Milling of Precision Gear-shaped Parts

Yanqing Wu\textsuperscript{1, a}, Jinghua Chen\textsuperscript{2, b}

\textsuperscript{1, 2} Research Institute of Physical and Chemical Engineering of Tianjin, Tianjin, China
\textsuperscript{a, b} wuyanqing0821@126.com

Abstract: Precision gear-shaped part is an important part of a new type reducer. Due to its high overall hardness, precise design requirements, and semi-closed processing area, the precision machining technology based on UG is studied by using UG software in view of this processing characteristics of precision gear-shaped parts, including high resistance in X and Y direction, difficulty in chip removal, easy damage of cutter, and difficulty in workpiece quality. It solves the difficulties in cutting tool damage and precision control in precision gear parts machining, and provides reference value for similar parts machining.

1. Introduction

Precision gear-shaped part is an important part of a new type reducer. Due to its conditions of use requirements, the overall high hardness, design requirements, and semi-closed processing area, cutting tool in machining process of the X, Y, resistance and chip removal difficult, cutting tool is easy to damage, to guarantee the quality of workpiece precision tooth shape parts adopt gear shaper is the main processing method, grinding and EDM\textsuperscript{[1-3]}, but this three kinds of processing methods of workpiece structure has the certain requirement, can meet the processing requirements, all kinds of tooth structure with machining center machine tool overall performance and the improvement of process system, The method of using high speed milling to process tooth parts is gradually adopted in China, but the production cost of parts is higher by using this method. In this paper, UG software is used to study the milling process of precision tooth parts from the aspects of processing mode, processing type and cutting parameter setting, etc., which solves the processing problem of precision tooth parts and provides some reference value for similar parts processing.

2. CAD modeling of precision gear-shaped parts parts

UG software is a CAD/CAE/CAM integrated software, with strong 3d modeling and CNC programming capabilities, providing full digital support for product design, analysis, processing and assembly, and is widely used in general machinery, automotive transportation, aerospace and industrial equipment and other fields\textsuperscript{[2-6]}. 
In the application of UG software for three-dimensional modeling of the gear-shaped parts, first of all, in the sketch drawing environment of UG software, according to its structure size, the section sketch of the gear-shaped parts is drew. Then, in the three-dimensional solid modeling environment, used the "stretch" command to stretch the sketch to generate the three-dimensional entity of gear shape. Finally, according to the part structure, the three-dimensional solid modeling of the tooth part is completed through commands such as bevel angle, hole feature and boolean operation, as shown in figure 1.

![Figure 1. 3d model of the gear-shaped part](image)

3. Process design of gear-shaped parts

3.1 Processing technology analysis

It can be seen from figure 1 that this part has three processing elements: hole, gear shape and chamfering along gear shape edge. The hole is through hole, cutting processing is also good, the diameter of 8mm and 15mm, so can choose the right diameter of the end milling cutter direct processing. The interference between the cutter and the workpiece is mainly considered in the machining of chamfering along the gear edge to prevent over-cutting. The complex shape of the gear, high precision requirements, cutting technology is also poor, is the difficulty of the whole parts processing. According to the analysis and design of the CNC machining process of tooth parts as shown in table 1.

