

Gears & Gear Manufacturing



Training Objective

After watching the program and reviewing this printed material, the viewer will gain knowledge and understanding of the purpose and function of gears and become aware of the various manufacturing and finishing methods used to produce gears.

- The basic physical elements of gears are explained
- Gear terminology is explored
- Gear manufacturing methods are demonstrated
- Gear finishing techniques are shown

Gear Descriptions and Functions

Gears are mechanical components within machines and mechanical assemblies which transmit power and motion through successive engagement of their peripheral teeth. Gears perform certain key functions with machines and assemblies, including:

- Reversing rotational direction
- Altering angular orientation of rotary motion
- Converting rotary to linear motion and vice-versa
- Altering speed and power transmission ratios

Gear design is based upon an involute curve form which imparts a rolling, rather than sliding action between engaging teeth. This rolling action provides a uniform rotary action that lowers both friction and wear of the gear teeth.

Gear Terminology

There are several gear and gear-tooth dimensions and terms important to the understanding of gear production and finishing processes. These terms include:

- Base Circle: The diameter from which the involute tooth profile is developed.
- Pitch Circle: The imaginary rolling circle produced by the meshing gears during rotation. Also known as the Pitch Diameter.
- Line of Centers: Line connecting the Pitch Circle centers of mating gears.
- Pitch Point: The point of tangency of two gear Pitch Circles, through the Line of Centers.
- Line of Action: A line tangent to the Base Circles of mating gears, through the Pitch Point and thus the path of tooth contact.
- Pressure Angle: The angle formed between the Line of Action and a line tangent to the Pitch Point.
- Outside Circle: The outside diameter of gear. Also known as the Addendum Circle.
- Root Circle: The diameter of the gear at the tooth base. Also known as the Dedendum Circle.
- Addendum: The radial distance between the Pitch Circle and the Outside Circle of the gear.
- Dedendum: The radial distance between the Pitch Circle and the Root Circle.
- Tooth Thickness: The thickness of the gear tooth measured along the Pitch Circle.
- Circular Pitch: The length of the arc along the Pitch Circle between corresponding points of adjacent teeth.
- Face Width: The width of gear tooth measured axially.
- Tooth Face: The mating surface of a gear tooth between the Outside Circle and the Pitch Circle.
- Tooth Flank: The mating surface of a gear tooth measured between the Pitch Circle and the Root Circle.

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Gear Types

Gears may have internal or external teeth and are available in forms that typically relate to axis positions, which include:

- Parallel axes, which pertain to two or more tangent pitch shafts using either spur gears-the most common type of gear, or helical gears.
- Intersection axes using straight bevel gears, spiral bevel gears, or zerol bevel gears.
- Non-intersecting, non-parallel axes, which refer to worms and worm gears, crossed helical gears, and hypoid gears.

Racks and pinions which are used to convert rotary motion to linear motion are other familiar gear types.

Gear Manufacturing

Materials used to produce gears may include steel-which is the most common material, and various non-ferrous materials including plastics and composites. Manufacturing methods include: machining, forging, casting, stamping, powder-metallurgy techniques, and plastic injection molding. Of these, machining is the most common manufacturing method used. Gear machining is classified into two categories:

- Gear Generating
- Gear Form-Cutting

Gear generating involves gear cutting through the relative motion of a rotating cutting tool and the generating, or rotational, motion of the workpiece. The two primary generating processes are hobbing and shaping.

Hobbing uses a helically fluted cutting tool called a hob. Both the hob and the workpiece rotate as the hob is fed axially across the gear blank. Hobbing is limited to producing external gear teeth on spur and helical gears. Hobbing can be performed on a single gear blank, but also allows for stacking of multiple workpieces, increasing production rates.

Shaping produces gears by rotating the workpiece in contact with a reciprocating cutting tool. The cutter may be pinion shaped, a multi-tooth rack-shaped cutter, or a single-point cutting tool.

