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THE GEAR BASIC THEORY

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INTRODUCTION

A gear is a rotating machine part having cut teeth, or cogs, which mesh with another toothed part in order to transmit torque. Two or more gears working in tandem are called a transmission and can produce a mechanical advantage through a gear ratio and thus may be considered a simple machine. Geared devices can change the speed, magnitude, and direction of a power source. The most common situation is for a gear to mesh with another gear; however a gear can also mesh a non-rotating toothed part, called a rack, thereby producing translation instead of rotation.

When two gears of unequal number of teeth are combined a mechanical advantage is produced, with both the rotational speeds and the torques of the two gears differing in a simple relationship.

In transmissions which offer multiple gear ratios, such as bicycles and cars, the term gear, as in first gear, refers to a gear ratio rather than an actual physical gear. The term is used to describe similar devices even when gear ratio is continuous rather than discrete, or when the device does not actually contain any gears, as in a continuously variable transmission.

TYPES OF GEARS

External vs. Internal Gears

An external gear is one with the teeth formed on the outer surface of a cylinder or cone. Conversely, an internal gear is one with the teeth formed on the inner surface of a cylinder or cone. For bevel gears, an internal gear is one with the pitch angle exceeding 90 degrees. Internal gears do not cause direction reversal.

Spur Gears

Spur gears or straight-cut gears are the simplest type of gear. They consist of a cylinder or disk with the teeth projecting radially, and although they are not straight-sided in form, the edge of each tooth is straight and aligned parallel to the axis of rotation. These gears can be meshed together correctly only if they are fitted to parallel axles.

Helical Gears

Helical gears offer a refinement over spur gears. The leading edges of the teeth are not parallel to the axis of rotation, but are set at an angle. Since the gear is curved, this angling causes the tooth shape to be a segment of a helix. Helical gears can be meshed in a parallel or crossed orientations. The former refers to when the shafts are parallel to each other; this is the most common orientation. In the latter, the shafts are non-parallel.

A disadvantage of helical gears is a resultant thrust along the axis of the gear, which needs to be accommodated by appropriate thrust bearings, and a greater degree of sliding friction between the meshing teeth, often addressed with additives in the lubricant.

Double Helical Gears

Double helical gears, or herringbone gear, overcome the problem of axial thrust presented by “single” helical gears by having two sets of teeth that are set in a V shape. Each gear in a double helical gear can be thought of as two standard mirror image helical gears stacked. This cancels out the thrust since each half of the gear thrusts in the opposite direction. Double helical gears are more difficult to manufacture due to their more complicated shape.

Bevel Gears

A bevel gear is shaped like a right circular cone with most of its tip cut off. When two bevel gears mesh their imaginary vertices must occupy the same point. Their shaft axes also intersect at this point, forming an arbitrary non-straight angle between the shafts. The angle between the shafts can be anything except zero or 180 degrees. Bevel gears with equal numbers of teeth and shaft axes at 90 degrees are called miter gears.

Hypoid Gears

Hypoid gears resemble spiral bevel gears except the shaft axes do not intersect. The pitch surfaces appear conical but, to compensate for the offset shaft, are in fact hyperboloids of revolution. Hypoid gears are almost always designed to operate with shafts at 90 degrees. Depending on which side the shaft is offset to, relative to the angling of the teeth, contact between hypoid gear teeth may be even smoother and more gradual than with spiral bevel gear teeth.

Crown Gears

Crown gears or contrate gears are a particular form of bevel gear whose teeth project at right angles to the plane of the wheel; in their orientation the teeth resemble the points on a crown. A crown gear can only mesh accurately with another bevel gear, although crown gears are sometimes seen meshing with spur gears. A crown gear is also sometimes meshed with an escapement such as found in mechanical clocks.

Worm Gears

Worm gears resemble screws. A worm gear is usually meshed with an ordinary looking, disk-shaped gear, which is called the gear, wheel, or worm wheel. Worm-and-gear sets are a simple and compact way to achieve a high torque, low speed gear ratio. For example, helical gears are normally limited to gear ratios of less than 10:1 while worm-and-gear sets vary from 10:1 to 500:1. A disadvantage is the potential for considerable sliding action, leading to low efficiency.

Non-Circular Gears

Non-circular gears are designed for special purposes. While a regular gear is optimized to transmit torque to another engaged member with minimum noise and wear and maximum efficiency, a non-circular gear's main objective might be ratio variations, axle displacement oscillations and more. Common applications include textile machines, potentiometers and continuously variable transmissions.

Rack and Pinion Gears

A rack is a toothed bar or rod that can be thought of as a sector gear with an infinitely large radius of curvature. Torque can be converted to linear force by meshing a rack with a pinion: the pinion turns; the rack moves in a straight line. Such a mechanism is used in automobiles to convert the rotation of the steering wheel into the left-to-right motion of the tie rod(s). Racks also feature in the theory of gear geometry.

Epicyclic Gears

In Epicyclic gearing one or more of the gear axes moves. Examples are sun and planet gearing and mechanical differentials.

Sun and Planet Gears

Sun and planet gearing was a method of converting reciprocal motion into rotary motion in steam engines. It played an important role in the Industrial Revolution. The Sun is yellow, the planet red, the reciprocating crank is blue, the flywheel is green and the driveshaft is grey.

Harmonic drive Gears

A harmonic drive is a specialized proprietary gearing mechanism.