| Processing steps | processing content       | tool number | tool specification          | process requirements                                             |
|------------------|--------------------------|-------------|-----------------------------|-----------------------------------------------------------------|
| 1                | Gear rough machining     | T01         | Φ8 keyway milling cutter     | To remove material, 0.5 mm allowance for semi-finishing, base amount |
| 2                | Gear semi-finishing      | T02         | Φ6 keyway milling cutter     | To ensure the precision, 0.05 mm allowance for finishing, base amount |
| 3                | Gear finishing           | T03         | Φ6 keyway milling cutter     | Ensure dimensional accuracy and roughness.                       |
| 4                | Chamfer along the gear    | T04         | Φ10 chamfer cutter          | To ensure uniform chamfering                                     |
| 5                | 16-Φ8 hole machining     | T05         | Φ8 end milling cutter        |                                                                 |
| 6                | 8-Φ15 hole machining     | T06         | Φ15 end milling cutter       |                                                                 |
3. 2 Semi-finishing of gear shape
After rough machining, the rough machining allowance of the part shape is removed. Due to restrictions on the size of the parts, outline the minimum radius for R4mm, therefore, in order to ensure the tooth shape integrity and machining precision, semi-finishing choose 6 mm solid carbide keyway milling cutter, processing type also uses the UG type for deep processing is commonly used in finish machining contour (Zlevel_Profile), choose tooth part for machining area. Maximum cutting distance of 1.5 mm, choose suitable way of milling, cutting sequence set to depth-first, cutter path is set to the fairing, feed type is set to the arc, and in order to ensure consistency of machining dimension requirement, lay a foundation for finish machining quality, increase the cutting tool in cutting tool path compensation Settings, use the cutting parameters are: speed $s$ of 5000 r/min, feed $f$ for 200 mm/min, cutting depth $a_p$ is 0.15 mm, tooth half finish machining tool path, as shown in figure 2.

![Figure 2. tool path for semi - precision machining of gear shape](image)

3. 3 Finishing of gear shape
In order to keep the tooth shape integrity and machining precision, and machining efficiency of give attention to two or more things, finishing still chose and semi-finishing tool (Φ 6 mm solid carbide keyway milling cutter), also uses the UG processing type for deep processing is commonly used in finish machining contour (Zlevel_Profile), choose tooth part for machining area. Maximum cutting distance of 9 mm, select inverse milling, cutting sequence set to depth-first, cutter path is set to the fairing, feed type is set to the arc, and to ensure consistency requirements of machining dimension and tolerance behavior such as vertical degree, coaxial degree requirements, increase the cutting tool compensation in cutting tool path Settings, and USES the whole tooth profile milling, cutting parameters for use: speed $s$ of 4000 r/min, feed $f$ 60 mm/min, cutting depth $a_p$ is 0.05 mm, tooth profile machining tool path, as shown in figure 3.

![Figure 3. tool path of tooth finishing](image)
3.4 Chamfering along the gear shape

There is no special operation for chamfering in UG processing, and chamfering is often used for deburring, so the requirements are generally not high, but the chamfering size of this part is required to be high, because the processing quality of chamfering affects the efficiency of the machine after assembly, so it is necessary to achieve accurate chamfering, and chamfering along the tooth shape. The machining type is Face milling area, and the cutting mode is contour machining. The highest surface of the tooth shape is selected as the boundary of the part, and the highest surface is also selected as the bottom surface. The key to realize precise chamfering is to set the machining allowance, which is equal to \(-\frac{D}{4}+\frac{C}{2}\). The component allowance is the same as the bottom allowance. If want to see the processing effect, can change the angle of cutting tool angle to 45°, chamfering processing cutting tool path as shown in figure 4.

![Figure 4. tool path of chamfering along tooth shape](image)

3.5 Cutting simulation and machining

After completely generated the tool path, the processing simulation function of UG software is used to simulate the whole processing process of parts. And intuitively observe whether the tool line is reasonable, whether there is a collision in the processing process. After the simulation verification, select the tool path, use the post-processing function of UG software, import the special post-processing file of DMG 1035eco vertical machining center, generate the NC machining code, and then use the U disk to transfer the program to the machine tool for the actual processing. Small batch production shows that the process has high efficiency, stable quality and reasonable programming.

![Figure 5. tool path simulation of precision tooth parts](image)

4. Summary
This paper provides a general method and procedure for machining such precision gear-shaped parts. According to the structural characteristics of the gear-shaped part, the reasonable machining process was designed, and then the tool path and numerical control program were generated by using the CAM function of UG software. The rationality of the numerical control program was verified by the actual machining on the DMG 1035eco vertical machining center. It solves the difficulty of chip removal and quality control in the machining of precision gear-shaped parts, and provides a certain reference value for the numerical control machining of similar parts.

5. References

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