Based on PowerMill and K2X8 Five Axis CNC Machine of Realization of Integral Impeller Machining

Xuanlin Ye¹, Wu Zhang¹, Zou Zou¹,* and Lianjiang Xu¹

¹College of Mechanical and Electrical Engineering, Yunnan Open University, ChengGong University City, Kunming City, Yunnan Province

*Corresponding author email: 57220495@qq.com

Abstract. Based on the powermill2019 software platform, taking the integral shunt impeller as an example, this paper analyzes the overall structure characteristics and machining difficulties of the integral shunt impeller, reasonably formulates the NC machining process plan, and uses the powermill2019 impeller machining module to plan the tool path, so as to generate the tool path file, and verifies the correctness of the tool path by simulation machining. Through the special post processor of powermill2019 five axis machining center, the NC program of integral shunt impeller is generated and uploaded to k2x8 five axis CNC machining center to complete the actual processing of integral shunt impeller. Through the inspection of impeller, the results show that the impeller fully meets the design and use requirements.

Keywords: Powermill2019 software; Integral split impeller; Five axis milling.

1. Introduction

As one of the key parts of the engine, the impeller structure is very complex, which is generally composed of the main blade and the splitter blade. The space between the adjacent blades of the overall impeller is small, and the channel is narrower and narrower along with the decrease of the radius in the radial direction. Therefore, when machining the surface of the impeller blade, in addition to the interference between the cutter and the machined blade, the cutter is easy to occur with the adjacent blades interference, in addition, the thickness of the integral impeller blade is relatively thin, and there is relatively serious elastic-plastic deformation in the processing process, so the processing of impeller has been puzzling people for a long time, which is a problem in the machining industry [1].

The commonly used software for impeller programming is UG and PowerMill. PowerMill2019 software is a powerful and world leading NC (NC is the abbreviation of Numerical Control) programming software developed by British company. The processing strategy is more abundant, and it has many advantages such as setting the cutter axis position at will.

2. Analysis of the Difficulties in Impeller Machining and Process Formulation

2.1. Analysis of Difficulties and Tasks in Impeller Machining

The integral diverter impeller has a complex shape and structure, which is mainly composed of three parts: main blade, diverter blade and hub. The blade is thin, the space distance between adjacent blades is small, the blade has an inverted hook surface, the ratio of main blade to flow blade length, and all blades are evenly and symmetrically distributed along the axial direction. Impeller belongs to thin-walled complex parts. According to different materials, its processing methods are also different. Due to the
difficulty of machining blade surface, the processing process is easy to deform, and its processing accuracy directly affects the spatial dynamic performance and mechanical efficiency of the engine, so it has high requirements for CNC (CNC is the abbreviation of Computer Number Control) machine tools and machining tools [2].

The diameter of the impeller processed this time is 80mm, and the material is 6061. The allowable maximum fillet radius of the blade root is 3mm, the blade shape error is $\pm$ 0.05mm, and the surface accuracy is Ra3.2.

2.2. Process Analysis of Impeller Machining

(1) Parameter analysis of cylindrical cam. According to the process arrangement, in order to improve the processing efficiency, the external contour of the impeller has been finished by turning, which will not be discussed here, as shown in Figure 1. According to the impeller model as shown in Figure 2, through measurement and analysis, the maximum blade root fillet radius is allowed to be R3. The blade shape error is $\pm$ 0.05mm, and the shape of the runner is reserved on the hub (the maximum road spacing is about 1.5mm). The diameter of the blank is $\varphi$80mm, which has been processed on the CNC lathe. It adopts Huronk2x8five machine tool, three jaw chuck clamping, cutter: $\varphi$8 flat base cutter, $\varphi$6 ball head cutter, $\varphi$4 ball head cutter.

(2) Make impeller processing route. For impeller machining, due to the large change of curvature and the large number of blades, the cutter space between the blades is small, and the interference between the cutter and the blade is very easy [3]. At the same time, the cutter path is required to strictly follow the direction of air flow. Therefore, according to the structural characteristics and application requirements of the impeller, the numerical control processing technology of the impeller is analyzed, and the processing route and strategy are formulated as follows: finish machining the blade crown → rough machining the impeller → finish machining the left-wing blade → finish machining the splitter blade → finish machining the hub, and the processing technology is shown in Table 1.

