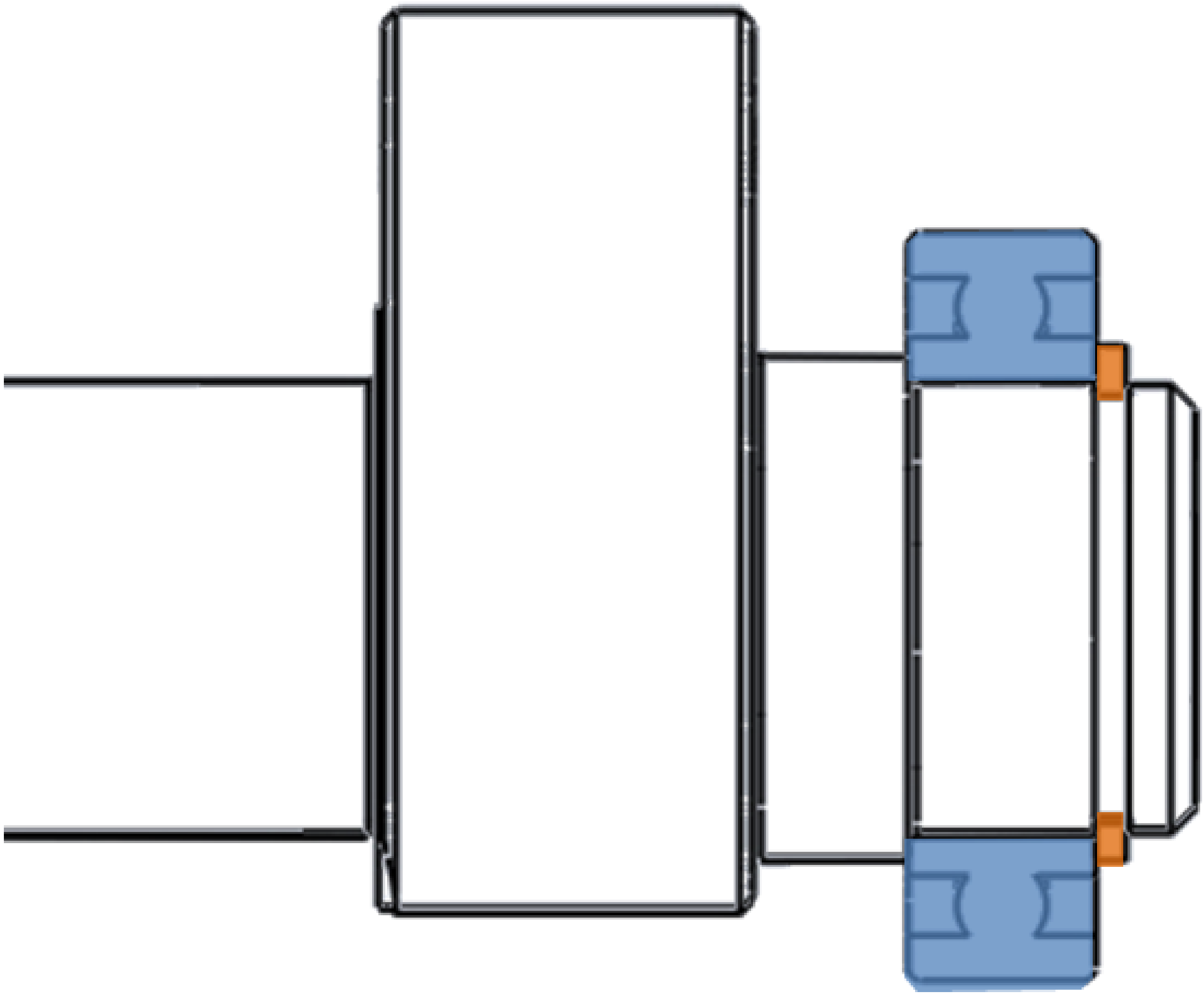
Designing Shafts for Bearings



Unit-II
IC Engine Components

Main parts
- structural parts (stationary p.)
- running parts

Systems

Structural parts

PURPOSE:

- to support running parts
- to keep them in position and line
- to provide jackets and passages for cooling water, sumps, for lube oil
- to form protective casing for running parts
- to support auxiliaries (valves, camshaft, turbo blowers)

Running parts

PURPOSE

- to convert the power of combustion in the cylinders to mechanical work

Systems

PURPOSE

- Supply of air
- Removal of exhaust
- Turbocharging
- Supply and injection of fuel
- Lubrication
- Cooling

Structural parts

bedplate

frame or column

engine or cylinder block

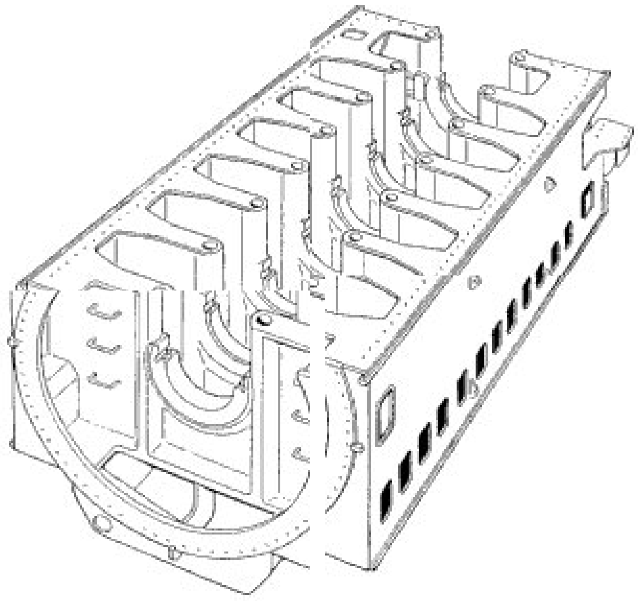
cylinder liners

cylinder head or cover

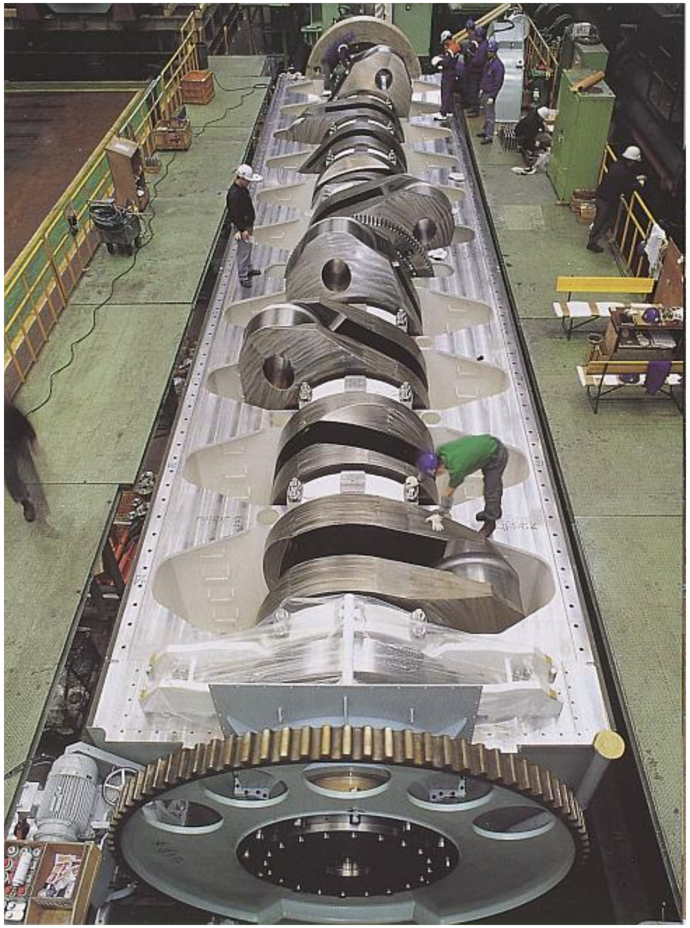
Bedplate

- foundation on which the engine is built
- must be rigid enough to support the rest of the engine and hold the crankshaft which sits on the bearing housing in alignment with transverse girders
- at the same time, the bedplate has to be flexible enough to hog and sag with the foundation plate to which it is attached and which forms part of the ship structure

Bedplate



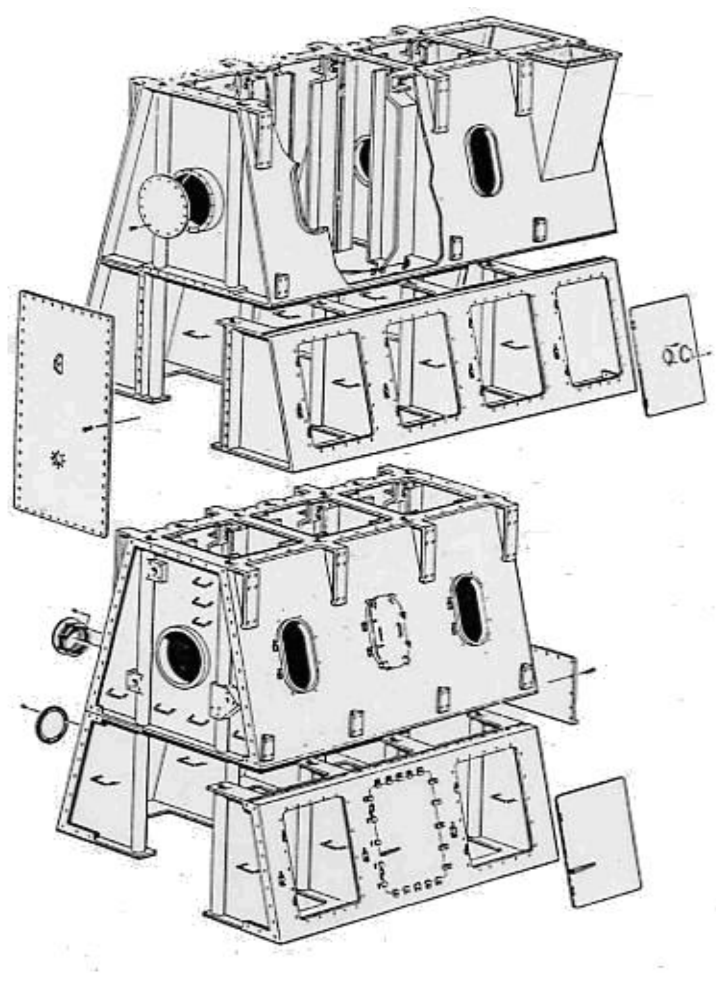
Bedplate



Frame

- load-carrying part of an engine
- it may include parts as the cylinder block,base, sump and end plates
- in two-stroke engines, frames are sometimes known as A-frames

Frame



(MAN engine)

Cylinder Block

=engine block

- part of the engine frame that supports the engine cylinder liners, heads and crankshafts
- cylinder blocks for most large engines are made of castings and plates that are welded horizontally and vertically for strength and rigidity (stiffener)
- *entablature* = cylinder block which incorporates the scavenge air spaces in two-

Cylinder block

Cylinder liner

- a bore in which an engine piston moves back and forth
- replaceable
- the material of the liner must withstand extreme heat and pressure developed within the combustion space at the top of the cylinder, and at the same time must permit the piston and its sealing rings to move with a minimum of friction

Cylinder liner

Dry liner

Wet liner

Cylinder liner

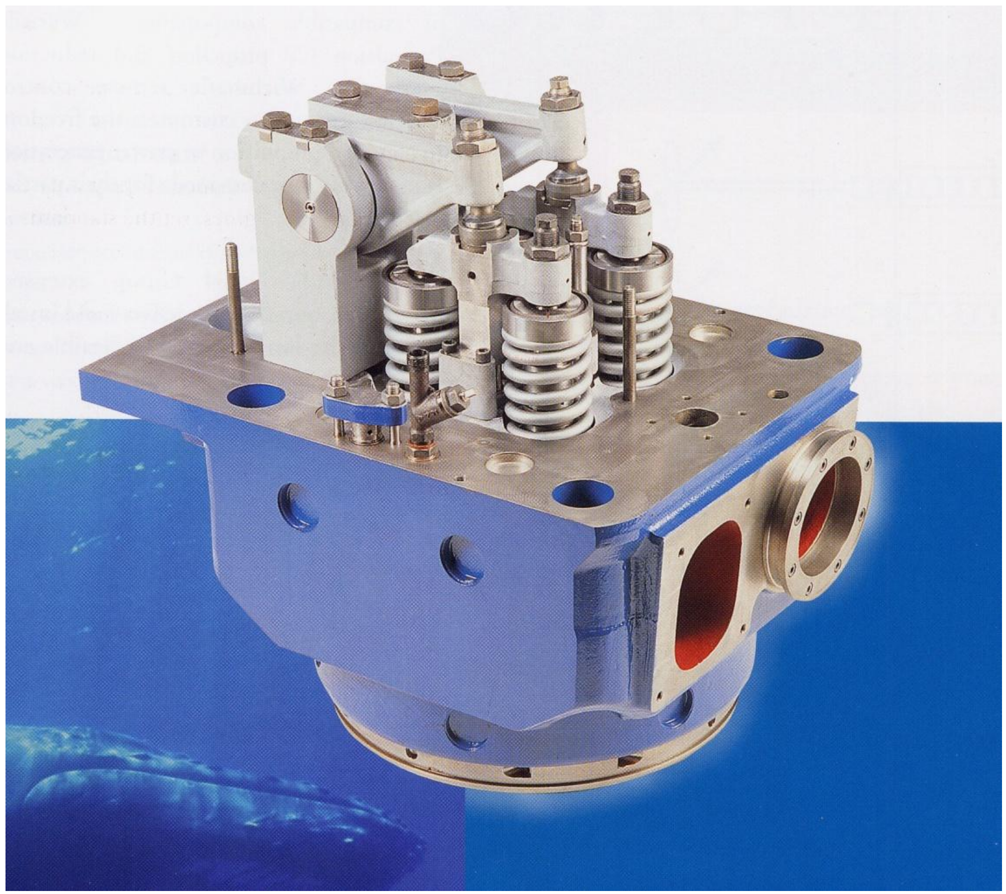
Cylinder head

= cylinder cover

- the space at the combustion chamber top is formed and sealed by a cylinder head
- the cylinder head of a four-stroke engine houses intake and exhaust valves, the fuel injection valve, air starting vale, safety valve

(the two-stroke engine lacks the intake valve)

Cylinder head



Major running parts

piston

piston rod

crosshead

connecting rod

crankshaft & its bearings

Piston

- one of the major moving parts
- crown
- skirt
- must be designed to withstand extreme heat and combustion pressure
- made of cast iron or aluminium (to reduce weight)

Piston

Piston rod

- connects the piston with the crosshead

Piston rod

Crosshead

- the crosshead pin connects the piston rod to the connecting rod
- crosshead slippers are mounted on either side of the crosshead pin
- the slippers run up and down in the crosshead guides and prevent the connecting rod from moving sideways as the piston and rod reciprocate

Connecting rod

- it is fitted between the crosshead and the crankshaft
- it transmits the firing force, and together with the crankshaft converts the reciprocating motion to a rotary motion

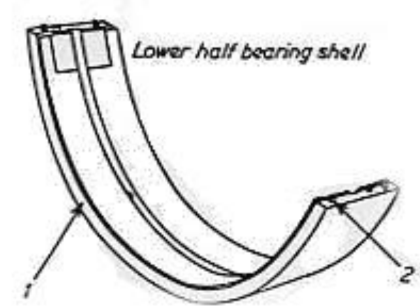
Connecting rod

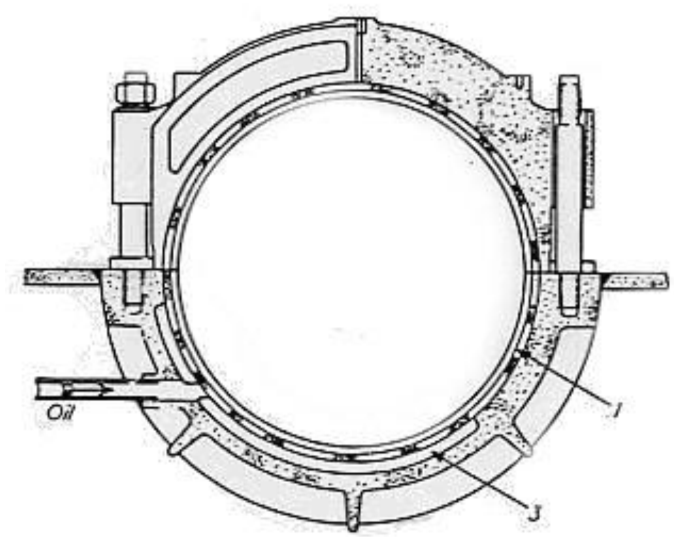
Crankshaft & its bearings

- one of the largest moving parts
- it consists of a series of cranks formed in a shaft
- converts reciprocating motion of the piston into rotary motion
- counterweights for balancing purposes

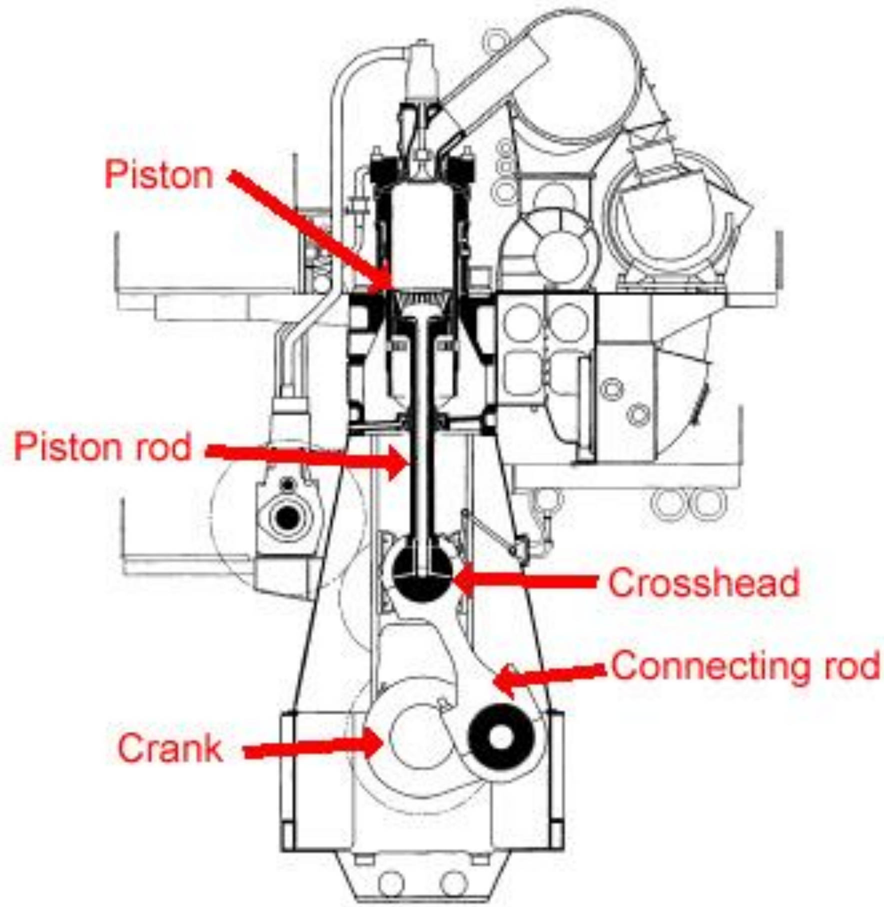
Crankshaft

Bearings





Major running parts



Arrangements for the air supply and gas exhaust:

valves (inlet & exhaust), valve gear (camshaft & camshaft drive, push rod, rocker arm, spring), manifolds, scavenging and supercharging (turboblower systems)

Fuel injection system

fuel pump, high pressure piping, injector, nozzle

Engine Parameters

- **Cylinder bore** – inner diameter of the cylinder (in mm or cm)
- **Stroke** – the distance the piston travels between top and bottom dead centers (in mm or cm)
- **Engine speed** – speed at which the crankshaft rotates (measured in revolutions per minute) between two consecutive overhauling

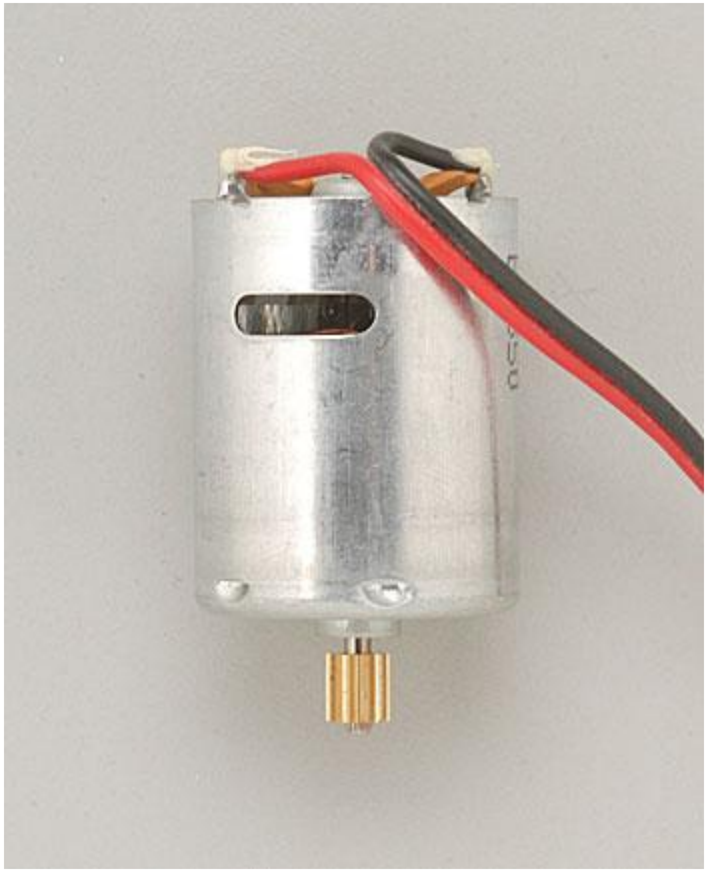
UNIT-3 : GEARS

Gears

- Rugged
- Durable
- Can transmit power with up to 98% efficiency
- Long service life

