The Analysis and Research of Gear Surface Machining

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Abstract. Through the analysis of the surface of the gear machining program, describes the characteristics and applications of various processing methods, the view of the article describes have a guiding role in the design and processing gears.

Technical requirements gear

Surface of parts have a certain shape and size, also a certain accuracy and surface quality. Gears are widely used in a variety mechanical transmission, for transmission of power and movement, and having to change speed and steering role. Widely used in machinery, equipment, instruments and working performance, carrying capacity, life and work of precision are closely related with the quality of the gear itself[1].

In addition to the dimensional accuracy of the gear, the shape precision and surface quality requirements, there are some special requirements.

1) The angular error motion precision gears of a circle must not exceed a certain limit, it is important to ensure that transmit motion ratio indicators. Therefore, the required gear teeth evenly divided, in order to avoid leaving due to the uneven distribution of teeth cyclical fluctuations in speed appears.

2) Accuracy means the stationary work in a smaller rotation angle error of the angle of the pair of gears, i.e. the instantaneous change of the size ratio. Mainly caused by the manufacturing error of the tooth profile, on the teeth leads to a change in the angle may appear several times when engaged, thereby generating vibration and noise.

3) The accuracy of the contact means meshing tooth surface exposure. The larger the contact area, the load borne per unit area is smaller, the more uniform force. In addition, the contact position tooth surfaces should be correct, otherwise it will affect the carrying capacity of the gear.

4) Gear backlash between the tooth surface should be a non-working clearance for storage lubricants, heat distortion compensation, processing and installation of the impact of error. Otherwise, the gear may be stuck or burned in the transmission process[2].

Precision gear divided 12 levels, order of 1，2, 3 ... 12. Which one, two for the vision level, seven is basic level, in actual use (or design) and precision grade of general application adopted hobbing, gear shaping, shaving three cutting process can achieve accuracy levels. Table 1 lists the most commonly used method for final processing and application range of 4 to 9 precision gears.

Gear blank machining is generally by the production batch size, the choice of different ways. In the unit, small batch production, processing by turning way, the large number of mass production, for small and medium size gear blanks, the selection of drilling broaching multi-tool turning mode processing.

The method of tooth processing, according to the principles of the formation of the tooth can be divided into two categories, the forming method and generating method. If the blade is cutting tooth shape with the same shape, tooth bladed straight cut, known forming methods such as gear milling, grinding teeth. According to the principle of gear meshing toothed work piece envelope formed by a blade with similar tooth, called the generating method, such as hobbing, gear shaping, shaving, honing, lapping.

Tooth machining program should be based on accuracy requirements, structure formation and the production volume and other factors to select.

Common processing methods Gear

Gear milling

Gear milling, the workpiece mounted on the dividing head milling machine, milling rotary motion, linear motion table. With disk-shaped gear cutter ($m<10-16$) or fingers gear ($m>10$) milling gullet, after a gullet after each machining, milling along the alveolar direction back to the original position, the workpiece indexing, and then milling next gullet. The above process is repeated continuously until all the gullet milling until the end, as shown in fig 1.

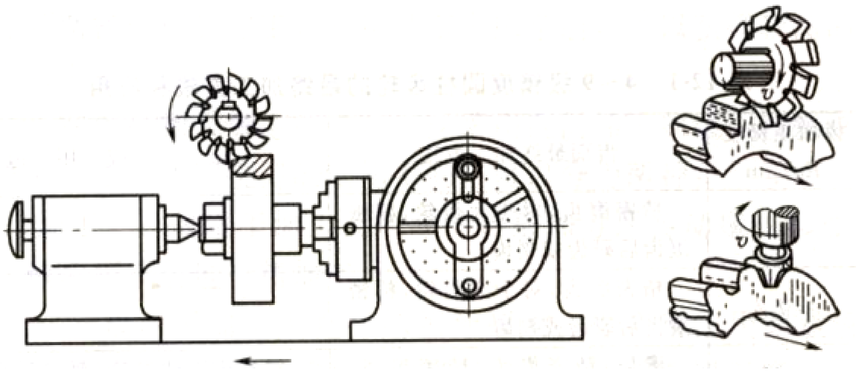

Fig.1: Gear milling

Gear milling has the following characteristics.

