

## UNIT - III

### GEAR MANUFACTURING PROCESS

#### SPRX1008 – PRODUCTION TECHNOLOGY - II

Gears are widely used in various mechanisms and devices to transmit power and motion positively (without slip) between parallel, intersecting (axis) and non-intersecting non parallel shafts,

- without change in the direction of rotation
- with change in the direction of rotation
- without change of speed (of rotation)
- with change in speed at any desired ratio

Often some gearing system (rack – and – pinion) is also used to transform Rotary motion into linear motion and vice-versa.

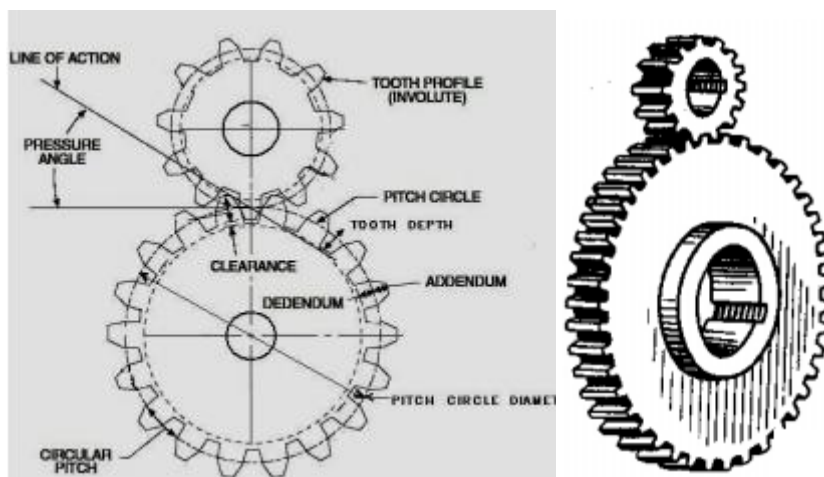


Fig.1 Features of Spur Gear

Gears are basically wheels having, on its periphery, equispaced teeth which are so designed that those wheels transmit, without slip, rotary motion smoothly and uniformly with minimum friction and wear at the mating tooth – profiles. To achieve those favorable conditions, most of the gears have their tooth form based on involute curve, which can simply be defined as Locus of a point on a straight line which is rolled on the periphery of a circle or Locus of the end point of a stretched string while its unwinding over a cylinder as indicated in Fig.

### General Applications of Gears

Gears of various type, size and material are widely used in several machines and systems requiring positive and stepped drive. The major applications are:

- Speed gear box, feed gear box and some other kinematic units of machine tools
- Speed drives in textile, jute and similar machineries
- Gear boxes of automobiles
- Speed and / or feed drives of several metal forming machines
- Machineries for mining, tea processing etc.
- Large and heavy duty gear boxes used in cement industries, sugar industries, cranes,

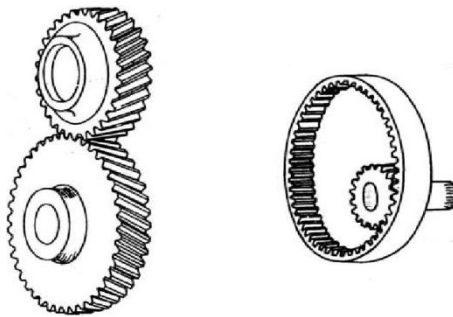
- conveyors etc.
- Precision equipments, clocks and watches
- Industrial robots and toys.

## Types of Gears and Their Characteristics

Gears are broadly classified

### (a) According to configuration (Fig.2)

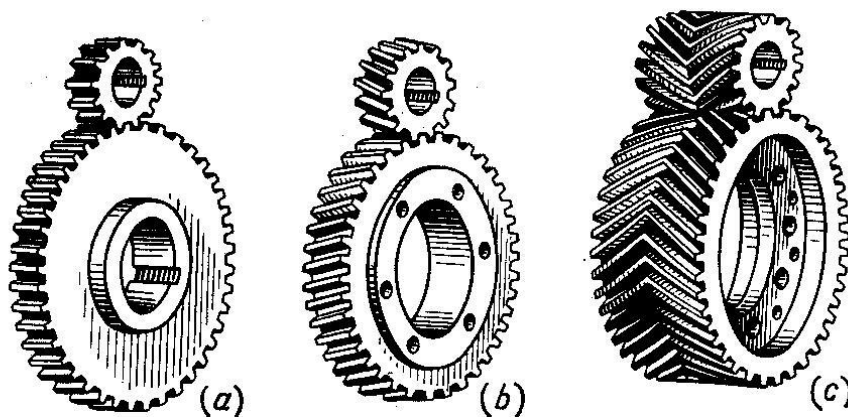
- External gear
- Internal gear



*Fig.2 Configuration of (a) external and (b) internal gears*

### (b) According to axes of transmission

- **Spur gears** – transmitting rotation between parallel shafts as shown in Fig.3
  - Straight toothed
  - Helical toothed
    - Single helical
    - Double helical (herringbone)



*Fig.3 (a) Straight toothed (b) Helical and (c) Double helical gears*

Compared to straight toothed gears, helical toothed gears run more smoothly and can transmit

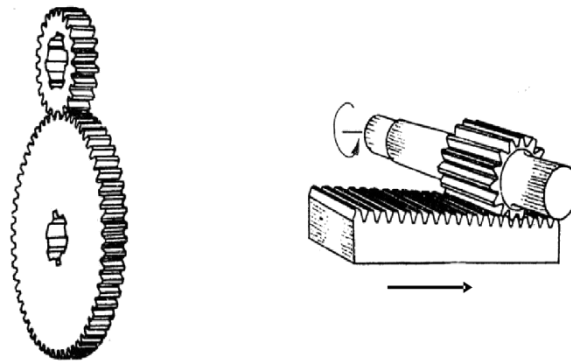
larger torque. Double helical gears are of large size and used for heavy torque transmission.