Cage Gears

A cage gear, also called a lantern gear or lantern pinion has cylindrical rods for teeth, parallel to the axle and arranged in a circle around it, much as the bars on a round bird cage or lantern. The assembly is held together by disks at either end into which the tooth rods and axle are set.

MANUFACTURING

Gear manufacturing refers to the making of gears. Because of their capability for transmitting motion and power, gears are among the most important of all machine elements. Special attention is paid to gear manufacturing because of the specific requirements to the gears. The gear tooth flanks have a complex and precise shape with high requirements to the surface finish. Gears can be manufactured by most of manufacturing processes discussed so far (casting, forging, extrusion, powder metallurgy, blanking). But as a rule, machining is applied to achieve the final dimensions, shape and surface finish in the gear. The initial operations that produce a semi finishing part ready for gear machining as referred to as blanking operations; the starting product in gear machining is called a gear blank.

VARIOUS PROCESSES CAME UNDER GEAR MANUFACTURING TECHNOLOGY

Gear Forming Process

Gear manufacturing can be divided into two categories namely forming and machining. Forming consists of direct casting, molding, drawing, or extrusion of tooth forms in molten, powdered, or heat softened materials and machining involves roughing and finishing operations.

Casting

- Sand casting, die casting and investment casting are the casting processes that are best suited for gears.
- Sintering or P/M process:
- The powder metallurgy technique used for gear manufacture.
- Accuracy similar to die-cast gears
- Material properties can be Tailor made
- Typically suited for small sized gears
- Economical for large lot size only

Injection Molding

Injection molding is used to make nonmetallic gears in various thermoplastics such as nylon and acetal. These are low precision gears in small sizes but have the advantages of low cost and the ability to be run without lubricant at light loads. Injection molded gears are used in cameras, projectors, wind shield wipers, speedometer, lawn sprinklers, washing machine.

Extruding

Extruding is used to form teeth on long rods, which are then cut into usable lengths and machined for bores and keyways etc. Nonferrous materials such as aluminium and copper alloys are commonly extruded rather than steels. This result in good surface finishes with clean edges and pore free dense structure with higher strength.

Stamping

Sheet metal can be stamped with tooth shapes to form low precision gears at low cost in high quantities. The surface finish and accuracy of these gears are poor.

Forging

Forging is the shaping of metal using localized compressive forces. Forging is often classified according to the temperature at which it is performed: '"cold," "warm," or "hot" forging. Forged parts can range in weight from less than a kilogram to 580 metric tons. Forged parts usually require further processing to achieve a finished part.

Gear cutting process

Gear cutting is the process of creating a gear. The most common processes include hobbing, broaching, and machining; other processes include shaping, forging, extruding, casting, and powder metallurgy. Gears are commonly made from metal, plastic, and wood.

Broaching

For very large gears or splines, a vertical broach is used. It consists of a vertical rail that carries a single tooth cutter formed to create the tooth shape. A rotary table and a Y axis are the customary axes available. Some machines will cut to a depth on the Y axis and index the rotary table automatically. The largest gears are produced on these machines.

Hobbing

Hobbing is a method by which a hob is used to cut teeth into a blank. The cutter and gear blank are rotated at the same time to transfer the profile of the hob onto the gear blank. The hob must make one revolution to create each tooth of the gear. Used very often for all sizes of production runs, but works best for medium to high.

Shaping

The old method of gear cutting is mounting a gear blank in a shaper and using a tool shaped in the profile of the tooth to be cut. This method also works for cutting internal splines. Another is a pinion-shaped cutter that is used in a gear shaper machine. It is basically when a cutter that looks similar to a gear cuts a gear blank. The cutter and the blank must have a rotating axis parallel to each other. This process works well for low and high production runs.

Gear Finishing Process

When high precision is required secondary operation can be performed to gears made by any of the above roughing methods. Finishing operations typically removes little or no material but improves dimensional accuracy, surface finish, and or hardness.

Shaving

Shaving is similar to gear shaping, but uses accurate shaving tools to remove small amounts of material from a roughed gear to correct profile errors and improve surface finish.

Grinding

In grinding, a contoured grinding wheel is run over machined surface of the gear teeth using computer control. With a small amount of metal removal high surface finish is obtained. Grinding is used to correct the heat-treatment distortion in gears hardened after roughing. Improvement in surface finish and error correction of earlier machining are added advantages.

Burnishing

In burnishing, an especially hardened gear is run over rough machined gear. The high forces at the tooth interface cause plastic yielding of the gear tooth surface which improves finish and work hardens the surface creating beneficial compressive residual stresses.

Lapping and Honing

Lapping and honing both employ an abrasive-impregnated gear or gear-shaped tool that is run against the gear to abrade the surface. In both cases, the abrasive tool drives the gear in what amounts to an accelerated and controlled run-in to improve surface finish and the accuracy.

GEAR MATERIAL

In order for gears to achieve their intended performance, life and reliability, the selection of a suitable gear material is very important. High load capacity requires a tough, hard material that is difficult to machine; whereas high precision favours materials that are easy to machine and therefore have lower strength and hardness ratings. Gears are made of variety of materials depending on the requirement of the machine. They are made of plastic, steel, wood, cast iron, aluminium, brass, powdered metal, magnetic alloys and many others. The gear designer and user face a myriad of choices. The final selection should be based upon an understanding of material properties and application requirements:

- Plastic Gears
- Steel Gears
- Cast Iron Gears
- Wood Gears
- Powdered Metal Gears
- Copper Gears
- Brass Gears
- Aluminium Gears etc