Chapter - 7

POWER TRANSMISSION DEVICES
&
MACHINE ELEMENTS

Individual Drive

When output from one prime mover is used to drive one and only one machine the arrangement is known as individual drive.

e.g. electric motor driving a compressor or pump.

Group Drive

When the output from one prime mover is used to drive number of machines, the arrangement is known as group drive.

e.g. a car engine is used to drive the car through a gear box, cooling water pump of radiator, cooling fan, air conditioner etc.

Advantage of Group Drive

- Only one prime mover generating sufficient power to drive all machines. Hence Initial cost is less.
- Prime mover can be placed far away from the place of use, thus noiseless and pollution free workplace.
- Less floor space is required for number of machines.
- Power losses in prime movers are less giving high overall efficiency.

Disadvantage of Group Drive

- The prime mover must be kept working even when one of the machine is to be operated.
- Failure of prime movers entirely paralyses all the operations.
- Not Suitable when machine is very small or total load is fluctuating.

Belt Drive

A belt is a looped strip of flexible material used to mechanically link two or more rotating shafts.

Belts are friction drives, which mean they depend on friction between the belt and pulley to transmit power.

- A belt drive offers smooth transmission of power between shafts at considerable distance.
- These are made up of materials like canvas, leather, rubber etc. Sometimes belts are reinforced with the wires to improve the strength.

Advantages of Belt Drives

- They don't require Parallel shafts.
- Eliminates the need for a more complicated arrangement of gears, bearings, and shafts.
- Noise and vibration are damped out. Machinery life is increased because load fluctuations are shock-absorbed.
- They are lubrication-free. They require less maintenance cost.
- Belt drives are highly efficient in use (up to 98%, usually 95%).
- They are very economical, when distance between shafts is very large.

Disadvantages of Belt Drives

- Heat buildup occurs. Speed is limited to usually 35 meters per second. Power transmission is limited to 370 kilowatts.
- Operating temperatures are usually restricted to –35 to 85°C.
- Belt drives are often a source of vibration due to misalignments, belt resonance, and belt wear.
- Low speed reduction ratio, up to 3:1.
- Belt tension needs to be adjusted periodically.

Types of Belts

- The most common types of belt drives include:

  a) Round belts

  b) V belts

  c) Flat belts

  d) Timing belts

Flat Belt

- Flat belts are most widely used when distance between two pulleys are large.
- They have a large width in comparison to thickness.
- They are used to transmit the moderate amount of power.
- Flat belts were commonly made from leather but today are usually made from rubber.
- Their ultimate tensile stress varies from 20 to 35 N/mm2.

V Belt

- V belts are most widely used when distance between two pulleys are less.
- V belts have a trapezoidal cross-section, which rests against the side of V pulley under tension and hence provides a better grip. The trapezoidal cross-section prevents belt from slipping off since area of cross section is more than that of flat belt.
- V belts are made of rubber, fabric, nylon and cotton.
- V belts operate most efficiently at speeds of about 20-25 m/sec.

Comparison Between Flat and V Belt

S. No	Flat Belt	V Belt
1	C/S Rectangular	C/S Trapezoidal
2	Made: Canvas, Leather	Made: Rubber, Reinforced with steel wire
3	Up to 5m	Up to 1m
4	Can be used for Non parallel shaft	Can be used for parallel shaft
5	Open as well as Crossed belting is possible	Only open belting is possible
6	Have a joint	These are endless
7	Can be repaired	No repair possible
8	High Slippage	Low Slippage
9	No standardization of Length	These are available only in standardization.

Rope Drive

- As discussed earlier flat belt drives are used to transmit the moderate power, if large amount of power is to be transmitted by flat belt, then it would result in excessive belt cross section.
- Rope drive is used to transmit the large amount of power over a large distance from one pulley to another.
- Rope is a bundle of wire twisted in a specific way.
- For successful work the pulleys must be large in diameter and must have a smooth surface where the rope bears upon them.
- Ropes is used in cranes, elevators etc.

Advantages of Rope Drive

The Advantages of rope drive are:

- A larger amount of power is transmitted.
- Smooth and quiet running is obtained.
- Electrical disturbances are absent.
- It can be run in any direction or to any distance.
- Economy is obtained in first cost and in maintenance.

Types of Rope

Fiber Rope

As the name indicates, the rope made up from fibrous material such as cotton, manila etc. is called as fiber rope.

The fiber ropes are used when the pulleys are 60m apart.

It has poor mechanical properties as compared to wire rope.

Advantages of Fiber Rope

- It gives smooth, steady and quiet service.
- The shafts may be out of strict alignment.
- The power may be taken off in any direction and in fractional parts of the whole amount.
- It gives high mechanical efficiency.

Wire Rope

Wire rope is a type of cable which consists of several strands of wire laid (twisted) into a helix.

It is made up from wrought iron, cast steel, alloy steel etc. For certain purpose it may be made up from stainless steel, copper, bronze etc.

The wire ropes are used when the pulleys are 150m apart.

The wire ropes are widely used in suspension bridges, mine hoists and various material handling devices etc.

These are having a good strength (Strength increases as size decreases) and ductility because they are made from cold drawing process.

Advantages of Wire Rope

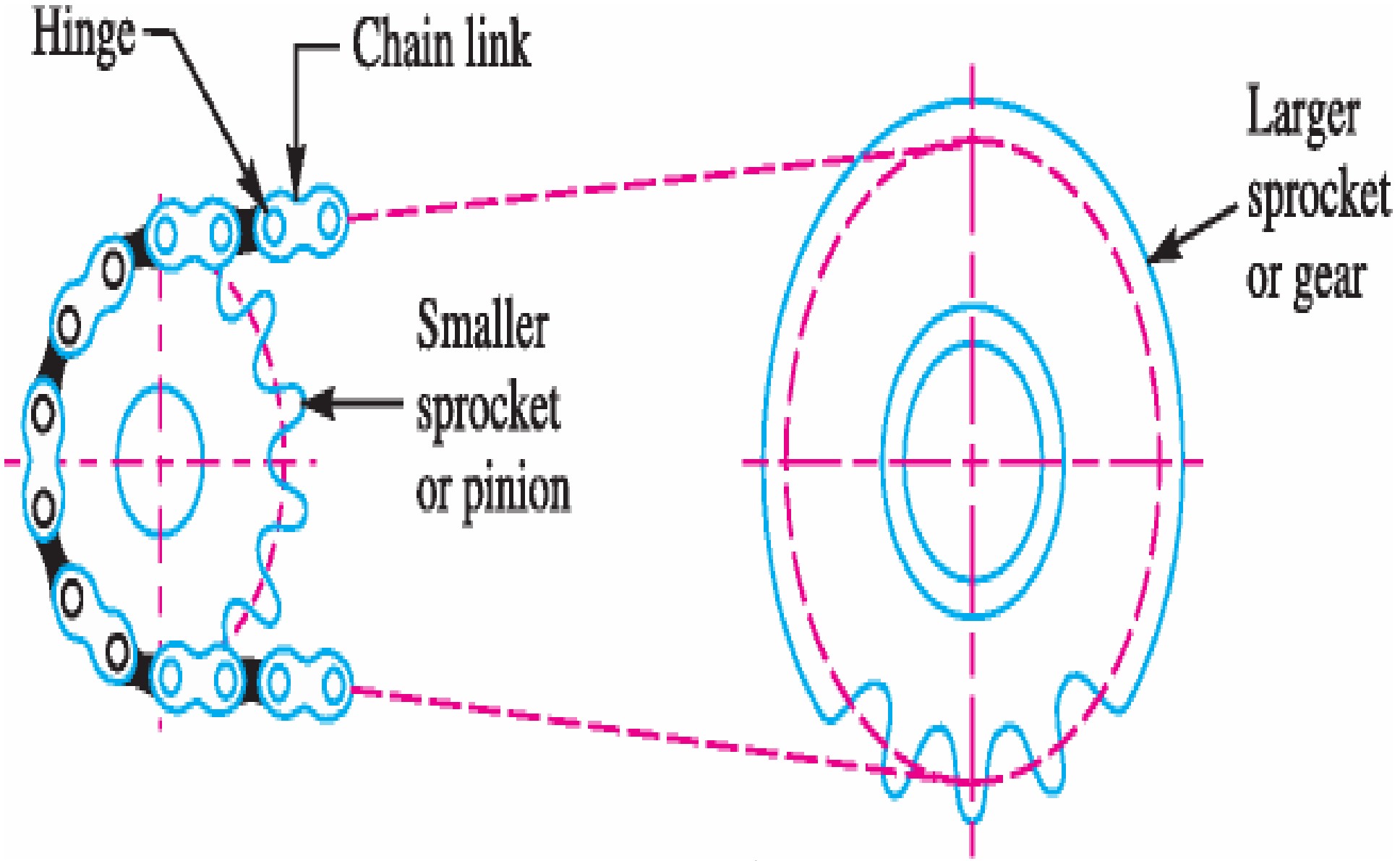
- These are lighter in weight
- These offer silent operation
- These are more durable
- These can withstand shock loads
- These are more reliable
- They do not fail suddenly