Motors

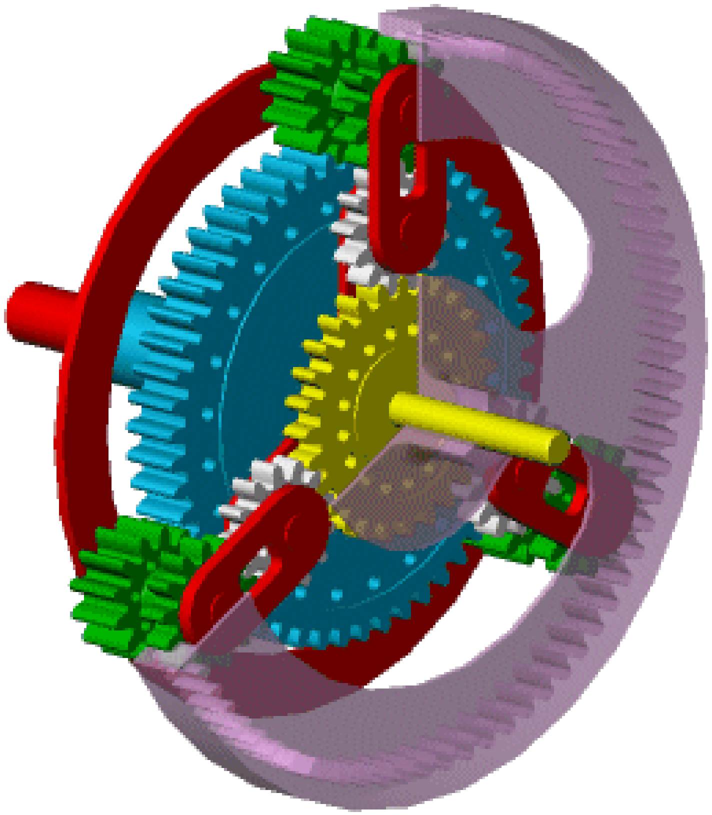
- Motors convert electrical energy to mechanical energy.
- Mechanical energy moves our robot
- Motors drive the gears



http://www2.towerhobbies.com/cgi-bin/wti0001p?&I=LR9520&P=DS

Gears

- Spur
  - Flat
  - Pinion
- Bevel
  - Crown
- Worm
- Rack and Pinion
- Differential



www.mathworks.com

Gears

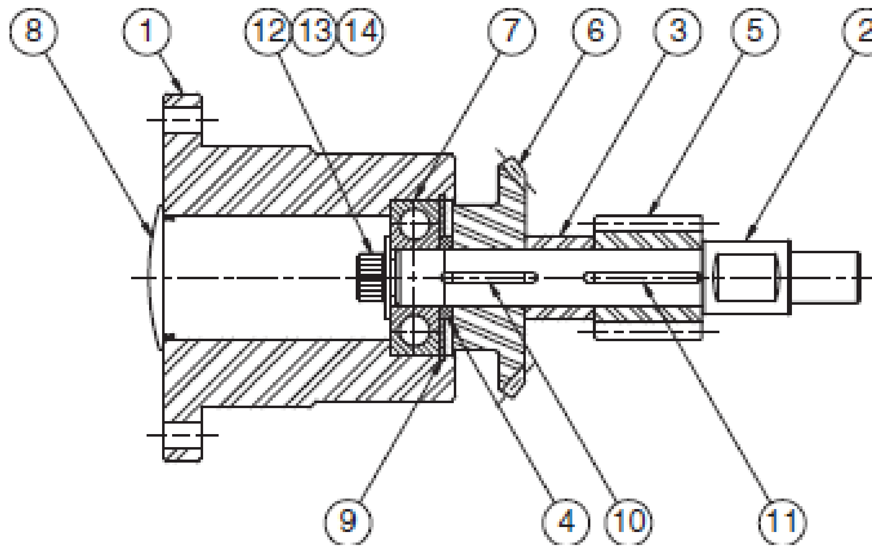
- Toothed wheels fixed to an axle.
- Drive gear – connected to the input axle.
- Driven gear – connected to the output axle.
- Gear train – when an number of gears are connected together.

$$\text{Gear Ratio} = \frac{\text{Number of driven teeth (output)}}{\text{Number of driver teeth (input)}}$$

Gear and Bearing Assemblies

- Use as few views as possible
  - A full sectional view may be the only view necessary
- Dimensions are normally omitted
- Typically include balloons correlated with a parts list
- May include torque data and lubricant information

Gear and Bearing Assemblies



Applications of Gears

- ***Toys and Small Mechanisms*** **– small, low load, low cost**

  kinematic analysis
- ***Appliance gears*** **– long life, low noise & cost, low to moderate load**

  kinematic & some stress analysis
- ***Power transmission*** **– long life, high load and speed**

  kinematic & stress analysis
- ***Aerospace gears*** **– light weight, moderate to high load**

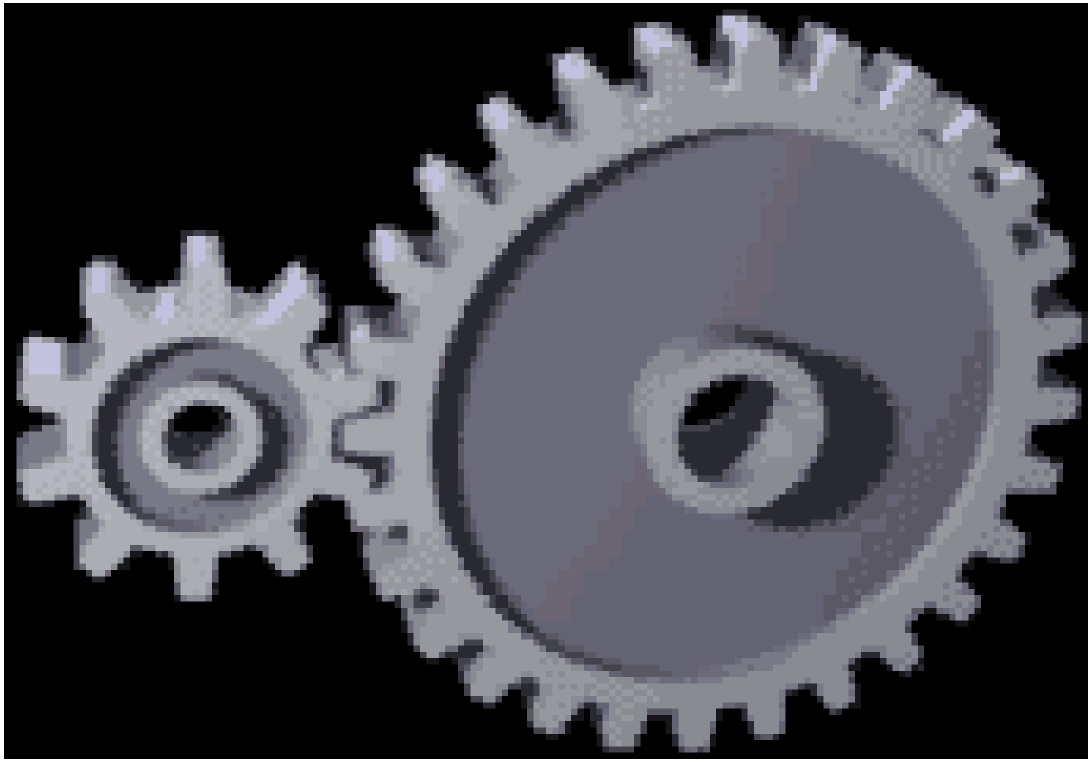
  kinematic & stress analysis
- ***Control gears*** **– long life, low noise, precision gears**

  kinematic & stress analysis

Spur Gears

- Straight teeth mounted on parallel shafts
- Many used at once to create very large gear reductions

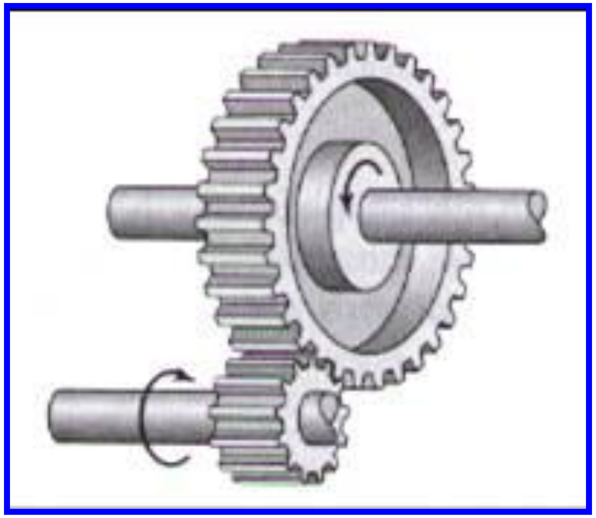
- Flat
- Pinion



http://en.wikipedia.org/wiki/Gear#Worm_gear

Types of Gears

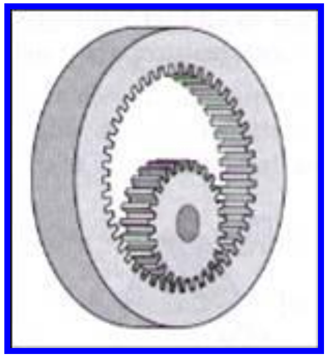
Gear (large gear)



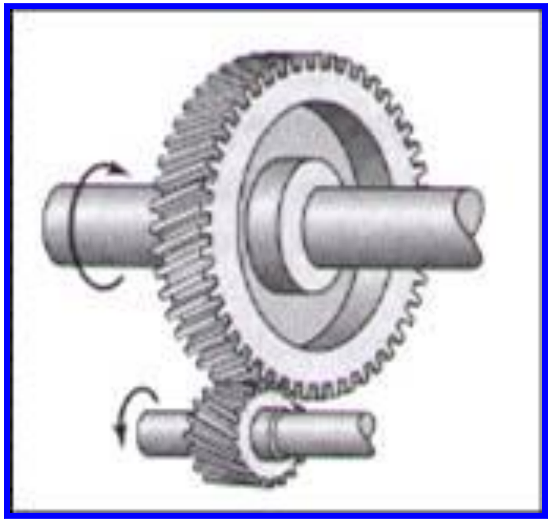
Pinion (small gear)

Spur gears – tooth profile is parallel to the axis of rotation, transmits motion between parallel shafts.

Internal gears



Helical gears – teeth are inclined to the axis of rotation, the angle provides more gradual engagement of the teeth during meshing, transmits motion between parallel shafts.



Spur Gear Terminology

- Teeth are straight and parallel to the gear shaft axis
- Establish gear tooth profile using an involute curve
- Basic rule:
  - No fewer than 13 teeth on the running gear and 26 teeth on the mating gear

Spur Gear Terminology

- Pressure angle
  - 14.5°and 20°are standard
- Diametral pitch
- Gear accuracy
  - Maximum tooth-to-tooth tolerances allowed, as specified by the American Gear Manufacturers Association (AGMA)
- Several additional formulas and specifications

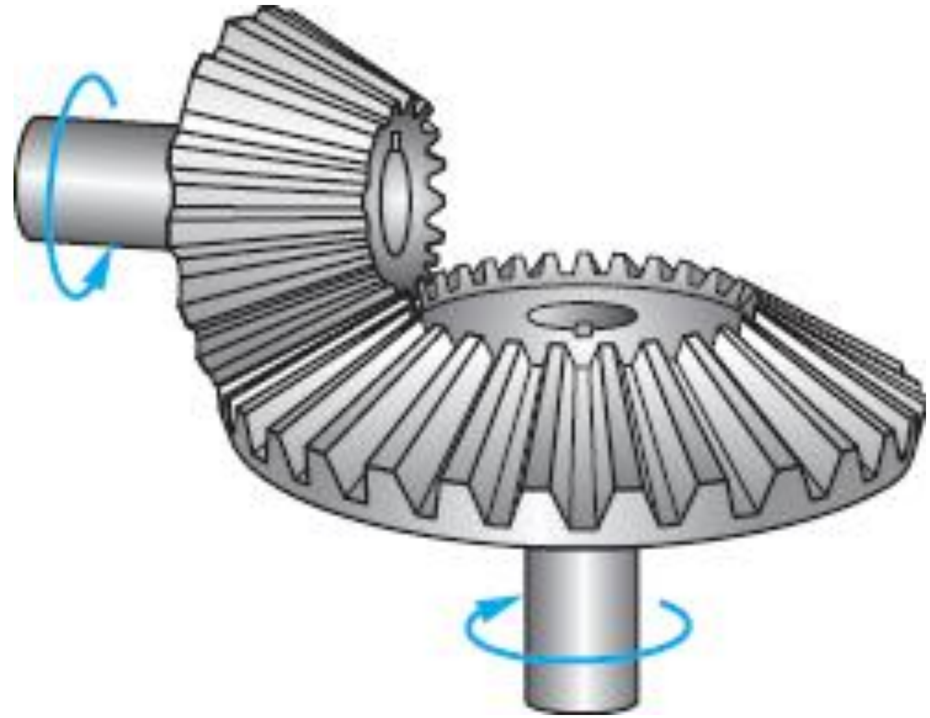
Bevel Gears

– Gears that mesh at an angle, usually 90°
– Changes the direction of rotation

http://science.howstuffworks.com/gear4.htm

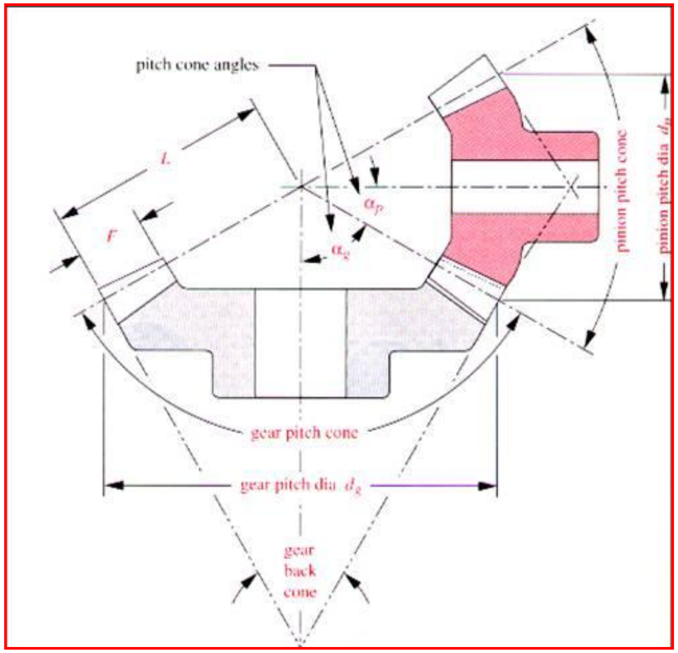
Bevel Gears

- Shafts of the gear and pinion can intersect at 90°or any desired angle
- Provide for a speed change between the gear and pinion, unless designed as miter gears

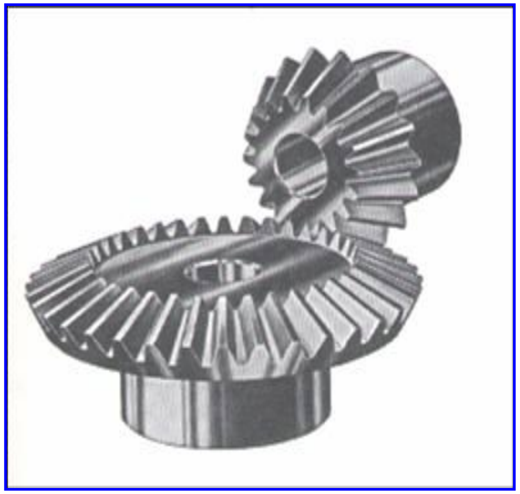


Types of Gears

Bevel gears – teeth are formed on a conical surface, used to transfer motion between non-parallel and intersecting shafts.



Straight bevel gear



Spiral bevel gear

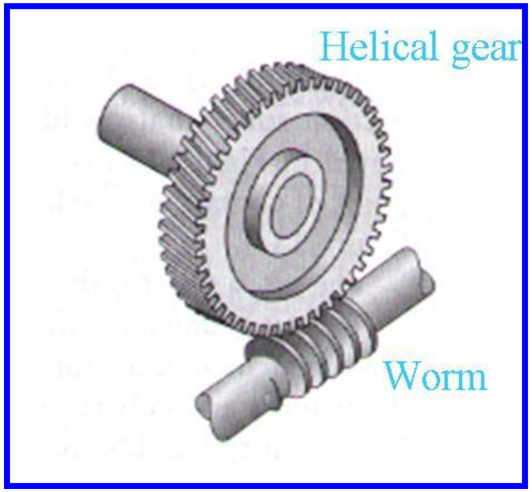
Crown Gears

- Special form of bevel gear
- Has right angles to the plane of the wheel

http://www.plastic-gear-manufacturer.com/industrial-gear.htm

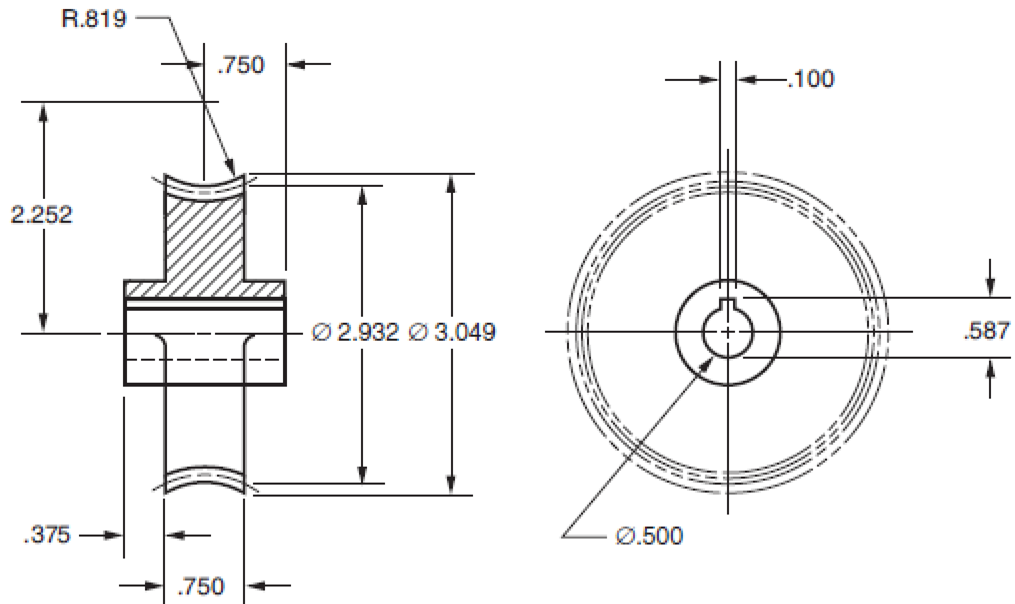
Worm Gears

- Changes the direction of turning motion by 90°
- Decreases the speed of turning from screw to gear and increases the force



http://blogs.toolbarn.com/brianm/labels/Tool%20Inner%20Workings.html

Worm Gear Print



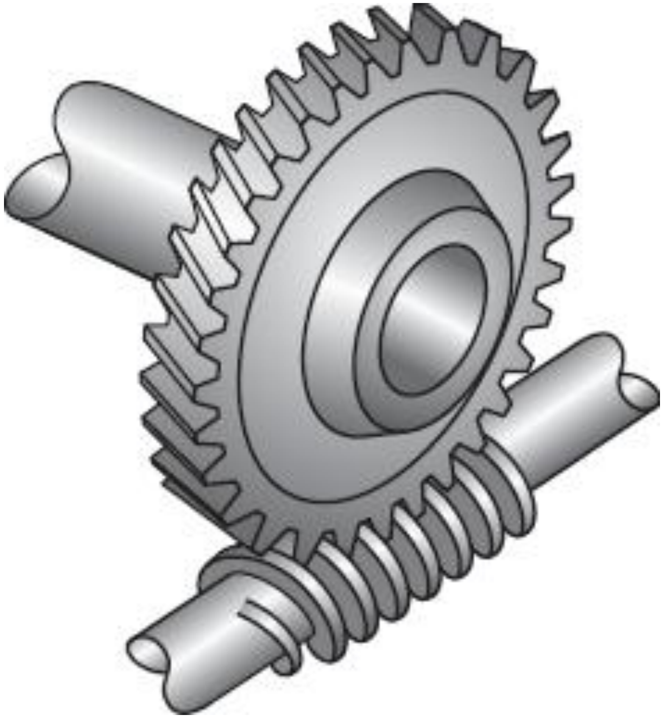
3. PITCH TOLERANCE ±.002.
2. INTERPRET GEAR DATA PER ANSI Y14.7.1.
1. INTERPRET DIMENSIONS AND TOLERANCES PER ANSI Y14.5M.

NOTES:

WORM GEAR DATA	
NUMBER OF TEETH	27
PITCH DIAMETER	2.933
ADDENDUM	.057
WHOLE DEPTH	.114
TOOTH THICKNESS	.100

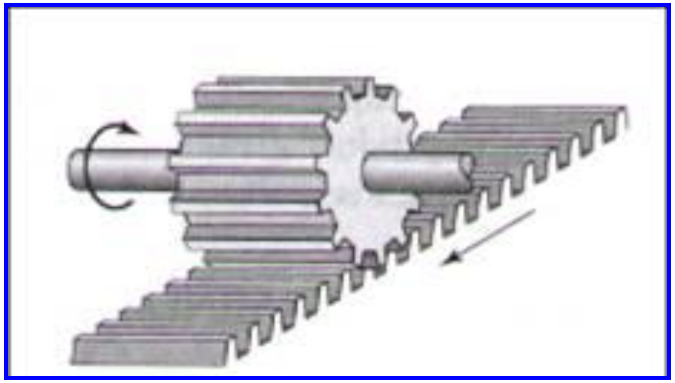
Worm Gears

- Use a worm and worm gear
- Large speed reduction in a small space
- Worm locks in place when not in operation

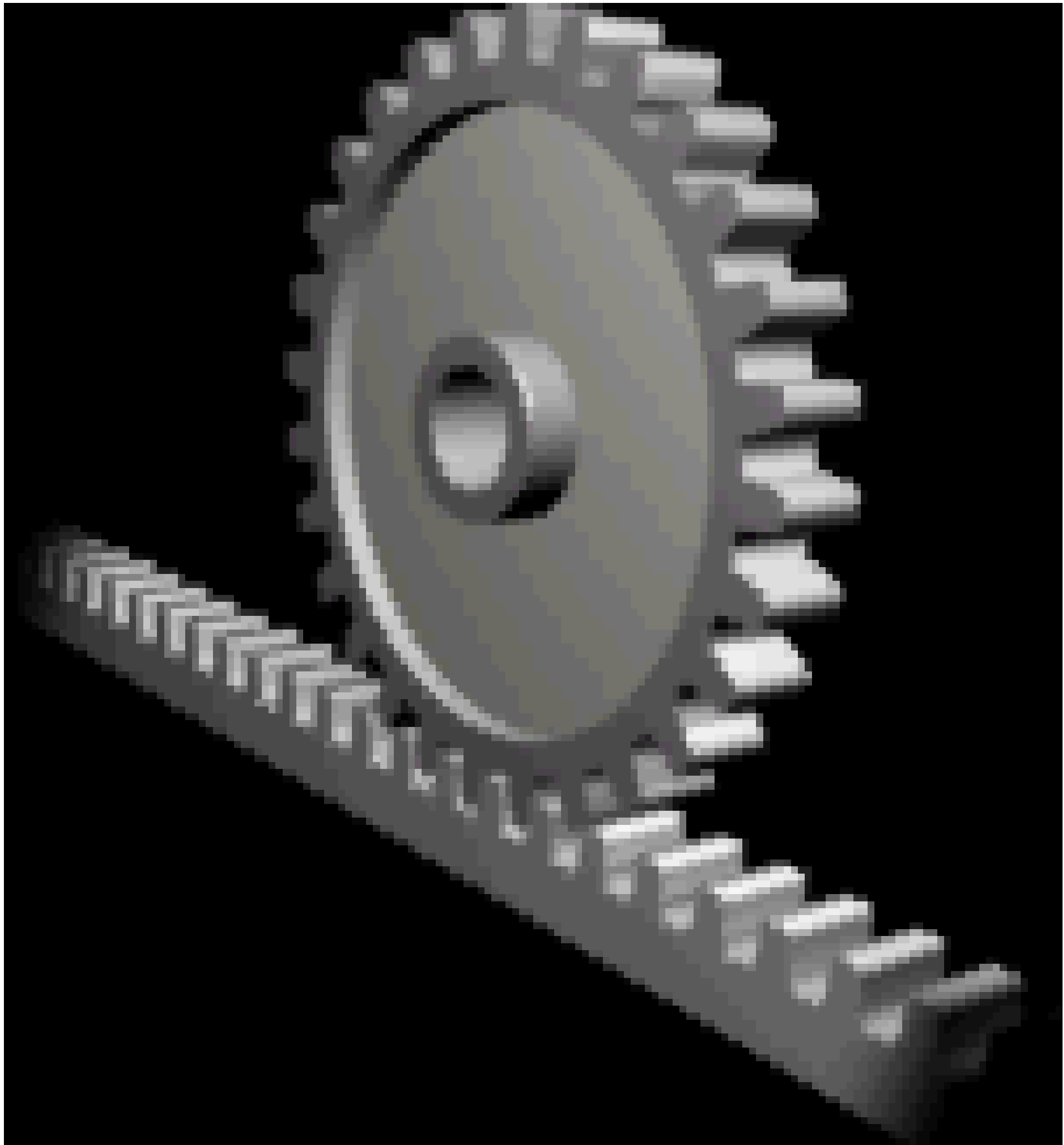


Rack and Pinion

– Converts rotary motion to back and forth motion

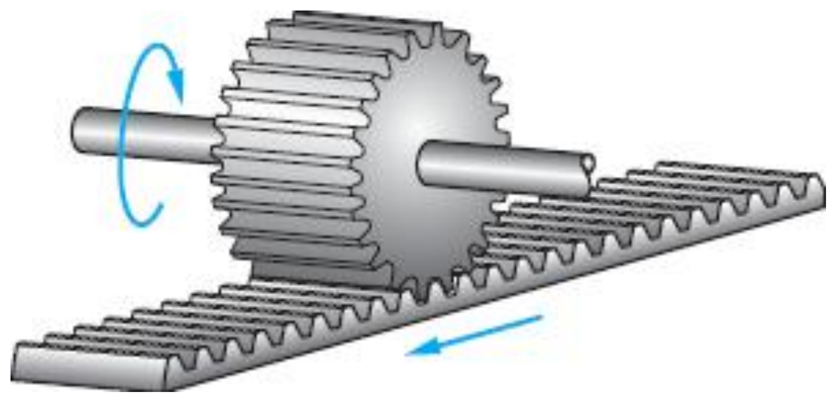


http://en.wikipedia.org/wiki/Gear#Worm_gear



Rack and Pinion

- Spur pinion operating on a flat straight bar rack
- Converts rotary motion into straight-line motion



