Gearboxes

Website: www.ttetraining.ltd.uk

CONTENT

What is a Gearbox

- Power transmission is the movement of energy from its place of generation to a location where it is applied to performing useful work
- An enclosed system of assembled gears that transmits mechanical energy from a prime mover to an output device. A gearbox can also change the speed, direction, or torque of mechanical energy.
- A gear is a component within a transmission device that transmits rotational force to another gear or device

Why Is a Transmission Necessary?

Provide torque multiplication at low speeds

Reduce driver RPM at high speeds

Allow the driving machine to operate within its most efficient RPM range

And can allow the driver to be disengaged for start-up and shut-down (torque converter & clutch)

GENERAL TYPES OF INDUSTRY GEARBOX'S

- Worm Gear units - single & double reduction
- Helical and worm combination gear units
- Helical gear units
- Helical and bevel helical gear units
- Shaft mounted helical gear units
- Variable speed drives
- Custom made worm gear sets - including dual lead technology
- Custom made and high volume loose helical gears
- Standard and custom made worm gear lift / escalators drive package
- Special custom made gear units and package drive solutions
- Gear unit service and refurbishment

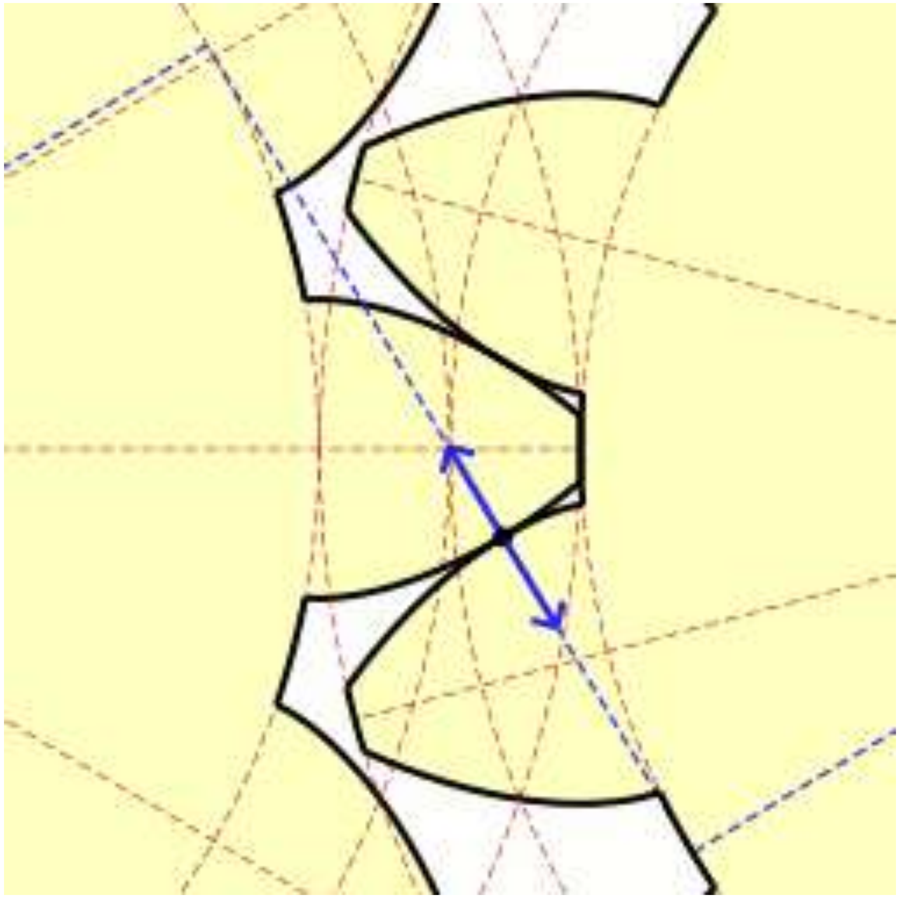
Gears and Tooth Form

The involute gear profile is the most commonly used system for gearing today.

In involute gear design contact between a pair of gear teeth occurs at a single instantaneous point (see next slide). Rotation of the gears causes the location of this contact point to move across the respective tooth surfaces.

The path traced by this contact point is known as the Line of Action (also called Pressure Line or Line of Contact)

Involute Gear Forms

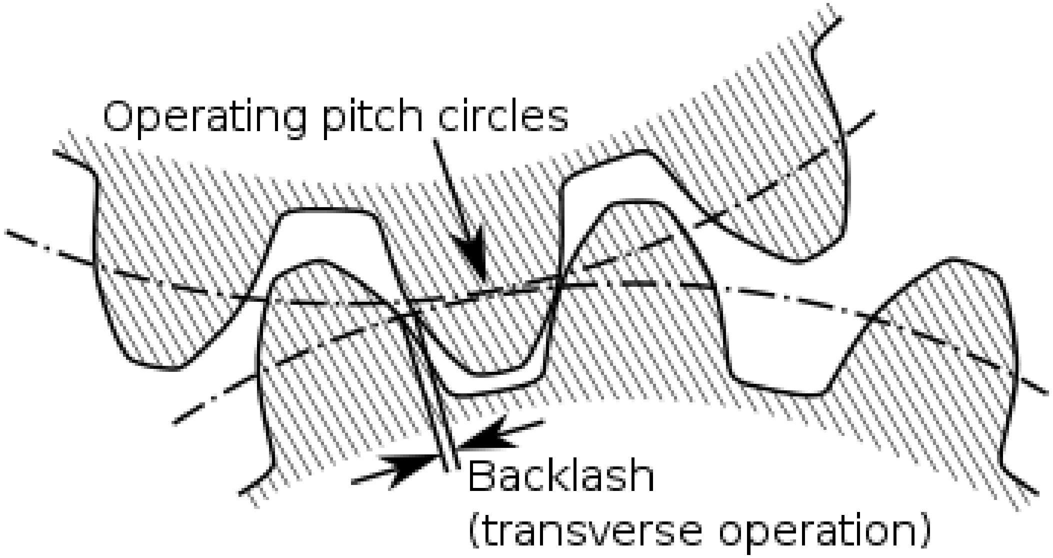


Gear Tooth Backlash

In the context of gears backlash, sometimes called **lash** or **play**, is clearance between mating components, or the amount of lost motion due to clearance or slackness when movement is reversed and contact is re-established. For example, in a pair of gears backlash is the amount of clearance between mated gear teeth.

Backlash

Reasons for requiring backlash include allowing for lubrication, thermal expansion, gears deflection under load and small manufacturing errors.