Why we need Chain Drivers?

On belt and rope drives that slipping may occur. In order to avoid slipping, chain drives are used.

Chain Drive

- A chain is built up of rigid links, which are hinged together in order to provide the necessary flexibility for wrapping action around the driving and driven wheels.
- These wheels have projecting teeth of special profile and fit into the corresponding recesses in the links of the chain.
- The toothed wheels are known as *sprocket wheels or simply sprockets.


Hinge
Chain link
Smaller
sprocket
or pinion
Larger
sprocket
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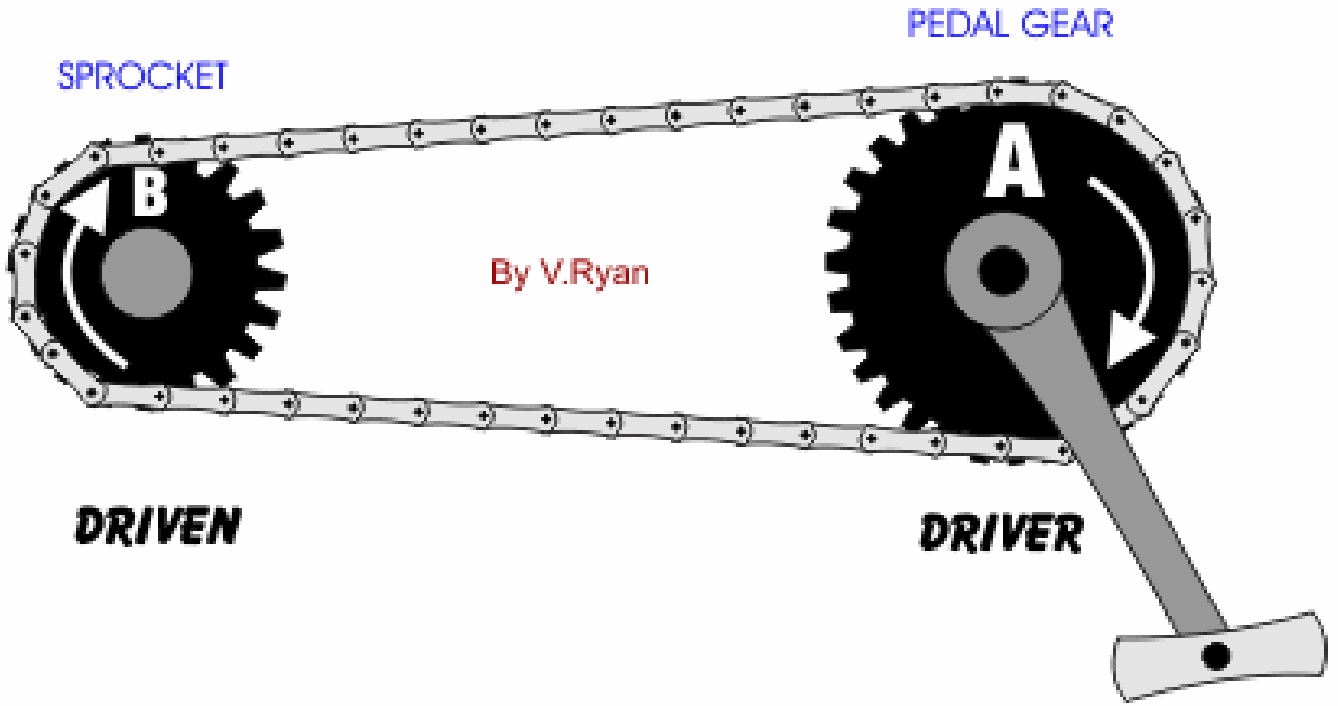
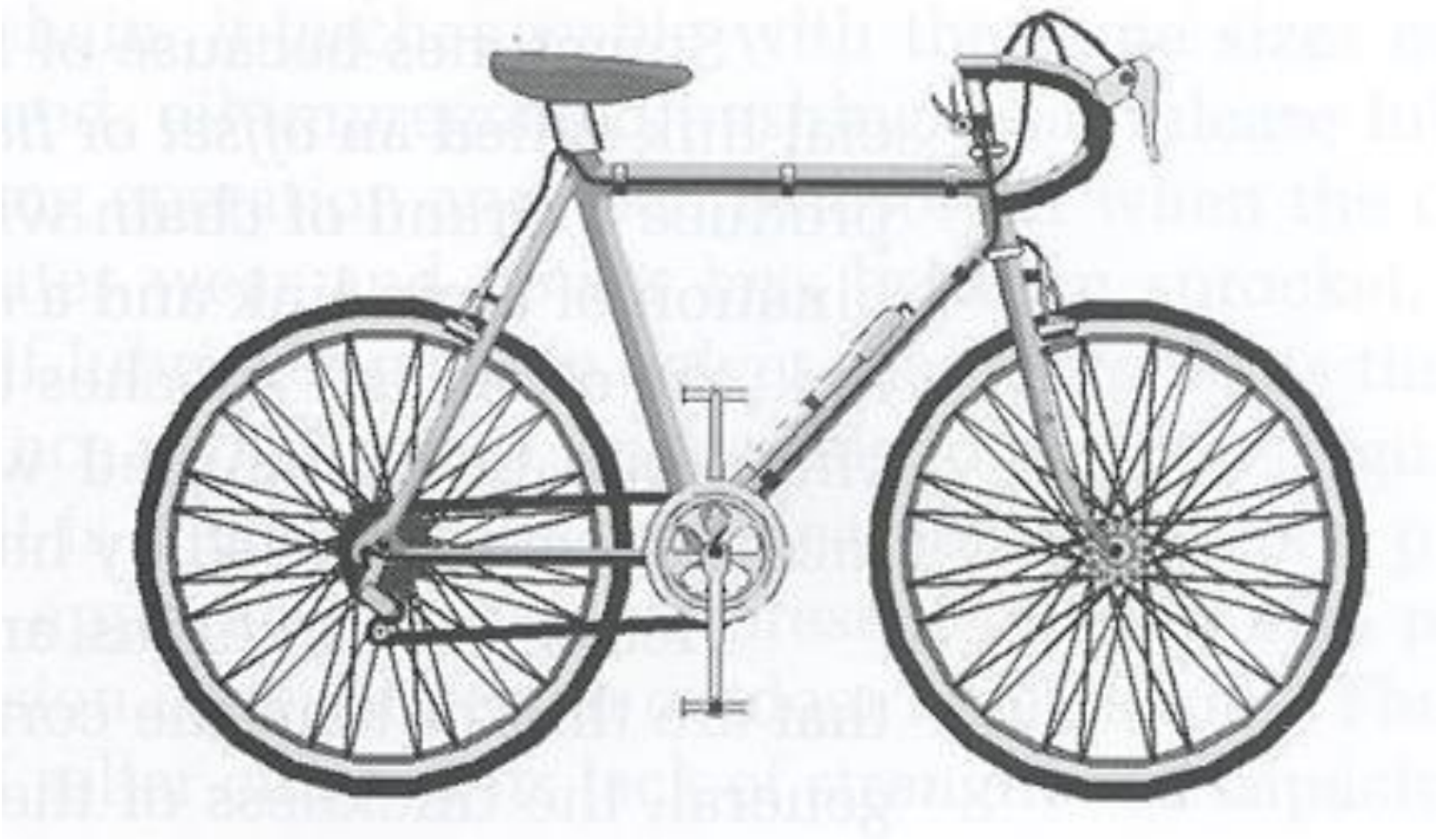