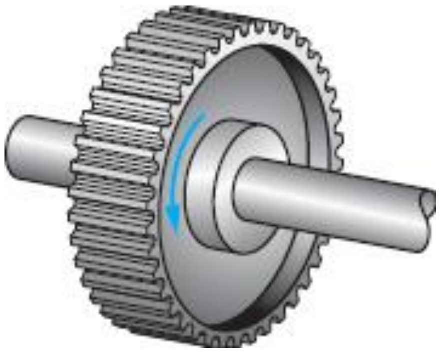
Differential Gears

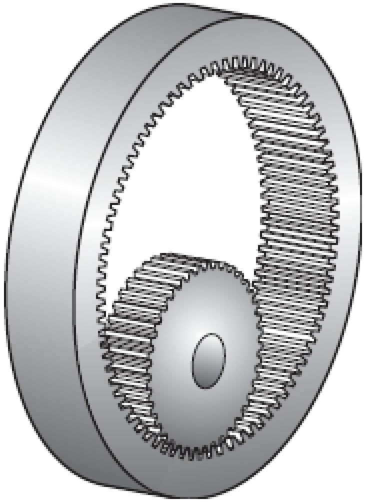
– Splits torque two ways, allowing each output to spin at a different speed

http://nxtasy.org/wp-content/uploads/2006/08/Differential2-00.html

Spur Gears

- Transmit motion and power between parallel shafts
- Two basic types:
  - External spur gears
  - Internal spur gears
- [Cluster gears]



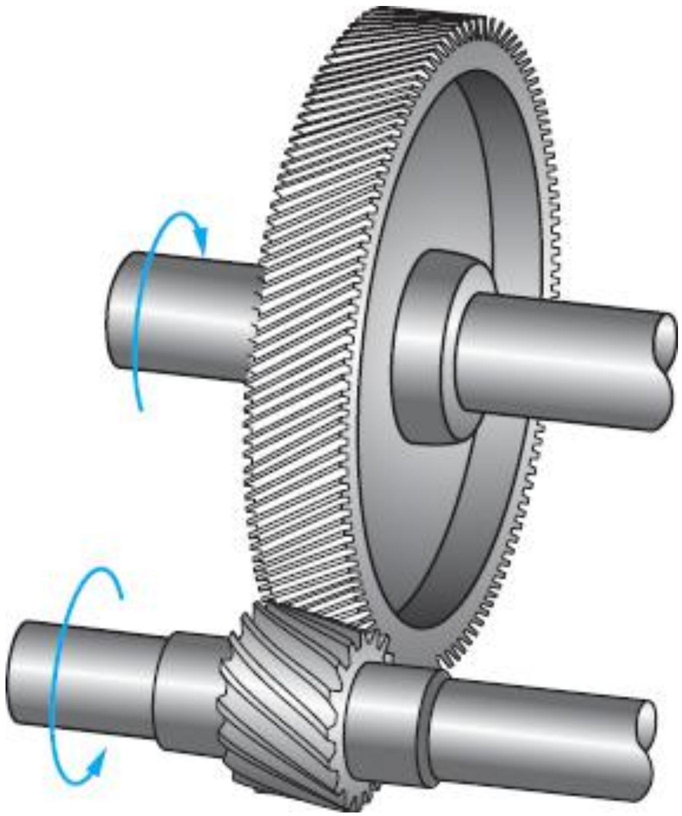


Spur Gears

- Advantages:
  - Economical
  - Simple design
  - Ease of maintenance
- Disadvantages:
  - Less load capacity
  - Higher noise levels

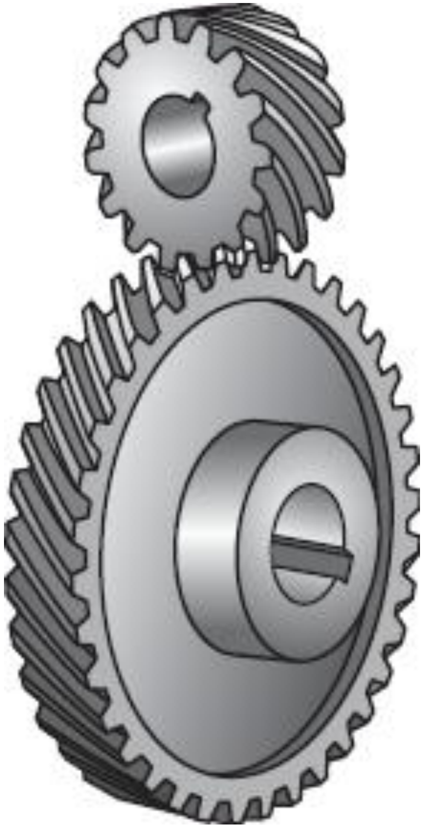
Helical Gears

- Teeth cut at an angle
  - Allows more than one tooth to be in contact



Crossed Helical Gears

- Also known as:
  - Right angle helical gears
  - Spiral gears
- Low load-carrying capabilities



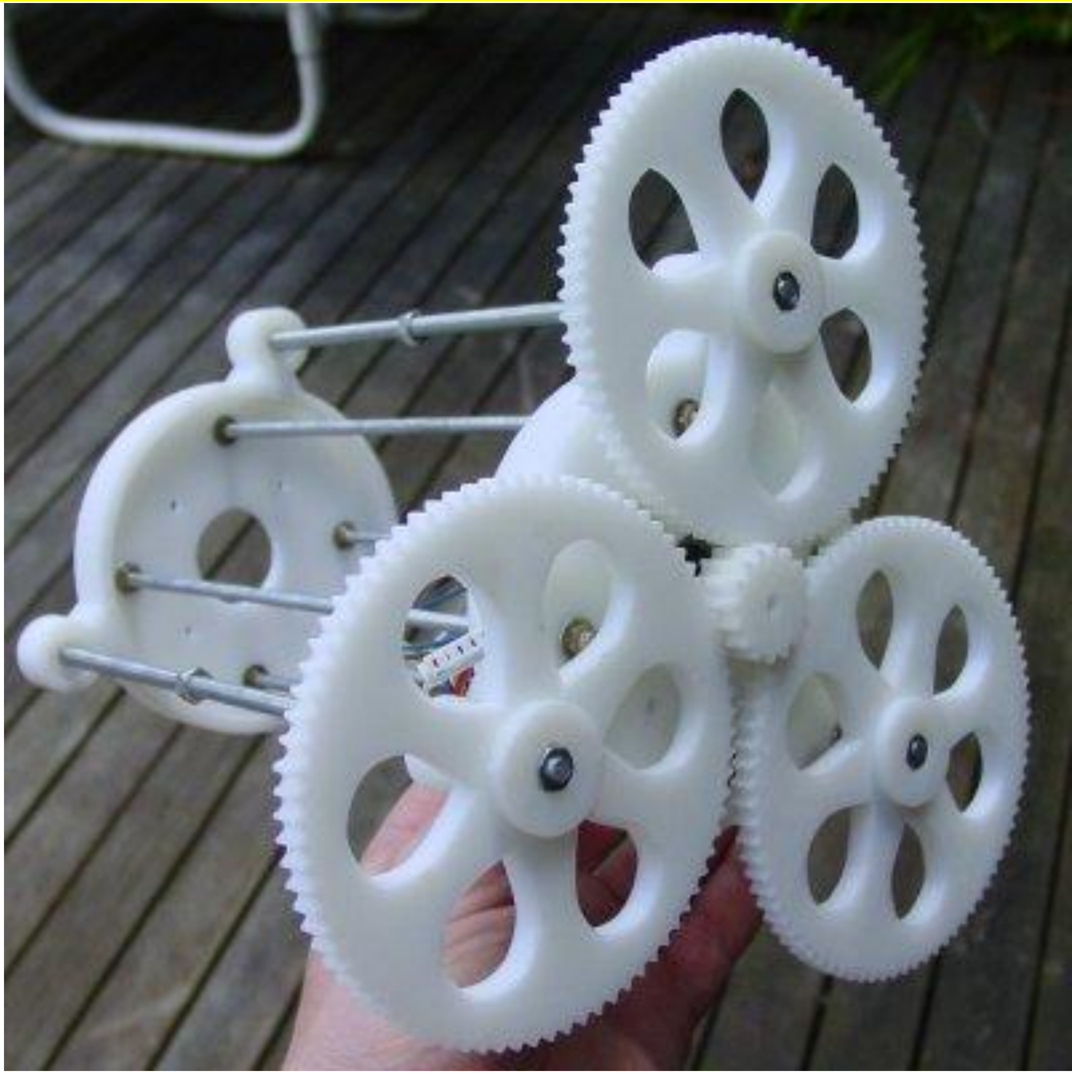
Helical Gears

- Carry more load than equivalent-sized spur gears
- Operate more quietly and smoothly
- Develop end thrust
  - Can be eliminated using double helical gears, such as a herringbone gear

Gear Assemblies

Gear Assemblies

– LEGO™ Technic 1031 Gear Assembly Activity
– Gearing up and Gearing down

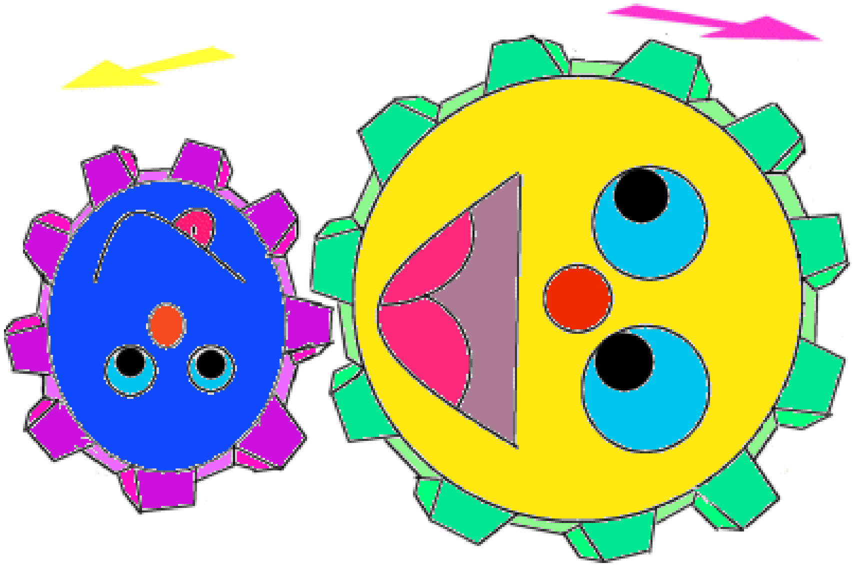


http://reprap.blogspot.com/2005_12_01_archive.html

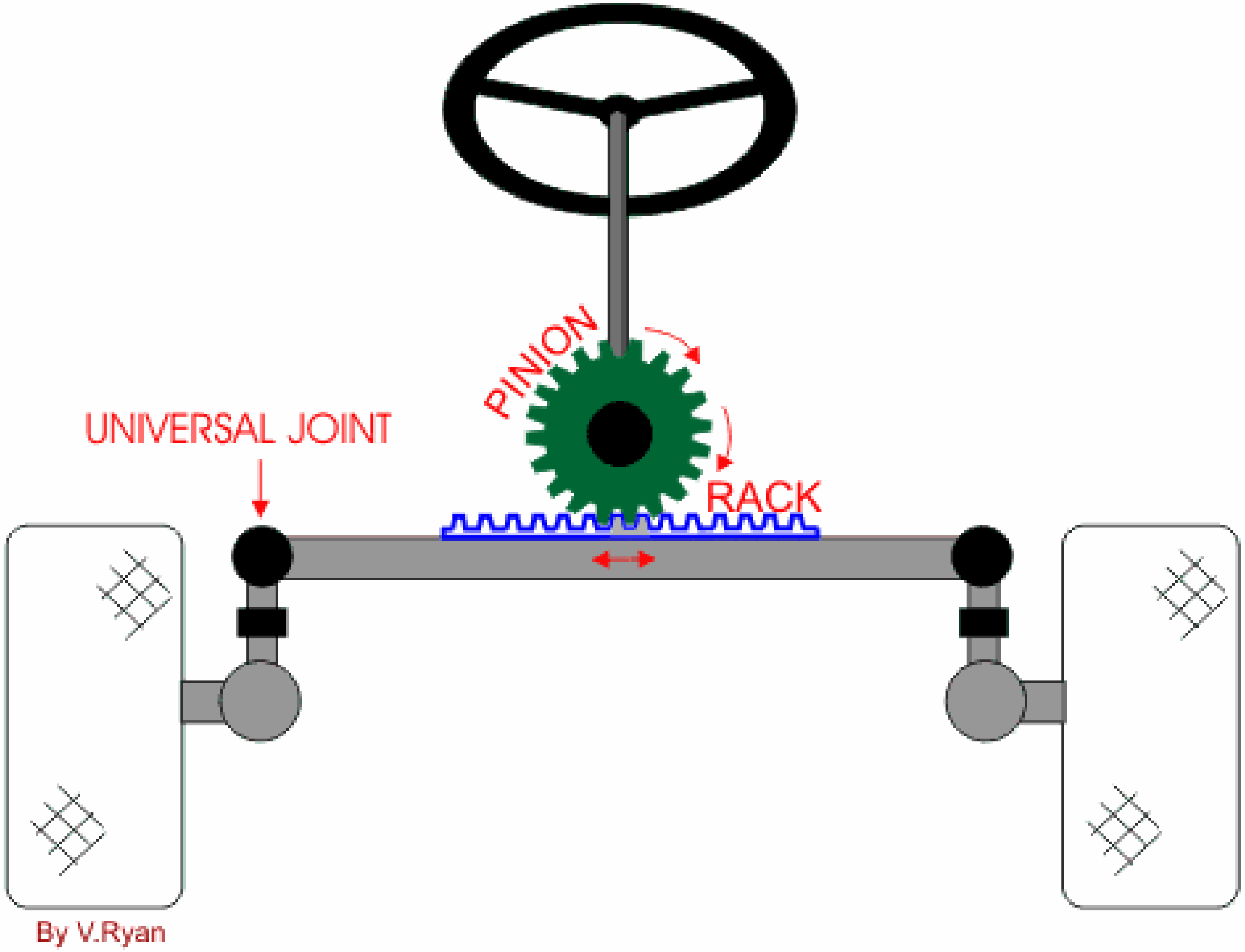
Cool Site

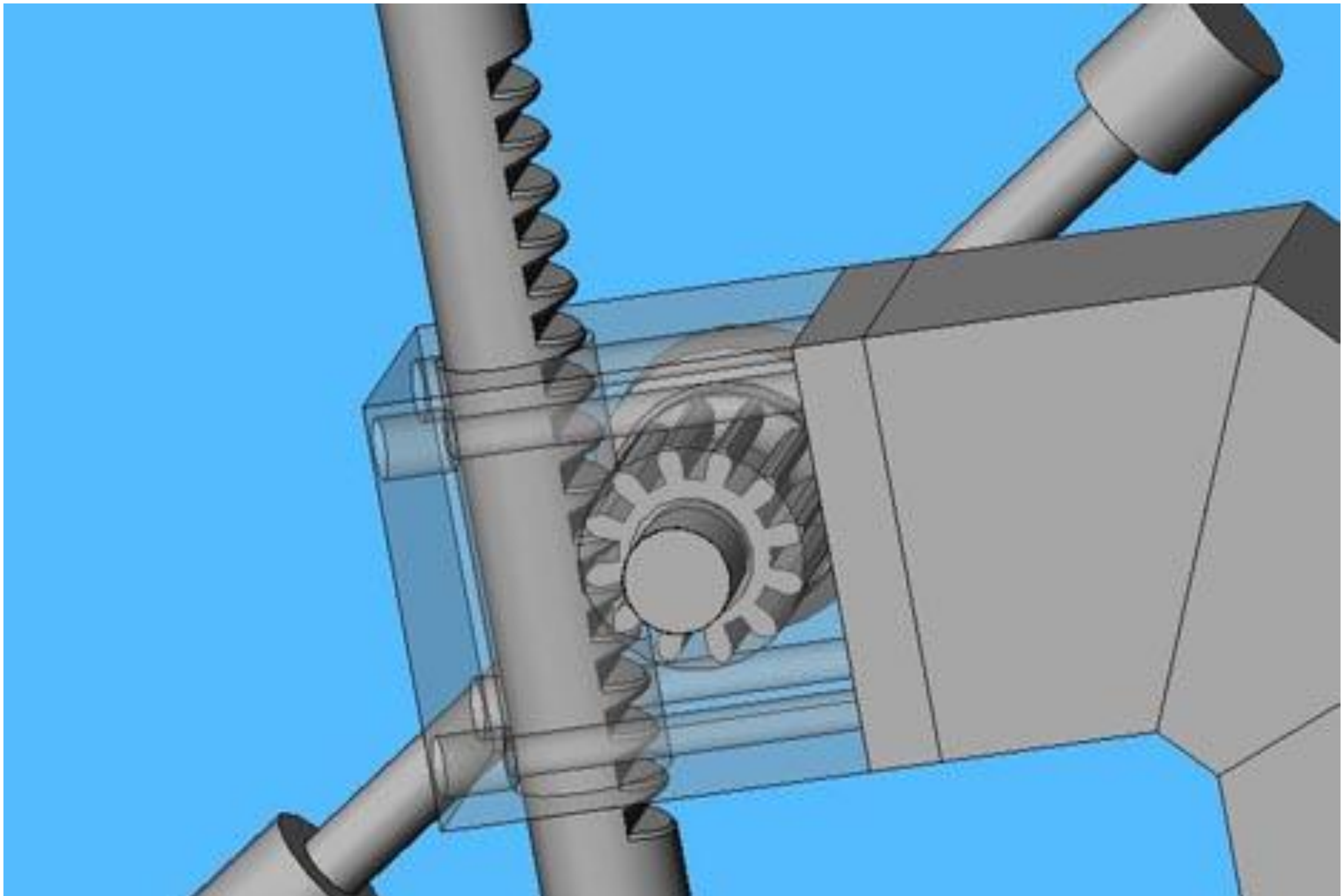
- http://nxtasy.org/
  - Includes plans!
- NXT Aerial Ropeway
- NXT Gymnast
- NXTWay-G: Balancing with a Gyro Sensor

GEARS-Wheel and Axel



- **Each gear in a series reverses the direction of rotation of the previous gear. The smaller gear will always turn faster than the larger gear.**


PINION
UNIVERSAL JOINT
RACK
By V.Ryan



Common Gear Materials

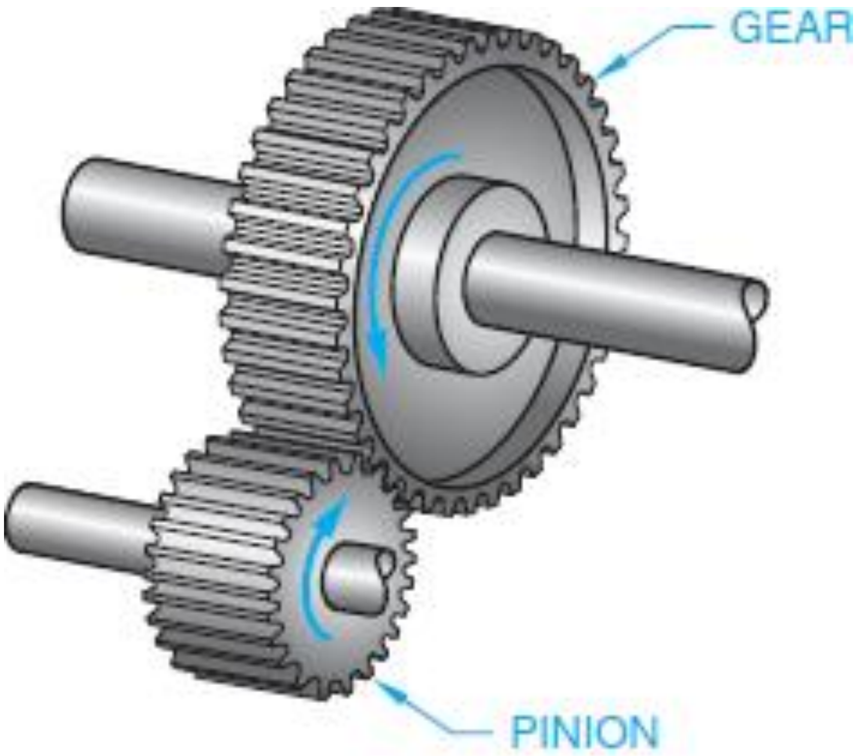
- Cast iron
- Steel
- Brass
- Bronze alloys
- Plastic

