Design and Research on the Special System for High Efficient Manufacturing of Blisk Based on UG

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Abstract

As one of the most important parts of aeroengine, blisk has complex structure and its material is titanium alloy hard to machine. It results in some difficulties in modeling and NC programming. In this paper, from the perspective of application, the secondary development technology of UG/Open Grip is used to design and develop the CAD/CAM module of blisk after analyzing structure feature and milling process of blisk. Firstly, it completes parametric modeling of blisk by establishing CAD module through the optimization of the original data points in NUBRS curve fitting and node interpolation technology; secondly, the inner and outer tolerance algorithm are applied to calculate the cutting step, and the row spacing is determined based on constant scallop height. Besides, tool axis vector is defined. All of these things are done to complete the establishment of the CAM module and realize trajectory planning of semi-finish machining of the blisk. It greatly improves the efficiency of programming and machining in blisks; finally, the module of blisk designed is used to model and program in the machining experiments in five axis machining center to verify correctness and reliability of the system. The results show that this module greatly improves manufacturing efficiency of blisk.

Keywords: UG/Open Grip, modular design, efficient manufacturing, blisk

1. Introduction

Blisk is a kind of new structure in the aero engine, widely used in engine fans, compressors and turbines to improve engine performance, simplify structure, reduce weight, reduce the failure rate and improve the durability and reliability. Blisk combines vanes and blade disk into a whole, saving tenon joint and tenon groove, which greatly simplifies the structure. In recent years, with the development of the aircraft industry and in order to meet the demand for high performance of the engine, there are more requirements on manufacturing blisk with typically complex structure and free surface. Because of the feature of thin blade, large distortion，long blade span and deformation under the stress, it is hard to design and manufacture. So, the engine design, blisk modeling and manufacturing method will play a very important role in improving performance of engine and shortening the development cycle of it [1-4].

Aimed at the modeling and NC programming of this kind of complex parts, some software is widely used in domestic and foreign, such as UG, POWERMILL, CATIA, MASTERCAM etc. The software has strong versatility, and the majority of parts can be designed by modeling and programming. But for some specific parts like blisk, there is no special module, which makes the operation process complicated. At the same time, it requires the programmer to own better ability. For developing CAD software, beginning from 1995, the foreign company GE in the USA has introduced thousands of sets of UG —a CAD/CAM/CAE software system, successfully completing high accuracy and no

margin machining the large titanium alloy rotor blades and turbine blisk, finally greatly reducing the cycle of development [5]. In 1997, German Ateeh Company developed CAD system for the design of parameterized blade based on ACIS for BMW Rosl-Ryoec Engine Company [6], American NASA Lewis Research Center, Iowa State University and Columbia labs have developed blade modeling CAD system [7-9]. Only a small number of domestic universities such as Northwestern Poly technical University, Beihang University, a few enterprises and units and parts of aerospace professional research make machining of blisk parts come true. Now China has begun to launch the research special software about the aspects of blisk parts by secondary development interface. From 1996, Northwestern Polytechnic University began to study CAD/CAM system, develop special CAD/CAM system for blade and research on parameter of modeling and NC machining [10-11]. But with the development of the aircraft industry, the design of blisk structure and blade surface become complex and the precision of the blade model is very strict, so simple quadratic curve can't ensure blisk modeling accurate.

There are a lot of technology methods to machine the blisk, and the most widely used is multi-axis NC machining technology. During the machining of the blisk, the choice of the machining method, the cutting tool and the cutting tool path trajectory planning deeply influence the production efficiency and the quality of the blisk surface. They are the key of the NC machining technology of blisk. In the field of CAM system, especially used for blisk, some blisk manufacturing companies abroad have set up their own special blisk manufacturing software based on secondary development technology of general software like UG，CATIA，Pro/E and so on. Software packages are developed by American NREC: MAX-5, MAX-AB and Hypermill and other special impeller machining software. They can achieve automatic modeling and processing of impeller and simple operation can make models good quality, but there is no external interface. What's more, machine tool processing program also has its limit. In addition, the software is expensive and it confines versatility and development of 3D modeling. The Aikoku Alpha Engineering Corporation in Japan developed special blisk software based on CATIA. It can achieve the machining and NC programming of the freedom surface. Northwestern Poly-technical University combined with Institute of China gas turbine and Beihang University developed "special multi-axis NC programming software for the impeller part". It can achieve the ability of multi-axis NC programming, measurement data preprocessing, the modeling of freedom surfaces, surface blanking, tool path calculation, tool verification and post-processing combined into one, and according to the different processing method it can calculate the tool path to meet the processing characteristics of high efficiency, high quality, then the algorithm combined with secondary development system to complete the machining of the impeller. Jiang *et al*. compiled an algorithm of interference-free tool path based on UG and VC++ development platform, UG/Open API interface, constant scallop-height method and correction principle of the global and local interference [12]. Calleja *et al*. calculated planned the complete toolpath based on cutting forces prediction. And results of a case study based on impeller and blisk blades flank milling are discussed. Applying this methodology, cutting forces can be taken into account as a decisive criterion for optimal tool path selection [13]. Yu *et al*. developed a special blisk NC machining software based on graphical programming technology and solved the problems of machining tool path and NC code of blisk. The development of NC machining software realizes seamless integration of the blisk from design to machining [14]. What is more, Zhang *et al*. used the empirical formula based on B-spline theory and feature point extraction algorithm to make a measure of the section lines and the points to be measured. The CATIA simulation is conducted to validate the correctness of the path planning algorithm for measurement. But the software above is studied just for machining, besides the algorithm implementation is quite complicated [15].