- Bevel gears – transmitting motion between intersecting shafts (axes) (Fig.4)
  - Straight toothed
  - Helical toothed
    - Spiral bevel gear
    - Hypoid gear

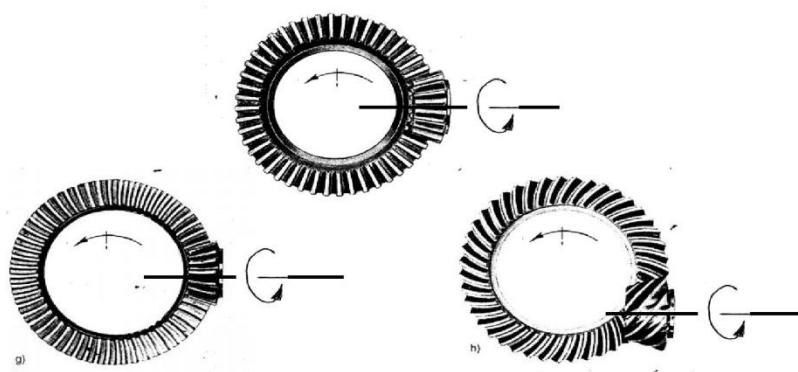
Helical toothed bevel gears are used for smoother and larger torque transmission.

- Gears transmitting motion and power between non-parallel non-intersecting shafts (Fig. 7.2.5)
  - Worm and worm wheel
  - Spiral gears
  - Skewed or hypoid bevel gears

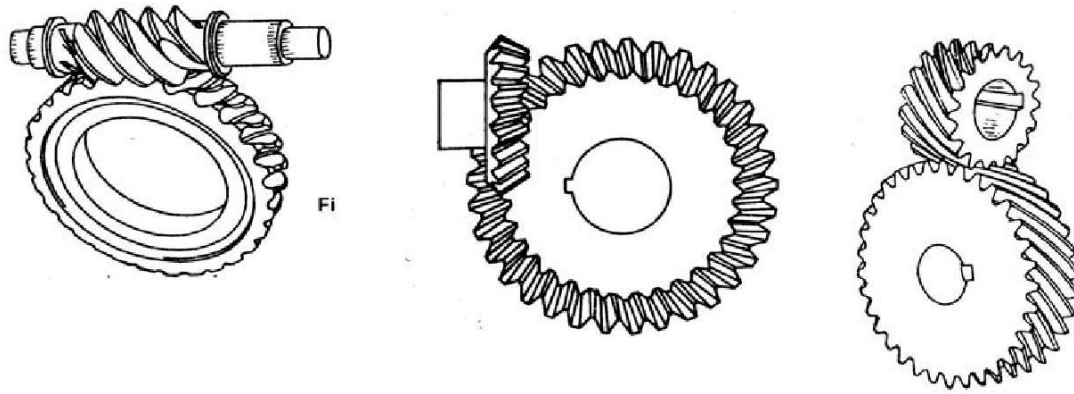
Worm and worm wheel are generally used for speed reduction but are irreversible i.e., rotation can be transmitted only from the worm to the worm wheel unless the helix angle is too large. Spiral gears are used when torque or power to be transmitted is insignificant.



**Fig.4** Bevel gears; (a) straight toothed, (b) spiral and hypoid gears



**Fig.5** Gears transmitting power between non-parallel non intersecting Shafts. (A) worm and worm wheel, (B) hypoid gear and (C) spiral gears.



*Fig.6 Gearing systems transforming (a) rotation to rotation and rotation to translation*

## Specification of Gears

Gears are generally specified by their

- Type; e.g. spur, bevel, spiral etc.
  - Material
  - Size or dimensions
  - Geometry
  - Special features, if any
- **Type of gears** – has already been discussed in the previous section (iii)
  - **Gear materials**

The materials of most of the gears used for transmitting reasonable torque and speed mainly need to be mechanically strong in shear and bending, sufficiently tough and resistant to wear, fatigue and chemical degradation.

However, the material for any gear is selected based on,

- o The working condition ie, power, speed and torque to be transmitted
- o Working environment, i.e., temperature, vibration, chemical etc.
- o Ease of manufacture
- o Overall cost of material and manufacture

The materials generally used for making gears are :

Ferrous metals – for high loads

- Grey cast iron – preferred for reasonable strength and wear resistance, ease of casting and machining and low cost
- Forged or rolled high carbon steels and alloy steels (Ni-Cr, Mo etc.) which are either fully hardened or surface hardened for use under high stresses and speed.

Non ferrous metals – for light load

- Aluminium, bronze and brass are used for making gears having fine teeth and working at very light load – e.g., in equipments, toys etc. or against hard steel mating gears
- Aluminium alloys like aluminium bronze, Zinc – Al. alloy etc.

Non-metals – widely used for light load, non-precision and noiseless operation. Polymers (plastics) : both thermoplastic and thermosetting type and various composites (metals, graphite, wood dust or ceramic powders dispersed in thermosetting plastics)

- **Size or major dimensions**

The dimensional features that are used to express or specify the gears are;

- For spur gears and worm wheels
  - number of teeth, z module, m
  - helix angle, if any ( $\theta$ )
  - width (b)

For example, pitch circle diameter (PCD) =  $mZ/\cos\theta$

- For worm (single or double toothed gears)
  - number of start
  - module helix angle length

- **Gear geometry**

Some geometrical features also need to be mentioned while specifying gears, such as,

- Pressure angle
- Addendum and addendum

- **Special features**

If there be any special feature, that also has to be included with gear specification, such as

- Tooth beveling for safe handling
- Tooth crowning for uniform wear and long service life
- Tooth rounding for easy engagement

## **Manufacture of Gears**

Manufacture of gears needs several processing operations in sequential stages depending upon the material and type of the gears and quality desired.