Types of Gears

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

a. Parallel

   1.Spur Gear

   2.Helical Gear

   3.Rack and Pinion

b. Intersecting

   Bevel Gear

c. Non-intersecting and Non-parallel

   worm and worm gears

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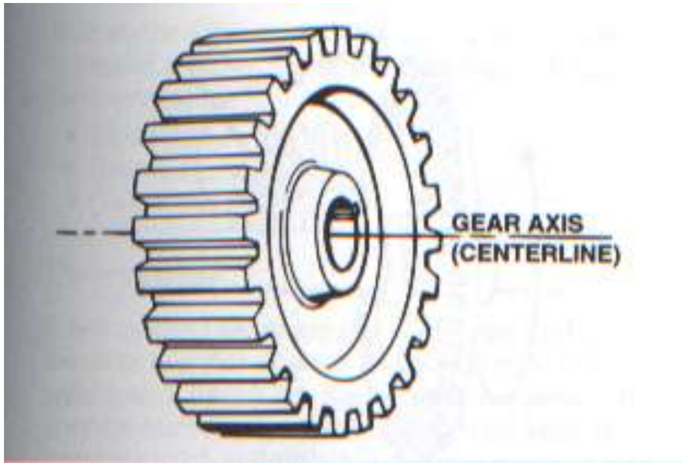
Spur Gear

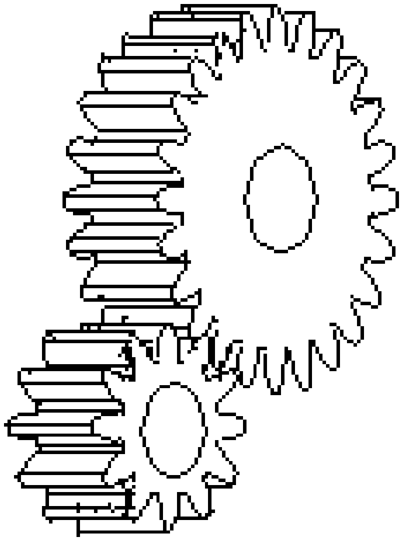
Teeth are parallel to axis of rotation

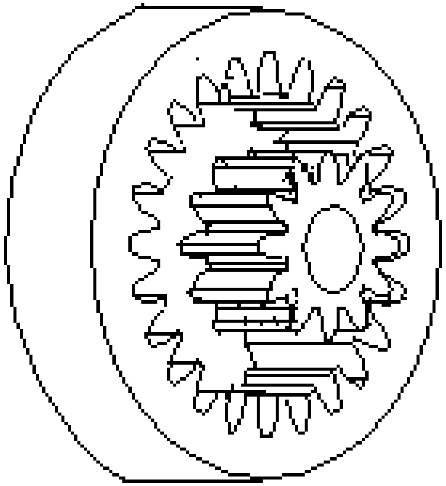
Transmit power from one shaft to another parallel shaft

The spur gear is the simplest type of gear tooth form and is the first choice option for gears except when high speeds (generally considered to be over 25 m/s), and smooth running are the main requirements.

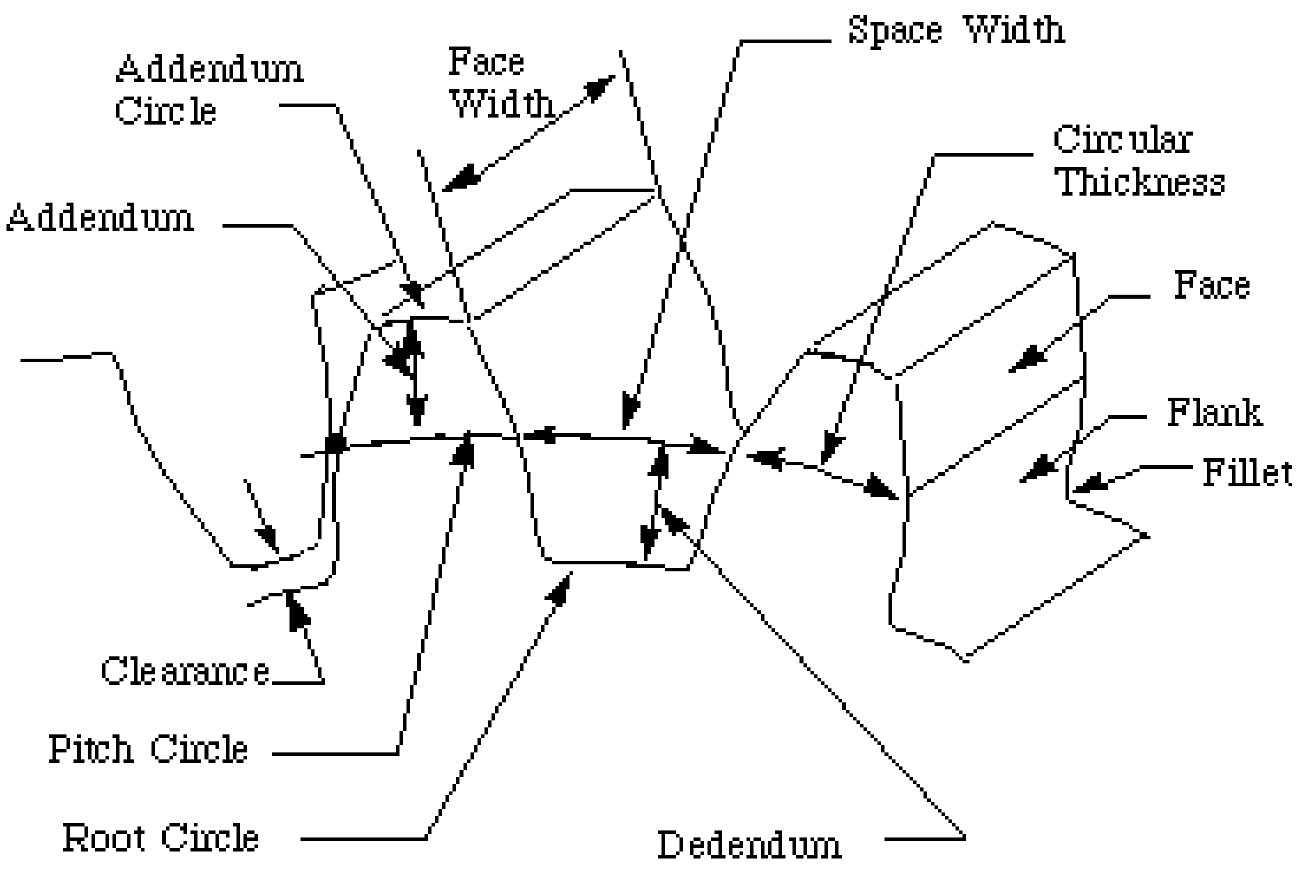


External and Internal Spur Gears





Nomenclature of Spur Gears



Nomenclature…

- **Pitch surface**: The surface of the imaginary rolling cylinder (cone, etc.) that the toothed gear may be considered to replace.

- **Pitch circle**: A right section of the pitch surface.

- **Addendum circle**: A circle bounding the ends of the teeth, in a right section of the gear.

- **Root (or dedendum) circle**: The circle bounding the spaces between the teeth, in a right section of the gear.

Nomenclature…

- **Addendum**: The radial distance between the pitch circle and the addendum circle.
- **Dedendum**: The radial distance between the pitch circle and the root circle.
- **Clearance**: The difference between the dedendum of one gear and the addendum of the mating gear.
- **Face of a tooth:** That part of the tooth surface lying outside the pitch surface.
- **Flank of a tooth:** The part of the tooth surface lying inside the pitch surface.