In conclusion, this paper develops a set of automatic modeling and processing module specialized for blisk based on the general CAD/CAM software UG, combined with

NUBRS curve fitting, node interpolation and the inner and outer tolerance algorithm after further studying design and manufacture. This CAD/CAM system can provide technical support for improving the efficiency of designing and manufacturing and lowering parts manufacturing costs.

2. The Design of CAD Module for Efficient Machining Blisk

2.1. The Application Design and Plan of the CAD/CAM Special Module

It is system engineering for machining blisk from modeling to generating the tool path, and every step plays a decisive role. The topic of this paper is to develop special CAD/CAM module of the blisk and building a model of the cutting tools for machining blisk, which makes the operating process simplified and accurate. After the deep research of UG secondary development, under the Windows system, the whole process mainly uses the method of UG/Open API and UG/Open Grip combined with Visual C^{++}6.0 platform to develop automatic modeling, the processing module and cutting tools model of the blisk,. It is convenient for system development.

Specific design is as follows,

(1) UG secondary development technology and human-machine interaction are researched.

(2) Structure characteristics and modeling technology of the blisk are researched, using UG/Open Grip module and considering the influence of surface about the performance of the blisk. It analyzes and processes the data points, and finally establishes a modeling module rapidly.

(3) The processing technology of the blisk is combined with machining technology at home and abroad. Choosing processing technology of high efficient and good quality and using UG/Open Grip NC function analyze the blisk model, optimize programming of different tool path and establish the CAM software of the blisk through the establishment of human-computer interaction. Overall design and planning are shown in Figure1.
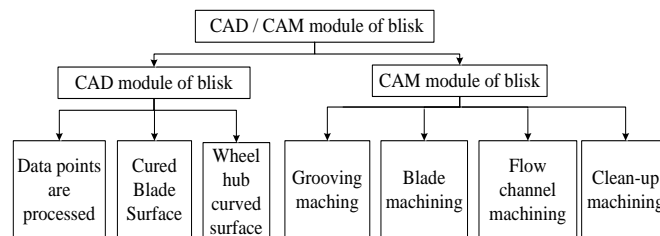

Figure1. CAD/CAM System Function Module of Blisk

2.2. The Research on the Design and Method of CAD Module of the Blisk

The blisk is mainly composed of hub and blade. Each part of the blisk is analyzed (as shown in Figure 2), thus making the sequence of modeling. The hub of blisk is formed by Z axis rotation of root curve, and the surface of blade is composed of the suction surface, the pressure surface, the leading and trailing edge surfaces (as shown in Figure 3). Modeling of the blade surface is the main part. It is the main principle of blisk modeling to ensure blade curve surface smooth.
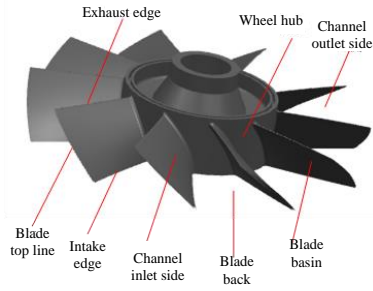
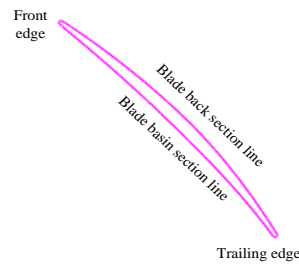**Figure 2. Blisk Structure**   **Figure 3. Blade Section Curve**

Blade of the blisk selected is fitted by data 3 sections data points, and the data points are from design of the aerodynamic performance. However the fitting surface is not only to ensure pneumatic properties of the blade, but also to ensure the smoother and higher requirements of the surface. Therefore, the lower the curve descends, the better the fairness is, and for relatively large curvature (*e.g.* leading edge of blade), distribution of data points are relatively dense. So CAD system developed in this paper needs to be provided control points of lines on each section by the customers, and the number of data points in each lines need to be same. Specific steps are as follows,

(1) Information of data points is read. Data points are written to the file location data points XXXX.dat by dialog box of solid modeling, and read through the function FETCH in UG/Open Grip. Data points are formatted as "XC, YC, and ZC".