Those stages generally are:

- Performing the blank without or with teeth
- Annealing of the blank, if required, as in case of forged or cast steels
- Preparation of the gear blank to the required dimensions by machining
- Producing teeth or finishing the preformed teeth by machining
  - Full or surface hardening of the machined gear (teeth), if required finishing teeth, if required, by shaving, grinding etc.
- Inspection of the finished gears.

In this section, performing, producing teeth by machining and gear teeth finishing have been discussed in detail.

Performing Gear Blanks

- **Casting**

Gear blanks and even gears along with teeth requiring substantial to little machining or finishing are produced by various casting processes.

- **Sand casting**

The blanks of large cast iron gears, if required to be made one or few pieces, are produced by sand casting. Then the blank is prepared to appropriate dimensions and the teeth are produced by machining that cast perform. Complete gears with teeth can also be directly produced by such casting and used at low speed in machineries like farm machinery and hand operated devices where gear accuracy and finish are not that much required.

- **Metal mould casting**

Medium size steel gears with limited accuracy and finish are often made in single or few pieces by metal mould casting. Such unfinished gears are used in several agro-industries. For general and precision use the cast preforms are properly machined.

- **Die casting**

Large lot or mass production of small gears of low melting point alloys of Al, Zn, Cu, Mg etc. are done mainly by die casting. Such reasonably accurate gears are directly or after little further finishing are used under light load and moderate speeds, for example in instruments, camera, toys.

- **Investment casting**

This near-net-shape method is used for producing small to medium size gears of exotic materials with high accuracy and surface finish hardly requiring further finishing. These relatively costly gears are generally used under heavy loads and stresses.

- **Shell mould casting**

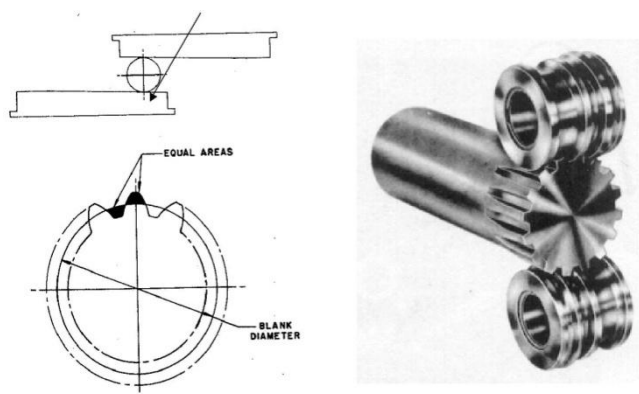
Small gears in batches are also often produced by this process. The quality provided by this process lies in between that of sand casting and investment casting.

- **Centrifugal casting**

The solid blanks or the outer rims (without teeth) of worm wheels made of cast iron, phosphor bronze or even steel are preferably preformed by centrifugal casting. The performs are machined to form the gear blank of proper size. Then the teeth are developed by machining.

- **Manufacture of gears by rolling**

The straight and helical teeth of disc or rod type external steel gears of small to medium diameter and module are generated by cold rolling by either flat dies or circular dies as shown in Fig. 7. Such rolling imparts high accuracy and surface integrity of the teeth which are formed by material flow unlike cutting. Gear rolling is reasonably employed for high productivity and high quality though initial machinery costs are relatively high. Larger size gears are formed by hot rolling and then finished by machining



*Fig. 7 Production of teeth of spur gears by rolling.*

- **Powder metallurgy**

Small size high quality external or internal spur, bevel or spiral gears are also produced by powder metallurgy process. Large size gears are rolled after briquetting and sintering for more strength and life. Powder metallurgically produced gears hardly require any further finishing work.

- **Blanking in Press tool**

Mass production of small and thin metallic gears requiring less accuracy and finish are often done by blanking from sheets by suitably designed die and punch. Such gears are used for clocks, watches, meters, toys etc. However, quality gears can also be produced by slight finishing (shaving) after blanking.

- **Plastic molding**

Small to medium size plastic gears with or without metal core are manufactured in large quantity by injection moulding. Such moderately accurate and less noisy gears, both external and internal types, are used under light loads such as equipments, toys, meters etc.

- **Extrusion process**

High quality small metallic or non metallic external gears are often produced in large quantity by extrusion. Number of gears of desired width are obtained by parting from the extruded rod of gear – section.

## **Production of Gear Teeth by Machining**

It appears from the previous section that gears are manufactured in several routes ;

The preformed blanks of approximate shape and irregular surface are machined to desired dimensions and finish and then the teeth are produced generally by machining and occasionally by rolling.

Full gears with teeth are made by different processes and then finished by further machining and / or grinding

Accurate gears in finished form are directly produced by near – net – shape process like rolling, plastic moulding, powder metallurgy etc. requiring slight or no further finishing.

The most commonly practiced method is preforming the blank by casting, forging etc. followed by pre-machining to prepare the gear blank to desired dimensions and then production of the teeth by machining and further finishing by grinding if necessary.

Gear teeth are produced by machining based on

- o **Forming** – where the profile of the teeth are obtained as the replica of the form of the cutting tool (edge); e.g., milling, broaching etc.
- o **Generation** – where the complicated tooth profile are provided by much simpler form cutting tool (edges) through rolling type, tool – work motions, e.g., hobbing, gear shaping etc.