Nomenclature…

- **Circular thickness** (also called the **tooth thickness**): The thickness of the tooth measured on the pitch circle. It is the length of an arc and not the length of a straight line.

- **Tooth space**: pitch diameter The distance between adjacent teeth measured on the pitch circle.

- **Backlash**: The difference between the circle thickness of one gear and the tooth space of the mating gear.

- **Circular pitch** (Pc) : The width of a tooth and a space, measured on the pitch circle.

Nomenclature…

- **Diametral pitch (**Pd): The number of teeth of a gear unit pitch diameter. The diametral pitch is, by definition, the number of teeth divided by the pitch diameter. That is,

  Where

  Pd = diametral pitch

  N = number of teeth

  D = pitch diameter

$$P_d = \frac{N}{D}$$

- **Module** (m): Pitch diameter divided by number of teeth. The pitch diameter is usually specified in inches or millimeters; in the former case the module is the inverse of diametral pitch.

m = D/N

SPUR GEAR NUMENCLATURE

Nomenclature	Symbol	Formulae
Module	m	m=p/Π = D/t
Diametral Pitch	D.P.	t/D = Π/p = 1/m
Pitch	P	P= Π.m = 3.14m
Number of teeth	t	t = D/m
Pitch Circle Diameter	D	D = t.m
Tooth height	h	h = 2.2 m
Addendum	h’	h’ = m
Dedendum	h”	h” = 1.2 m
Root circle diameter	D1	D1 = Do – 4.4m
Outside diameter	Do	Do = m (t+2)
Distance between the axis of the two mating gears t 1 & t2	A	A = (t1 + t2) m/2
Pressure angle	α	20˚(usually) or 14½°

Helical Gear

The teeth on helical gears are cut at an angle to axis, this reduces the teeth contact area and therefore reduces the amount of power that can be transmitted.

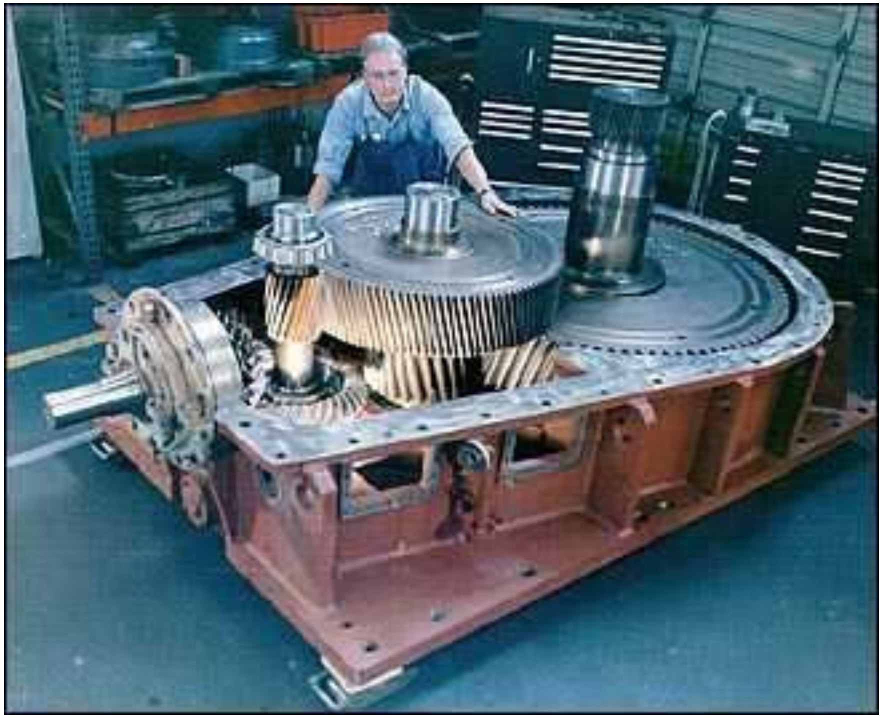
The teeth of the gears have gradual engagement thus making helical gears operate much more smoothly and quietly than spur gears and eliminates the sudden change in driving force from one tooth to the next

Most helical meshing gear trains the will have at least two teeth in contact but constantly changing.

Helical Gears

Some narrow helically cut gears, if the angles of the gear teeth are correct, they can be mounted on perpendicular shafts, adjusting the rotation angle by 90 degrees

A typical helical gearbox set-up



Herringbone Helical Gears

Herringbone helical are expensive to manufacture but they have a significant improvement over ordinary helical cut gears in that they balance out any thrust forces between meshing gears.

Herringbone gears

To avoid axial thrust, two helical gears of opposite hand can be mounted side by side, to cancel resulting thrust forces

Herringbone gears are commonly used on high speed heavy machinery reduction gearboxes such as steam turbine drives.

Rack and pinion

Rack and pinion gears are used to convert rotation (From the pinion) into linear motion (of the rack)

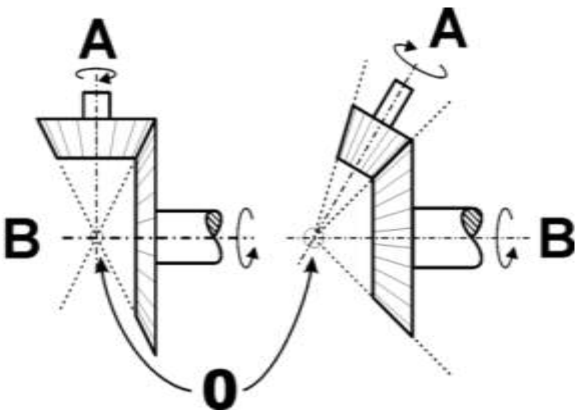
A perfect example of this is the steering system on many cars or Alpine railway systems

Bevel gears

- **Bevel gears** are useful when the direction of a shaft's rotation needs to be changed
- They are usually mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well
- The teeth on bevel gears can be **straight**, **spiral** or **hypoid.**
- Locomotives, marine applications, automobiles, printing presses, cooling towers, power plants, steel plants, railway track inspection machines, etc.

Bevel Gears

Bevel gears are designed to drive at an angle, most often mounted on shafts that are 90 degrees apart, but can be designed to work at other angles as well



Straight and Spiral Bevel Gears

Helical Bevel Gears

Again the direction of drive from drive pinion is at 90 degrees to drive the crown wheel (ring gear). The helical design produces less vibration and noise than conventional straight-cut or spur-cut gear with straight teeth.