(2) Blade surface modeling method. According to the character of complex surface shape of blisk, the NURBS (Non-uniform rational b-spline) is chosen to fit blade surfaces. NURBS is superior than any other ways because it has adjustable control points and weights, also it precisely expressed free-form curves and *k*-th order NURBS lines of rational fraction (equation 1) with math form.

$$P(u) = \sum_{i=0}^{n} w_i d_i N_{i,k}(u) / \sum_{i=0}^{n} w_i N_{i,k}(u) \tag{1}$$

Where $w_i \left(w_0, w_n > 0, \text{others } w_i \geq 0 \right) (i = 0,1,...,n)$ is represented as sequence of weights, and $d_i \left[x_{is}, y_{is}, z_{is} \right]$ is its corresponding control vertex.

The curve surface approximation problem is transformed into an approximation in v (or u) direction. Firstly, each curve of surface v direction is approximated. Then, it is the same to u. $p \times q$ order, NURBS curve can be represented as the following equation (2), and it has the same properties of surfaces NURBS curve.

$$S(u,v) = \frac{\sum_{j=0}^{m} \sum_{i=0}^{n} w_{ij} d_{ij} N_{i,k}(u) N_{j,l}(v)}{\sum_{j=0}^{m} \sum_{i=0}^{n} w_{ij} N_{i,k}(u) N_{j,l}(v)} \tag{2}$$

Where $N_{i,k}(u)$ is u the *k*-th order b-spline function, $N_{j,l}(v)$ is the *k*-th order b-spline function in the direction of v

(3) Data points optimization. Using spline interpolation technique to make a interpolation for *k*-th order NURBS spline, new control points d_i^* are gotten. Equation (3) is shown between the connection d_i^* and d_i.

$$d_i^* = \frac{(1-\xi_i) w_{i-1} d_{i-1} + \xi_i w_i d_i}{(1-\xi_i) w_{i-1} + \xi_i w_i} \tag{3}$$

Equation (4) is full factorial relationship.

$$w_i^* = (1-\xi_i) w_{i-1} + \xi_i w_i \tag{4}$$

When points of cross section line are bad or its quantity is not enough, one or more nodes can be inserted in an area. What's more, blade section curve is adjusted to improve

its smoothing degree, which is a good basement on blade shape.

3. The Design of CAM Module for Efficient Machining Blisk

3.1. The Plan of Structure Design of CAM Module of the Blisk

The main function of CAM system about blisk is generating source file about its tool path. CAM system in UG provides a solution for complex curve surfaces in numerical control machining, but it does not focus on special complex components in programming. It is very important to set process parameters of blades and select about machining. At present, these depended on experience of programmers. Therefore, this paper develops a programming module of blisk, and combines knowledge and experience of programmers into CAM module in order to save programming time. Blisk is programmed by CAM in UG (as shown in Figure 4).
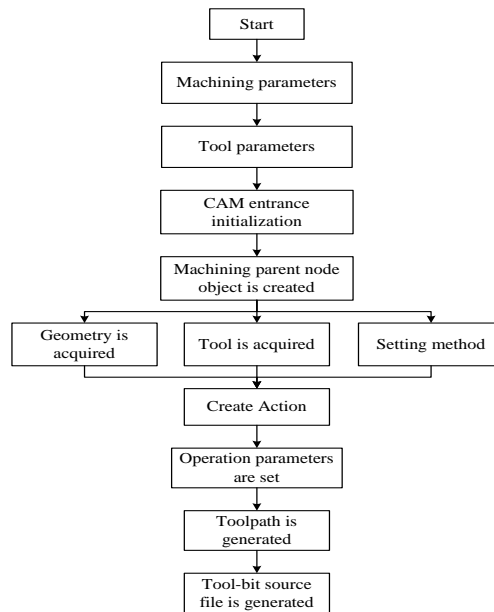