## Methods of production of gear teeth by machining on forming principle

### o Shaping, planning and slotting

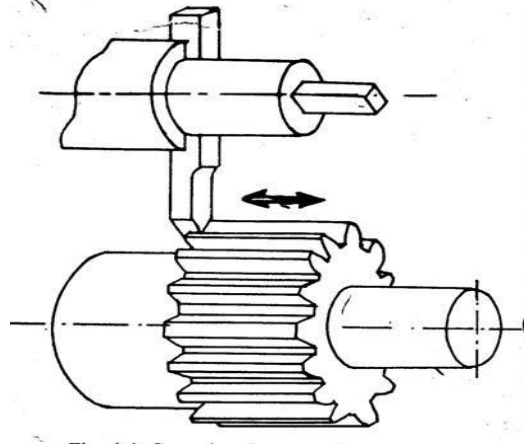
Fig. 8 schematically shows how teeth of straight toothed spur gear can be produced in shaping machine, if necessary. Both productivity and product quality are very low in this process which therefore, is used, if at all, for making one or few teeth on one or two pieces of gears as and when required for repair and maintenance purpose. In principle planning and slotting machines work on the same principle. Planing machine is used, if required at all, for making teeth of large gears whereas slotting, generally, for internal gears.

### o Milling

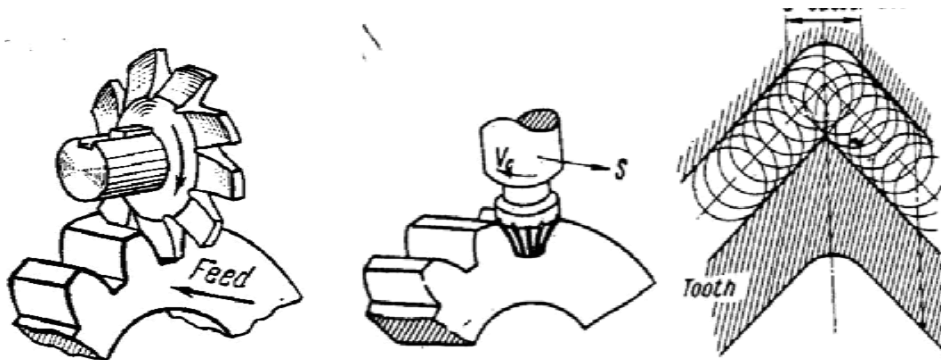
Gear teeth can be produced by both disc and end mill type form milling cutter as shown in Fig.9

Production of gear teeth by form milling are characterised by :

- use of HSS form milling cutters
- use of ordinary milling machines
- low production rate for
  - need of indexing after machining each tooth gap
  - slow speed and feed
- low accuracy and surface finish
- inventory problem – due to need of a set of eight cutters for each module – pressure angle combination.
- End mill type cutters are used for teeth of large gears and / or module.



*Fig. 8 Gear teeth cutting in ordinary shaping machine.*



*Fig. 9 Producing external teeth by form milling cutters (a) disc type and end mill type for (b) single helical and (c) double helical teeth*



## Production of gear teeth by machining on Generation principle

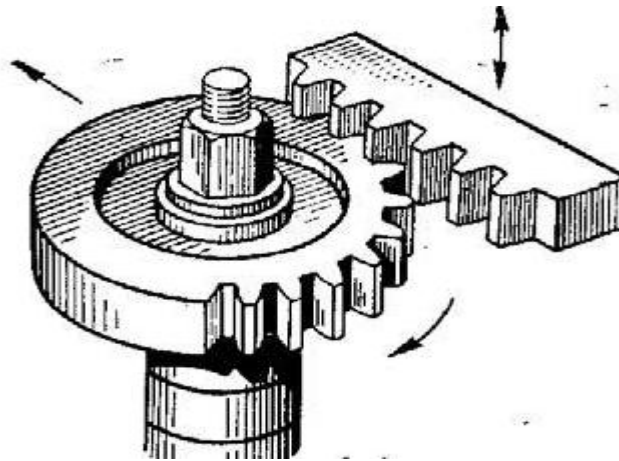
Generation method is characterised by automatic indexing and ability of a single cutter to cover the entire range of number of teeth for a given combination of module and pressure angle and hence provides high productivity and economy.

### o Sunderland method using rack type cutter

Fig.10 schematically shows the principle of this generation process where the rack type HSS cutter (having rake and clearance angles) reciprocates to accomplish the machining (cutting) action while rolling type interaction with the gear blank like a pair of rack and pinion. The favorable and essential applications of this method (and machine) include:

- moderate size straight and helical toothed external spur gears with high accuracy and finish
- cutting the teeth of double helical or herringbone gears with a central recess (groove)
- cutting teeth of straight or helical fluted cluster gears

However this method needs, though automatic, few indexing operations.



*Fig. 10 External gear teeth generation by rack type cutter  
(Sunderland method)*

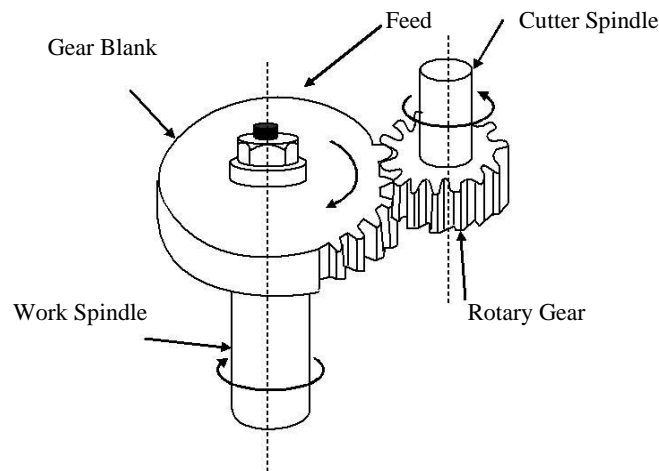
## Gears Shaping

Gear shaping is one of the gear generating methods. In this process gear tooth are accurately sized and shaped by cutting them by a multipoint cutting tool. Various gear shaping processes are listed and then described below :

- (a) Gear cutting by gear shaper.
- (b) Rack planning process.
- (c) Hobbing process.