PEDAL GEAR
SPROCKET
B
A
By V.Ryan
DRIVEN
DRIVER

Practical Applications of Chain Drives

- The chains are mostly used to transmit motion and power from one shaft to another, when the center distance between their shafts is short such as in bicycles, motor cycles, agricultural machinery, conveyors, rolling mills, road rollers etc.
- Chains can be used in many forms to move, slide, carry, push and pull a variety of materials.
- Chain drives can also be used to synchronize or time movement e.g. industrial combustion engines use chain drives to control valve timing.
- Chain drives are recommended to transmit power up to 100kw and velocity ratios 10:1. Chain drives are intermediate between belt drives and gear drives; it shares the features of both the drives.



Chain Drive Advantages

- Chain drive is a positive drive having no slip or creep.
- There is no power loss due to slippage; therefore, it gives high transmission efficiency (up to 98%) than belt drives.
- Chain drives are more compact than belt drives.
- Wear and tear is less and thus maintenance cost is less in chain drives as compared to belt drive.
- Initial tension is not required in chain drive, whereas in belt drive it is essential.
- Chain drives operate effectively at high temperatures.
- Chain drives are often easier to install than belts on power transmission drives.
- Do not deteriorate due to environmental conditions like water, sunlight, dust etc.
- Chain drives can withstand abrasive conditions.

Chain Drive Disadvantages

- Chain drives are more complicated in design thus production cost is relatively high.
- Chain drives require more precise alignment than belt drives.
- Frequent lubrication is required.
- Chain drives are noisy and can cause vibrations.
- Do not have the load capacity or service life characteristics those of gear drives.

Sprockets

- Made of cast iron, cast steel or fabricated steel.
- Drive chain sprockets require a locking device.
- Most common is the key-way, key and set-screws.
- Double pitch chain uses either single duty or double duty sprockets.

Sprocket Types

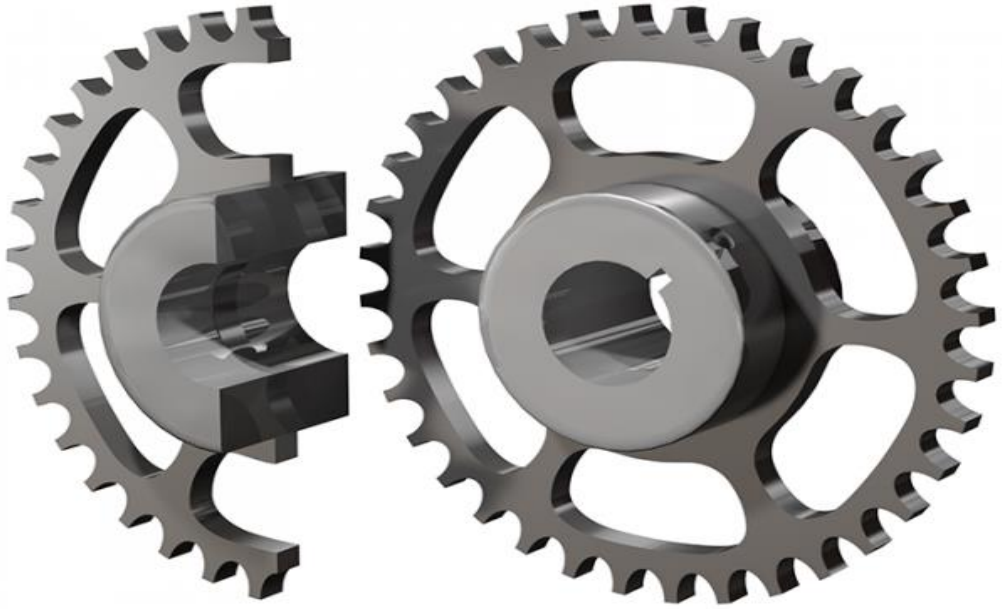
Sprockets are designed with four distinct hub classes and are designated Type A, B, C, D.

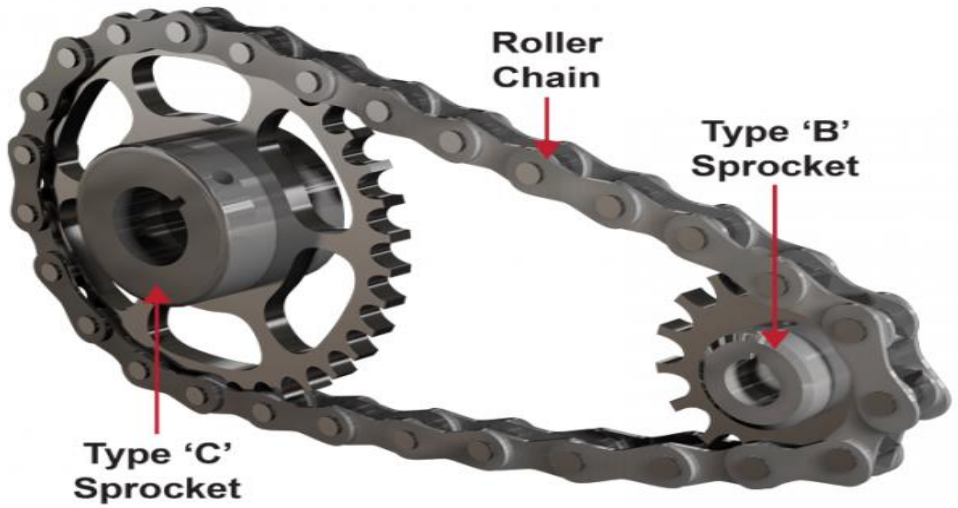
- Style A - Flat sprocket plate wheel with no hub extension either side.
- Style B - Sprocket with hub extension one side.
- Style C - Sprocket with hub extension both sides.
- Style D - Sprocket with a detachable bolt on hub attached to a plate.