Hypoid Gears

The hypoid gear set is similar to the spiral bevel gear set-up but the pinion is placed to one side of the crown wheel (ring gear) centre line. This allows the pinion to be larger in diameter and have more contact area

Worm & Wheel Gears

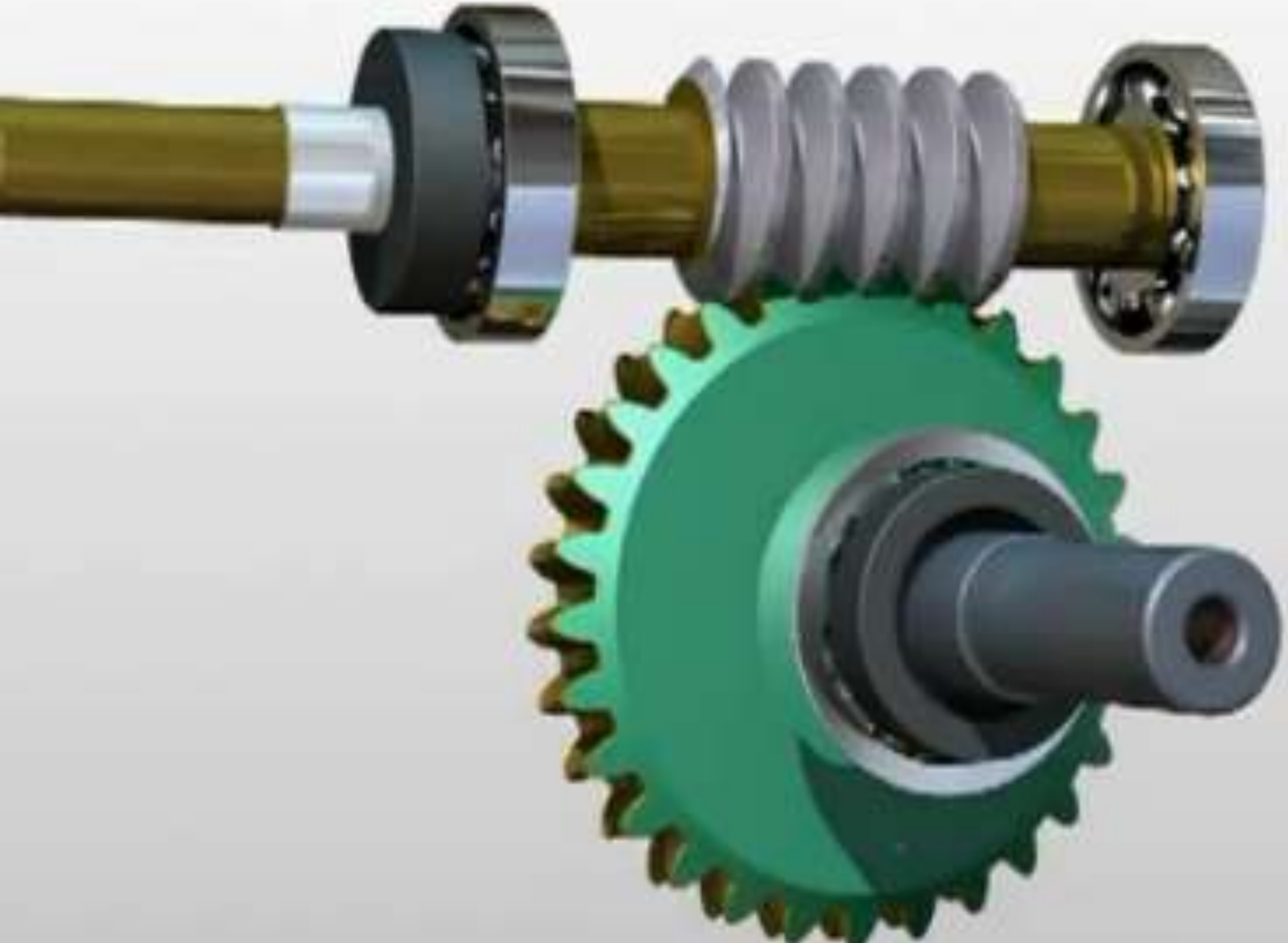
The terminology is often confused by imprecise use of the term *worm gear* to refer to the worm, this actually a screw that engages with a large diameter wheel. Like other gear arrangements, a worm drive can reduces rotational speed and also provides a very high torque on the output shaft.

Worm and Wheel Gears

- **Worm gears** are used when large gear reductions are needed. It is common for worm gears to have reductions of 20:1, and even up to 300:1 or greater
- Many worm gears have an interesting property that no other gear set has: the worm can easily turn the gear, but the gear cannot turn the worm
- Worm gears are used widely in material handling and transportation machinery, machine tools, automobiles etc

Worm and Wheel Setup

When Worm and Wheel type gearboxes and some bevel gear drives are out for maintenance inspection or repair, they have to be adjusted so that the setup enables them to run reliably. Failure to do this will lead to very early failure of the gears in service. The type of setup needed along with the adjustment of the contact markings for direction of rotation is covered on a separate information sheet and practical exercise.