Gear Selection and Design

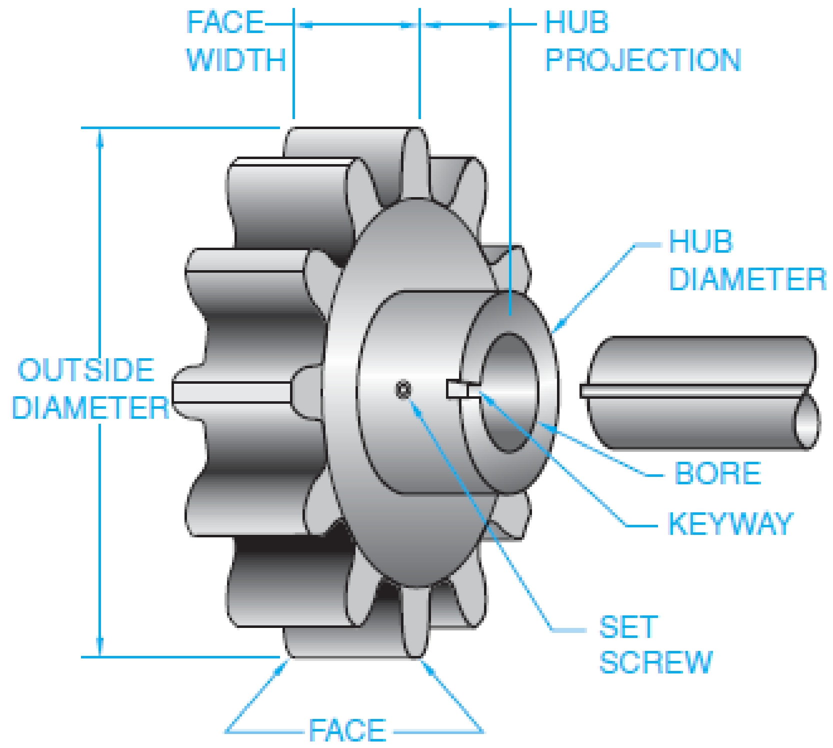
- Often done through vendors' catalogs or the use of standard formulas
  - American Gear Manufacturers Association (AGMA)
    - AGMA 2000-A88, Gear Classification and Inspection Handbook - Tolerances and Measuring Methods for Unassembled Spur and Helical Gears, including Metric Equivalents
  - American Society of Mechanical Engineers (ASME)
    - ASME Y14.7.1 Gear Drawing Standards - Part 1: For Spur, Helical, Double Helical and Rack
    - ASME Y14.7.2 Gear and Spline Drawing Standards - Part 2: Bevel and Hypoid Gears

Gear Train

- Increase or reduce speed
- Change the direction of motion from one shaft to another



Gear Structure



Splines

- Often used when it is necessary for the gear or pulley to easily slide on the shaft
- Can also be nonsliding
- Stronger than keyways and keys

Intersecting Shafting Gears

- Bevel gears
- Face gears

Face Gears

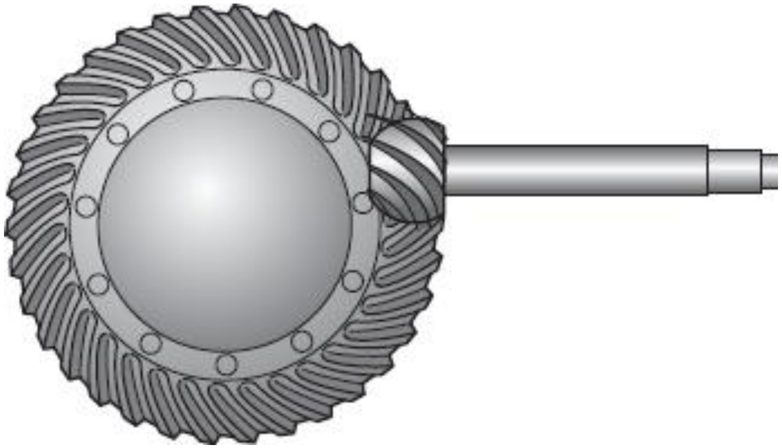
- Combination of bevel gear and spur pinion, or bevel gear and helical pinion
- Requires less mounting accuracy
- Caries less load

Nonintersecting Shafting Gears

- Crossed helical gears
- Hypoid gears
- Worm gears

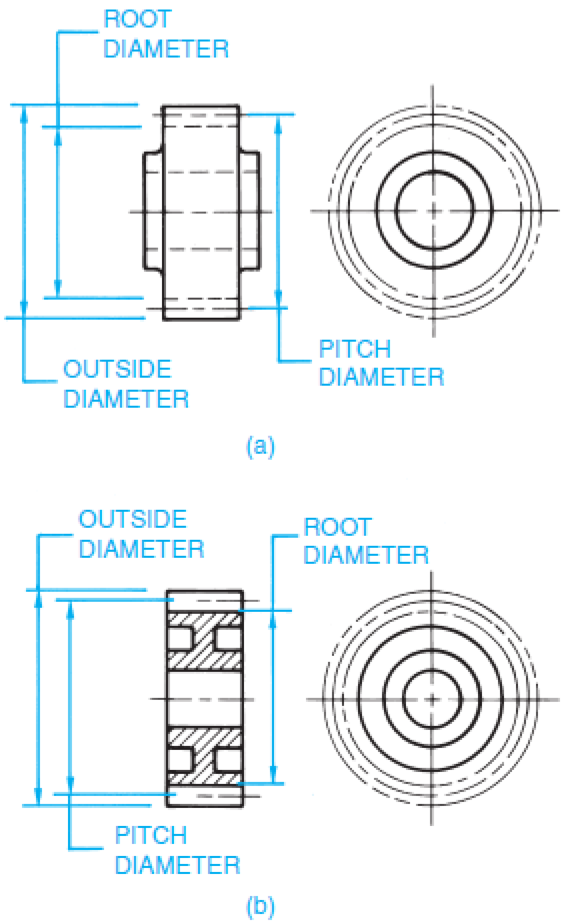
Hypoid Gears

- Offset, nonintersecting gear shaft axes
- Very smooth, strong, and quiet

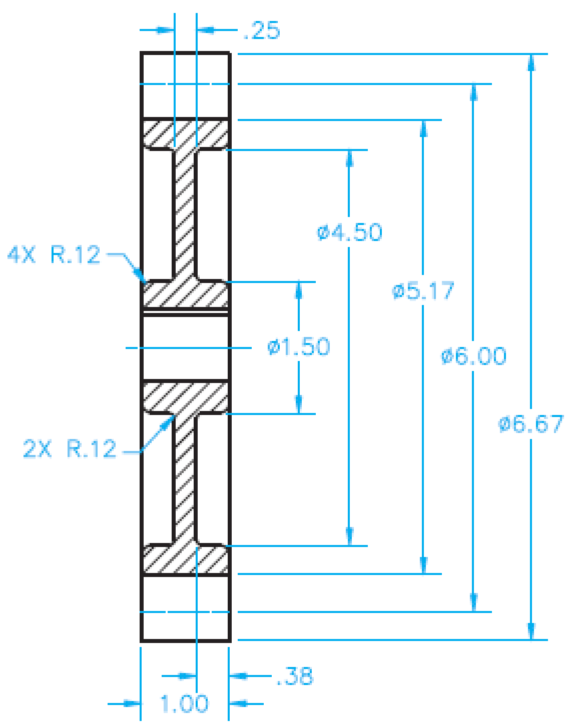


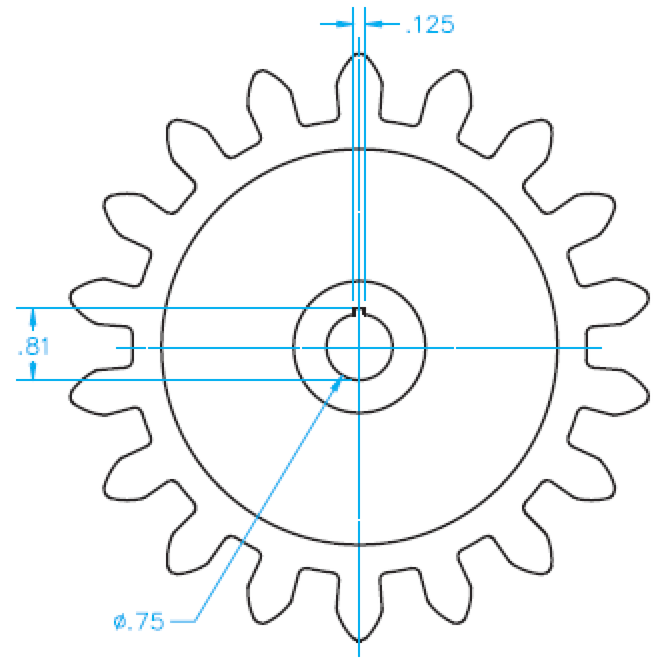
Hypoid Gear Representations

Simplified Gear Representation



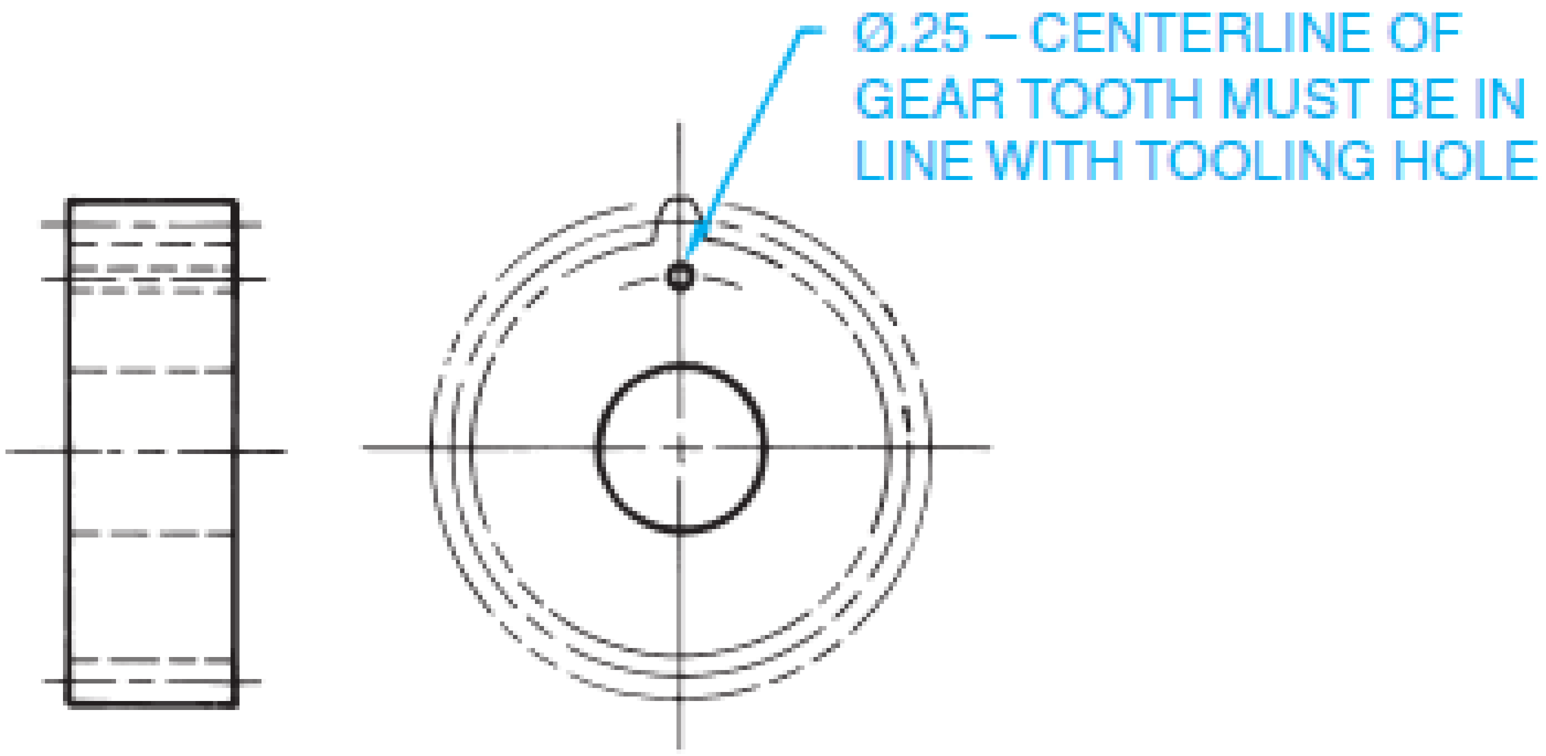
Detailed Spur Gear Representation



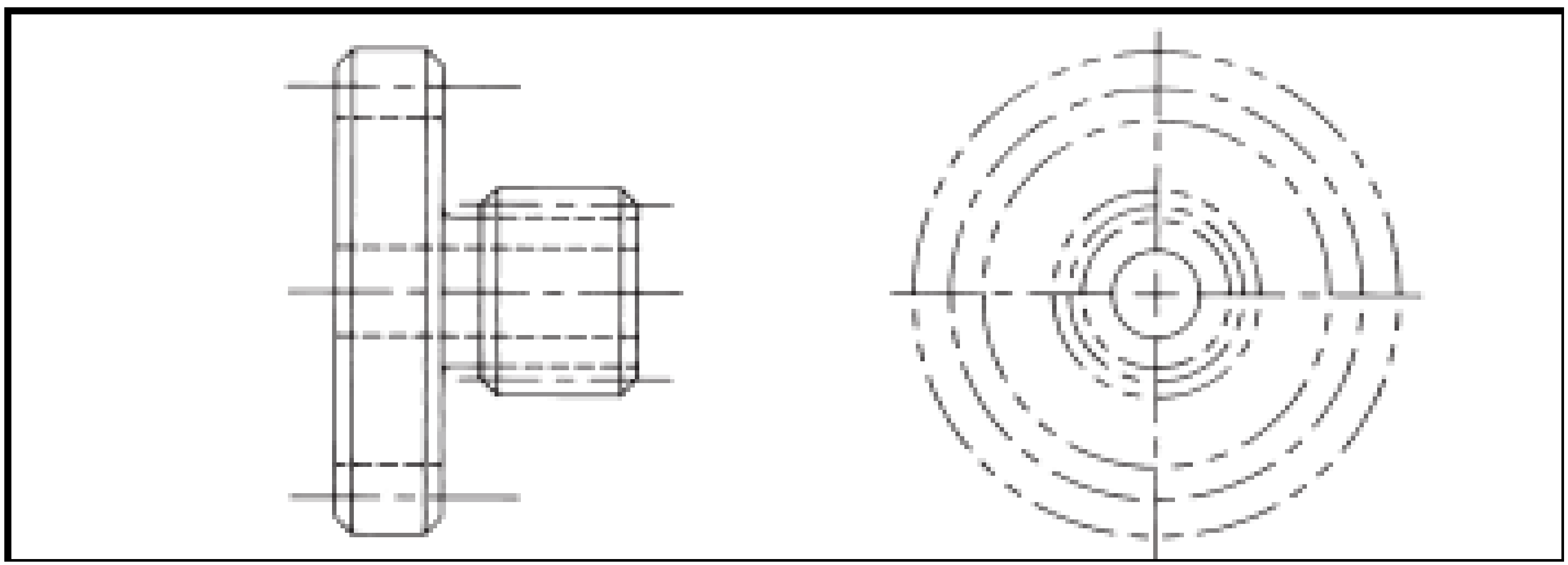


SPUR GEAR DATA	
NUMBER OF TEETH	18
DIAMETRAL PITCH	3
PRESSURE ANGLE	20°
ADDENDUM	.333
DEDENDUM	.417

Showing a Gear Tooth Related to Another Feature



Cluster Gear Print



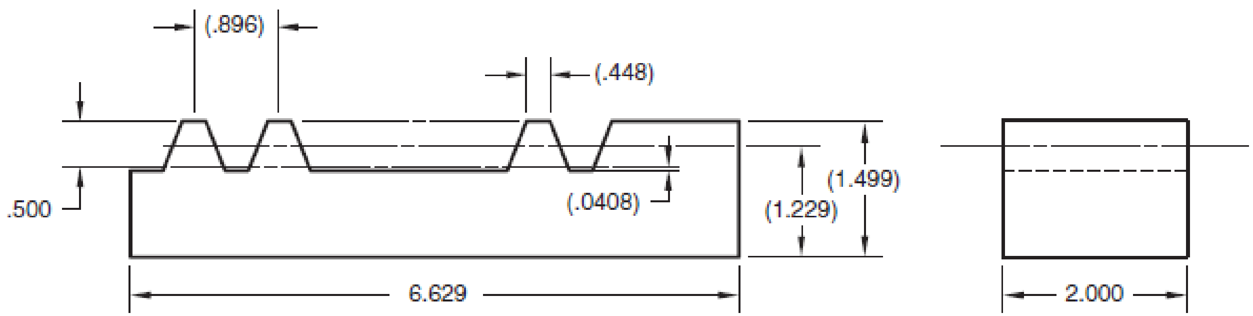
Gear Trains

- Transmit motion between shafts
- Decrease or increase the speed between shafts
- Change the direction of motion

Gear Ratio

- Important when designing gear trains
- Applies to any two gears in mesh
- Expressed as a proportion, such as 2:1 or 4:1

Rack and Pinion Print



SPUR RACK DATA	
NUMBER OF TEETH	8
CIRCULAR PITCH	.896
LINEAR PITCH	1.229
PRESSURE ANGLE	20°
TOOTH THICKNESS AT PITCH LINE	.448
MINIMUM CLEARANCE	0.408

3. ALL TOOTH ELEMENT SPECIFICATIONS ARE FROM SPECIFIED DATUMS.
2. PITCH TOLERANCE .004.
1. INTERPRET GEAR DATA PER ANSI Y14.7.1.
NOTES:

unless otherwise specified
INCHES

1. PLACE	+/- .1
2. PLACE	+/- 0.1
3. PLACE	+/- .805
ANGULAR	+/- 90°
FRACTIONAL	+/- 1/32
FINISH	125 µ
FIRST USED ON	SIMILAR TO

CLACKAMAS
TOOL & DIE CO.

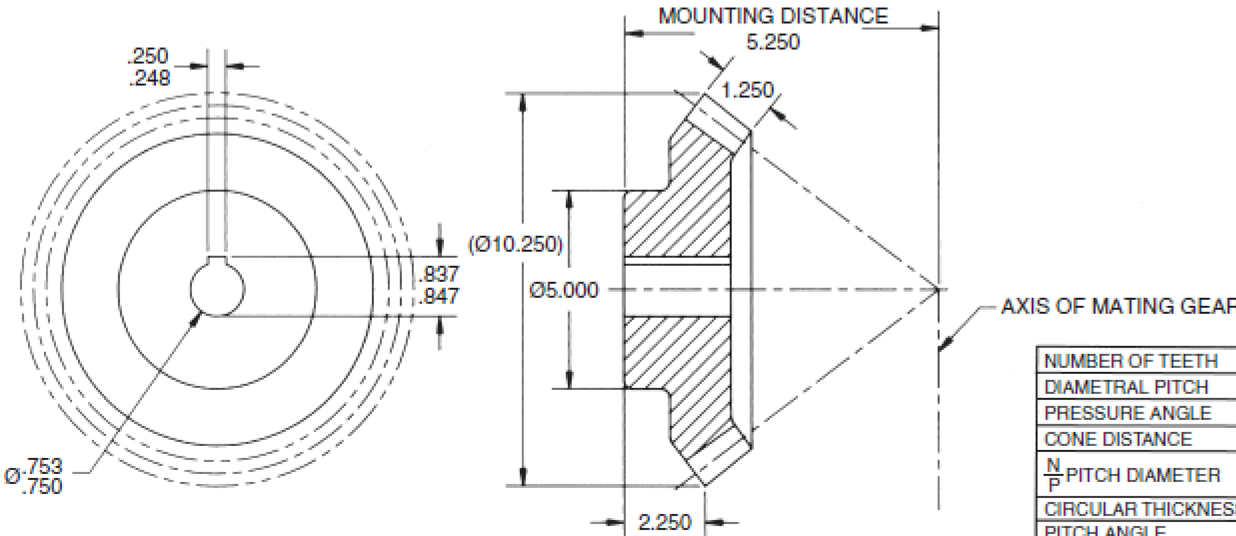
DR.	SCALE	DATE	APPD'
JAS	1/1	7/1/00	

MATERIAL SAE 4320

NAME SPUR RACK

	PART NO.	REV.
C	30403#4	0

Bevel Gear Print



NOTES:

1. DIMENSIONS AND TOLERANCES PER ASME Y14.5-2009.
2. INTERPRET TOOTH DATA PER ANSI Y14.7.1
3. ALL FILLETS AND ROUNDS R.13 UNLESS OTHERWISE SPECIFIED.

NUMBER OF TEETH	75
DIAMETRAL PITCH	10
PRESSURE ANGLE	20°
CONE DISTANCE	3.908
$\frac{N}{P}$ PITCH DIAMETER	7.750
CIRCULAR THICKNESS (REF)	.126
PITCH ANGLE	73.65°
ROOT ANGLE	71.296°
ADDENDUM	.058
WHOLE DEPTH	.221
CHORDAL ADDENDUM	.058
CHORDAL THICKNESS	.125
GEAR TOOTH DATA	

Plastic Gears

- Generally designed in the same manner as gears made from other materials
- Glass fiber adds reinforcement and reduces thermal expansion
- Additives that act as built-in lubricants and provide increased wear resistance:
  - Polytetrafluoroethylene (PTFE)
  - Silicones
  - Molybdenum disulphide

Advantages of Molded Plastic Gears

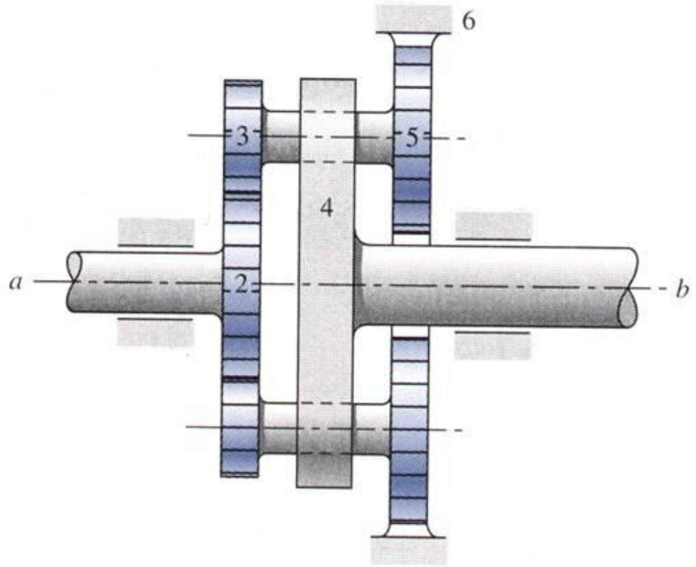
- Reduced cost
- Increased efficiency
- Self-lubrication
- Increased tooth strength with nonstandard pressure angles
- Reduced weight
- Corrosion resistance
- Less noise
- Available in colors

Disadvantages of Molded Plastic Gears

- Lower strength
- Greater thermal expansion and contraction
- Limited heat resistance
- Size change with moisture absorption

Planetary Gear Trains - Example

For the speed reducer shown, the input shaft *a* is in line with output shaft *b*. The tooth numbers are N_2=24, N_3=18, N_5=22, and N_6=64. Find the ratio of the output speed to the input speed. Will both shafts rotate in the same direction? Gear 6 is a fixed internal gear.



$$\text{Train value} = (-N_2 / N_3)(N_5 / N_6) = (-24/18)(22/64) = -.4583$$

$$-.4583 = (\omega_L - \omega_{arm}) / (\omega_F - \omega_{arm}) = (0 - \omega_{arm}) / (1 - \omega_{arm})$$

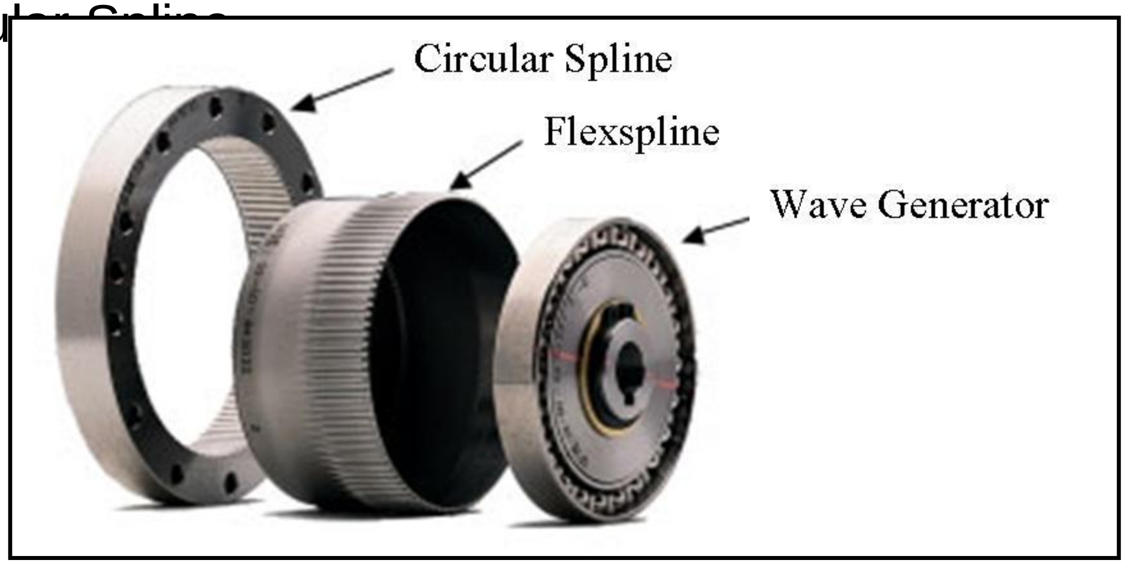
ω_{arm} = .125, reduction is 8 to 1

Input and output shafts rotate in the same direction

$$d_2 + d_3 = d_6 - d_5$$

Harmonic Drive

The mechanism is comprised of three components: Wave Generator, Flexspline, and Circular Spline.



