Study on Processing Technology of Integral Titanium Alloy Impeller Based on Powermill

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Abstract: The characteristics of titanium alloy impeller are with complex shapes, long and thin leaves and hard machining, in order to improve the processing efficiency, processing quality and reduce processing costs, using the "3+2" fixed axis method and layered impeller.

Keywords: titanium alloy; integral impeller; Powermill; fixed axis machining; layered processing; machining efficiency.

1 INTRODUCTION
The whole impeller is a key component of aviation, aerospace, marine engines, the main material of its parts is titanium alloy and superalloy. Titanium alloy parts are used for the cold end of the aeroengine (fans and compressors, etc.), while the high temperature alloy parts are mainly used in hot end parts (turbines, etc.)\cite{1}. Widely used five-axis CNC machine tools are used to complete the processing of impeller, machine using fee is higher. In addition the overall processing of the impeller is generally time-consuming, low efficiency, and thus high processing costs. Therefore, to improve the overall processing of titanium alloy impeller to improve its processing efficiency, improving the quality of processing and reducing processing costs is very necessary \cite{2}.

2 ANALYSIS OF NC MACHINING PROCESS OF TITANIUM ALLOY IMPELLER
An engine impeller (Figure 1) material for the titanium alloy, diameter 180mm, blade length 42mm, the hub of the narrowest 4.5mm, blade thickness 2mm. Because the blades of the impeller are long and thin, the
surface is distorted and the blade spacing is small, if the blade removal model of the blade programming module of Powermill is used for roughing, the five-axis roughing of the impeller can be achieved uniform, smooth processing track, but because the hub is only 4.5mm narrow, can only use the diameter of 4mm tool open rough, obviously, for the titanium alloy difficult to process materials, so opening rough efficiency is very low, and the elongated tool rigidity is poor, it's easy to break. Therefore, the improvement of the efficiency of the impeller processing is mainly due to the improvement of the roughing efficiency. Since the ball knife can only be used for processing, there is a case where the processing efficiency is low. Several cutting experiments shows that the use of "3 +2" fixed axis can achieve the rough processing of the impeller, while the choice of larger diameter round knife and taper cutter is efficient than the five-axis linkage, it will be open great room for improvement in the processing.

For the general impeller runner, if the curvature of the blade is not large, may be two as the fixed axis of the shaft can be completed to complete the workload, but if the curvature of the blade is too large twist, the second fixed shaft can't completely remove the residual material when you need three times to set the axis to open the rough work to complete the task. That is to say three different viewing directions, with three completely able to clear the flow path blank view respectively define three different working coordinate system, and then three different coordinates of the Z-direction vector to define the three fixed shaft open rough road Knife axis vector. After the completion of the rough, the use of Powermill's impeller module for wheel and blade finishing. In summary, the development of titanium alloy impeller CNC machining process as shown in Table 1.

FIGURE 1. Overall Impeller.

- Physical map
- Three-dimensional renderings
3 IMPELLER CNC MACHINING PROGRAMMING PROCESS

3.1 Programming Preparation

Before proceeding with the program, you need to make some necessary preparations for the machining parts, such as setting the processing coordinate system, setting the blanks, establishing the machining tools, etc., as described in detail below.

1) The Establishment of Blanks

In order to reduce the processing time of the impeller, the blank can be processed in place on the CNC lathe. The five-axis machining is only the material in the processing channel. Therefore, the end face of the impeller, the hole step, the meridional surface (casing) come out, as shown in Figure 2 (a). According to the 3 + 2 fixed shaft roughing process in Table 1, the opening of the runner groove is open to one by one. Therefore, it is only necessary to create a blank of a flow path during programming, as shown in Fig. 2 (b, c). Creating a blank can be set in the UG software, in powermill through the "triangle model" to open the blank. Specific steps: Click the "blank" button on the toolbar, the system pops up the "blank" dialog box, select the "triangle" blank, specify the open blank path input blank.

![Figure 2](image.png)