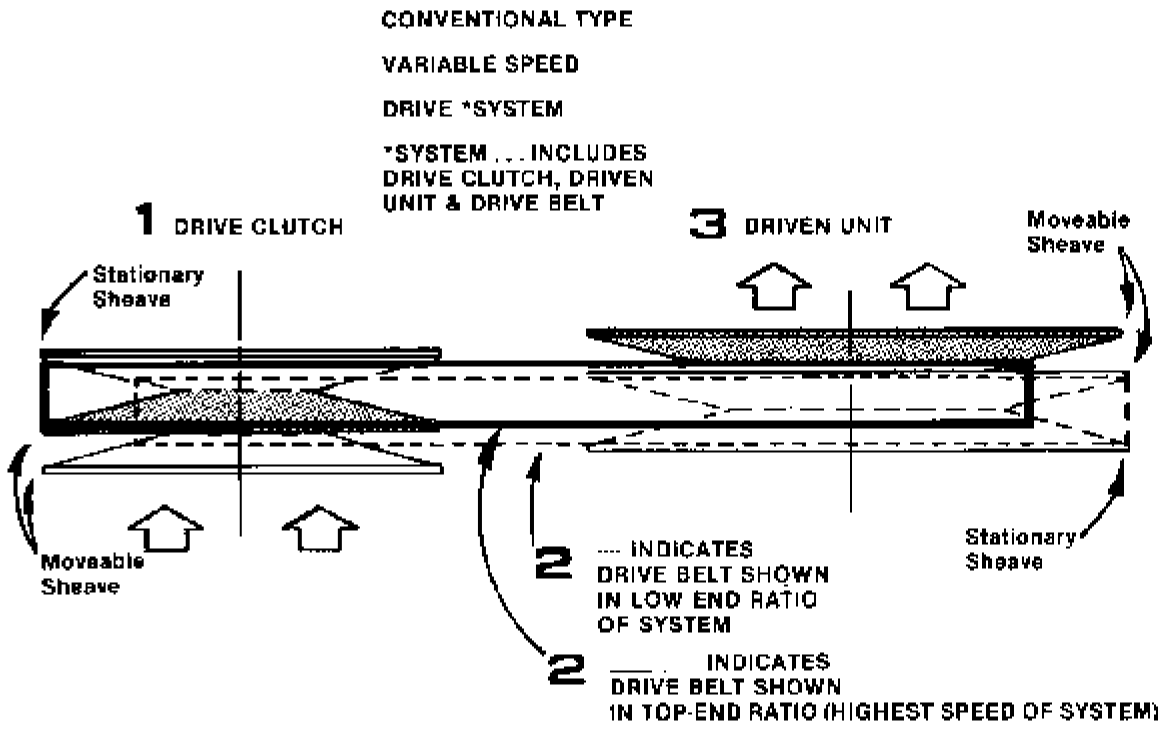


Variable Speed Gearboxes

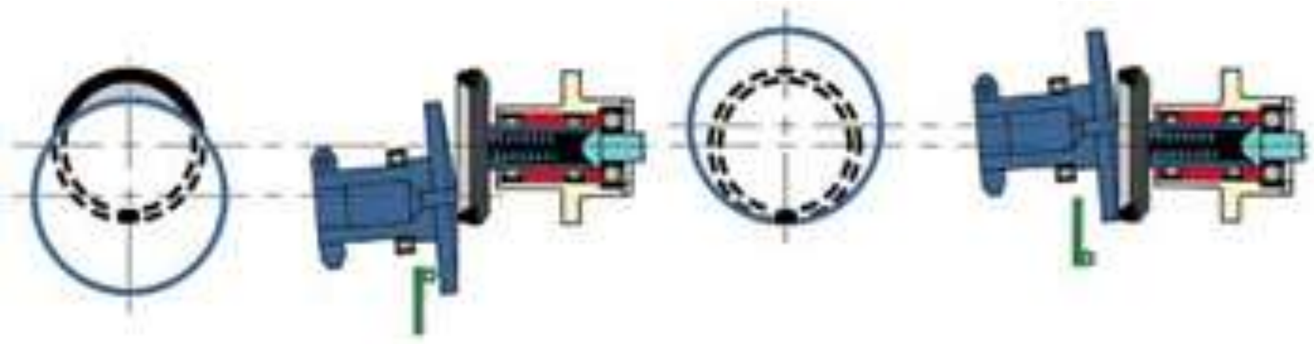
A gearbox transmits drive by the torque and speed of both the input and output shafts, in general variable speed gearboxes such as hydraulic couplings or variable ratio based on chains or belts.

Mechanical variable speed gearbox drives include the following subtypes:

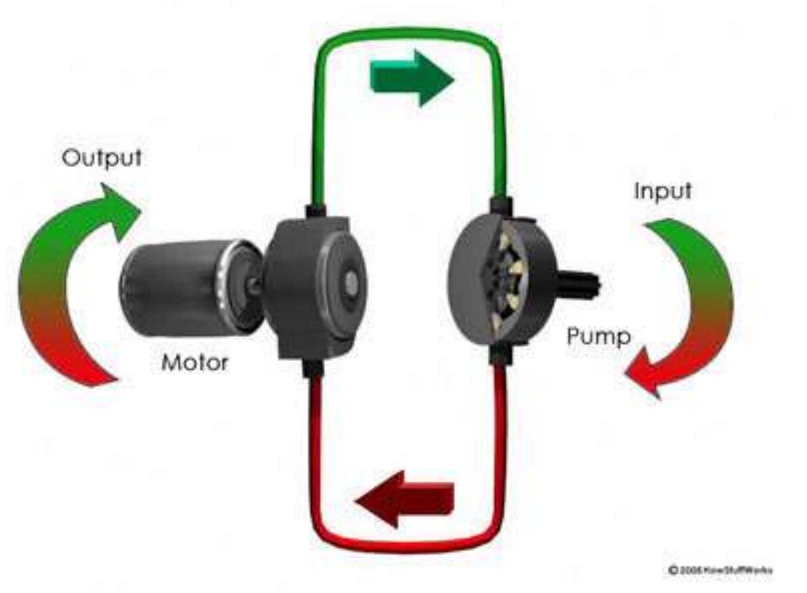
A variable pitch drive is a belt and pulley drive where the pitch diameter of one or both pulleys is adjustable, giving a multi ratio and hence a variable output speed.



Traction drive gearbox system is were the diameter of the contact path of two mating metal rollers is adjustable, giving a multi ratio hence a variable output speed.