Wave Generator

Consists of a steel disk and a specially design bearing. The outer surface has an elliptical shape. The ball bearing conforms to the same elliptical shape of the wave generator. The wave generator is usually the input.

Flexspline

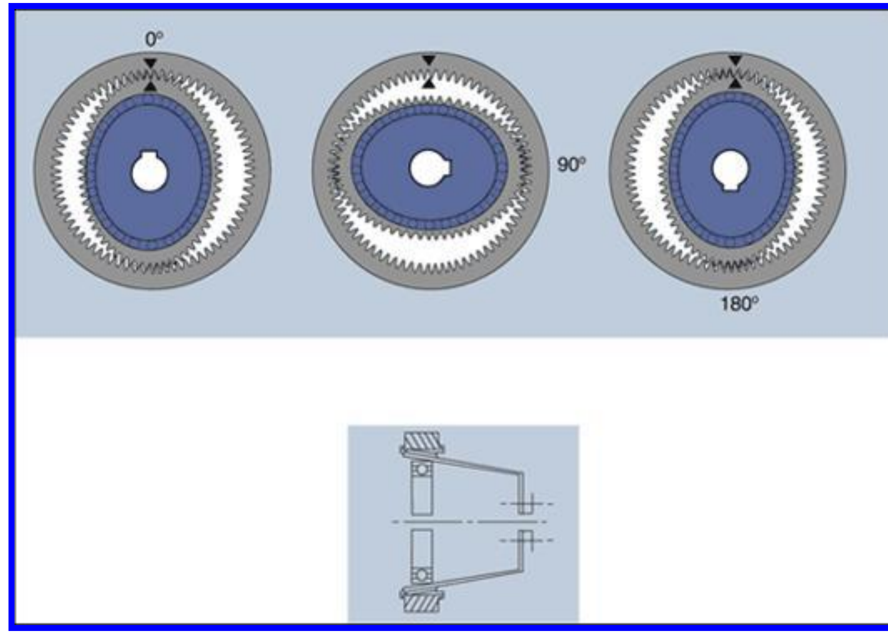
The Flexspline is a thin-walled steel cup with gear teeth on the outer surface near the open end of the cup. Flexspline is usually the output.

Circular Spline

Rigid internal circular gear, meshes with the external teeth on the Flexspline.

Harmonic Drive

Teeth on the Flexspline and circular spline simultaneously mesh at two locations which are 180^o apart.



As the wave generator travels 180^o, the flexspline shifts one tooth with respect to circular spline in the opposite direction.

The flexspline has two less teeth than the circular spline.

$$\textbf{Gear Ratio} = -(N_{flex\ spline})/2$$

$$\omega_{\text{Wave Generator}} = \text{input}, \quad \omega_{\text{Flexspline}} = \text{output}, \quad \omega_{\text{Circular Spline}} = 0$$

Bearings

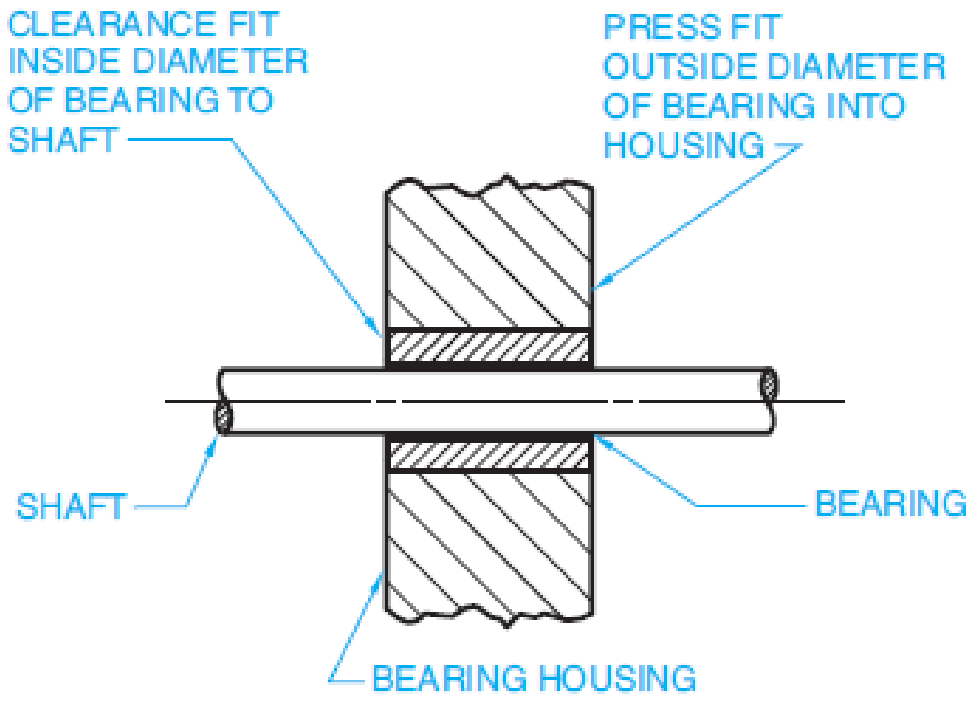
Bearings

- Two large groups:
  - Plain bearings
  - Rolling element bearings
- Accommodate either rotational or linear motion

Plain Bearings

- Often referred to as:
  - Sleeve bearings
  - Journal bearings
  - Bushings
- Operation is based on a sliding action between mating parts
- Clearance fit between the inside diameter of the bearing and the shaft is critical

Plain Bearings

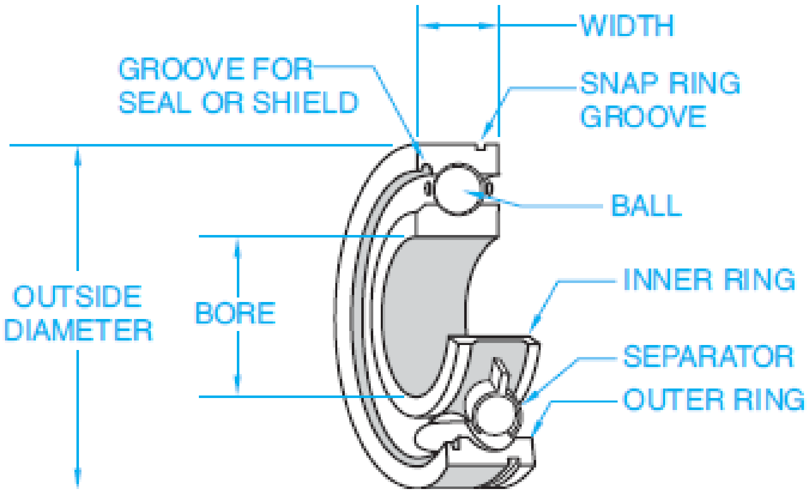


Rolling Element Bearings

- Common classes:
  - Ball bearings
  - Roller bearings

Ball Bearings

- Typically have higher speed and lower load capabilities than roller bearings
- May have a shield or seal

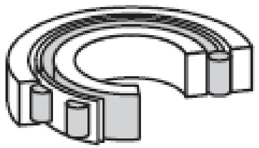


Typical Ball Bearings

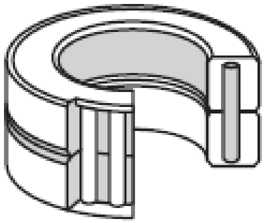
- Single-row ball bearings
- Double-row ball bearings
- Angular contact ball bearings
- Thrust bearings

Roller Bearings

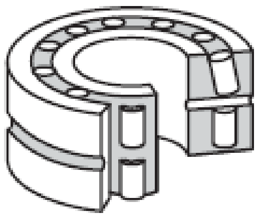
- More effective than ball bearings for heavy loads



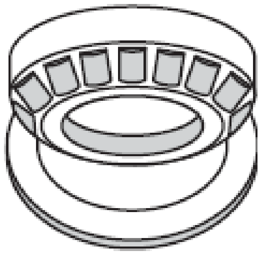
CYLINDRICAL ROLLER BEARING



NEEDLE ROLLER BEARING



SPHERICAL ROLLER BEARING



TAPERED ROLLER BEARING

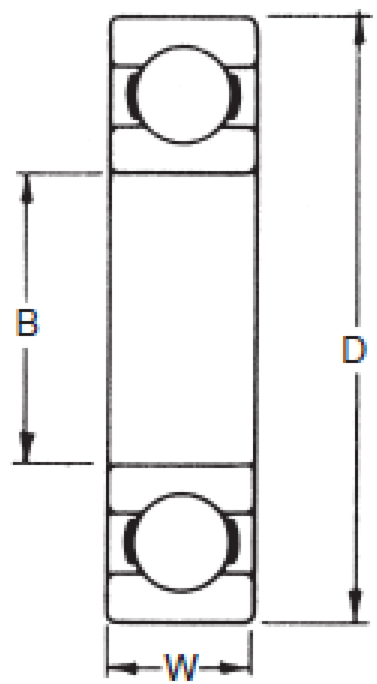
Bearing Codes

- Typically specify:
  - Material
  - Bearing type
  - Bore size
  - Lubricant
  - Type of seals or shields

Bearing Selection

- A variety of bearing types are available depending on use requirements
- Common classes:
  - Light bearings
  - Medium bearings
  - Heavy bearings

Bearing Bore, Outside Diameters, and Width



Shaft and Housing Fits

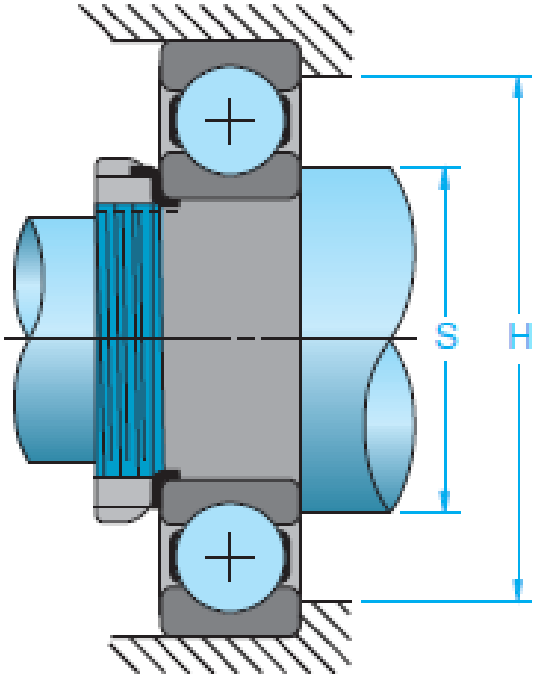
- Important consideration
  - Tight fits can cause failure of the balls, rollers, lubricant, or overheating
  - Loose fits can cause slippage of the bearing in the housing, resulting in overheating, vibration, or excessive wear

Shaft and Housing Fits

- General shaft fits
  - Shaft diameter and tolerance are the same as the bearing bore diameter and tolerance
- General housing fits
  - Minimum housing diameter is .0001 larger than the maximum bearing outside diameter
  - Maximum housing diameter is .0003 larger than the minimum housing diameter

The Shaft Shoulder and Housing Shoulder Dimensions

- Shoulders should be large enough to rest flat on the face of the bearing and small enough to allow bearing removal



Surface Finish of Shaft and Housing

- Shafts under 2 inches (50 mm) in diameter:
  - 32 microinches (0.80 micrometer)
- Shafts over 2 inches in diameter
  - 63 microinch (1.6 micrometer)
- Housing diameter:
  - 125 microinch (3.2 micrometer)

Bearing Lubrication

- Necessary requirement based on:
  - Type of operation, such as continuous or intermittent
  - Service speed in rpm (revolutions per minute)
  - Bearing load, such as light, medium, or heavy

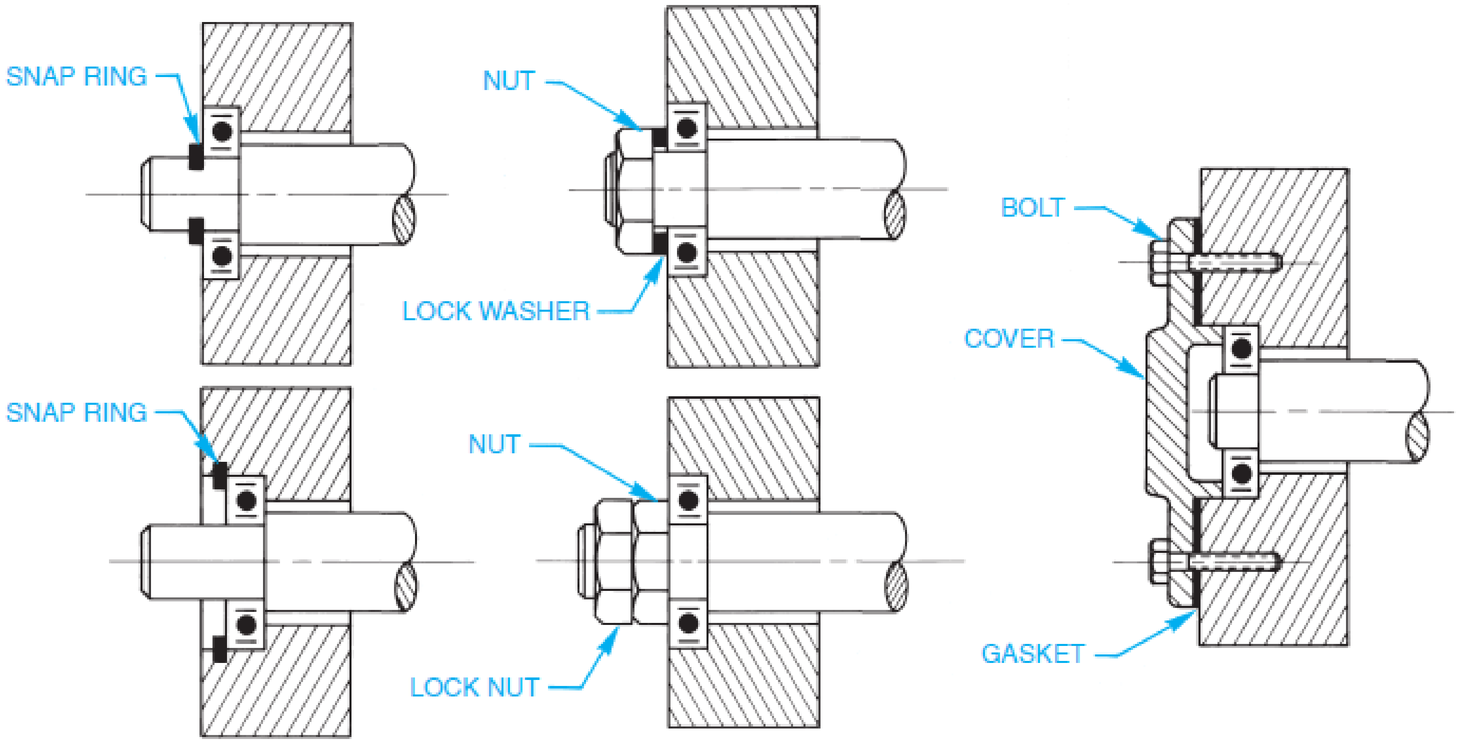
Oil Grooving of Bearings

- Grooves for the proper flow of lubrication to the bearing surface
  - Help provide the proper lubricant between the bearing surfaces and maintain cooling
- Several methods available

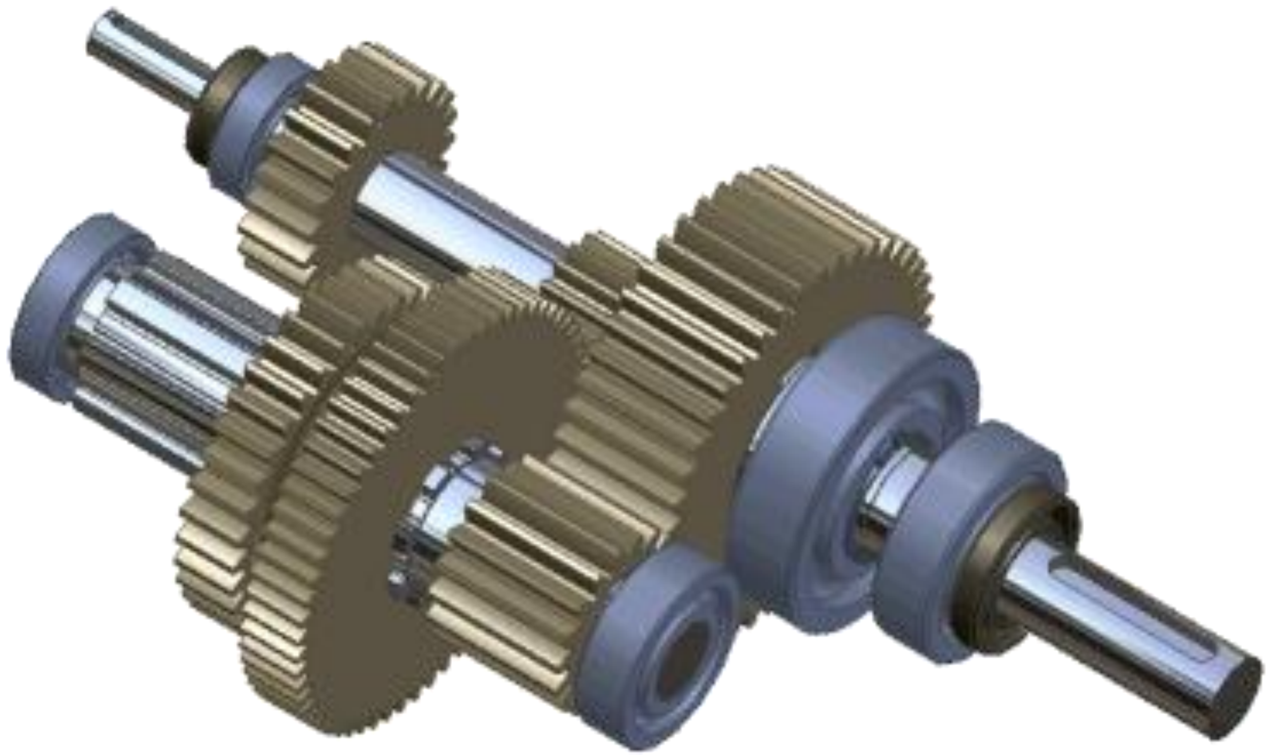
Sealing Methods

- Static sealing
- Dynamic seals
- Gaskets
- Molded lip packings
- Molded ring seals
  - Labyrinth
  - O-ring seal
  - Lobed ring seal
- Felt seals and wool seals

Bearing Mountings



Kinematics of Gears



UNIT-4 Introduction

- Rotating elements which possess mechanical energy has to be utilized at required place by transmitting.
  - From prime mover to machine
  - From one shaft to another

Transmission system

- The system that is used to transmit power from one mechanical element to another mechanical element.

Types of transmitting system

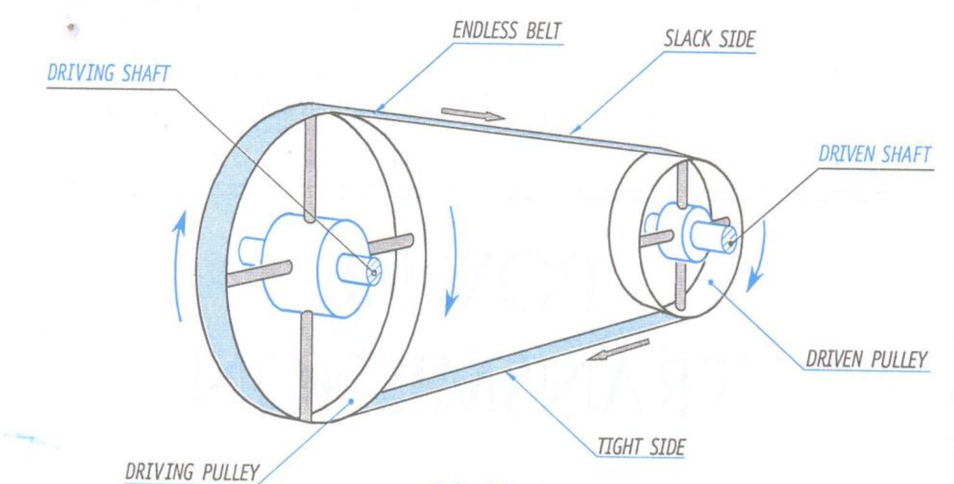
- Belt drives
- Rope drives
- Chain drives
- Gear drives

Factors to select transmission system

- Distance between driver and driven pulley shaft.
- Operational speed.
- Power to be transmitted.

Belt drive

- Power is to be transmitted between the parallel shaft.
- Consists of two pulleys over which a endless belt is passed encircling the both.
- Rotary motion is transmitted from driving pulley to driven pulley.



Belt Drive
Fig. 9.1

Terminology of a belt drive

- Driver : in a transmission system the one which drives or supplies power to other mechanical element.
- Driven : in a transmission system the one which follows the driver or receives power from driver.
- Tight side : the portion of the belt in maximum tension. Denoted by T1 Newton.
- Slack side : the portion of the belt in minimum tension. Denoted by T2 Newton.