![Figure 1: Five axis rough machining.](image1)

![Figure 2: Impeller model.](image2)

| Serial number | Processing procedure | Processing content | Cutter | Allowance (radial) | Allowance (axial) | Tolerance |
|---------------|---------------------|--------------------|--------|--------------------|------------------|-----------|
| 1             | Finish machining    | integral shroud    | $\varphi$8 (Flat-bottomed cutter) | 0      | 0                 | 0.01      |
| 2             | Open rough blade    | blisk              | $\varphi$6 (ball-end cutter) | 0.3    | 0.3               | 0.1       |
| 3             | Finish machining    | blade              | $\varphi$4 (ball-end cutter) | 0      | 0                 | 0.01      |
| 4             | Finish machining    | Splitter blades    | $\varphi$4 (ball-end cutter) | 0      | 0                 | 0.01      |
| 5             | Finish machining    | Hub                | $\varphi$4 (ball-end cutter) | 0      | 0                 | 0.01      |
3. Programming and Simulation of Impeller

3.1. Introduction of Impeller Model and Establishment of Machining Coordinate System

Powermill2019 software has strong programming ability, but it is relatively weak in parts modeling. This time, UG10.0 modeling is used to model impeller parts, impeller sleeve surfaces, impeller blanks and other components, and then import them into powermill2019 software for relevant settings before programming. In the left project tree, right-click layer and combination, and select generate layer in the pop-up right-click shortcut menu. The system will create a new layer 1, right-click layer 1, and select Rename in the pop-up right-click menu to name layer 1 as hub. Repeat the above operations to create "sleeve", "left-wing blade", "right-wing blade" and "splitter blade" [4]. According to the characteristics of the existing machine tool and the principle of determining the origin of the workpiece, the machining coordinate system is set on the rotation center of the bottom surface of the impeller. At the same time, it is used as the output user coordinate system in post-processing.

3.2. Cutter Definition

According to the actual situation of production, the tool can be completely defined by measuring the data of its tip, handle, collet and other parts. Interference and over cutting inspection can be carried out during programming, so as to improve the quality and efficiency of the program. According to the tools listed in Table 1, HSK tool handle of 1:10 is selected, its model is HSK63SRKIN6L120, the flat end milling cutter with diameter of \( \phi 8 \) is tool T01, the ball end milling cutter with diameter of \( \phi 6 \) is tool T02, and the ball end milling cutter with diameter of \( \phi 4 \) is tool T03.

3.3. Strategy Selection and Simulation of Impeller Machining

Machining strategy refers to the formation of tool path when cutting part surface. According to the impeller processing process table, the impeller processing flow can be divided into several processing strategies: crown finishing, disk rough processing, blade finishing, splitter blade finishing, hub finishing and so on.

(1) Crown finishing. Select "finish machining" \( \rightarrow \) "surface finish machining" machining strategy. Set the following machining parameters: tolerance 0.01mm, allowance 0mm, row spacing 0.2mm, undercut step spacing 1mm, generate the blade path for crown finishing, as shown in Figure 3, and simulation machining as shown in Figure 4.

(2) Rough machining of disk. Select the machining strategy of "disk area clearing". Set the following machining parameters: tolerance 0.1mm, allowance 0.3mm, row spacing 5mm, undercut step spacing 0.8mm, offset mode is based on the hub surface, upward offset, cutting direction is milling, machining method is parallel, cutter axis is automatic, cutter axis elevation mode is radial vector, angle is 24°, generate single blade rough machining tool path, through tool path editing \( \rightarrow \) tool path editing transformation \( \rightarrow \) Multiple transformation \( \rightarrow \) round rounding list the remaining 5 Blade rough machining tool paths, as shown in Figure 5, and simulation machining is shown in Figure 6.