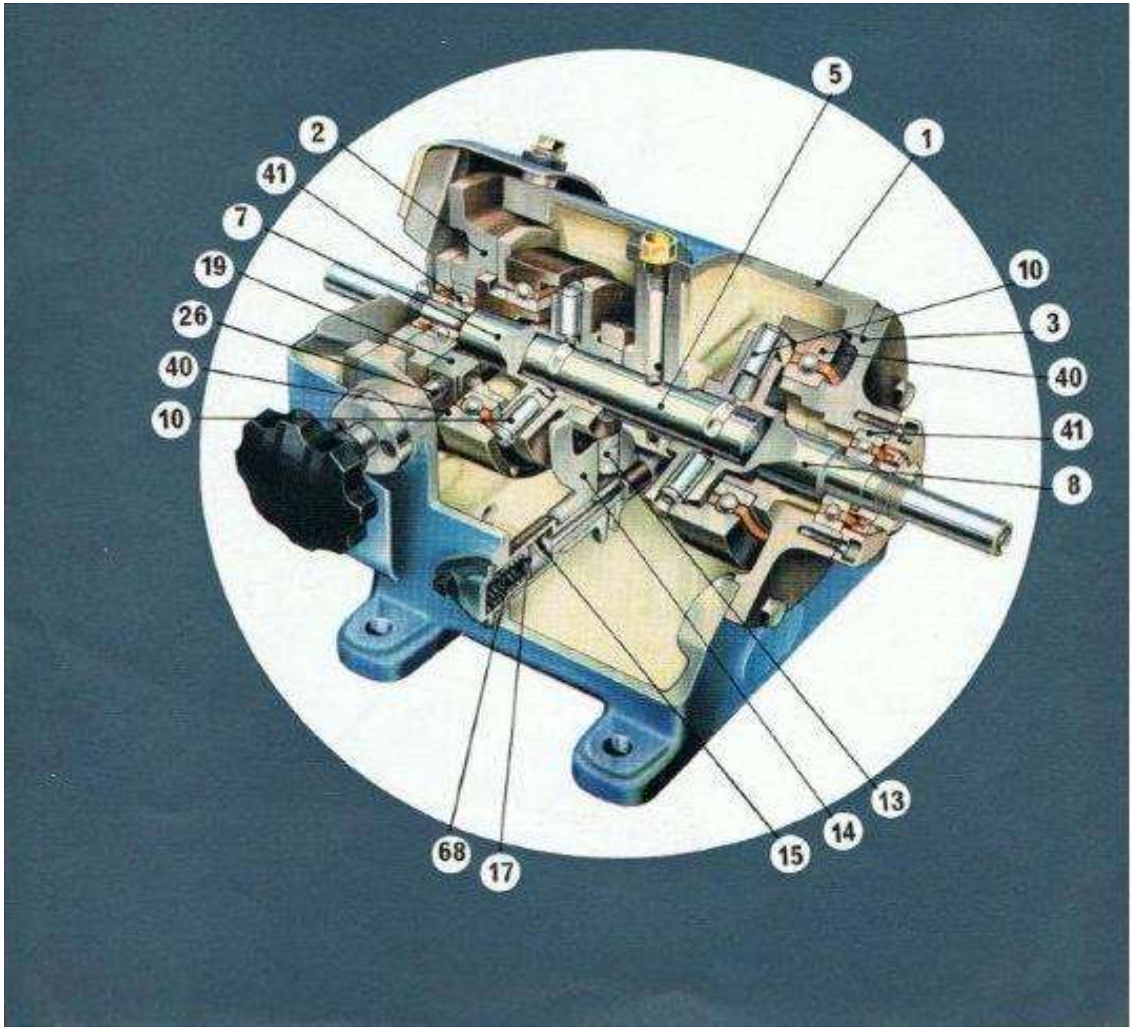


Hydraulic hydrostatic drive is a positive displacement hydraulic pump and motor where the volumetric fluid output of the pump is varied through valves or by varying the displacement.



The Carter Gearbox is a very common example of the type of hydraulic drive were the speed on the output shaft is directly proportional to the amount of oil that is displaced and transferred on the input shaft through a set of radial pistons pumping the oil to a matched set of pistons that drive the output shaft.

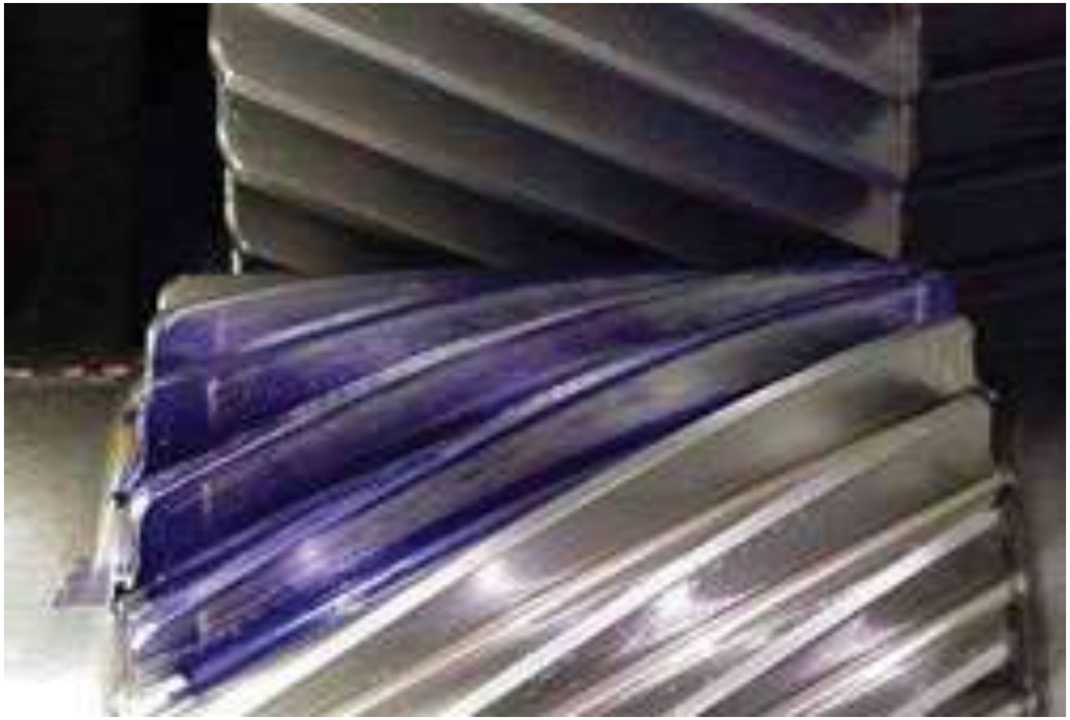
The Carter Gearbox

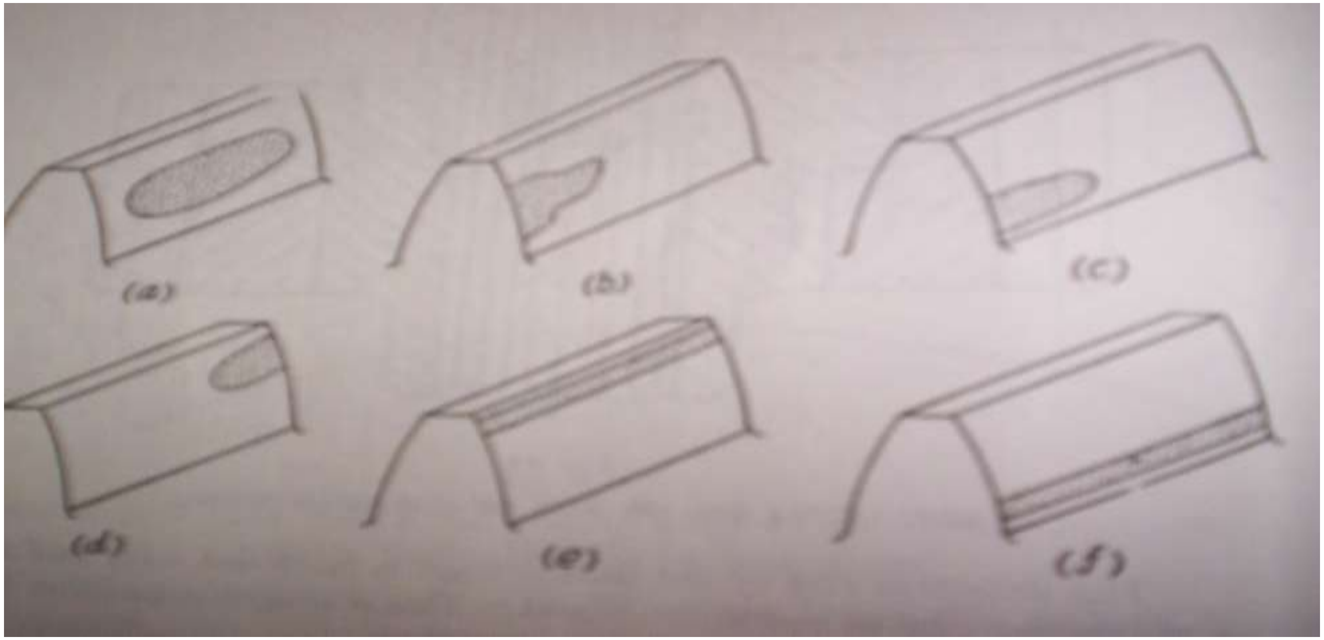


Variable Speed Gearboxes

It must be noted that all variable speed drive gearbox are in some form a friction drive systems and therefore torque limited. Also with the advent of modern electronic inverter drives for electric motors, has made it possible for A.C. motor to have variable speed capability. Therefore these types of mechanical gearbox speed controllers are becoming less common.