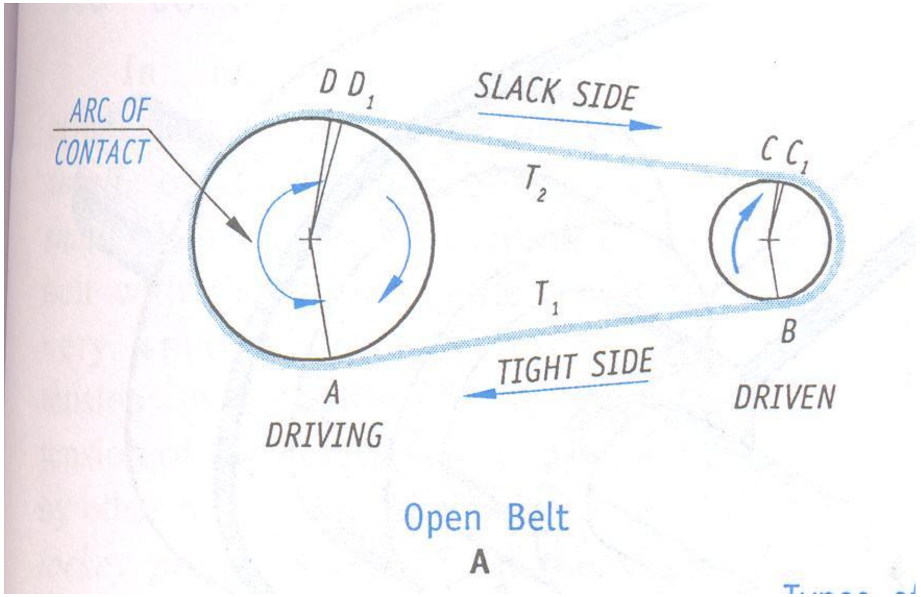
Belt materials

- Rubber
- Leather
- Canvas
- Cotton
- Steel

Classification

Open belt drive

- Both driver and driven pulley rotate in both direction.
- Belt is passed over driver and driven.
- Driver pulley pulls the belt from one side and delivers to other side.
- Tension is more in lower side then upper side.

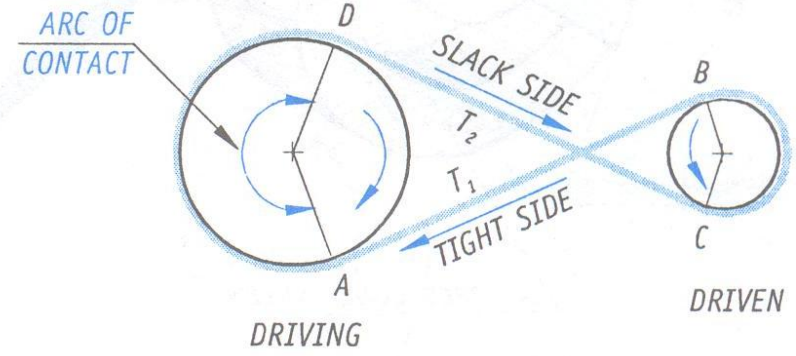


Open Belt
A

Cross belt drive

- Driven rotates in opposite direction to that of driver.
- At the point were the belt crosses it rubs against each other and there will be wear.
- To avoid this speed of belt should be less than

  15 m/s.



Cross Belt
B

of Belt Drives
Fig. 9.2

Comparison between Open belt drive and Close belt drive

Open Belt Drive	Cross Belt Drive
Both driver and the driven rotates in the same direction	Driver and driven rotates in opposite direction
When the shafts are horizontal, inclined it is effective to transmit the power	Even if the shafts are vertical it is effective to transmit the power
As there is no rubbing point, the life of the belt is more	Due to the rubbing point, the life of the belt reduces.
Require less length of the belt compared to crossed belt drive for same centre distance, pulley diameters.	Require more length of belt compared to open belt drive for the same centre distance, pulley diameters.

Definitions in belt drives

- Velocity Ratio:

Velocity ratio of belt drive is defined as the ratio between the speed of the driving pulley and the speed of the driven pulley.

Assuming there is no slip between the belt and the pulley rim, the linear speed at every point on the belt must be same. Hence

$$\pi d_1 n_1 = \pi d_2 n_2$$

Or

$$d_1 n_1 = d_2 n_2$$

$$n_1/n_2 = d_2/d_1$$

i.e., $$\frac{\text{speed of driving}}{\text{speed of driven}} = \frac{\text{Diameter of driven}}{\text{Diameter of driver}}$$

The ratio $\frac{n_1}{n_2} = \frac{d_2}{d_1}$ **is called as** velocity ratio **or** "transmission ratio" **of the belt drives**

When thickness (t) of belt is considered

$$\frac{n_1}{n_2} = \frac{d_2 + t}{d_1 + t}$$

Creep

The relative motion between the belt and the pulley surface due to contraction and expansion of belt is defined as "creep".

Creep increases with load as it is caused by the elasticity of the belt.

It reduces the speed of the driven pulley which results in loss of power transmission.

Slip

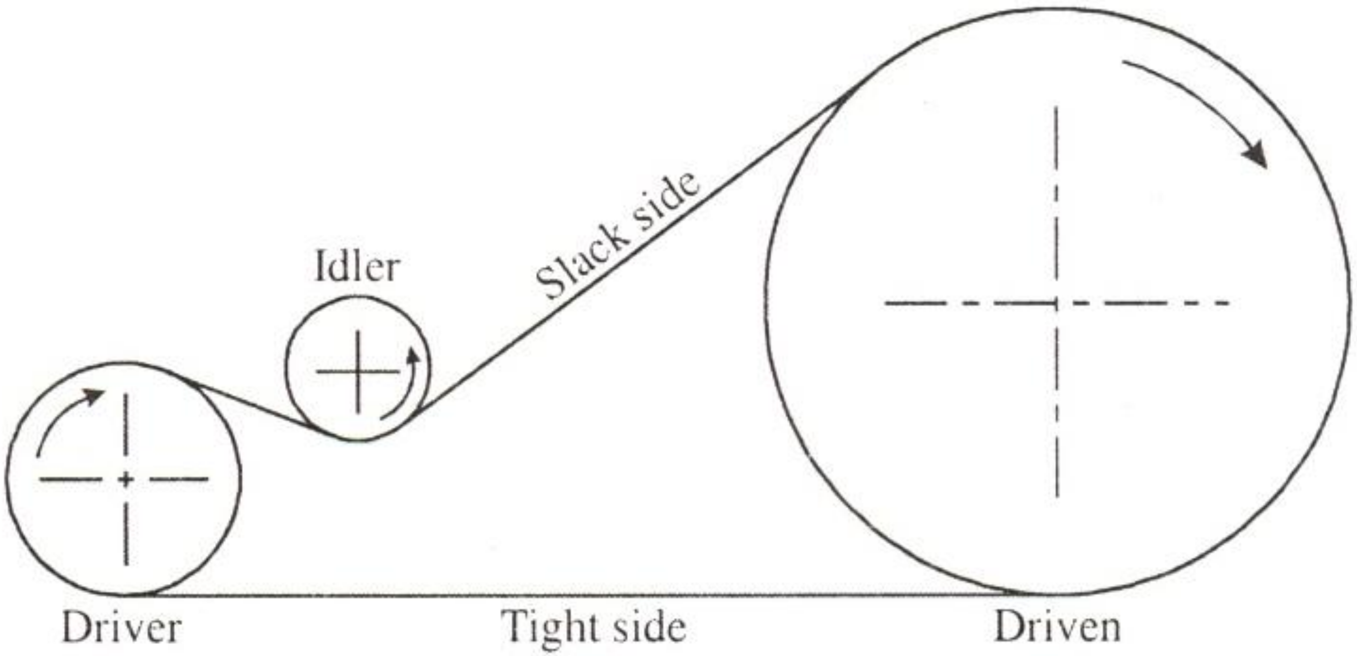
Relative motion between pulley and the belt passing over it is defined as "slip".

Velocity ratio (when slip is considered)

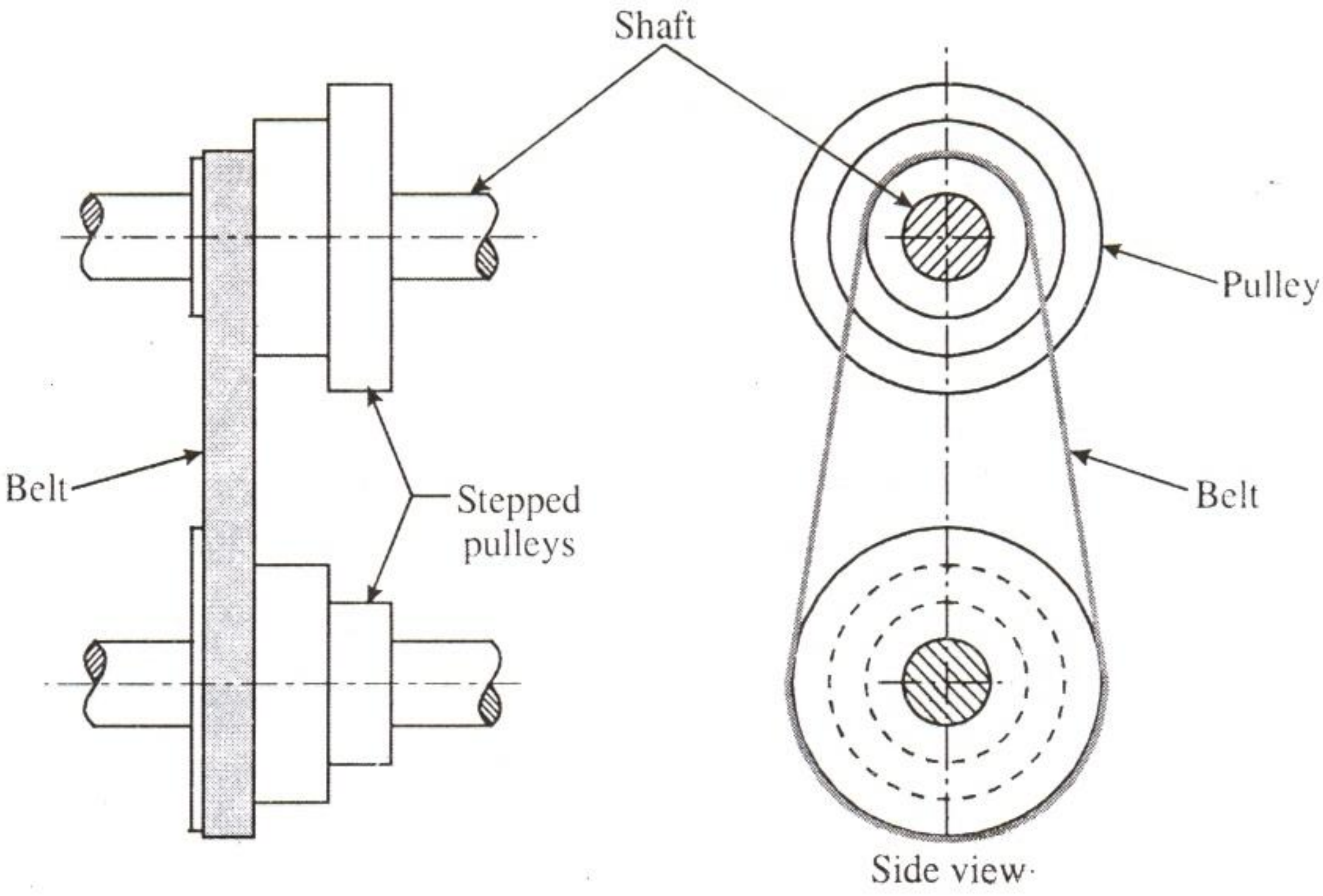
$$= \frac{n1}{n2} = \frac{d2}{d1} \left\{ \frac{100}{100-S} \right\}$$

Where S= % slip

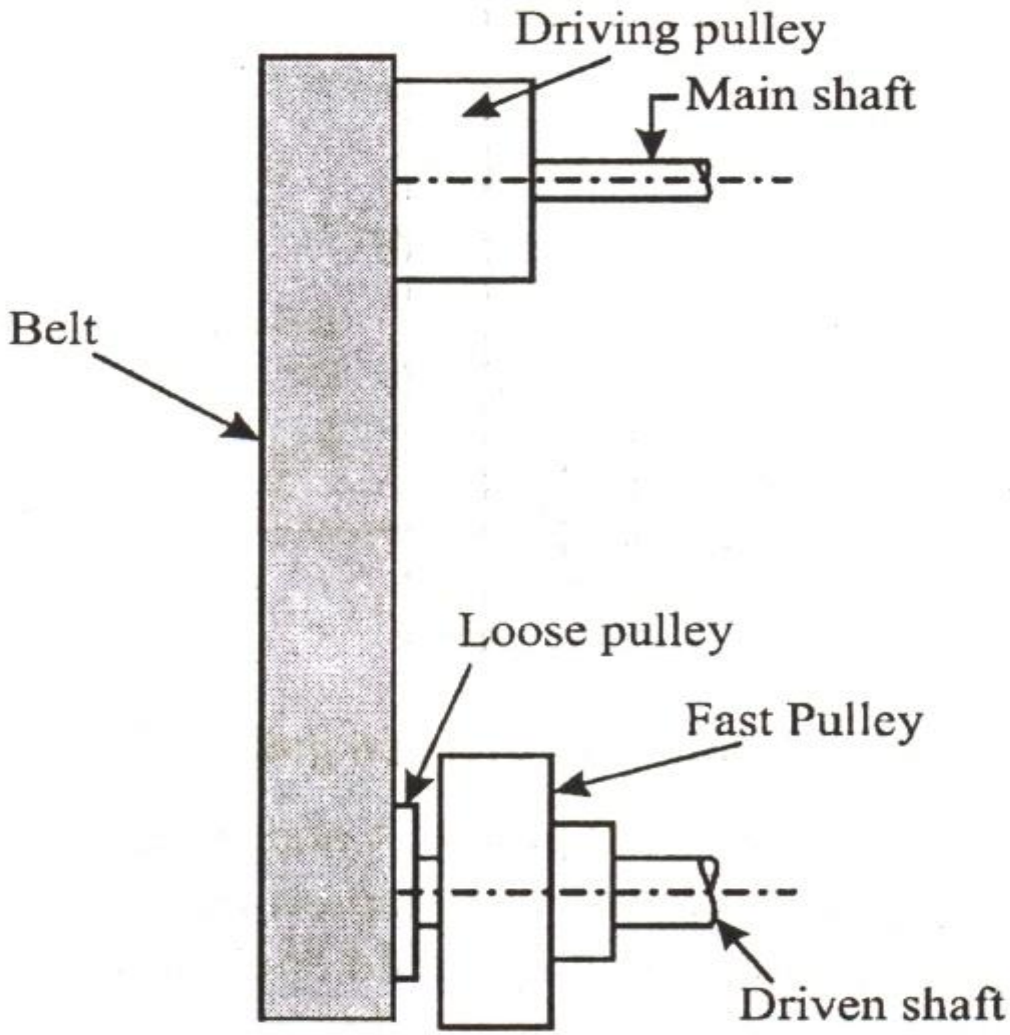
Idler pulley



Stepped Pulley



Fast and loose pulley



Advantages of flat belt drives

- **Running and maintenance cost is low.**
- **Possibility to transmit power over a moderately long distance.**
- **Efficient at high speeds.**

Disadvantages

- **Not preferred for short centre distance.**
- **Belt joints reduces the life of the belt.**
- **Loss of power due to slip and creep.**

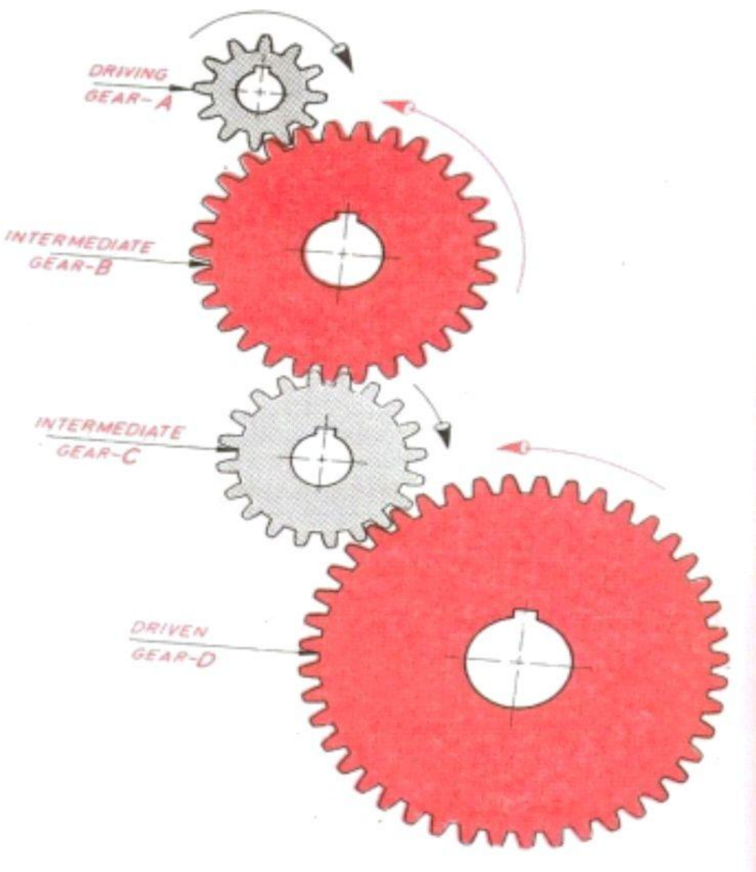
Gear Trains

- **When two or more gears are made to mesh with each other to transmit power from one shaft to other. Such an arrangement is called <u>gear train</u>.**

- **Simple gear train (SGT)**

- **Compound gear train (CGT)**

Simple gear train



Simple Gear Train

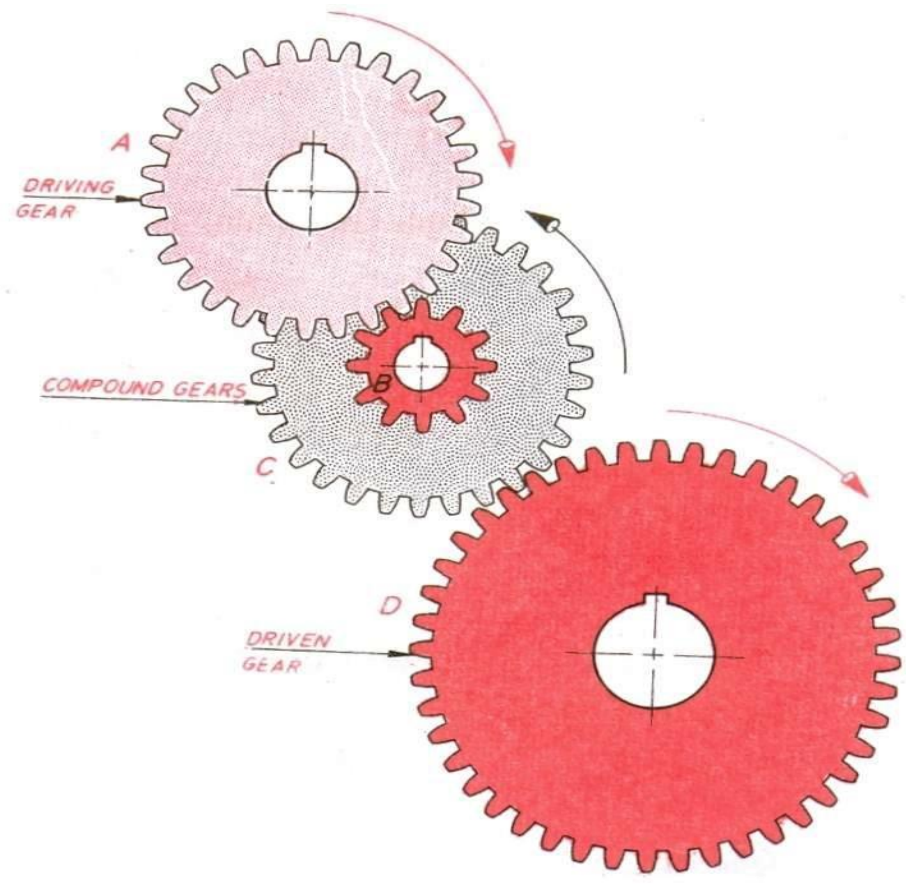
- **Arrangement of gears in series is known as <u>simple gear train</u>.**
- **Intermediate gears are provided between the driver and driven.**

The function of the idler gears is

1. To cover the space between the driver and driven gears and to
2. Obtain the desired direction of driven

Compound gear train

- When two or more gears are compounded, then the gear train is known as compound gear train.



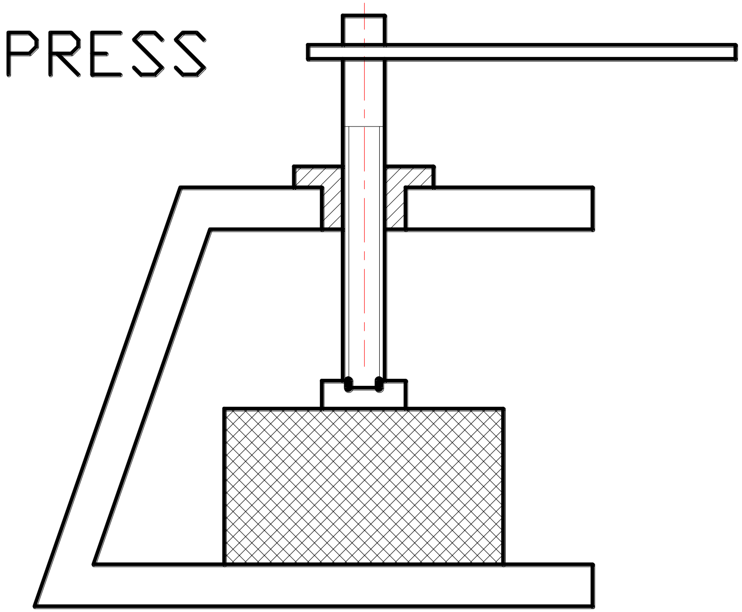
Compound Gear Train

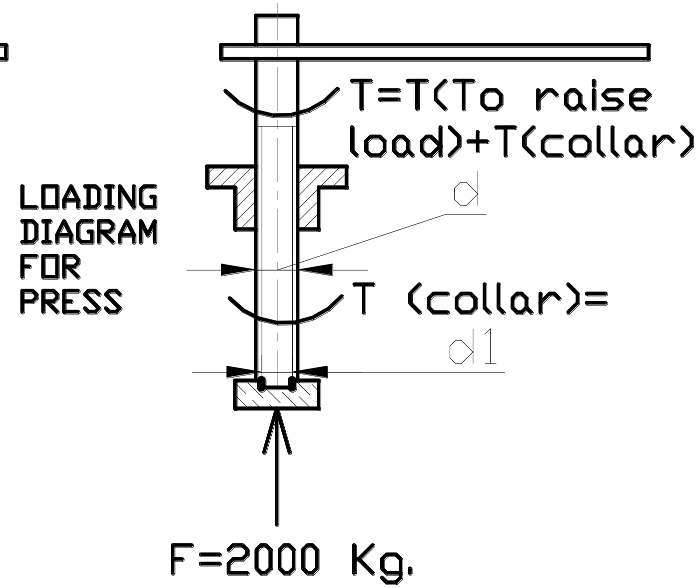
UNIT-V : APPLICATION OF POWER SCREWS

- **FUNCTION OF A POWER SCREW IS**
- Provide a means for obtaining a large mechanical advantage
- Transmit power by converting angular, into linear motion
- Common applications include
- Lifting jacks, presses, vices, and lead screws for lathe machines
- **Figure 1.1** shows the application in a lifting jack, while **Figure 1.2** shows the same concept when used for a press.