Style A -Flat sprocket plate wheel with no hub extension either side

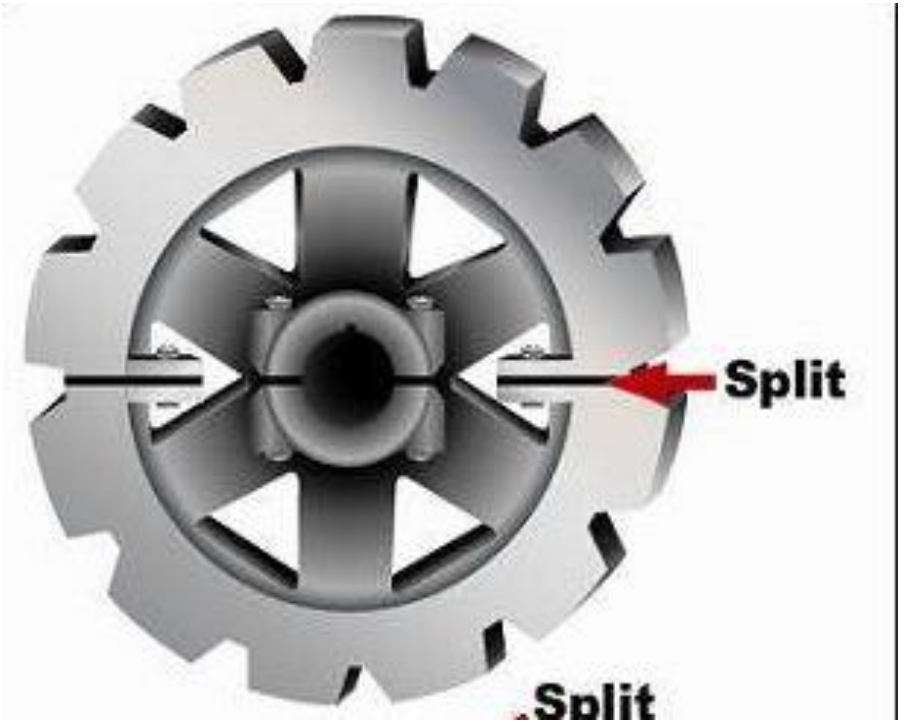
Style B - Sprocket with hub extension one side

Style C - Sprocket with hub extension both sides





Style D - Sprocket with a detachable bolt on hub attached to a plate

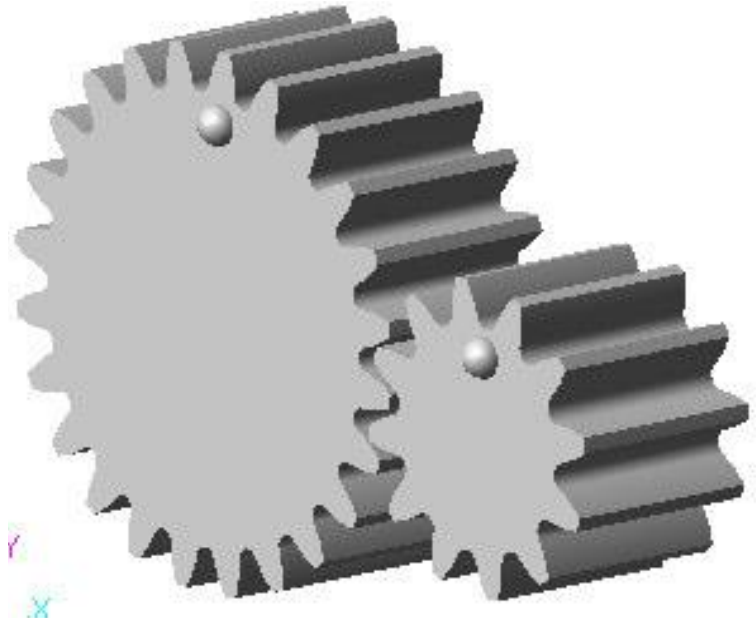


Gear Drive

Gears are machine elements that transmit motion by means of successively engaging teeth. The gear teeth act like small levers.

or

A toothed wheel that engages another toothed mechanism in order to change the speed or direction of transmitted motion.



Gear Classification

Gears or toothed wheels may be classified as follows:

1. According to the position of axes of the shafts.

The axes of the two shafts between which the motion is to be transmitted, may be

a. Parallel

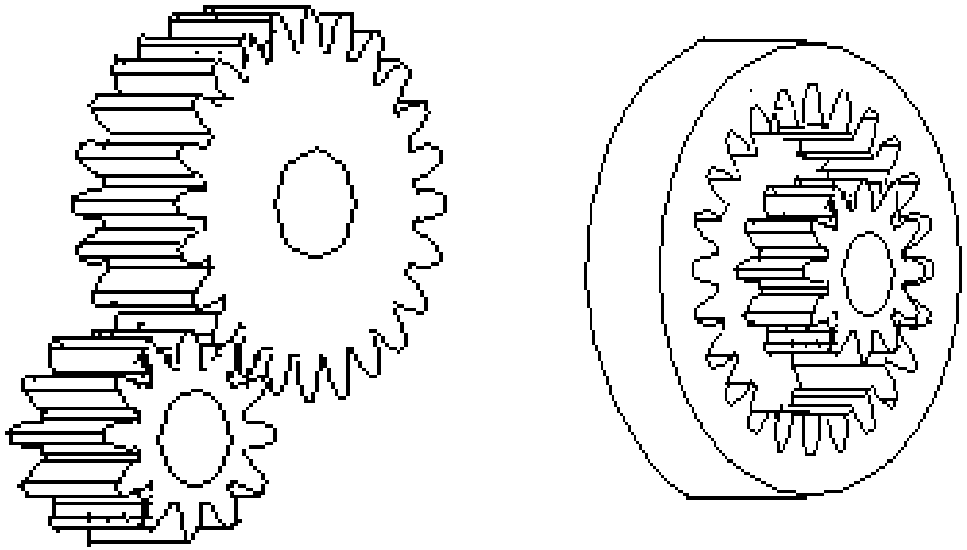
b. Intersecting

c. Non-intersecting and Non-parallel

Gears for Connecting Parallel Shafts

Spur Gears

- In the spur gears the teeth are parallel to the axes of the shaft and the meshing will be along the line.
- They are used under high speed and high load conditions.
- The left pair of gears makes external contact, and the right pair of gears makes internal contact.

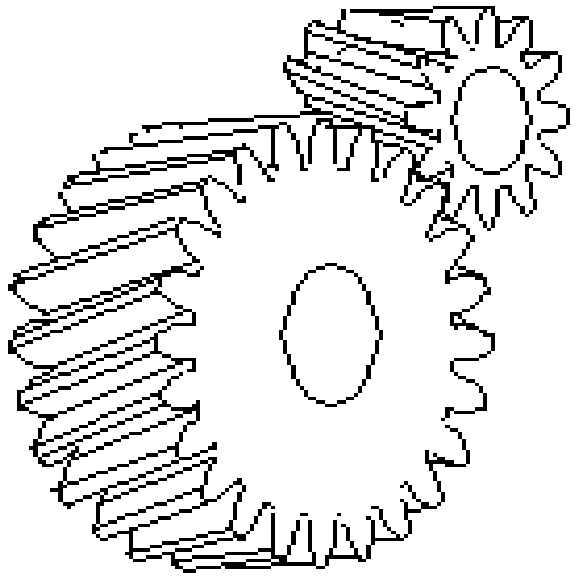


Applications of Spur Gear

Electric screwdriver, oscillating sprinkler, windup alarm clock, washing machine and clothes dryer