Meshing of Gears





(a) Correct meshing covering 70 – 80% tooth surface contact.

(b) Axis not parallel.

(c) Axis not parallel and distance between them is too small.

(d) Axis not parallel and distance between them is excess.

(e) Axis are parallel and distance between them is excess.

(f) Axis are parallel and distance between them is too small.

Typical Gear Damage

Poor gear meshing alignment for whatever reason or lubrication problems can have a dramatic effect on the reliability of any gear train system

Limits of Wear for Replacing Gear Sets

OPEN GEAR TRANSMISSION and the surface speed up to 2 meter / second – The tooth thickness (Sx) reduces due to wear by (0.5m) mm, where m is the module, or about 33% of the original tooth thickness.

CLOSED GEAR TRANSMISSION (GEAR BOXES) for surface speeds over 2 meter / sec. – the tooth thickness (Sx) reduces due to wear by (0.3m) mm or about 20% of the original tooth thickness.

Defects in Gear Sets

- Wear of one, few or all the teeth.
- One or few teeth broken or twisted.
- Burrs on the bore or the key way.
- Burrs on the internal splines of the gear bore or the tooth surface.
- Crack or damage on the rim or the bore of the gear wheel.

Maintenance and inspection of gearboxes fitted with spur, helical and herringbone gear sets are in most cases confined to checking for gear tooth wear damage and bearing condition. As you can see from the photo the gearbox structure once manufactured has no room for adjustments other than the scraping in of white metal bearing if they are fitted.

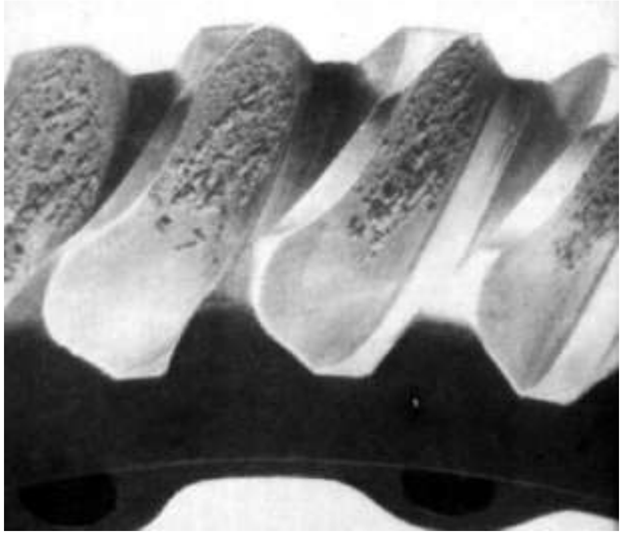
Worm and Wheel Gear Failure

CAUSES OF WORM GEAR FAILURE AND CRITERION OF DESIGN

- Types of failure of worm gearing
- Sliding can not be totally avoided and therefore the principal causes of worm gearing failure are surface damage, tooth wear and seizing. Fatigue pitting is observed mainly in gearing with a worm gear made of seizure-resistant bronze. Breakage can be found mainly after severe wear, and usually only the teeth of the worm gear are broken.

Worm gears operate with a unidirectional sliding movement between the worm and the wheel teeth. The worm is usually hardened and requires a very high standard of surface finish because of its high sliding speed and relatively low film thickness compared to an equivalent plain bearing surface.

The worm wheels are usually made of bronze although cast iron and non metallic materials can also be used. The worm and wheel need setting to give a clearance at the in-going side and thus to form a tapered load carrying oil film.



The worm wheel usually suffers more damage than the worm and this may be of two kinds scuffing and incipient seizure due to lack of lubrication, or surface pitting due to long operation at high load.

Gear Trains

- A gear train is two or more gear working together by meshing their teeth and turning each other in a system to generate power and speed

- It reduces speed and increases torque

- Electric motors are used with the gear systems to reduce the speed and increase the torque

Types of Gear Trains

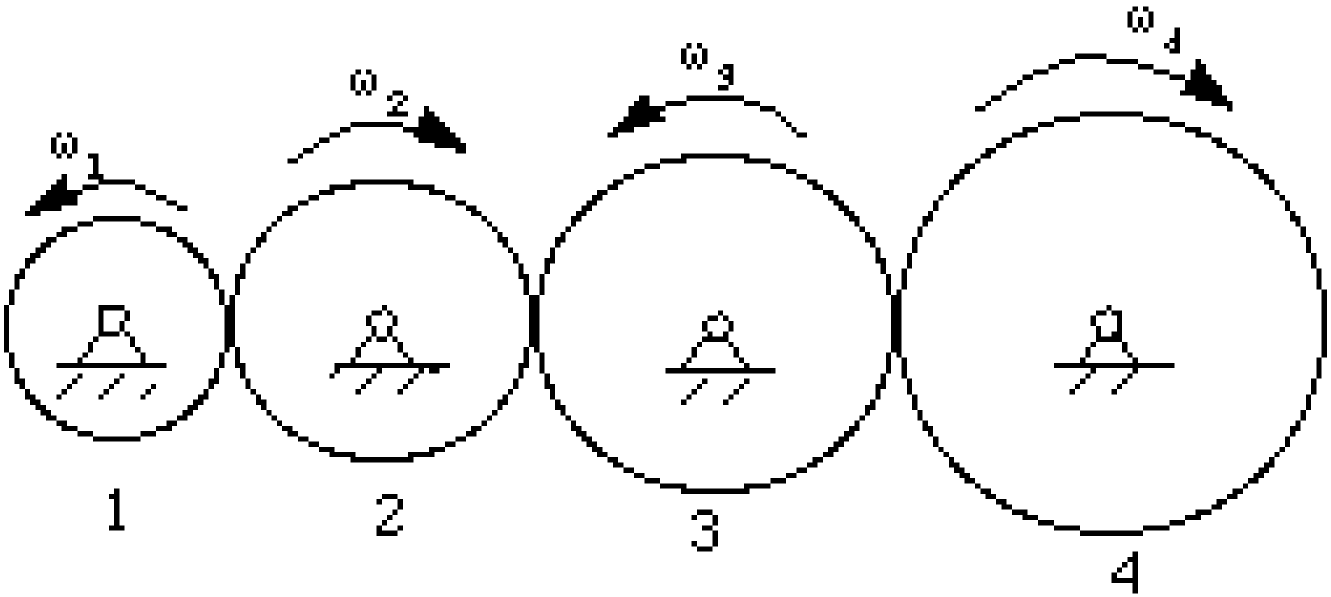
- Simple gear train
- Compound gear train
- Planetary gear train

Simple Gear Train

- The most common of the gear train is the gear pair connecting parallel shafts. The teeth of this type can be spur, helical or herringbone.
- Only one gear may rotate about a single axis