**FIGURE 2.** Impeller Profile.

2) Tool Selection

CNC machining tool not only requires good rigidity, high precision, and

### TABLE 1. Overall impeller CNC machining program.

<table>
<thead>
<tr>
<th>No.</th>
<th>Processing strategy</th>
<th>Tool path name</th>
<th>Tool name</th>
<th>Step /mm</th>
<th>Cutting depth /mm</th>
<th>Margin /mm</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Offset area clearance model</td>
<td>N01 D10R2 ROUGH</td>
<td>D10R2</td>
<td>5</td>
<td>1</td>
<td>0.5</td>
<td>3 + 2 fixed</td>
</tr>
<tr>
<td>2</td>
<td>Offset area clearance model</td>
<td>N02R3T3L65 ROUGH</td>
<td>R3T3L65</td>
<td>3</td>
<td>1</td>
<td>0.5</td>
<td>shaft open</td>
</tr>
<tr>
<td>3</td>
<td>Offset area clearance model</td>
<td>N03 R2T3 ROUGH</td>
<td>R2T3</td>
<td>2</td>
<td>1</td>
<td>0.5</td>
<td>rough</td>
</tr>
<tr>
<td>4</td>
<td>Blade finishing</td>
<td>N04 R3T3L65 JIN</td>
<td>R3T3L65</td>
<td></td>
<td>0.3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Blade finishing</td>
<td>N05 R2T3 JIN</td>
<td>R2T3</td>
<td></td>
<td>0.3</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Blade finishing</td>
<td>N06R2T3 INGGEN</td>
<td>R2T3</td>
<td></td>
<td></td>
<td>0</td>
<td>Clear root</td>
</tr>
<tr>
<td>7</td>
<td>Wheel finishing</td>
<td>N07 R2T3 LUNGU</td>
<td>R2T3</td>
<td></td>
<td>1.5</td>
<td>0</td>
<td></td>
</tr>
</tbody>
</table>
requires dimensional stability, high durability, chip breaking and chip performance, and requires easy installation and adjustment, so as to meet the requirements of high efficiency CNC machine tools [3]. In order to improve the strength of the tool, use R3T3, R2T3 taper cutter, as shown in Figure 3, in order to improve the strength of the tool, use the D10R2 fillet cutter.

![a rounded cutters](image1) ![b taper cutter](image2)

**FIGURE 3.** Uses The Tool.

When programming, you need to set the tool and clamp according to the actual tool size and the size of the handle. In order to ensure that the preparation of the knife and rail can be used for actual processing.

3.2 "3 + 2" Fixed Shaft Open Rough

Parts of the roughing is to remove the excess material as soon as possible, because the case of the impeller surface distortion, leaf spacing is small, if the use of five-axis linkage open, you can use the maximum diameter of the tool 4mm, open rough efficiency, machine rotation Shaft swing amplitude, poor machine stability, vibration, increased tool wear, shorten the tool life. Therefore, this case with 3+2 fixed axis way to open, reduce the rotation of the axis of the movement, greatly improving the efficiency. After analysis and multiple verification, need to open three times to remove the excess material, the first open rough use D10R2 tool to remove the spacious parts of the material and add to the residual model as the next open rough, and then use R3T3 Taper cutter change orientation angle for the second time open the same, then add it to the residual model, the narrowest part of the blade only 4.5mm, but also need to use R2T3 taper cutter for the third time open, tolerance 0.1, Z axis Under the knife with oblique feed, check the contours smooth (corner radius of 0.1) and the balance of light margin (15%). Rough machining parameters and tool paths are shown in Figure 4, Figure 5, and Figure 6.

After the above steps, you can complete a runner of the rough, the remaining runner can be opened by the above tooling to achieve the transformation of the rough, that is, the tool rail rotation 400 to process the next runner. This method to open a rough knife orbit looks a bit messy, but the processing efficiency is very high, verified by the actual processing, compared to the five-axis linkage to open a rough, this open method saves about an hour and ten minutes. Greatly improving the production efficiency and extending the life of the tool, thus saving costs, with high practical value.
3.3 Impeller Finishing

After three roughing, basically remove the excess material, then you can directly use the powermill impeller module programming, taking into account the roughing of the remaining margin is not uniform, the use of stratification finishing blade, while a flow channel of the three leaves (left leaves, right leaves and split blades) layered processing, which can reduce the tool side edge and blank material collision, to ensure the stability of processing. Therefore, the finishing process with R3T3 tool on the upper part of the blade finishing (Figure 7a), the location of the processing and then R2T3 tool processing (Figure 7b), the leaves clear the roots and then the hub (flow) finishing. Here is no longer described in detail, the knife and rail as shown in Figure 8a, b.
a blade upper finishing b Whole blade finishing


a blade clear root processing b wheel finishing

FIGURE 8. Blade Clear Root Machining And Wheel Finishing.

4 POST PROCESSING AND VERICUT SIMULATION CUTTING VERIFICATION

Using the post-processing file to have prepared a good knife path to generate CNC machine tool processing code, with Vericut simulation software simulation cutting verification, confirm the program code will be copied to the NC machine tool for the actual processing.
In the Vericut software to build a good G996RT five-axis machining center simulation model, kinematic chain tree and machine model shown in Figure 9,10. Adjust the program code, set the tool, coordinate system and other parameters after the simulation. After the end of the simulation results analysis, check whether the parts cut, cut and so on. If you are not satisfied with the cutting model, you need to adjust or replace the CNC machining program until the cutting model is consistent with the design prototype.

5 CONCLUDING REMARKS
This paper analyzes the whole titanium alloy impeller in the five-axis machine tool processing. In order to reduce the processing costs, improve the processing efficiency and parts quality, adjust the CNC machining process, put forward a new rough processing technology, that is, from different angles, many times using "3 +2" of the material to solve the five-axis CNC machine tool processing costs high, the use of layered method to achieve the overall titanium alloy impeller in the five-axis machine on the high speed, high feed processing. The actual processing shows that the process can be high efficiency, high quality to complete the overall titanium alloy impeller CNC machining.

6 REFERENCES