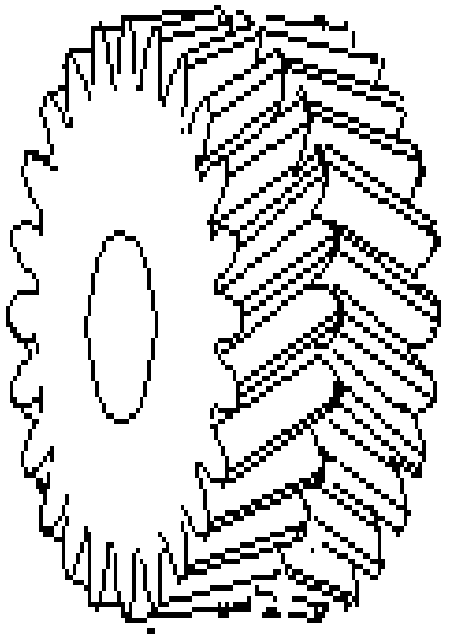
Parallel Helical Gears

- In helical gears the teeth are inclined at any angle with the axes of the gears which is called helix angle.
- Smooth and gradual transfer of load and low impact load leads towards reduction of noise.

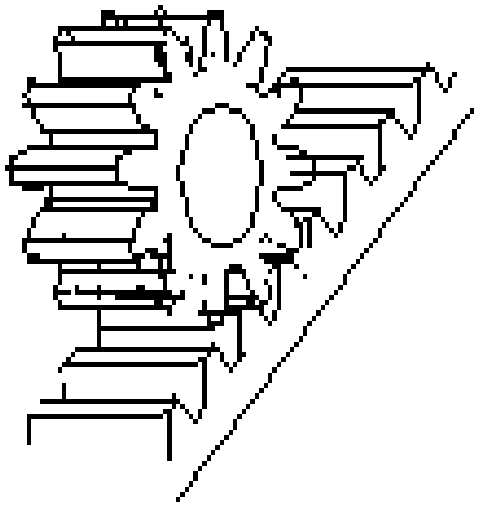


Double Helical Gears or Herringbone Gear

A double helical Gear is the combination of pair of helical gears having equal helix angle, one having right hand helix and other having left hand helix angle.



Rack and Pinion



The rack is like a gear whose axis is at infinity.

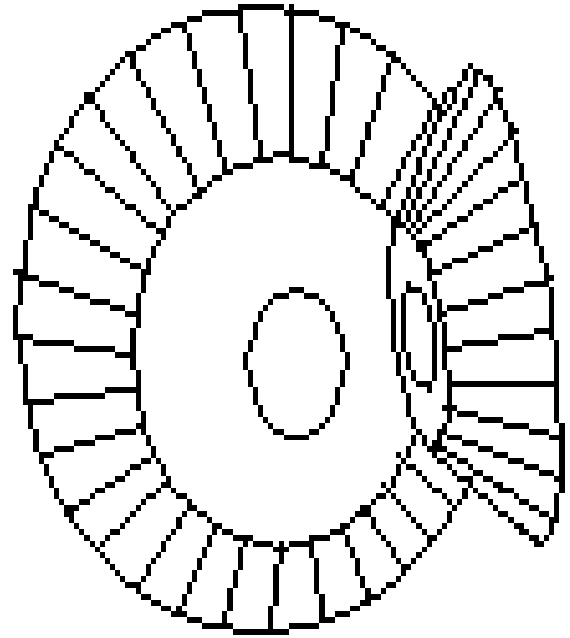
Rack and pinion gears are also used in some scales to turn the dial that displays your weight.

Gears for Connecting Intersecting Shafts

Straight Bevel Gears

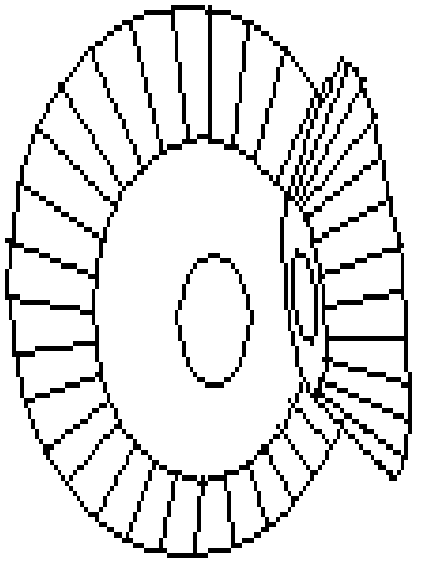
The straight bevel gears have straight teeth which are radial to point of intersection of shaft axes.

Teeth vary in cross section throughout the length.



Spiral Bevel Gears

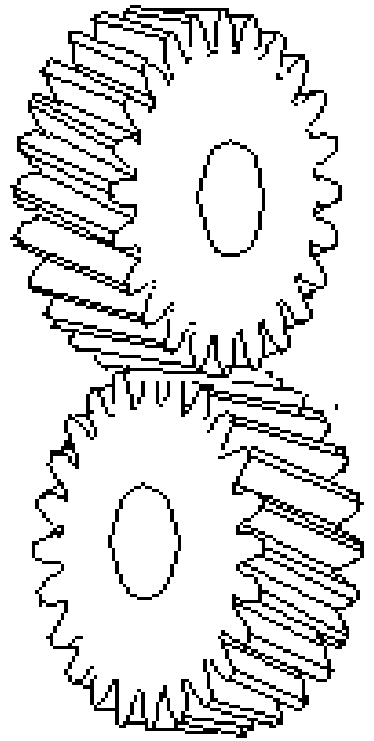
The teeth are in curved shape and oblique i.e. they lie in a different direction.



Gears for Connecting Neither parallel nor intersecting shafts

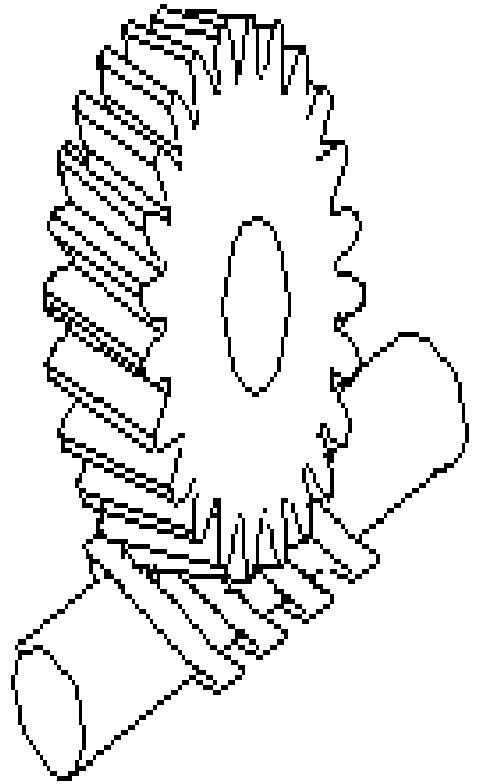
Crossed Helical Gears

- These types of teeth are very similar to the helical teeth.
- The only difference is that instead of simple helical teeth they have a pair of helical teeth which have equal helix angle, one having a right hand helix and the other have a left hand helix.