SCREW PRESS APPLICATION

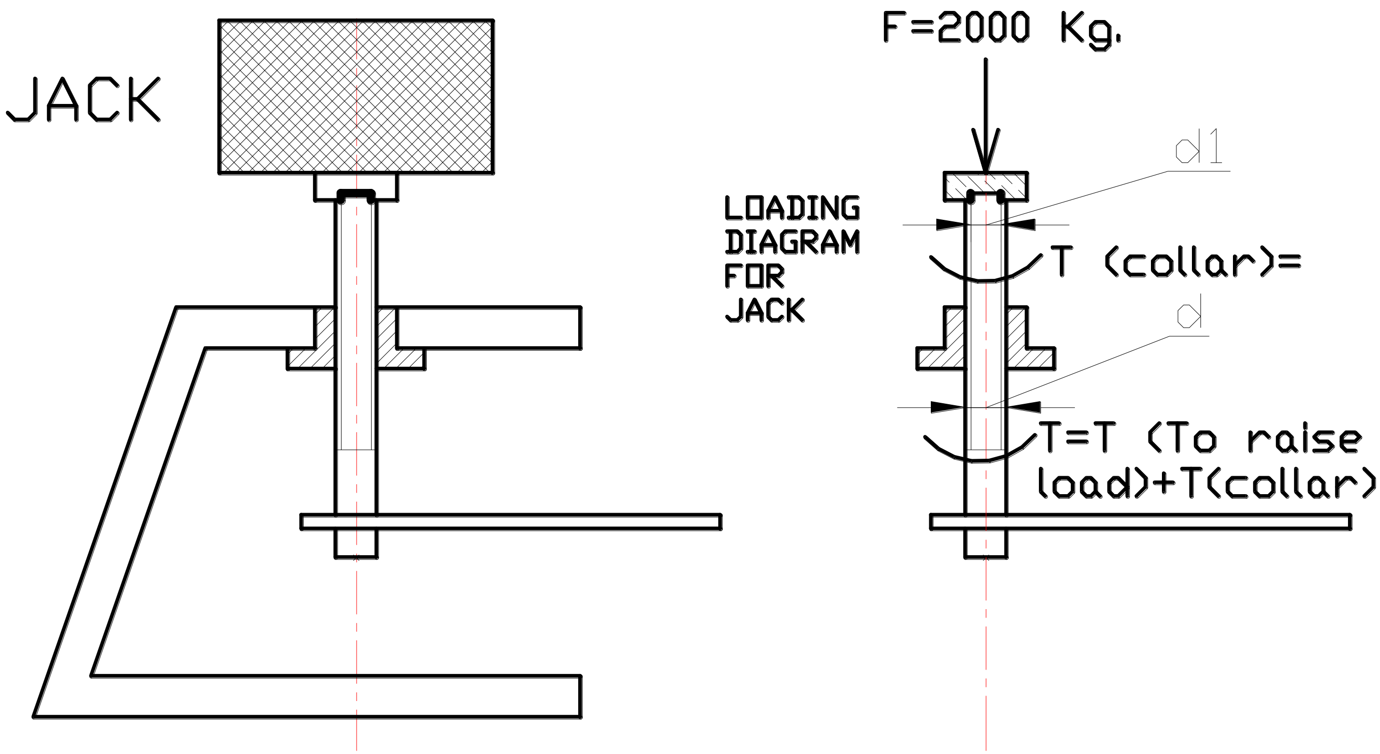
- **LOADING DIAGRAM**





SCREW JACK APPLICATION

- **LOADING DIAGRAM**



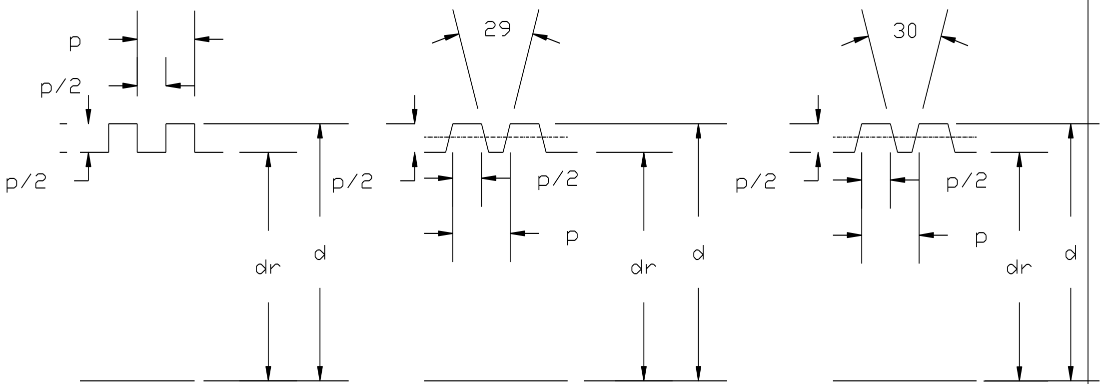
THREAD FORMS FOR POWER SCREWS

- **POWER SCREWS USE EITHER SQUARE, OR TRAPEZOIDAL THREAD FORMS**
- Two types of trapezoidal thread forms are
- **ACME** thread standard, used widely in the English speaking countries, and based on the inches units,
- **Metric trapezoidal** standard, originating in Europe, and now adopted by the International Standards Organisation (ISO).
- **Figure 1.3** shows the three geometric profiles of the three thread forms used for power screws.

THREAD FORMS FOR POWER SCREWS

- **SQUARE AND TRAPEZOIDAL THREAD STANDARDS**

FIGURE 1.3:THREADS USED IN POWER SCREWS



(a) Square Threads (b) ACME Threads (c) (ISO) Metric Trapezoidal Threads

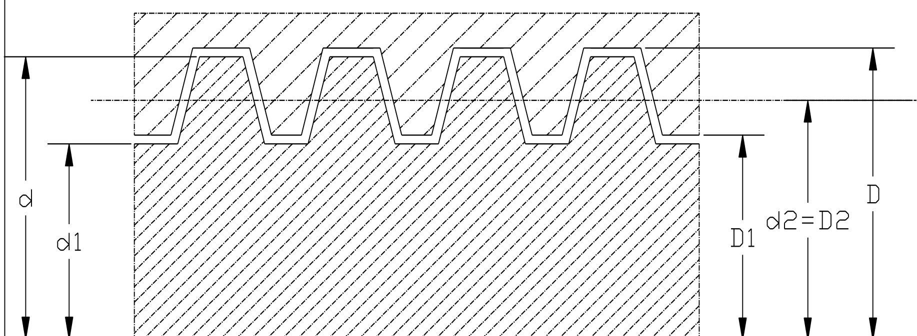
THREAD FORMS FOR POWER SCREWS

- **(ISO) METRIC TRAPEZOIDAL THREAD FORM STANDARD SPECIFICATIONS RELATE**
- Screw shaft DIAMETER to PITCH, as shown in next slide
- For the SQUARE and ACME thread form standards, only the geometric profile of the thread form is specified
- The designer is left to chose the size of thread for each screw shaft diameter
- This does not pose any serious problem because each power screw application is often a special case.

(ISO) METRIC TRAPEZOIDAL SCREW THREAD STANDARDS

- **ISO Metric Trapezoidal Thread Standard**

FIGURE 1.4: (ISO) METRIC TRAPEZOIDAL THREAD STANDARD



Key to Table 1.1

(ISO) METRIC TRAPEZOIDAL SCREW THREAD STANDARDS

- **DIAMETER, PITCH SPECIFICATIONS**

Nominal (***Major Exernal***) Diameter	**Pitch p**			**Pitch Diameter d2=D2**	**Major Internal Diameter D**	**Minor Diameter**	
	Coarse	**Medium**	**Fine**			**External d1**	**Internal D1**
8		**1.5**		**7.25**	**8.30**	**6.20**	**6.50**
10		**2**	**1.5**	**9.00**	**10.50**	**7.50**	**8.00**
12		**3**	**2**	**10.50**	**12.50**	**8.50**	**9.00**
16		**4**	**2**	**14.00**	**16.50**	**11.50**	**12.00**
20		**4**	**2**	**18.00**	**20.50**	**15.50**	**16.00**
24	**8**	**5**	**3**	**21.50**	**24.50**	**18.50**	**19.00**
28	**8**	**5**	**3**	**25.50**	**28.50**	**22.50**	**23.00**
32	**10**	**6**	**3**	**29.00**	**33.00**	**25.00**	**26.00**
36	**10**	**6**	**3**	**33.00**	**37.00**	**29.00**	**30.00**

MECHANICS OF POWER SCREW (SQUARE THREADED)

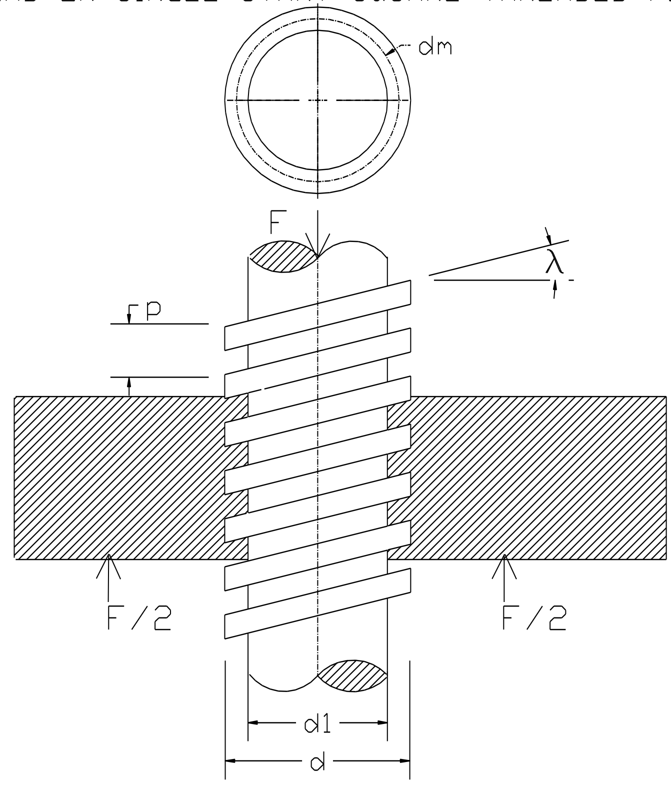
- **GEOMETRY AND DIMENSIONS**

1) **<u>Square threaded</u>** power screw
2) With a single start thread
3) Shown in next slide

MECHANICS OF POWER SCREW (SQUARE THREADED)

- Geometry and dimensions

FIGURE 1.5: LOAD ON SINGLE START SQUARE THREADED POWER SCREW

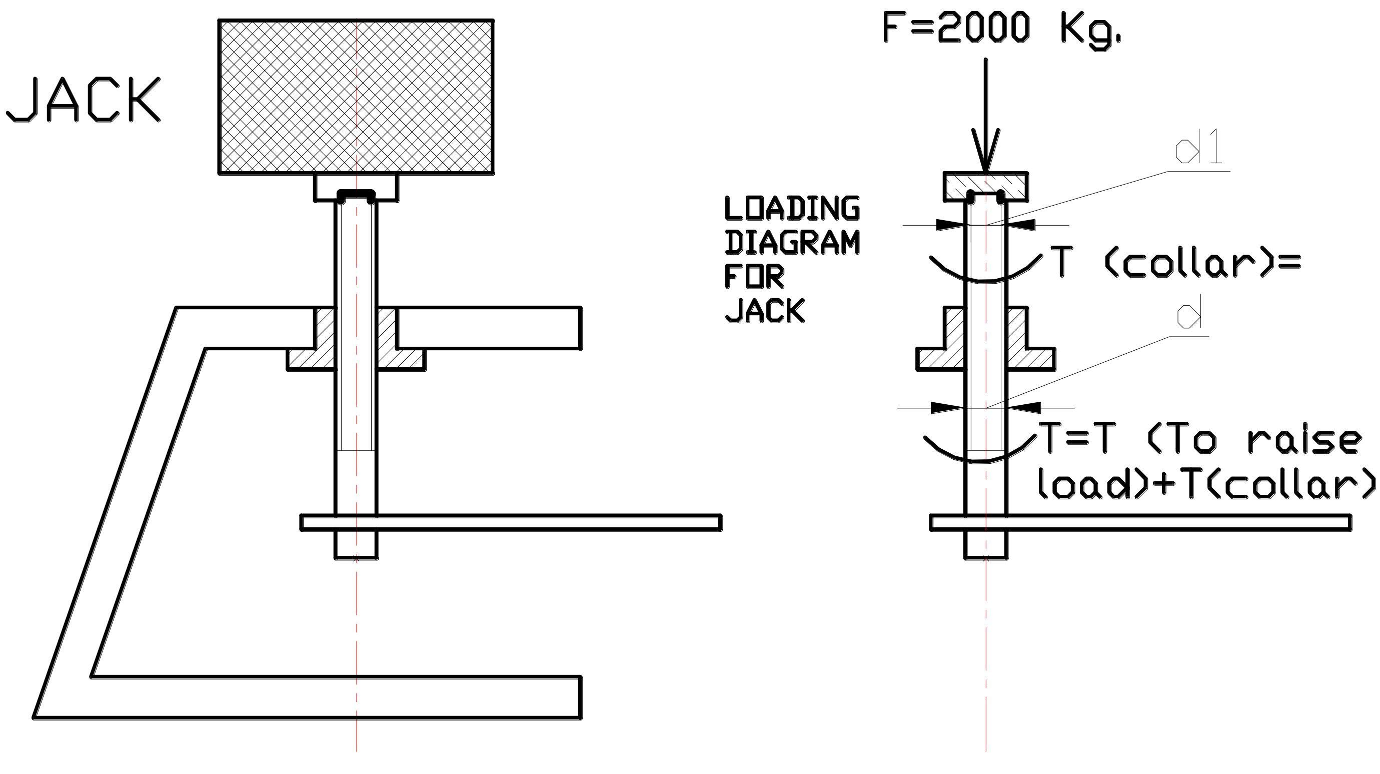


MECHANICS OF POWER SCREW (SQUARE THREADED)

- **GEOMETRY AND DIMENSIONS**
- The power screw carries an axial load F
- This is to be raised or lowered by applying a turning moment or torque on the screw shaft
- The screw and nut machine then coverts the torque on the screw shaft, into the desired axial load
- This is the typical situation in the screw jack, and the screw press concepts shown at slides 3 and 4

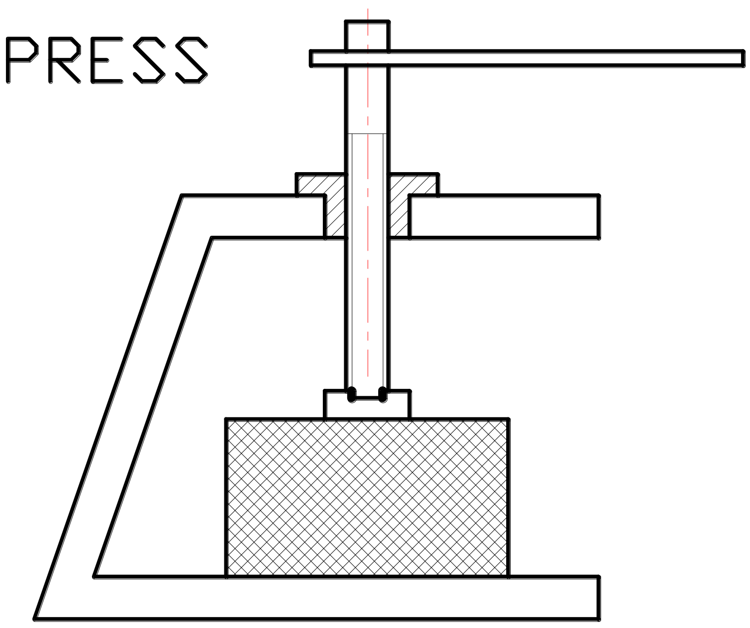
SCREW JACK APPLICATION

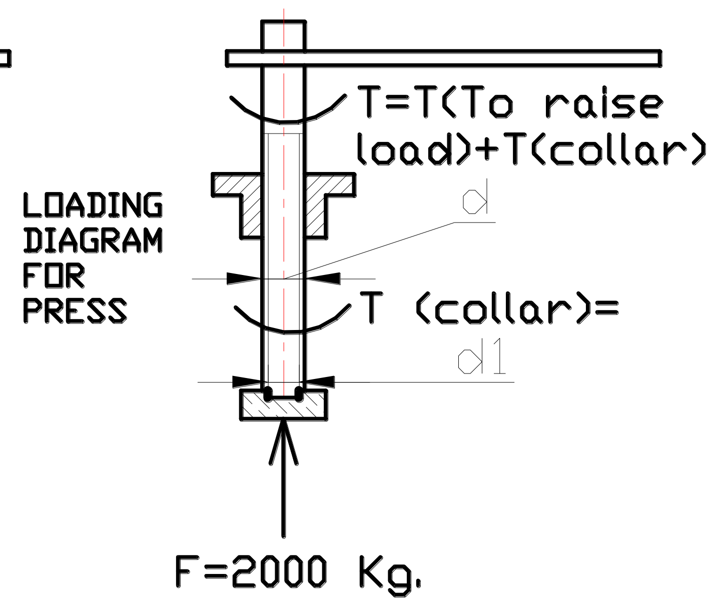
- **LOADING DIAGRAM**



SCREW PRESS APPLICATION

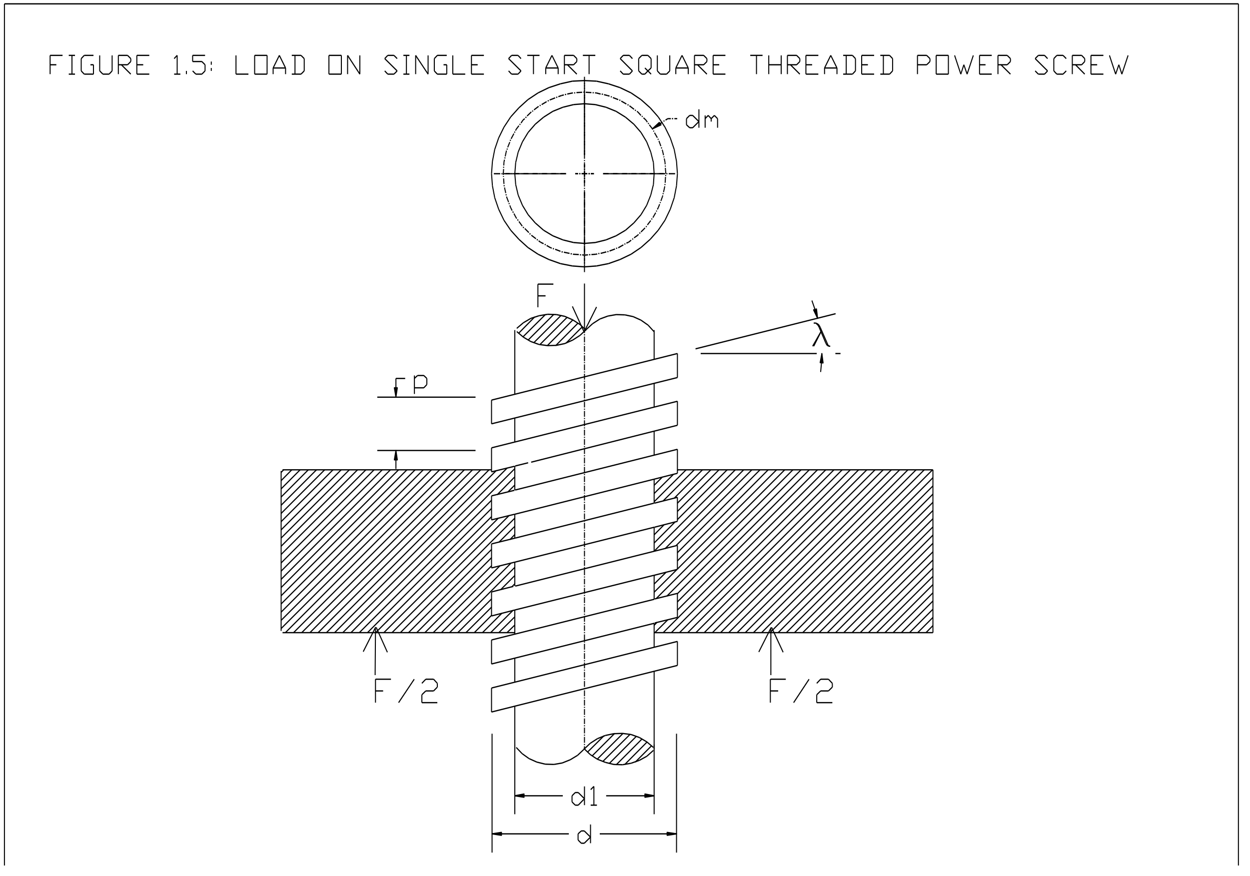
- **LOADING DIAGRAM**





MECHANICS OF POWER SCREW (SQUARE THREADED)

- Geometry and dimensions



MECHANICS OF POWER SCREW (SQUARE THREADED)

- **FORCES IN SCREW-NUT INTERACTION**
- Axial load F carried by screw shaft
- Resisted by an equal and opposite force acting on the nut.
- The rest of the variables in next slide

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **VARIABLES IN SCREW-NUT INTERACTION**

$$F = Axial \quad Load \quad to \ be \ raised \quad or \ lowered$$

$$\lambda = Helix \quad angle \quad for \ thread$$

$$p = Pitch \quad of \quad thread$$

$$d_m = Mean \quad diameter \quad of \quad screw \quad thread$$

$$d_m = \frac{D_1 + d}{2}$$

MECHANICS OF POWER SCREW (SQUARE THREADED)

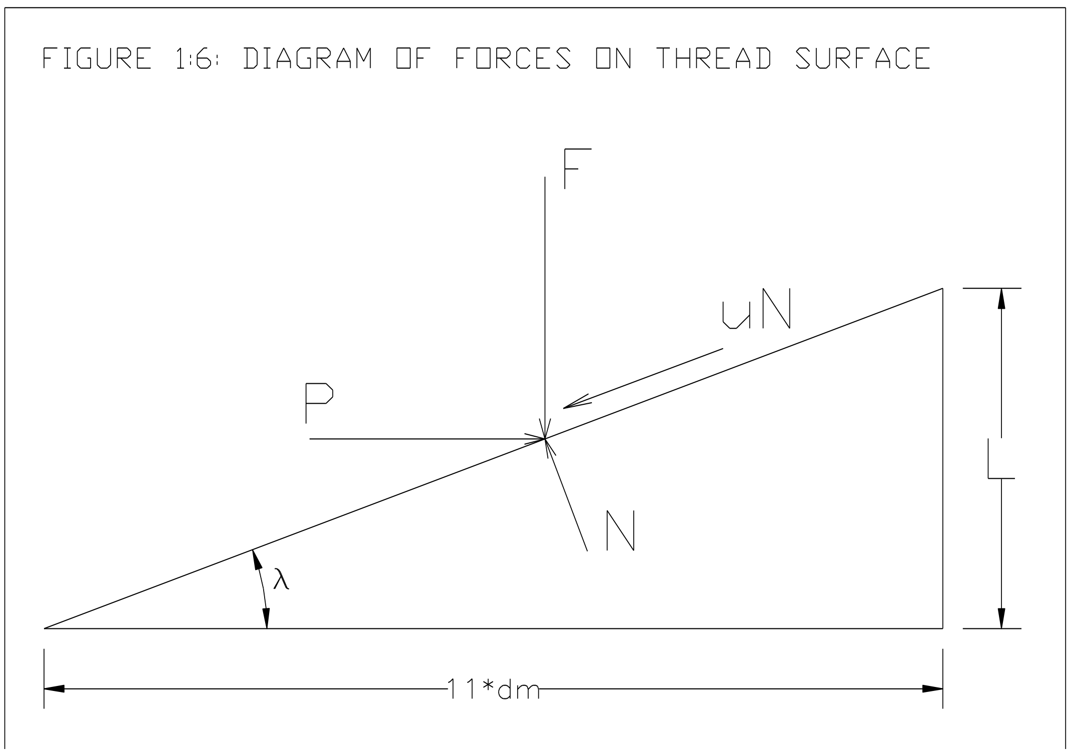
- **EXTERNAL LOAD ON SCREW SHAFT**
- **TORQUE REQUIRED IN A SQUARE THREADED POWER SCREW**
- To determine the torque required in a power screw, as a function of the axial load to be raised or lowered
- This torque comprises one of the external loads that the screw shaft and its threads must withstand
- This torque load is a function of
  1) Axial load F,
  2) Geometry and dimensions of the screw shaft and its threads
  3) The co-efficient of friction between screw and nut threads.