1) Low cost. Gear milling can be performed on universal milling machines, tool also simpler than other gear cutters, thus lower processing costs.

2) Productivity is low. Due to the cutter cut a gullet each, must be repeated consumption cut, cut out, retraction and indexing and other auxiliary time, so lower productivity.

3) Lower accuracy. The gears of the same modulo but different number of teeth, its involute shape are different, if the teeth more, then the greater the radius of curvature of the involute. The accuracy of milling gear and cutting gear depends on the accuracy of cutter tooth. Theoretically, the gears of the same modulo but different number of teeth should be processed with a special cutter, greatly increasing production costs. In order to reduce processing costs, actual production, the same modulus of gear by the number of teeth is divided into eight groups, Each group to be machined uses the same number of milling cutter. Table 1 lists divided into 8 groups, the respective numbers of teeth milling range. Each number cutter tooth is design and manufacturing based on the minimum number of teeth of the gear tooth, processing other gear teeth, can only obtain approximate tooth, it will generate an error in the tooth. In addition, the dividing head milling machine used is a universal accessory, indexing accuracy is not high, so it is low milling machining accuracy.

Milling can be processed straight teeth, helical, herringbone spur gear, bevel gear rack and so on. However, due to the above features, it only applies to units of small batch production or maintenance work is not high precision low gear[3].

Table 1: Gear cutter semicolon

Cutter No.	Teeth of milling machining
1	12~13
2	14~16
3	17~20
4	21~25
5	26~34
6	35~54
7	55~134
8	more than 135

Gear slotting and hobbing

Although gear slotting and hobbing process both belong to generating method, but because they use different tools and machines, the specific processing principle, cutting sports, technology features and applications is not the same.

1) Essentially gear slotting process is the equivalent of a pair of cylindrical gears meshing, one of the cylindrical gear make of high-speed steel cutting tools, with the cutting gear blanks are engaging movement. The basic movement slotting machining shown in figure 2.

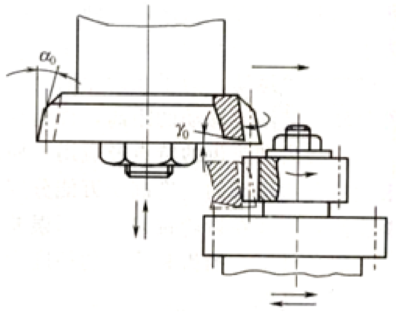

Fig. 2: Gear slotting machining movement

Cutting motion is gear slotting tools linear reciprocating, representation with gear slotting tools reciprocating teeth per minute, the unit is $str/\min$.

Sub-tooth movement is to maintain meshing relationship sports between gear slotting tools and gear cut.

In sub-tooth movement, gear slotting tools forth every time in the pitch circle turn of the arc (mm/rt), known as the circumference of the feed rate.

The radial feed amount: the depth of the workpiece tooth height is gradually cut into, so gear slotting tools have a radial feed. gear slotting tools forth every time the radial distance (mm/rt) movement is called the radial feed amount.

Let the tool movement: gear slotting tools in the linear reciprocating motion, when the return trip back, the tool will scratch the surface of the workpiece has been processed and tool wear. So when gear slotting tools return, the piece should give way to avoid making contact with the tool,when gear slotting tools do working stroke, the workpiece is returned in situ. This movement is called to let the knife movement[4-6].

2) Gear hobbing is working teeth with hobbing tools on the hobbing device, contour shape of the hobbing tools contour shape like a worm, it is cut gear blanks for engaging movement, with the cutting gear blanks are engaging movement,shown in figure 3, hobbing material is high-speed steel. Hobbing sports include cutting exercise, divided tooth movement and axial feed movement.