Worm and Worm Gear

- Worn is cylindrical body having one or more threads cut on it in the form of helix.
- Drive is used for high speed ratio up to 500:1



Comparison of Different Drives

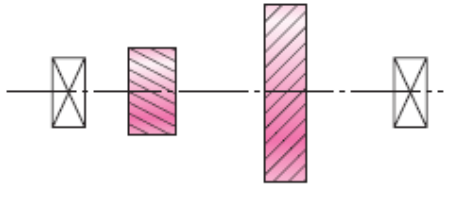
	Shaft	Belt	Chain	Gear
Required alignment accuracy	High	Medium	Medium	High
Positive drive	Yes	No (except toothed)	Yes	Yes
Efficiency	High	Medium	High	Variable
Stiffness	High	Low	High	High
Strength	Medium	Low-medium	High	High
Ability to span large distances	Low	Medium	Medium	Low
Maintenance	Low	Medium	High	Medium
Cost	Low	Low	Low	Medium

Shafts

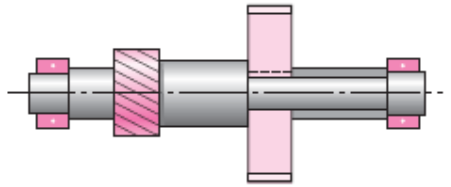
- When a tangential force is acting on the shaft, a turning moment is set up.
- A shaft is a rotating member, usually of circular cross section, used to transmit power or motion.
- It provides the axis of rotation, or oscillation, of elements such as gears, pulleys, flywheels, cranks, sprockets, and the like and controls the geometry of their motion.

Shaft Layout

- Shaft, Bearings, Gears, Shoulder



(a)



(b)

Shaft Layout

- In most cases, Only two bearings should be used in most cases.
- Load bearing components should be placed next to the bearings to minimize the bending due to large forces.
- Shafts should be kept short to minimize bending and deflection.

Shoulder

- It allows precise positioning
- Support to minimize deflection.
- In cases where the loads are small, positioning is not very important, shoulders can be eliminated.

Shaft Material

- Generally for regular shafts carbon steels are used.
- However for higher strengths Ni, Ni-Cr steels are used.

Axle

- An “axle” is a non-rotating member that supports wheels, pulleys,… and carries no torque.

Applications:

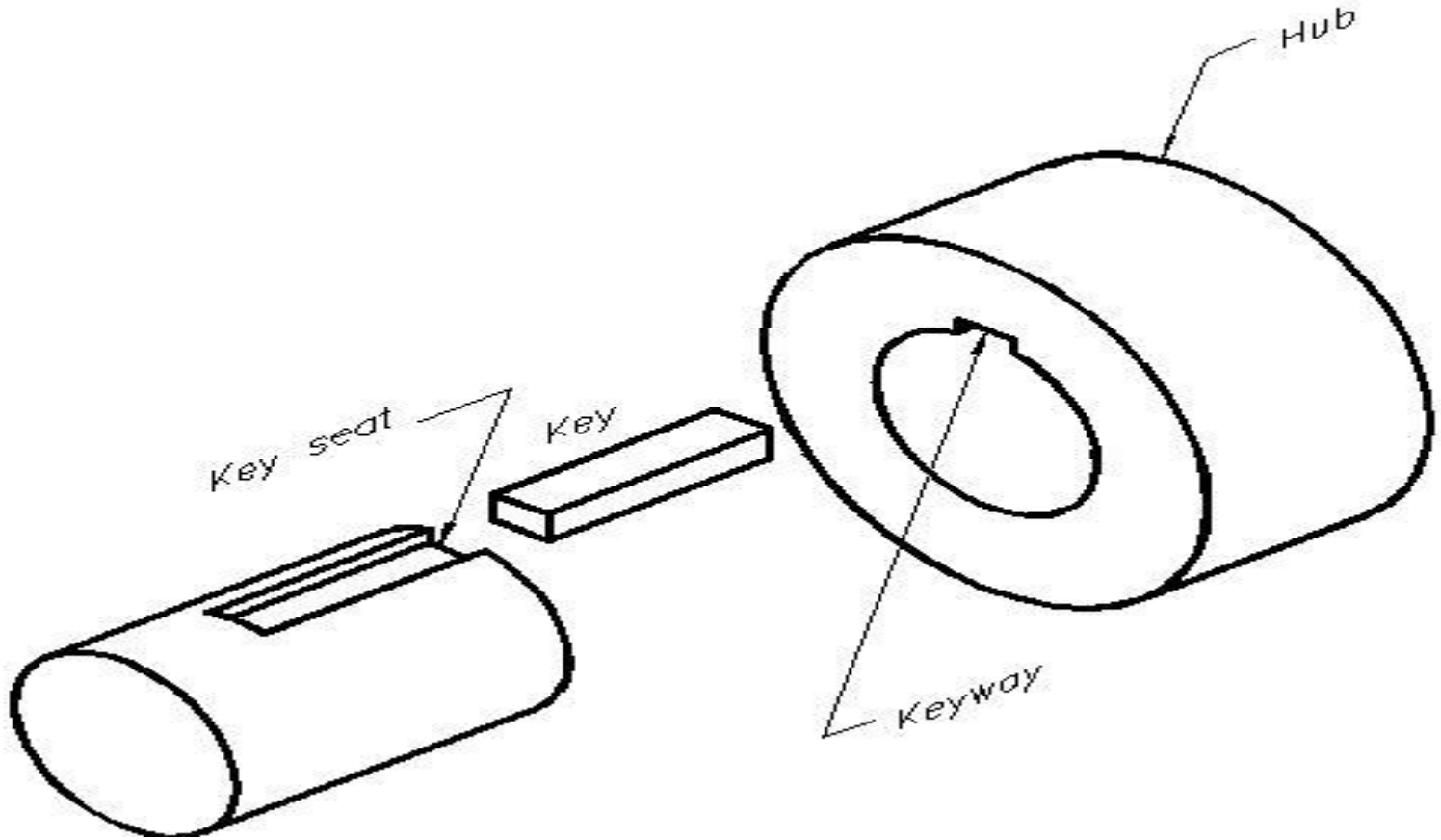
- Pulley mounted on the axle on the wells, where pulley is rotating, when the rope is pulled and the axle is stationary.

Spindle

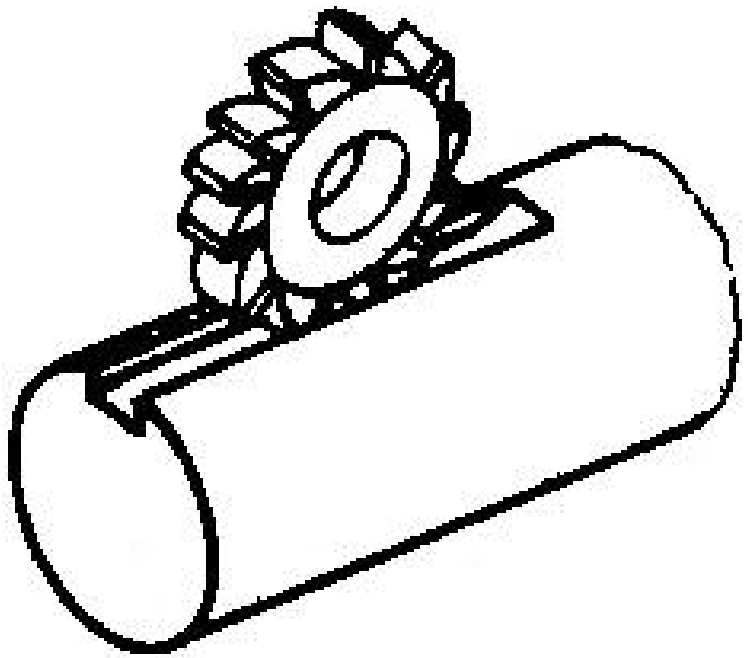
A “spindle” is a short shaft. Terms such as line shaft, head shaft, stub shaft, transmission shaft, countershaft, and flexible shaft are names associated with special usage.