### Gear Cutting by Gear Shaper

This process uses a pinion shaped cutter carrying clearance on the tooth face and sides and a hole at its centre for mounting it on a stub arbor or spindle of the machine. The cutter is mounted by keeping its axis in vertical position. It is also made reciprocating along the vertical axis up and down with adjustable and predecide amplitude. The cutter and the gear blank both are set to rotate at very low rpm about their respective axis. The relative rpm of both (cutter and blank) can be fixed to any of the available value with the help of a gear train. This way all the cutting teeth of cutter come in action one-by-one giving sufficient time for their cooling and incorporating a longer tool life. The specific advantages of the process over other processes, its product cycle time is very low and negligible dimensional variability from one unit to other in case of mass production. The principle of gear cutting by this process as explained above is depicted in the Figure 6.3. The main parameters to be controlled in the process are described below.



**Fig: 11 Process of Gear Cutting by Shaper Cutter**

### *Cutting Speed*

Shaper cutter can move vertically upward and downward during the operation. The downward during the operation. The downward movement of the cutter is the cutting stroke and its speed (linear) with which it comes down is the cutting speed. After the completion of cutting stroke, cutter comes back to its top position which is called return stroke. There is no cutting in the return stroke. Length of cutting stroke can be adjusted to any value out of available values on the machine.

### *Indexing Motion*

Indexing motion is equivalent to feed motion in the gear shaping operation. Slow rotations of the gear cutter and workpiece provide the circular feed to the operation. These two rpms are adjusted with the help of a change gear mechanism. The rpm are relatively adjusted such that each rotation of the cutter the gear blank revolves through  $n/N$  revolution. Where  $n \rightarrow$  Number of teeth of cutter, and

$N =$  Number of teeth to be cut on the blank.

### *Depth of Cut*

Indexing movement or circular feed and reciprocating motions continue until the required numbers of teeth to the required depth are made all along the periphery of the gear blank. The required depth is maintained gradually by cutting the teeth into two or three pass. In each successive pass, the depth of cut is increased as compared to its previous path. This gradual increase in depth of cut takes place by increasing the value of linear feed in return stroke.

The whole of this process is carried out on a gear shaping machine which is of the shape of a column and knee type milling machine. All the motions given to gear blank and gear cutter are set controlled very precisely.

### *Advantages of Gear Shaping Process*

Main advantages of gear shaping process are described below :

- (a) Shorter product cycle time and suitable for making medium and large sized gears in mass production.
- (b) Different types of gears can be made except worm and worm wheels.
- (c) Close tolerance in gear cutting can be maintained.
- (d) Accuracy and repeatability of gear tooth profile can be maintained comfortably.
- (e) For same value of gear tooth module a single type of cutter can be used irrespective of number of teeth in the gear.

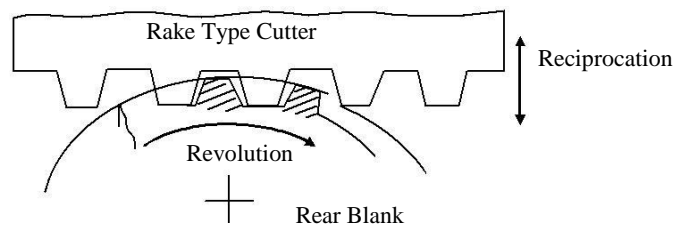
## Limitations

Main limitations of gear shaping process are described below :

- (a) It cannot be used to make worm and work wheel which is a particular type of gear.
- (b) There is no cutting in the return stroke of the gear cutter, so there is a need to make return stroke faster than the cutting stroke.
- (c) In case of cutting of helical gears, a specially designed guide containing a particular helix and helix angle, corresponding to the teeth to be made, is always needed on urgent basis.

## • Rack Planning Process

This process is used for shaping of spur and helical gear teeth with the help of a rack type cutter. In this process the gear blank is mounted on a horizontal axis and rotated intermittently. At the same time the gear blank is kept in mesh with a reciprocating rack type cutter. The teeth cutter gradually removes material to cut the teeth and to make the required profile. The whole operation includes some important operations. These are feeding cutter into the blank, rolling the blank intermittently and keeping cutter in mesh with the rolling gear blank. After each mesh the gear blank is rolled by an amount equal to one pitch of gear tooth. After each cutting, the rack is withdrawn and re-meshed after the rotation of gear blank.



**Fig: 12 Rack Planning process**

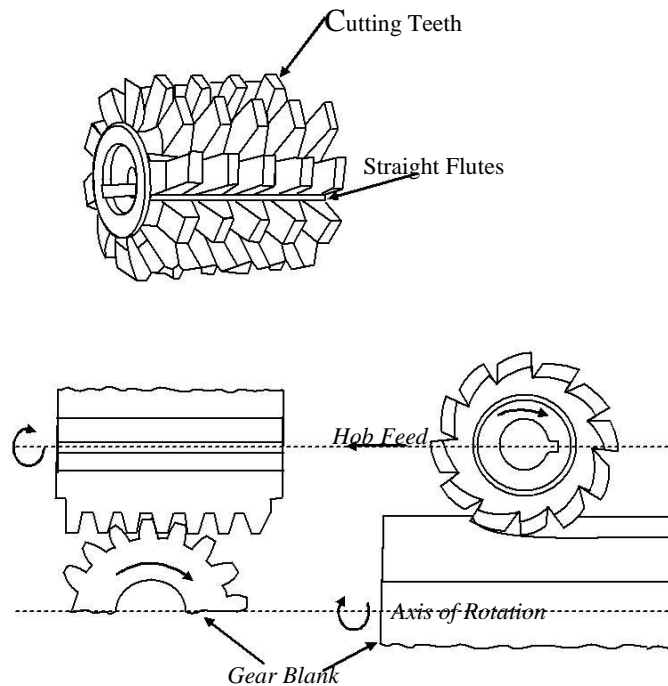
A few of the initial teeth of rack type cutter perform the cutting action and remaining teeth to very small removal of work piece material, these are used to maintain dimensional accuracy of the already cut teeth and to provide them a good finishing.