Figure 4. Flow and Struction in CAM Module

Main function of the module is focusing on generating cutter location source file in blisk machining. It includes cutter sizes, location, posture, process assisted command, and so on. Developing semi-finishing process about CAM system, building blisk complex construction (as show in Figure 5) are machined by using point milling, but it causes a long processing time. In order to improve machining efficiency, scholars at home and abroad study tool path in side milling. It means that tool and workpiece have a connected area, which is side edge and the way of contact is linear. UG provides side cutting driving tool axis control mode. In this paper main choice ways are relative driving and side driving. Side driving allows defining cutter axis that is moving along the side cutting line in driving curve surfaces. This sort of cutter allows its side to cut driving curve surfaces, while cutting tool vertex is cutting component surface.
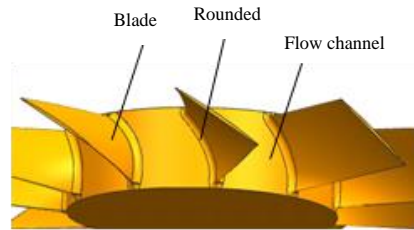
Figure 5. Unprocessed Surfaces of Blisk

3.2. The Research on Design Method of CAM Module of the Blisk

The choice of the machining method, the cutting tool and the cutting tool path trajectory planning deeply influence the production efficiency and the quality of the blisk surface are the key of the NC machining technology of blisk [16]. This paper completes high efficient semi-finishing planning of blisk by choosing feeding method in machining, determination of cutting step-length, control of cutter axis vector and determination of step distance based on iso-scallop method.

(1) The choice of feeding method in machining. There are two main feeding methods for machining blades. They are helical milling and Zig-Zag processing. In this paper helical milling is adopted (as shown in Figure 6. It means that cutters rotate around blades when blade is processed, and its processing path is a consequence helical line. This method may finish whole blades with one time, avoiding traverse feeding, improving continuity of processing paths, preventing overcut when cutters make a large angle turning, decreasing blade deformation when cutters are feeding and rising frequently. Meantime, Helical milling way improves processing efficiency of the blade and achieves true high-speed milling.

(2) Determination of cutting step-length. Cutting step-length is the distance between two adjacent cutter-contact points in tool path, and it is controlled by the number of driving points in UG. For complex components, the shorter distance between driving points is, the better quality and higher efficiency are. There are equal step discretization approximation, equal parameter discretization, inside and outside between tolerances to define the tool path in UG (as shown in Figure 7). The smaller tolerance is, the more driving points are. The denser tool path is, the more precise driving curve surface is. Step-length depends on the number of driving points, which are established along every processing path. If the step-length makes machining accuracy exceed the range of tolerance, the systems will add automatically additional driving points in order that tool path within the range of tolerance follows surface profiles of components. When this method is adopted to determine cutting step-length, the number of driving points is needed as much as possible in order that cutter can obtain the precise geometry shape, otherwise it may cause unreasonable structure.
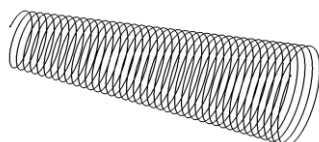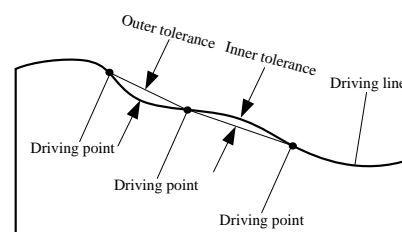

Figure 6. Helical Feeding Method

Figure 7. Defination of Step About Outer and Inner of Tolerance

(3) Control of cutter axis vector. Controlling mode of cutter axis vector is an important factor to affect the five-axis machining. In general, the choice of cutter axis determines the high cutting efficiency and quality, at the same time it avoids cutter interference problem in the processing. Cutter interference problem is a difficulty for five-axis NC machining surface, and it is more important for engine blisks complex curved surface. In blade processing, the interference phenomenon easily occurs because of the small blade spacing and the depth channel. Commonly using tool axis control mode is perpendicular to the surface, parallel to the surface and inclined to the surface. Former inclination α (the angle of cutter axis around the b-axis), roll angle β (the rotation angle of cutter around the surface normal vector n) are defined in the programming to control the tool axis vector L (as shown in Figure 8), making sure that both sides of the tool don't interfere with the blade and the cutters have better cutting performance.
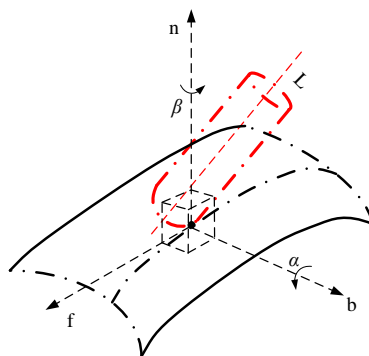

Figure 8.Tool Axis Vector Diagram

$$L_1 = b \cdot \cos\alpha + n \cdot \sin\beta \tag{5}$$

$$L = L_1 \cdot \cos\beta - n \cdot \sin\beta + n \cdot (L_1 \cdot n) \cdot (1 - \cos\beta) \tag{6}$$

Where $b = n \times f$, L_1 is the rotation angle of α is a vector of the tool axis.