(3) Blade finishing. Select the "blade finishing" strategy. Parameters: tolerance 0.01mm, allowance 0mm, row spacing 2mm, undercut step spacing 0.2mm, cutting direction: down milling, up offset, operation: Machining left-wing blade, starting position: bottom, cutter axis automatic, cutter axis elevation mode: radial vector, angle: 20°, generating a single blade finishing tool path, and listing the
remaining 5 Blade finishing tool paths according to the method in step (2), as shown in Figure 7, simulation processing is shown in Figure 8.

(4) Fine machining of splitter blades. Select the "blade finishing" strategy. Parameters: tolerance: 0.01mm, allowance: 0mm, row spacing: 2mm, undercut step spacing: 0.2mm, cutting direction: down milling, up offset, operation: Machining splitter blade, starting position: bottom, cutter axis automatic, cutter axis elevation mode: radial vector, angle: 22°, generating a single splitter blade finishing tool path, and finishing the remaining 5 splitter blades according to the method in step (2) The tool path is shown in Figure 9, and the simulation machining is shown in Figure 10.

(5) Hub finishing. Select the "hub finishing" strategy. The tolerance is 0.01mm, the allowance is 0mm, the line spacing is 1.5mm, the undercut step spacing is 0.2mm, the cutting direction is down milling, the cutter axis is automatic, the cutter axis elevation mode is radial vector, the angle is 22°, and a single hub finishing tool path is generated. The remaining 5 hub finishing tool paths are listed according to the method in step (2), as shown in Figure 11, and the simulation processing is shown in Figure 12.
4. Actual Machining of Impeller
After the simulation processing is correct in Powermill2019 software, after repeated tests, the following parameters are obtained: rough machining spindle rotation of 6000r/ min, cutting feed rate of 3000mm/ min, undercutting feed rate of 1500mm/ min, passing feed rate of 10000mm/ min, finishing spindle rotation of 12000r/ min, cutting feed rate of 4000mm/ min, undercutting feed rate of 2000mm/ min and passing feed rate of 10000mm/ min. Then right click the "NC program" and "create NC program" buttons, input "impeller machining" in the name of the pop-up dialog box, click accept, right click the preference of NC program, input "{ncprogram}.NC" in the output file column, and select the post-processing file of k2x8five axis NC machining center in the output file column of machine tool. Select the tool path for impeller machining, right-click, and click the "add to" and "NC program" buttons. Right click "NC program" and "write" button to get NC code of impeller NC machining [5]. Upload the post-processing NC program to the K2X8 five axis CNC machining center for actual cutting, and the actual processing results are shown in Figure 13. Through the measurement of the impeller, the size of each part of the blade is correct and the thickness is uniform. The results show that the distance between the flow channels on the hub surface meets the use requirements and ensures the smooth air flow path.

5. Conclusion
In this paper, the overall structure characteristics and machining difficulties of the integral shunt impeller are analyzed. Combined with the actual production situation, the NC machining process plan of the impeller is reasonably formulated. The tool path file of the impeller machining is generated by using the Powermill2019 impeller machining module, and the tool path file is simulated to verify the correctness of the plan. Through the actual measurement of the impeller products, the results show that the impeller completely meets the design and use requirements.

Acknowledgements
Project (2013FD062) supported by Yunnan Science and Technology Department of China.

References
[1] Y.Wei, X.Han, H.Lan, C.G.Yan. Research on five axis NC machining of integral impeller based on ug8.0 [J]. Journal of Dalian Jiaotong University. 36(2016) 99-102.
[2] L.N.Xu, H.Sun, D.Tian. Research on five axis NC machining of integral split impeller based on NX platform [J]. Modern Manufacturing Engineering. 40(2019) 85-89.

[3] X.N.Zhu, Y.Li. Application of PowerMILL software in high speed machining of thin wall parts [J]. Manufacturing Technology & Machine Tool. 59(2010) 29-31.

[4] P. Zhang. Five axis machining of turbocharged impeller based on PowerMill [J]. New Technology & New Products of China. 26(2019) 45-46.

[5] Y. L.Huang, J. T.Yuan, Z. H.Wang. Research on post-processing of five axis high speed machining of integral impeller based on PowerMill [J]. Machine Tool & Hydraulics. 39(2012) 12-14.