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- To determine the relationships between
  1) Torque required, and
  2) Axial load to be raised F,
- Screw thread is simplified into an inclined plane as shown in the next slide
- Slide shows a single thread of the screw, unrolled or developed,
- Slide shows the forces operating on the thread surface when the load F is being raised
- The axial load F is then considered as representing the summation of all the unit forces acting in the direction of the axial load to be raised.

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**



MECHANICS OF POWER SCREW (SQUARE THREADED)

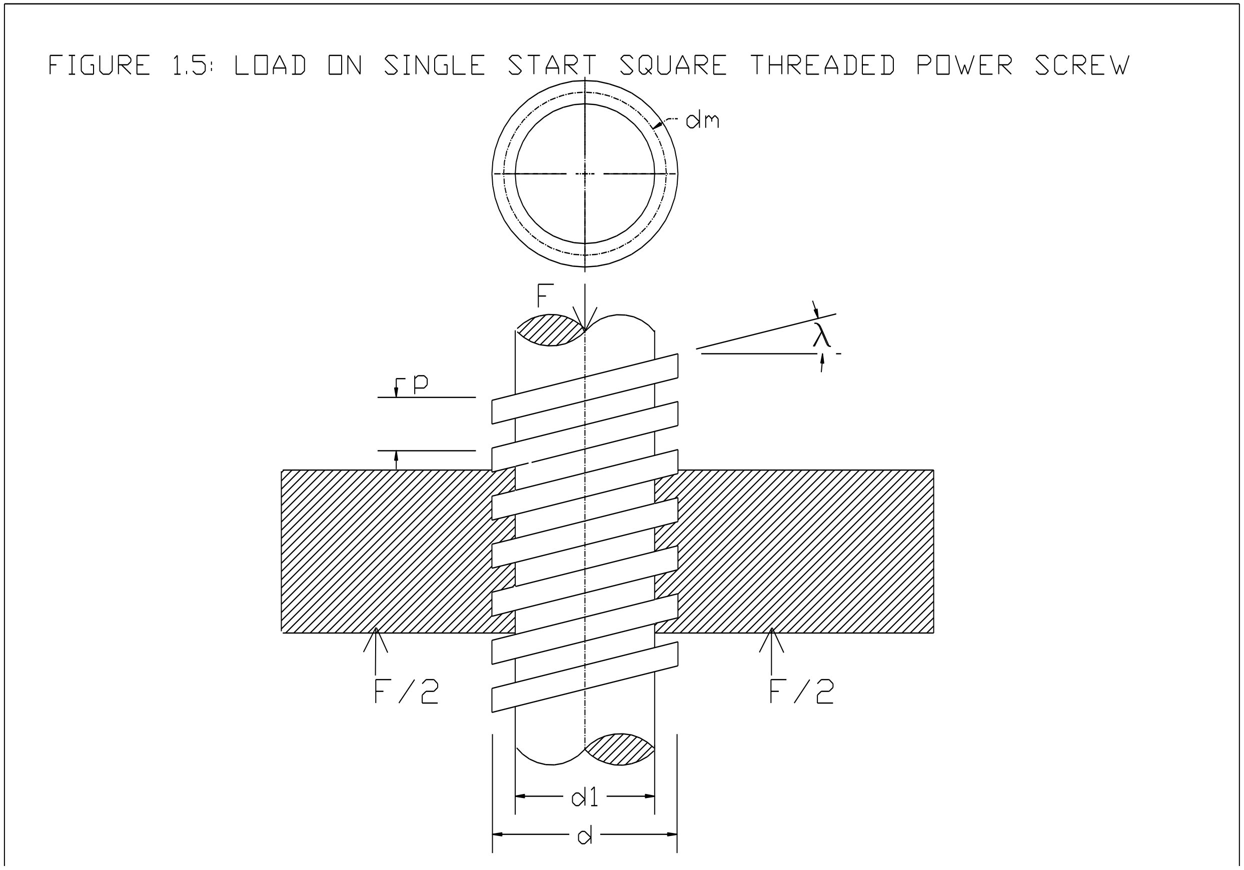
- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- In previous slide, the horizontal force P is the resultant force arising out of the applied torque
- It operates to move the axial load F, along the inclined plane formed by the developed thread surface.

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- The unit forces, whose summation is F and P, act on the entire thread surface between minor internal diameter and the major external diameter
- These resultant forces are simplified as concentrated forces at the mean of the two diameters

MECHANICS OF POWER SCREW (SQUARE THREADED)

- Geometry and dimensions



MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- **For single start thread, the inclined plane, along which the load F is moved, is therefore a triangle whose angle of inclination is the helix angle of the screw thread**
- **This helix angle is defined by**
  1) **The length of the side opposite to the lead angle which is equal to the lead of the screw thread.**
  2) **The base of the triangle is equal to the circumference of the mean thread diameter, which equals .**

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- The triangle in the previous slide applies to one turn of a thread,
- Is similar to the case of the entire length of engaged threads.
- The forces F and P can therefore represent the summation of forces on the entire surface of the engaged threads.

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- **In reaction to the forces F and P, operating on the surface of the threads,**
- **There is a normal force N, and a frictional resistance given by the product of N and the friction co-efficient between the screw and nut thread surfaces**
- **The unknown forces in this system of forces can be determined as shown in the next slide by the requirements of equilibrium:**

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**

$$\Sigma F_h = P - N \sin \lambda - \mu N \cos \lambda = 0$$

$$\Sigma Fv = F + \mu N \sin \lambda - N \cos \lambda = 0$$

Where

F_h = *Horizontal forces*

F_v = *Vertical forces*

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**

Solving the two equations for F and P

$$P = N \sin \lambda + \mu N \cos \lambda$$

$$F = N \cos \lambda - \mu N \sin \lambda$$

$$Substituting \ for \ \tan \lambda = \frac{l}{\pi d_m}$$

$$and \quad P = F \left[\frac{l + \mu \pi d_m}{\pi d_m - \mu l} \right]$$

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**
- But the torque resulting from the force P, is given by
- The product of
    1) Turning Force P
    2) Mean radius at which the force P acts
- Consequently, the torque T is given by the expression in the next slide

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**

$$T = \frac{F d_m}{2}\left[\frac{l + \mu\pi d_m}{\pi d_m - \mu l}\right]$$

MECHANICS OF POWER SCREW (OTHER THREAD FORMS)

- **THE CASE OF ANGULAR THREAD FORM**
- **The equation for the torque required on the screw shaft to raise an axial load F, has been derived, and is therefore valid, for the square thread form, where**
  1) **Normal thread loads are parallel to the axis of the screw shaft.**
- **In the case of an angular thread form, such as ACME, (ISO) Metric Trapezoidal or other angular thread forms used in fasteners,**
- **Thread angle for the various thread forms is as shown in the next slide:**

MECHANICS OF POWER SCREW (OTHER THREAD FORMS)

- **TORQUE TO RAISE AXIAL LOAD WITH OTHER THREAD FORMS**

Thread Form	Thread angle =2*α (in degrees)
ACME	29
(ISO) Metric Trapezoidal	30
Metric Fasteners	30

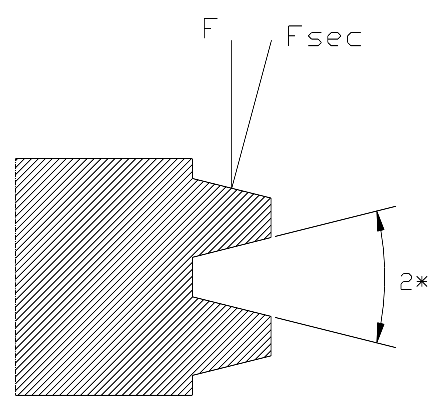
MECHANICS OF POWER SCREW (ANGULAR THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH ANGULAR THREAD FORM**
- In these angular thread forms, the load normal to thread surface, which causes friction, is inclined to the axis of the screw shaft by
  1) An angle α, or half the thread angle
- This is illustrated in the next slide

MECHANICS OF POWER SCREW (ANGULAR THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH ANGULAR THREAD FORM**

FIGURE 1.7: NORMAL LOAD ON ANGULAR THREAD FORM



MECHANICS OF POWER SCREW (ANGULAR THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH ANGULAR THREAD FORM**
- **The effect of this inclination of the normal load on thread surface to the axis of the screw shaft is**
  1) **To increase the frictional force on the thread surface, by the wedging action of the threads.**
  2) **The frictional force is increased by a factor equal to the reciprocal of cos α.**
- **To account for this increased frictional force, the frictional terms in the torque equation are divided by cos α.**
- **The equation for the torque required when raising an axial load F, where the screw thread form has a thread angle of 2*α, is therefore as shown in the next slide**

MECHANICS OF POWER SCREW (ANGULAR THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH ANGULAR THREAD FORM**

$$T = \frac{Fd_m}{2}\left[\frac{l + \pi\mu d_m \sec\alpha}{\pi d_m - \mu l \sec\alpha}\right]$$

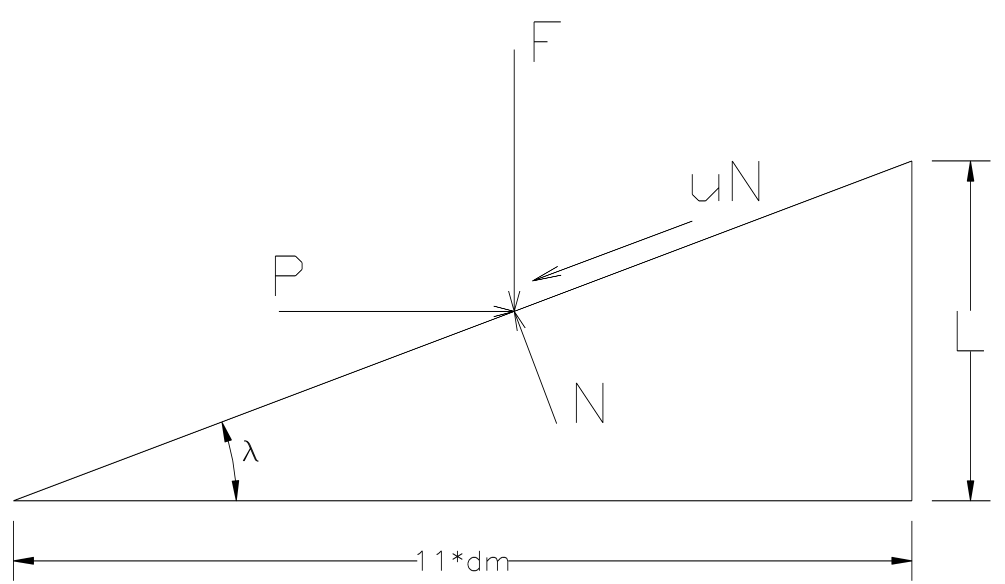
MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE REQUIRED TO LOWER LOAD**
- **From the force diagram in next slide, it is seen that when raising an axial load F**
- **Force P (and hence the torque T), has to overcome both the axial load F, as well as the friction on the thread surface**

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE TO RAISE AXIAL LOAD WITH SQUARE THREAD FORM**

FIGURE 1:6: DIAGRAM OF FORCES ON THREAD SURFACE



MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE REQUIRED TO LOWER LOAD**
- **When lowering the axial load F, the force P, result in movement in the direction of axial load F and the load itself assists the torque T to overcome the thread friction.**
- **The torque required to lower load is therefore given by the expressions in the next slide**

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **TORQUE REQUIRED TO LOWER LOAD**
- **Square thread form**

$$T = \frac{Fd_m}{2}\left[\frac{l - \pi\mu d_m}{\pi d_m + \mu l}\right]$$

MECHANICS OF POWER SCREW (ANGULAR THREADED)

- **TORQUE REQUIRED TO LOWER LOAD**
- Angular thread form

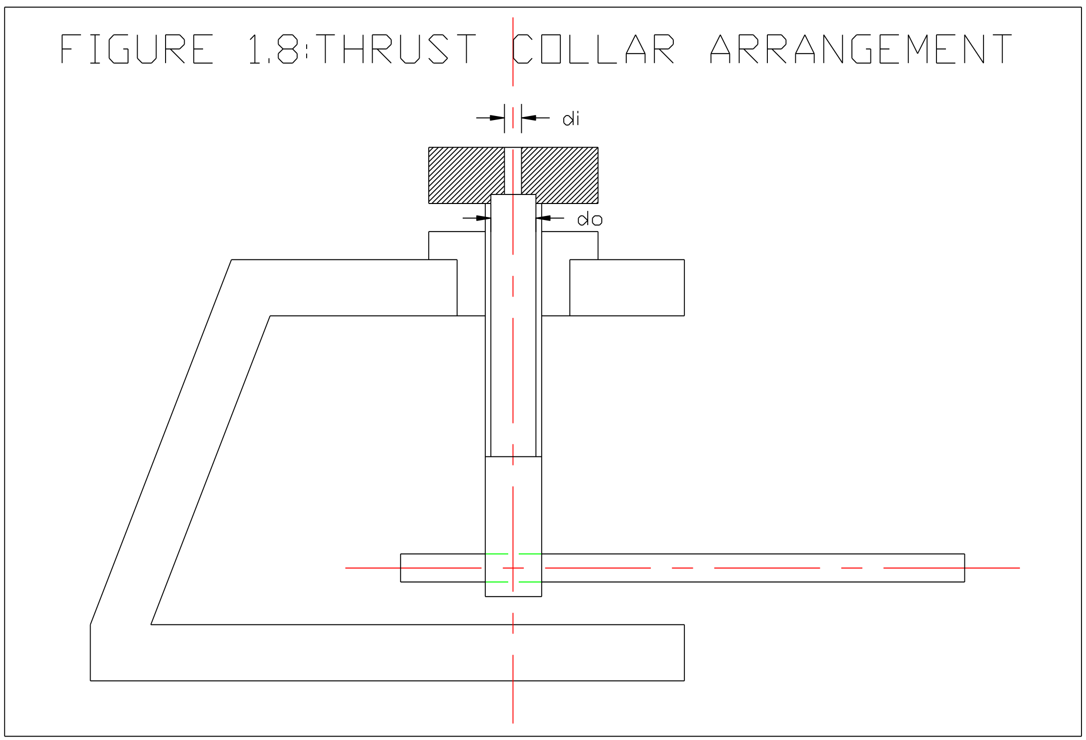
$$T = \frac{Fd_m}{2}\left[\frac{l - \pi\mu d_m \sec\alpha}{\pi d_m + \mu l \sec\alpha}\right]$$

MECHANICS OF POWER SCREW COLLAR FRICTION

- **TORQUE TO OVERCOME COLLAR FRICTION**
- **In most power screw applications, the axial load F must be transmitted through a thrust collar.**
- **This is necessary so that while the screw shaft rotates, the collar (load application) pad may remain stationary as the load is lifted, or as the work is pressed, this is shown in the next slide**

MECHANICS OF POWER SCREW COLLAR FRICTION

- TORQUE TO OVERCOME COLLAR FRICTION



MECHANICS OF POWER SCREW COLLAR FRICTION

- **TORQUE TO OVERCOME COLLAR FRICTION**
- For this reason, an additional friction force appears at the collar pad
- The external torque required to operate the power screw is therefore increased by
- An additional torque required to overcome collar friction.

MECHANICS OF POWER SCREW COLLAR FRICTION

- **TORQUE TO OVERCOME COLLAR FRICTION**
- Diagram in previous slide shows a typical thrust collar arrangement
- Thrust load assumed to be concentrated at the mean collar diameter
- Torque required to overcome collar friction is then given approximately by the expression in the next slide

MECHANICS OF POWER SCREW COLLAR FRICTION

- **TORQUE TO OVERCOME COLLAR FRICTION**

$$T_c = \frac{F \mu_c d_c}{2}, \quad Where \quad ,$$

$$F = Axial \quad load \quad to \quad be \quad raised \quad , \quad \mu_c = Co - efficient \quad of \quad collar \quad friction$$

$$d_c = Mean \quad collar \quad diameter \quad , \quad d_c = \frac{d_i + d_o}{2} \; (approximately)$$

$$d_i = Inner \quad diameter \quad of \quad collar \quad , \quad d_o = Outer \quad diameter \quad of \quad collar$$

$$T_c = Torque \quad to \quad overcome \quad collar \quad friction$$

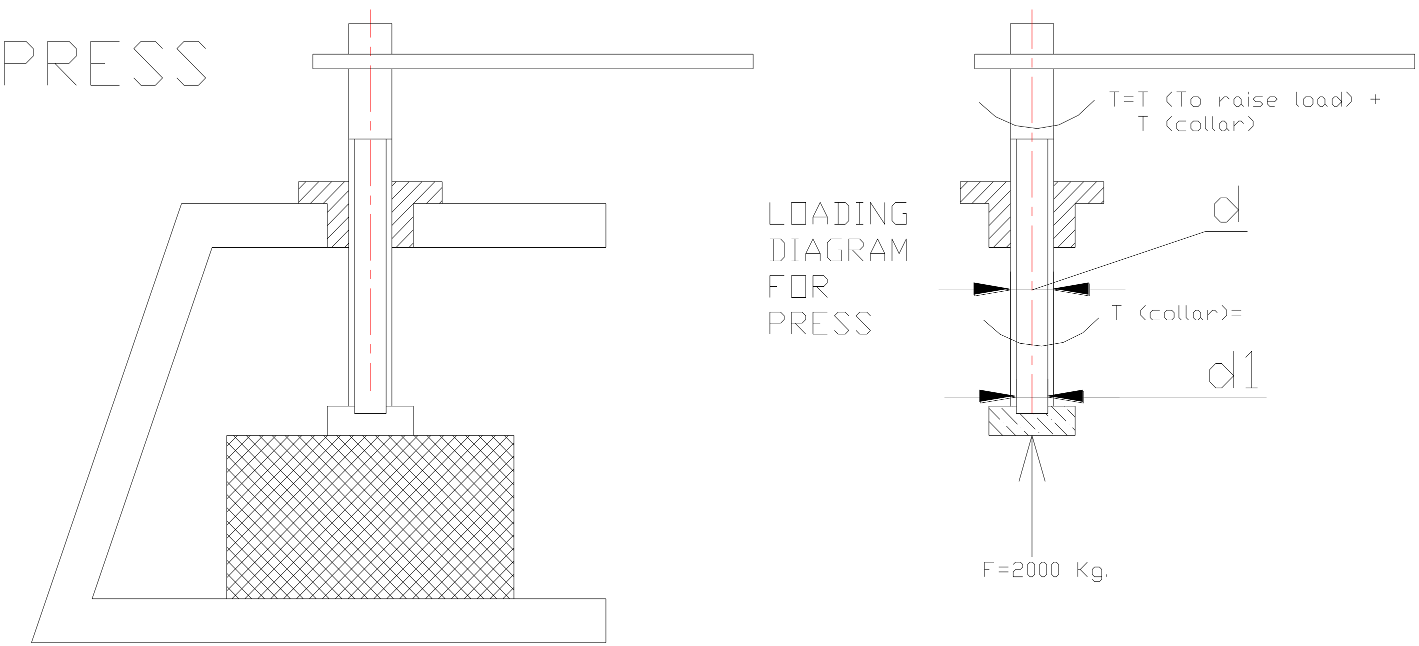
MECHANICS OF POWER SCREW (ANGULAR THREADED)

- **TOTAL TORQUE TO RAISE AXIAL LOAD WITH ANGULAR THREAD FORM**

$$T = \frac{Fd_m}{2}\left[\frac{l + \pi\mu d_m \sec\alpha}{\pi d_m - \mu l \sec\alpha}\right] + Tc$$

SCREW PRESS APPLICATION

- **LOADING DIAGRAM**



MECHANICS OF POWER SCREW

- **COEFFICIENT OF FRICTION-THREADS**

	Nut material			
Screw material	Steel	Bronze	Brass	Cast iron
Steel, dry	0.15-0.25	0.15-0.23	0.15-0.19	0.15-0.25
Steel, machine oil	0.11-0.17	0.10-0.16	0.10-0.15	0.11-0.17
Bronze	0.08-0.12	0.04-0.06	-	0.06-0.09

MECHANICS OF POWER SCREW

- **COEFFICIENT OF FRICTION-COLLAR PAD**

COMBINATION	Running	Starting
Soft steel on cast iron	0.12	0.17
Hard steel on cast iron	0.09	0.15
Soft steel on bronze	0.08	0.10
Hard steel on bronze	0.06	0.08

MECHANICS OF POWER SCREW COEFFICIENT OF FRICTION

- **From the tables quoted previously, it can be seen that coefficient of friction varies very little with axial load, speed, and even material combination**
- **The values to be used for both <u>thread friction</u> and <u>collar friction</u> are**

$$\mu = 0.10 - 0.15$$

MECHANICS OF POWER SCREW COLLAR FRICTION

- **TORQUE TO OVERCOME COLLAR FRICTION**
- **For large collars, the friction torque at collar bearing or pad will be more accurately computed as is done for a disc clutch.**

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **THREAD STRESSES**
- These are given by the expressions:

$$\tau_s = \frac{2F}{\pi d_1 h}, \qquad \tau_n = \frac{2F}{\pi d h}, \qquad \sigma_b = \frac{4pF}{\pi h (d^2 - d_1^2)}$$

$Where\ ,\ h = Height\ of\ nut\ ,\ and\ p = pitch\ of\ screw\ threads$

$\tau_s = Average\ shear\ stress\ on\ screw\ threads$

$\tau_n = Average\ shear\ stress\ on\ nut\ threads$

$\sigma_b = Bearing\ stress\ on\ thread\ surfaces$

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **THREAD STRESSES**
- When thread stresses given in the previous slide are computed
- They should not exceed the limiting values for the chosen materials.

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **ALLOWABLE BEARING PRESSURES**
- Limiting values of bearing pressures on thread surfaces are given for various combination of screw and nut material
- These have been determined empirically and are as shown in the next slide

MECHANICS OF POWER SCREW (SQUARE THREADED)

- **SAFE BEARING PRESSURES**

Type of Power Screw	Material		Sb Mpa	Rubbing Speed m/min
	Screw	Nut		
Hand press	Steel	Bronze	17.0-24.0	Low speed, well lubricated
Jack-screw	Steel	Cast iron	12.0-17.0	Low speed <2.5
Jack-screw	Steel	Bronze	11.0-17.0	Low speed<3
Hoisting screw	Steel	Cast iron	4.0-7.0	Medium speed (6-12)
Hoisting screw	Steel	Bronze	5.5-10.0	Medium speed (6-12)
Lead screw	Steel	Bronze	1.0-1.6	High speed>15

References

- Shigley, Joseph; Mechanical Engineering Design, Seventh Edition, 2003,McGraw Hil, pg 396
- VB Bandari; Design of Machine Elements, 1994, Tata McGraw Hill, pg 175

UNIT-II
IC Engine Components