The basic principle of gear shaping is same but by slight altering the process some more different methods of gear shaping are discussed below.

## • Gear Hobbing

In addition to the gear shaping process another process used for gear generation is gear hobbing. In this process, the gear blank is rolled with a rotating cutter called hob. Gear hobbing is done by using a multipoint cutting tool called gear hob. It looks like a worm gear having a number of straight flutes all around its periphery parallel to its axis. These flutes are so shaped by giving proper angles to them so that these work as cutting edges. In gear hobbing operation, the hob is rotated at a suitable rpm and simultaneously fed to the gear blank. The gear blank is also kept as revolving. Rpm of both, gear blank and gear hob are so synchronized that for each revolution of gear hob the gear blank rotates by a distance equal to one pitch distance of the gear to be cut. Motion of both gear blank and hob are maintained continuously and steady. A gear hob is shown in Figure 6.8 and the process of gear hobbing is illustrated in Figure 6.9. The hob teeth behave like screw threads, having a definite helix angle. During operation the hob is tilted to helix angle so that its cutting edges remain square with the gear blank. Gear hobbing is used for making a wide variety of gears like spur gear, helical, hearing-bone, splines and gear sprockets, etc.

The tool-work configuration and motions in hobbing are shown in Fig. 13, where the HSS or carbide cutter having teeth like gear milling cutter and the gear blank apparently interact like a pair of worm and worm wheel. The hob (cutter) looks and behaves like a single or multiple start worm. Having lesser number (only three) of tool – work motions, hobbing machines are much more rigid, strong and productive than gear shaping machine. But hobbing provides lesser accuracy and finish and is used only for cutting straight or helical teeth (single) of external spur gears and worm wheels.



**Fig.13** Generation of external gear teeth by Hobbing : (a) straight tooth (b) helical tooth and (c) worm wheel

Three important parameters are to be controlled in the process of gear hobbing indexing movement, feed rate and angle between the axis of gear blank and gear hobbing tool (gear hob). The axis of hob is set at an inclination equal to the helix angle of the hob with the vertical axis of the blank. If a helical gear is to be cut, the hob axis is set at an inclination equal to the sum of the helix angle of the hob and the helix angle of the helical gear. Proper gear arrangement is used to maintain rpm ratio of gear blank and hob.

The operation of gear hobbing involves feeding the revolving hob till it reaches to the required depth of the gear tooth. Simultaneously it is fed in a direction parallel to the axis of rotation. The process of gear hobbing is classified into different types according to the directions of feeding the hob for gear cutting. The classification is described as given below.

#### *Hobbing with Axial Feed*

In this process the gear hob is fed against the gear blank along the face of the blank and parallel to its axis. This is used to make spur and helical gears.

#### *Hobbing with Radial Feed*

In this method the hob and gear blanks are set with their axis normal to each other. The rotating hob is fed against the gear blank in radial direction or perpendicular to the axis of gear blank. This method is used to make the worm wheels.

#### *Hobbing with Tangential Feed*

This is also used for cutting teeth on worm wheel. In this case, the hob is held with its axis horizontal but at

right angle to the axis of the blank. The hob is set at full depth of the tooth and then fed forward axially. The hob is fed tangential to the face of gear blank.

#### *Advantages and Limitations of Gear Hobbing Process*

Advantages of gear hobbing process are described below :

- (a) Gear hobbing is a fast and continuous process so it is realized as economical process as compared to other gear generation processes.
- (b) Lower production cycle time, i.e. faster production rate.
- (c) The process has a larger variability's in the following of sense as compared to other gear machining processes.

Capable to make wide variety of gears like spur gear, helical gears, worms, splines, sprockets, etc.

Process of required indexing (named so) is quite simplified and capable to make any number of teeth with consistent accuracy of module.

A special type of gear named herringbone gear can be generated by gear hobbing exclusively.

Wide variety of batch size (small to large volume) can be accommodated by this process.

- (d) Several gear blanks, mounted on the same arbor, can be processed simultaneously.
- (e) Hob is multipoint cutting tool having multi cutting teeth or edges at a time few number of cutting edges work so lots of time is available to dissipate the generated heat. There is no over heating and cutting tool.

- **Manufacture of worm**

The screw like single or multi-start worms (gears) made of steel are generally made by machining like long thread milling or by cold rolling like thread rolling followed by heat treatment for surface hardening and finishing by grinding.

- \* **Manufacture of bevel gears generation**

In manufacture of bevel gears, first the blanks are performed by casting or forging followed by machining to desired dimensions in lathes or special purpose machine.

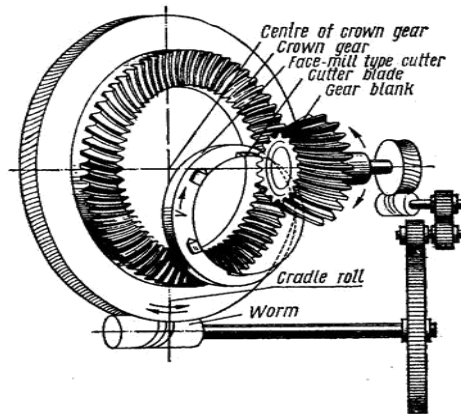
Then the teeth are produced in the blank by machining. The way of machining and machine tool are chosen based on the form of teeth and volume of production as follows:

Straight toothed bevel gear

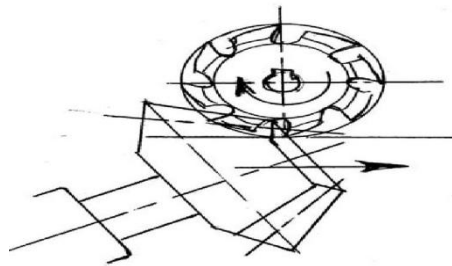
- o Forming by milling cutter – low productivity and quality hence employed for production requiring less volume and precision
- o Generation – high accuracy and finish, hence applied for batch to mass production.