Cutting campaign that is rotational movement of the hob. If the rotational speed is n, the cutting speed can be written as follows:

$$v = \pi Dn(m/\min) \tag{1}$$

The D is hobbing tool radius.

Points tooth movement is to ensure proper engagement between the hob tools speed and the workpiece speed n. When the hob tools revolution, if it is a single head hob tools, cut gears should be turned $1/z$ circle, z is the number of teeth of the workpiece, If the hob tools for longs, for number of head k, cut gears should be turned k/z circle.

Axial feed motion :in order to cut out tooth on the full width of the gear teeth , hob tools need feed movement with axial of the workpiece. Each piece a turn away from the hob tools to move, called axial feed rate s ($mm/$ workpiece per revolution).

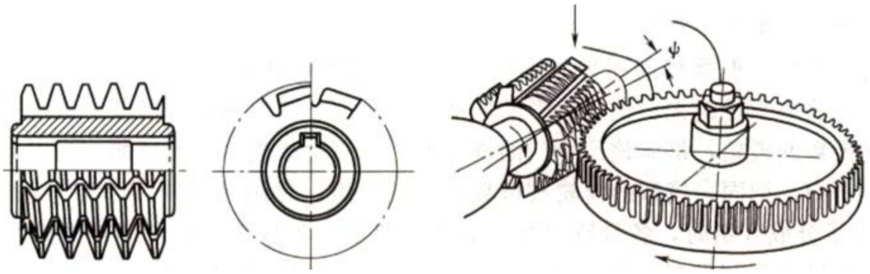

Fig.3: Gear hobbing tool and gear hobbing

3) Features and application of gear slotting and hobbing

Gear slotting and hobbing accuracy comparable, relatively high milling. Because, the precision of slotting machine and points tooth movement of hobbing machine is higher than the universal indexing accuracy, gear hobs and shaper cutters accuracy is high than precision gear cutter, gear cutter profile error does not exist.

Under normal conditions, the precision of gear slotting and hobbing is 7 to 8, precision slotting or precision hobbing accuracy is 6, precision milling accuracy is only 9[7].

Despite the tool and machine used the hobbing and slotting is complicated than milling machine and costly,but because good processing quality, high production efficiency, batch and mass production can still receive good economic results. Even in single and small batch production,in order to ensure processing quality, but also often used hobbing or slotting processing.

The tooth surface roughness of gear slotting is smaller than the gear hobbing. Because gear slotting tools along the longitudinal direction of the tooth is continuous machining, while gear hobbing cutting along the longitudinal direction of the teeth is connection and made by a series of arcs.

Gear slotting and hobbing productivity is much higher than gear milling. Because gear slotting and hobbing are multi-tool cutting and gear milling is single-handedly cutting, the indexing movement and cutting motion of gear slotting and hobbing productivity are simultaneously, while gear milling can be conducted indexing only when cutting motion stops after, so increasing the non-cutting time.

Gear slotting productivity is slightly lower than gear hobbing,Because cutting motion slotting process empty, and reciprocating speed of slotting tools is inappropriate for high.

In processing gear tooth, the most widely used hobbing, it not only can be processed spur gear, can also be processed helical gears, turbines, etc, but generally can not be processed Internal gear and close proximity of multi-gear. Slotting applications are more, it can be processed in addition to straight teeth and helical gears, but especially suitable for processing by the internal gear hob difficult to process, multi-gear or gear with shoulder and so on.

Despite the hobbing tool and machine and slotting milling machine used than is complicated and costly, but because good processing quality, high production efficiency, batch and mass production can still receive good economic results. Even in single and small batch production, in order to ensure processing quality, but also often used hobbing or slotting processing[8].

Gear finishing

For the gear precision greater than 6, roughness $Ra < 0.4\mu m$, in the roll and insert processing after need for finishing. Finishing methods commonly used are gear shaving, gear honing, gear grinding.