Gear form-cutting uses formed cutting tools that have the actual shape, or profile, desired in the finished gear. The two primary form-cutting methods are broaching and milling.

Broaching is the fastest method of machining gears and is performed using a multi-tooth cutting tool called a broach. Each tooth on the broach is generally higher than the preceding tooth. As a result, the depth of cut increases with each tooth as the broaching operation progresses. Broaching is typically used to produce internal gear teeth. External teeth can be broached using "pot broaching". In this process a hollow broaching tool, called the pot, is used to cut the gear teeth.

Milling is a basic machining process which uses the relative motion between a rotating, multi-edge cutter and a workpiece to cut individual gear teeth. A variation of the process, called "gashing", is used to produce large, coarse-pitch gears. Gashing is used on heavy-duty milling machines and involves plunging the rotating cutter into a blank for rapid metal removal.

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Gear Finishing

After manufacturing, gears require a number of finishing operations. Finishing operations include heat treatment and final dimensional and surface finishing. This finishing can be accomplished using:

- Shaving
- Grinding
- Honing

Shaving is performed with a cutter having the exact shape of the finished gear tooth. Only small amounts of material are removed by a rolling and reciprocating action. The process is fast but generally expensive due to the cost of machinery and tooling. Shaving is typically performed prior to heat treating.

Grinding sometimes serves as an initial gear production process, but is most often employed for gear finishing. Grinding is classified as either form grinding or involute-generation grinding.

Form grinding uses wheels having the exact shape of the tooth spacing. The grinding wheels are either vitrified-bond wheels, which require periodic re-dressing, or Cubic Boron Nitride (CBN) wheels, which can last hundreds of times longer than vitrified wheels without dressing.

Involute-generation grinding refers to a grinding wheel or wheels used to finish the gear tooth by axially rotating the workpiece while it is reciprocated in an angular direction, which in turn is determined by the type of gear being finished. This type of grinding is performed either intermittently or continuously. Intermittent grinding uses tooth profiles dressed on cup wheels, or on one or two single-rib wheels. Each tooth is ground individually, then the next is indexed to the wheel. Continuous grinding uses grinding wheels with the rack profile dressed helically on the outside diameter. Both the grinding wheel and the work turn in timed relationship for continuous finishing.

Honing involves the meshing of the gear teeth in a cross axis relationship with a plastic, abrasive impregnated gear shaped tool. The tool traverses the tooth surface in a back and forth movement parallel to the workpiece axis. Honing polishes the gear tooth surface and can be used to correct minor errors in gear tooth geometry.

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Review Questions

1. The rolling action between engaging gear teeth is due to:
 - a. high viscosity lubricants
 - b. points of tangency between teeth
 - c. the involute curve form
 - d. gear rotational synchronization

2. The imaginary rolling circle produced by meshed gears during rotation is called the:
 - a. Pitch Circle
 - b. Base Circle
 - c. Dedendum Circle
 - d. Addendum Circle

3. The most common type of gear is the:
 - a. spur gear
 - b. helical gear
 - c. straight bevel gear
 - d. hypoid gear

4. A worm gear is an example of a gear type used along:
 - a. parallel axes
 - b. non-intersecting, non-parallel axes
 - c. connecting axes
 - d. intersecting axes

5. The most common gear manufacturing method is:
 - a. forging
 - b. machining
 - c. injection molding
 - d. stamping

6. Hobbing is used to produce only:
 - a. helical gears
 - b. spur gears
 - c. external gear teeth
 - d. internal gear teeth

7. Gear form cutting involves the use of:
 - a. hobbing and shaping
 - b. shaping and milling
 - c. multiple stacked blanks
 - d. broaching and milling

8. The gear finishing method typically performed prior to heat treatment is:
 - a. honing
 - b. continuous grinding
 - c. form grinding
 - d. shaving

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Answer Key

1. c
2. a
3. a
4. b
5. b
6. c
7. d
8. d