Fig. 14 schematically shows the principle of forming and generation of teeth of straight toothed bevel gear. In generation process, the inner flanks of two adjacent teeth are developed with involutes profile by the straight teeth of the cutters under rolling action.

Teeth of spiral and hypoid bevel gears are produced by almost the same generation principle but the cutter resembles face milling cutter as shown in Fig.15.



**Fig.14 Production of teeth of straight toothed spur gear by (a) forming and (b) generation**



**Fig. 15 Generation of teeth of spiral and hypoid bevel gear.**

## Finishing of Gear Teeth

For smooth running, good performance and long service life, the gears need

- to be accurate in dimensions and forms
- to have high surface finish and
- to be hard and wear resistive at their tooth flanks

Which are achieved by some gear teeth finishing work after near accurate performing and machining. Small gears made by cold rolling generally do not require further finishing. If a rolled gear needs further surface hardening only then little finishing by grinding and / or lapping is done after hardening.

Gears produced to near-net-shape by die casting, powder metallurgy, extrusion, blanking etc. need little finishing.

But machined and hardened gear teeth are essentially finished for accuracy and surface finish.

Common methods of gear teeth finishing

Gear teeth, after performing and machining, are finished generally by;

- o for soft and unhardened gears
  - gear shaving
  - gear rolling or burnishing
- o for hard and hardened gears
  - grinding
  - lapping
- o for soft but precision gears
  - shaving followed by surface hardening and then lapping

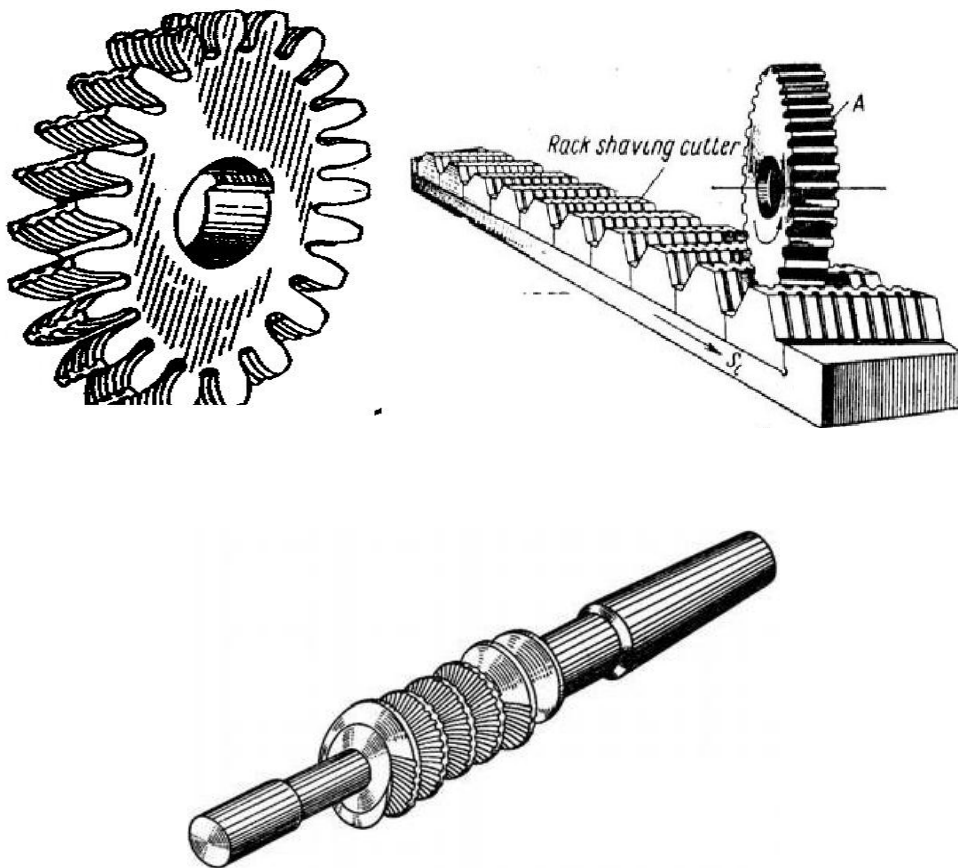
- o **Gear shaving**

The teeth of straight or helical toothed external spur gears and worm wheels of moderate size and made of soft materials like aluminum alloy, brass, bronze, cast iron etc. and unhardened steels are mostly finished by shaving process. Fig. 16 shows the different types of shaving cutters which while their finishing action work apparently as a spur gear, rack or worm in mesh with the conjugate gears to be finished. All those gear, rack or worm type shaving cutters are of hard steel or HSS and their teeth are uniformly serrated as shown in fig.16 (a) to generate sharp cutting edges.

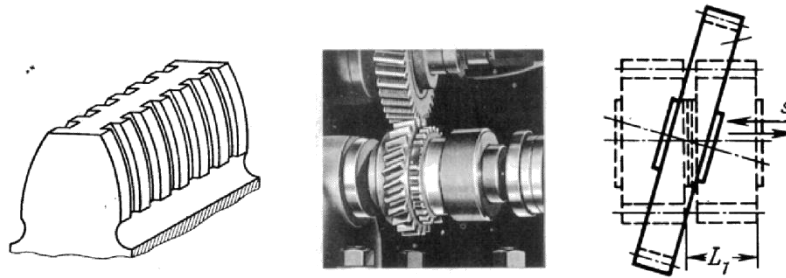
While interacting with the gears, the cutting teeth of the shaving cutter keep on smoothening the mating gear flanks by fine machining to high accuracy and surface finish. For such minute cutting action, the shaving teeth need an actual or apparent movement relative to the mating teeth along their length as indicated in Fig. 16(b).