1) Gear shaving tool shape as a helical gears, the creation of many small groove tooth surface to form a cutting edge, shown in figure 4. When processed,fixed on the workpiece spindle driven by the shaving tool rotation,sometimes forward, sometimes reverse.the teeth are shaved one side of the turn, when the reverse is the other side of the tooth shaving, shaving tool face numerous teeth cutting edge, the tooth surfaces of the workpiece from filamentous shaved chips, thereby improving the accuracy of the tooth, the tooth surface roughness is reduced.

Shaving is conducted in the meshing process shaving cutter and workpiece, it belongs to generating method processing. Shaving cutter higher costs, but shaving machine is simple, easy to adjust, shaving is multi-tools and multi-blade cutting, so high productivity, shaving gear higher quality, accuracy up to 5 to 6. But razor applies only to non-quenched (hardness of less than $35HRC$) of spur and helical gears.

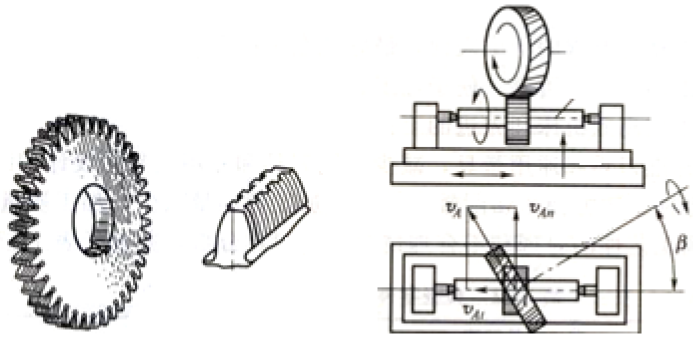

Fig. 4: Gear shaving tool and gear shaving

2) Gear honing the principle is exactly the same gear shaving, but is not shaving tool, but with honing wheel.honing wheels is cast or hydraulic made from abrasive and epoxy resin and with high profile accuracy of helical gears. When it is driven at high speed rotation of the workpiece, the workpiece can be cut at the tooth surface a thin layer of metal, so that the tooth surface roughness Ra value is reduced to $0.4\mu m$ or less. Gear honing to improve the accuracy of the tooth is not, primarily to reduce the roughness of tooth surfaces after heat treatment. The difference between honing machine and shaving machine is unlikely, but a much higher speed[9].

3) Gear grinding is the most important gear finishing method. It has two basic types of molding method and generating method.

Molding this processing method grinding teeth of the gear milling cutter similar, but the use of the cutting tool is shaped grinding wheel, its cross-sectional shape is consistent with a workpiece repair ground gear cogging, machining accuracy is low, the actual production less application.

Generating method grinding teeth is Corrected the side of the grinding wheel to the cone, constitute imaginary rack teeth, making it meshed with the grinding gears.when grinding wheel for high-speed rotation, it while the workpiece is reciprocated along the axial direction of the workpiece, in order to grind the whole tooth width. Workpiece is strictly in accordance with a gear rack for pure rolling along a fixed manner, while rotating and movement. When the counter-clockwise rotation of the workpiece and move to the right, the right side of the grinding wheel grinding the right flank of the gears. When the right flank of the gears is grinding finished from the tooth root to the tooth tip, the workpiece is obtained above exactly the opposite movement bymachines, use the left side of the grinding wheel to grinding the right flank of the gears. When the left flank of the gears is grinding finished, the grinding wheel automatic withdrawal from the workpiece, the workpiece automatic indexing. After indexing, the grinding wheel teeth enter into the next and re-start grinding. So automatic cycle until all teeth grinding is completed[10].

High precision gear grinding, usually ranging from 4 to 6. Gear tooth is gradually grind by tooth root to the addendum, so it is low productivity. Grinding machine is expensive, so gear grinding is only for quenching, important, finishing high speed gears.

Summary

By surface machining program gears analysis illustrates the integrated application of various processing methods for the design and processing gear has a guiding role. In addition, a high cutting speed can be shortened machining time and improve surface quality, adjustment machine and tool, the workpiece exchange,high-speed implementation, the processing time can be shortened, to achieve efficient processing.

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