Typical Reduction Gearbox

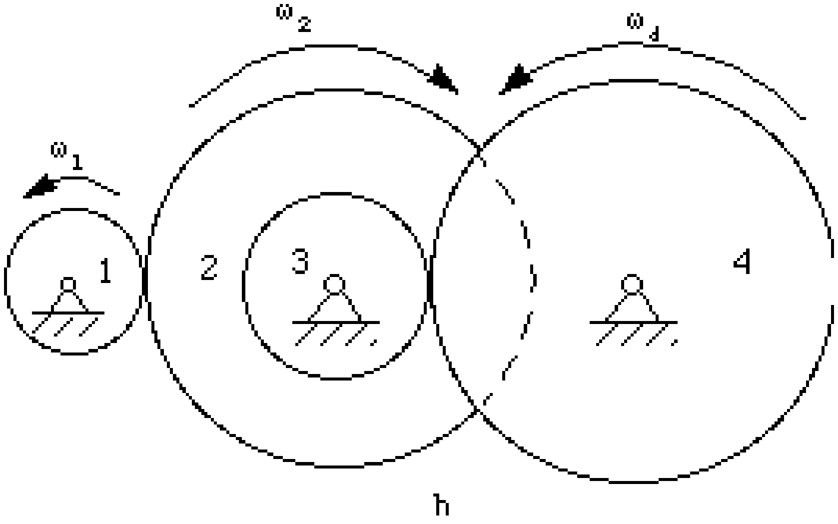
Simple Gear Train



Compound Gear Train

- For large velocities, compound arrangement is preferred

- Two or more gears may rotate about a single axis



Gears and Train Ratio

When two gears are in mesh, a gear ratio exists

Driven Gear = Ratio

Example:

Drive gear has 14 teeth

Driven gear has 28 teeth

$28 \div 14 = 2:1$ ratio (two to one ratio)

The drive gear must rotate twice to make the driven gear rotate once

Gears Ratio and Speed

The gear train ratio is also an element in the speed ratio, as in the ratio of the angular velocity of the input gear to the angular velocity of the output gear. This ratio can be used to calculated directly from the numbers of teeth on the gears in the gear train.

Diver divided Driven X R.P.M. of driver = R.P.M. of Driven

This Formula calculating speed can be used for both simple and compound gear trains, the only difference is when used in the compound train, the speed of the driven becomes the speed of the driver as you move through the train with the larger or smaller number of teeth.

Gears Ratio and R.P.M.

This Formula calculating speed can be used for both simple and compound gear trains, the only difference is when used in the compound train, the speed of the driven becomes the speed of the driver as you move through the train with the larger or smaller number of teeth.

Note that as gearboxes are used for speed change they also have a dramatic effect on the amount of torque generated

Torque Multiplication

The change in torque from the input gear to the output gear is directly proportional to the gear ratio

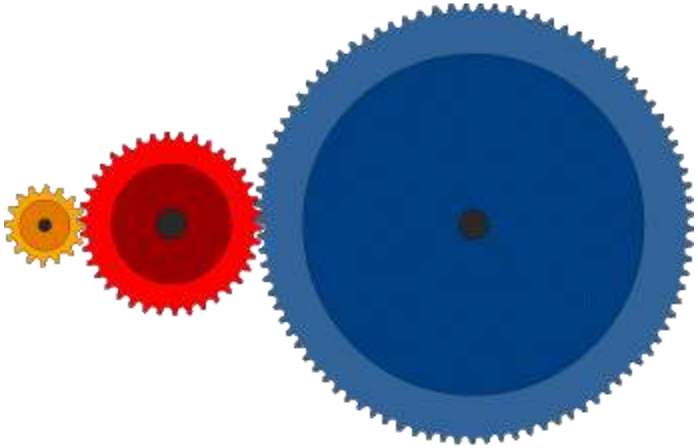
Example: 3:1 gear ratio

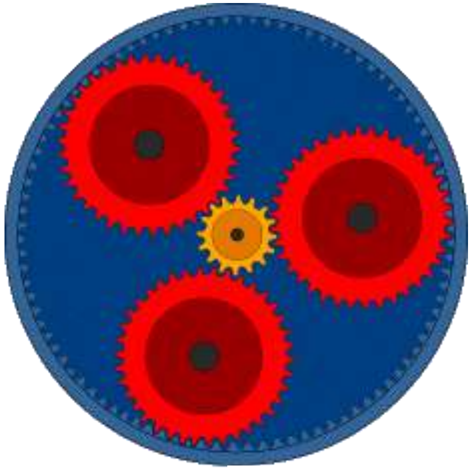
A motor turns input shaft gear at 900 RPM with 50 lb/ft of force.

The output gear turns driveshaft at 300 RPM with 150 lb/ft of force

Planetary Gear Train

(Epicyclic Gear Train)





Planetary Gear Train…

- In this train, the blue gear has six times the diameter of the yellow gear
- The size of the red gear is not important because it is just there to reverse the direction of rotation
- In this gear system, the yellow gear (the sun) engages all three red gears (the planets) simultaneously
- All three are attached to a plate (the planet carrier), and they engage the inside of the blue gear (the ring) instead of the outside.

Planetary Gear Train…

- Because there are three red gears instead of one, this gear train is extremely rugged.

- Planetary gear sets is that they can produce different gear ratios depending on which gear you use as the input, which gear you use as the output, and which one you hold still.

Planetary Gear Train…

- They have higher gear ratios.
- They are popular for automatic transmissions in automobiles.
- They are also used in bicycles for controlling power of pedaling automatically or manually.
- They are also used for power train between internal combustion engine and an electric motor

Typical Planetary Designs Set-up

Lubrication

Proper Lubrication with timely addition / replacement plays vital role in maintaining the gear boxes with efficiency and increasing its working life.

Oil level should be checked in all the gear boxes oil indicators / dip sticks.

Oil level should be in between the minimum and maximum limits of the dip stick (or indicator).

Lubrication…

Testing of the lubricating oils used to be carried out periodically. The following tests are to be done…

1. Dirt contamination
2. Moisture
3. Volatile materials (Benzene, kerosene, spirit etc,)
4. Viscosity
5. Acidity
6. Alkalinity

Types Gearbox Lubrications

Most lubricants for gearboxes contain extreme pressure (EP) additives and anti-wear additives to cope with the small area contact and sliding action found in the helical and hypoid bevel gear sets, these tend to make the oil very think and viscous. There also has to be a compromise with this oil for bearing lubrication and flow for cooling.

Types Gearbox Lubrications

Application-related advantages often prevail, increasing the use of synthetic lubricants as gear lubricants, especially under critical operating conditions. The most common synthetic types used include synthetic hydrocarbon oils (SHC), polyglycols (PAG) and ester oils (E).

Common Applications-PAG's

- Common uses PAG's:
  - Rotary screw and centrifugal compressors
  - Enclosed gear boxes
  - Worm gears
  - Fire-resistant hydraulic fluids
  - Food Grade ISO 150
  - Hydrocarbon flooded rotary screw compressors
  - High pressure ethylene compressors in HDPE production
  - Angeles Seamer-ISO 150

Lubrication Feed

Water Cooling Tower Environment

The End
Any Questions?