- o **Gear rolling or burnishing**

In this method the machined gear is rolled under pressure with three hardened master gears of high accuracy and finish. The minute irregularities of the machined gear teeth are smeared off by cold plastic flow, which also helps in improving the surface integrity of the desired teeth.



**Fig.16** Gear shaving cutters of (a) spur gear type (b) rack and (c) worm type



**Fig.17 Cutting teeth of gear shaving (a) cutter and its (b) action**

o **Gear teeth grinding**

Grinding is a very accurate method and is, though relatively expensive, more widely used for finishing teeth of different type and size of gears of hard material or hardened surfaces. The properly formed and dressed wheel finishes the gear teeth flanks by fine machining or abrading action of the fine abrasives.

Like gear milling, gear grinding is also done on two principles

forming

Generation, which is more productive and accurate

- **Gear teeth grinding on forming principle**

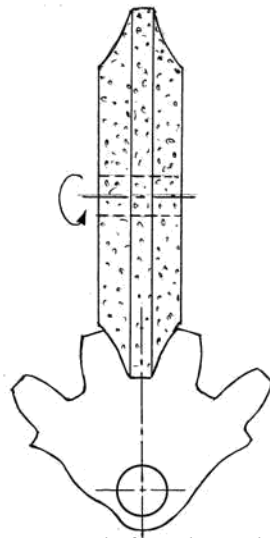
This is very similar to machining gear teeth by a single disc type form milling cutter as indicated in Fig. 18 where the grinding wheel is dressed to the form that is exactly required on the gear. Need of indexing makes the process slow and less accurate. The wheel or dressing has to be changed with change in module, pressure angle and even number of teeth. Form grinding may be used for finishing straight or single helical spur gears, straight toothed bevel gears as well as worm and worm wheels.

- **Gear teeth grinding on generation principle**

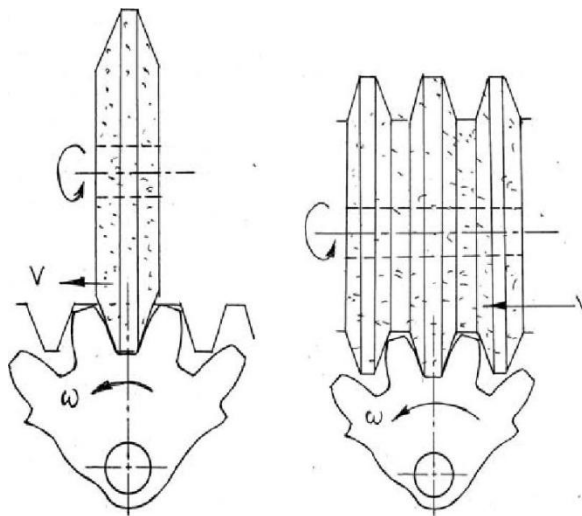
Fig.19 schematically shows the methods of finishing spur gear teeth by grinding on generation principle.

The simplest and most widely used method is very similar to spur gear teeth generation by one or multi-toothed rack cutter. The single or multi-ribbed rotating grinding wheel is reciprocated along the gear teeth as shown. Other tool – work motions remain same as in gear teeth generation by rack type cutter as indicated in Fig. For finishing large gear teeth a pair of thin dish type grinding wheels are used as shown in Fig. 19 (c). Whatsoever, the contacting surfaces of the wheels are made to behave as the two flanks of the virtual rack tooth.





**Fig. 18 Gear teeth finishing by form grinding**



**Fig.19 Gear teeth grinding on generation principle.**

- **Gear teeth finishing by lapping**

Gear lapping is the process of imparting a very fine finish and high degree of accuracy to gear teeth, by using a lapping tool and applying a fine-grained abrasive between a work material and a closely fitting surface, called a lapping plate.

The lapping process only corrects minute deviations from the desired gear tooth profiles. The gear to be finished after machining and heat treatment and even after grinding is run in mesh with a gear shaped lapping tool or another mating gear of cast iron. An abrasive lapping compound is used in between them. The gear tooth contact substantially improves by such lapping.

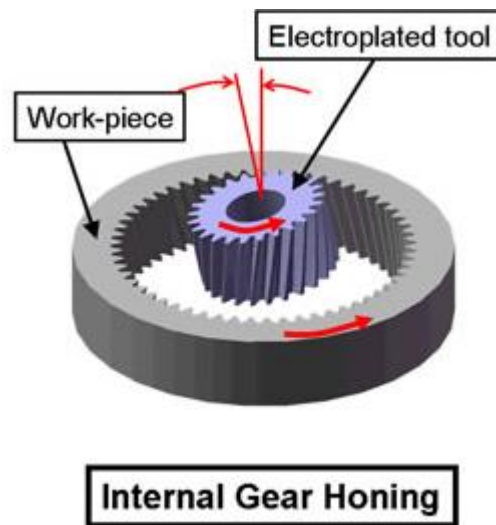


**Fig: 20 Gear Lapping**

- **Gear Honing**

**Honing** is an abrasive machining process that produces a precision surface on a metal work piece by scrubbing an abrasive stone against it along a controlled path. Honing is primarily used to improve the geometric form of a surface, but may also improve the surface texture. Typical applications are the finishing of cylinders for internal combustion engines, air bearing spindles and gears. There are many types of hones but all consist of one or more abrasive stones that are held under pressure against the surface they are working on.

In terms of sharpening knives, a honing steel does not actually hone knives, but simply realigns the metal along the edge. Other similar processes are lapping and super finishing.



**Fig: 21 Gear Honing**