Keys

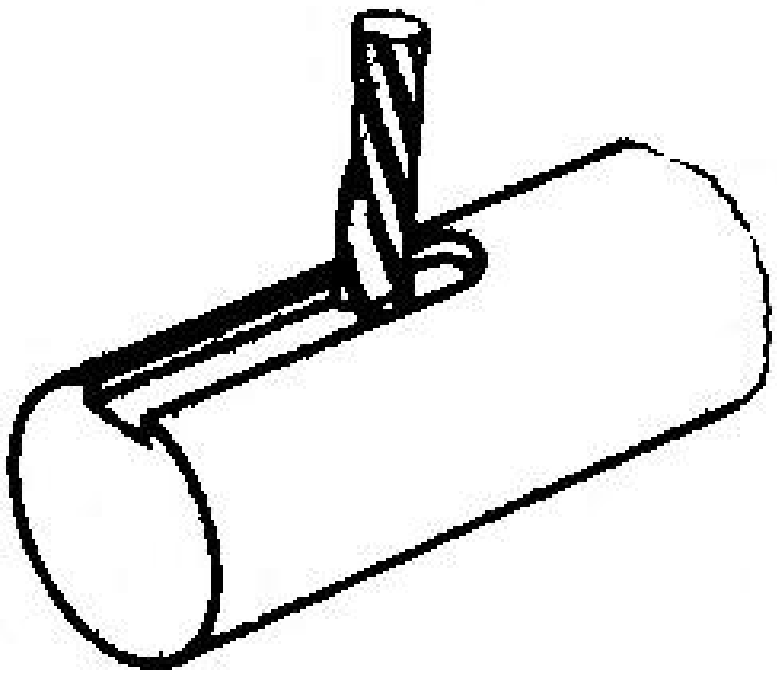
- It is the piece inserted in a axial direction between a shaft and hub to prevent relative rotation but allow sliding movement along the shaft if required.
- Keys are temporary fastening and are always made of mild steel because they are subjected to shearing and compressive stresses caused by the torque they transmit.
- A keyway is the groove cut in the shaft or hub to accommodate a key. Key ways can be milled horizontally or vertically .


Hub
Key seat
Key
Keyway

Keyway Milled



horizontally



vertically

Classification of Keys

Sunk Keys

a) Parallel sunk key

b) Taper sunk key

- Gib-head key

c) Feather key

d) Woodruff key (adjustable key)

e) Round or Pin keys

- Parallel pin
- Taper pin

f) Splines

Saddle keys

a) Hollow saddle key

b) Flat saddle key

Sunk Keys

- Sunk keys are standard form of keys and may be either of square or rectangular cross-sections.
- These are generally heavy duty keys since they rely on positive drive as half part of its nominal thickness is sunk into the keyway of shaft and remaining half portion fits into the keyway of hub.

Parallel Sunk Key

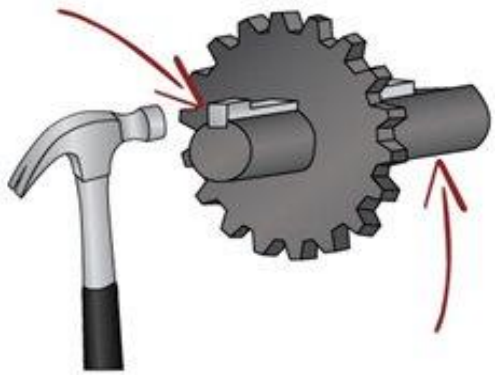
- Parallel keys are the most widely used.
- They have a square or rectangular cross-section.
- Square keys are recommended for small size (up to 22mm diameter) and rectangular keys are for large size (above 22mm diameter).
- Parallel sunk key is taper less and uniform in thickness and width along the length.

Taper Sunk Keys

- These are similar to the parallel sunk keys excepting that it has taper in its thickness along the length.
- The standard taper of this key is 1 in 100 in thickness but uniform in width.
- A taper key joint prevents relative rotational as well as axial movement between the two pieces.

Gib Head Keys

- It is a rectangular taper key with a head at one end called Gib-head usually provided to facilitate the removal of key.
- The slot for Gib-head key must have an open end to permit assembly. For this reason it is placed at the end of a shaft.
- Such keys are used where the shaft and hub are required to remove frequently.

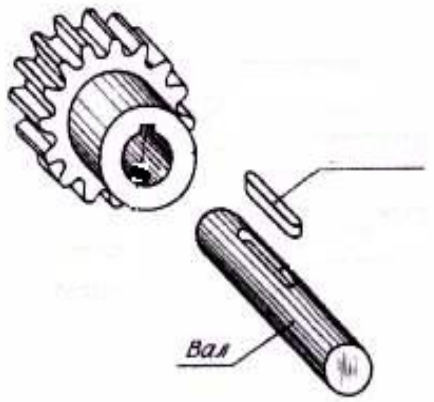


Difference between Parallel and Taper Sunk Key

S. No	Parameter	Parallel Sunk Key	Taper Sunk Key
1	Thickness of Key	Uniform over its length	Non-uniform (Changes) over its length
2	Removal of Key	Difficult removal of key	Easy removal of key
3	Working Clearance	It is provided at the top and sides	It is not provided
5	Machining Cost	Low	High
6	Applications	It is used when the parts to be mounted is required to slide along the shaft axially.	It is used when there is no axial movement along the shaft.

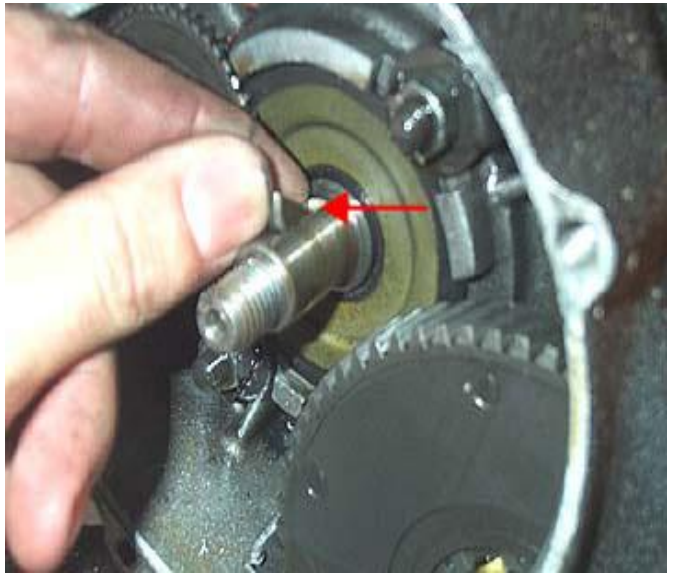
Feather Keys

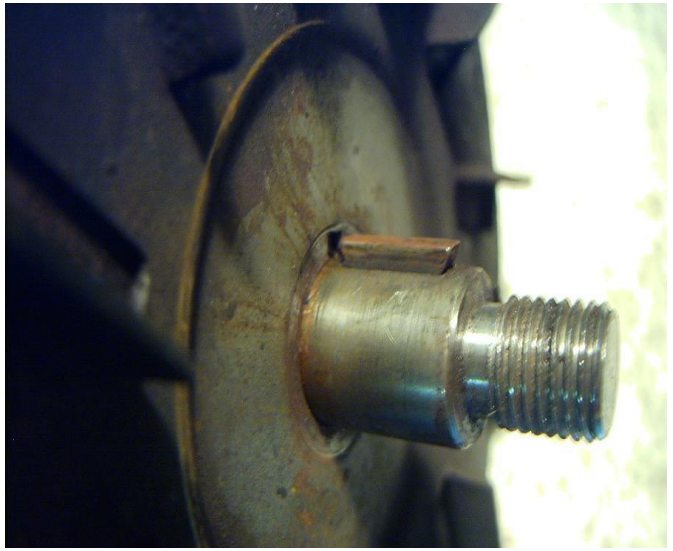
- When there is a requirement of sliding or axial movement of mating piece on the shaft, a feather key is used.
- It is a sunk key of uniform width and thickness with rectangular or square in cross-section.
- This key attached to one member of the pair, either to the shaft by means of two cap-screws, having countersunk heads or the mating piece and free to slide in the keyways in the shaft.
- It is generally used in drilling machines and clutches. These keys are also classified as peg feather key, single headed and double headed feather key.



Woodruff Keys

- It is an adjustable sunk key.
- It is in the form of a semi-circular disc of uniform thickness.
- The key fits into a semi-circular keyway in the shaft and the top of the key fits into a plain rectangular key way in the hub of the wheel.
- Since the key and the key seat bear the same radius , it has the advantage of adjusting itself to any taper of the slot of the hub or boss of wheel.





Advantage of Woodruff Key

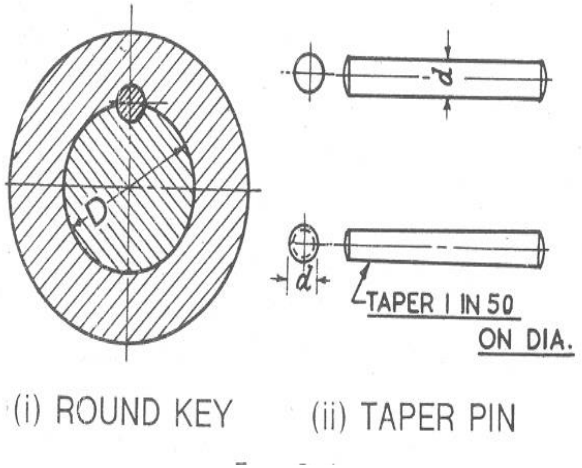
- It can align itself with the taper of the hub by slight rotation in the seat.
- Its extra depth prevents the shaft from slip.

Disadvantage of Woodruff Key

- Extra depth of keyway in the shaft weakens the strength and increase stresses.
- It does not give axial movement between shaft and hub.

Round Keys (Parallel and Taper)

- Round keys are circular in cross-section and inserted in a hole drilled partly in the shaft and partly in the hub of mating piece.
- A round or taper pin is commonly used for fastening a collar and pulley to shaft.
- These are considered to be most appropriate for low power drives.



Splines

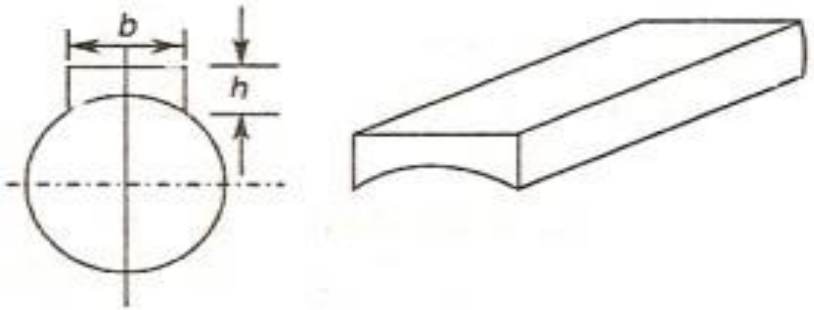
- To prevent the keys working loose, to reduce the working stresses and to give a greater bearing surface sometimes, keys are made integral with the shaft which fits in the keyways of hub.
- In case of splined shaft, the number of splines can be four, six, ten or sixteen.
- The splines are relatively stronger than shafts having single keyway.
- For high torque transmission and for axial or sliding movement spline shafts are used.
- Splines are used in clutch and gear boxes of automobiles.

Saddle Keys

- Saddle keys are standard form of keys and may be either of square or rectangular cross-sections.
- These are generally light duty keys since they rely on non-positive drive or friction drive alone and are liable to slip on the shaft under load.
- Saddle keys are attached to the hub portion and just sit over the shaft. There is key way only in one matting portion generally the hub.
- Saddle keys are also made in two forms i.e. hollow and flat.

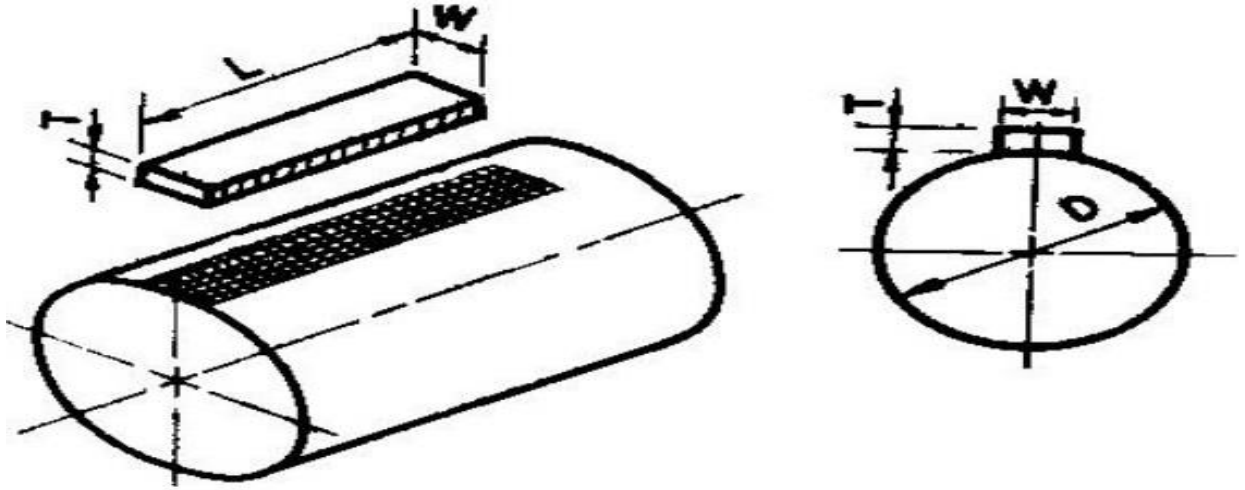
Hollow Saddle Keys

- A hollow saddle key has its underside hollow so that it can be placed on the curved surface of the shaft.
- The keyway is cut in the mating piece (hub) only. Hollow saddle key is used for light duty.



Flat Saddle Keys

- A flat saddle key inserted on a flat surface provided on the shaft.
- In this, holding force is comparative large than the hollow saddle key.



Difference between Sunk and Saddle Key

S. No	Parameter	Sunk Key	Saddle Key
1	Key Placement	Half in the shaft and half in hub.	Entirely either in hub or in shaft.
2	Nature of Drive	Positive Drive	Non-Positive Drive
3	Keyway Required	More than One	Only One
4	Machining Cost	High	Low
5	Manufacturing	Difficult	Easy
6	Applications	It is used for heavier loads.	It is used for lighter loads.