(4) Determination of step distance based on iso-scallop method. There are many tool path generation methods, commonly such as iso-parametric line method, the equidistant section plane method, the equidistant bias method, iso-scallop method and so on. In the machining way of equal parametric curves, the distribution of the machining contact path is in accordance with the minimum cutting bandwidth calculation, in order to achieve the accuracy requirements. However, it makes the adjacent tool path generate a large number of repeated cutting, causing the lower cutting efficiency. Cutting bandwidth of plane cutting method is generally equidistant. Machining width is often determined according to the maximum allowable scallop-height. The processing efficiency is low for large curvature changes surface. In contrast, iso-scallop method can make sure that the scallop height remains the same by controlling the distance between adjacent tracks. The method is proposed by the University of California K. Suresh and D. Yang. It discusses iso-scallop method to calculate the step distance, making sure that residual height between adjacent tracks (ridges) values are equal to the maximum allowable residual height in order to increase the processing step distance to shorten the path length, saving processing time [17].

Scallop-height h is cutting line width L_h, effective cutting tool radius R and leading direction along the surface curvature radius $R*$ function. As shown in Figure 9.
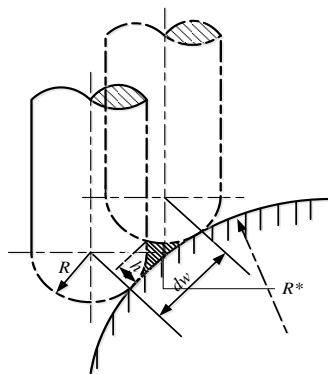
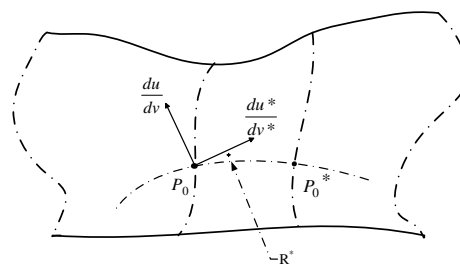Figure 9. Determine the Pass Spacing by Scallop Height Method

Figure 10. Curved Trajectories

Set the equation of processed surface as formula (7)

$$L_h \approx 2\sqrt{2Rh}\sqrt{\frac{R^*}{R^*+R}} \tag{7}$$

Assuming a tool path is $P(u(t),v(t))$ shown in Figure 10, P_0 is the curve of cutter location point. According to the geometric properties of the geodesic P_0 adjacent equal residues point P_0^* can be obtained. And according to first basic equation and second basic equation of the curve surface, the geodesic curvature radius $R^*=\left|\dfrac{\varphi_1}{\varphi_2}\right|$ can be calculated, Where φ_1、φ_2 are respectively the first, second basic equation(8):

$$\begin{cases} \varphi_1 = E\left(du^*\right)^2 + 2Fdu^*dv^* + G\left(dv^*\right)^2 \\ \varphi 2 = L\left(du^*\right)^2 + 2Mdu^*dv^* + N\left(dv^*\right)^2 \end{cases} \tag{8}$$

Where E, F, G is the first kind of basic amount, L, M, N is the second kind of basic amount. du^*, dv^* are parameters of the direction of geodesic, by defining a vector perpendicular to the direction of the tool path. Proportional relationship of du^* and dv^* can be obtained and brought $R^*=\left|\dfrac{\varphi_1}{\varphi_2}\right|$, curvature radius as shown in equation (9)

$$R^* = \left|\frac{E+2F\alpha+G\alpha^2}{L+2M\alpha+N\alpha^2}\right| \tag{9}$$

Cutting line distance is calculated through curvature of the surface where there is the cutter location point. Local surface is divided into three types. There are plane, convex and concave curved surfaces. Different surfaces have different equations to calculate spacing.

When the local surface is planar, line width L_h is calculated as follows:

$$L_h \approx 2\sqrt{2Rh} \tag{10}$$

When the local surface is convex surface, line width L_h is calculated as follows:

$$L_h \approx 2\sqrt{2Rh}\sqrt{\frac{R^*}{R^*+R}} \tag{11}$$

When the local surface is concave surface, line width L_h is calculated as follows :

$$L_h \approx 2\sqrt{2Rh}\sqrt{\frac{R^*}{R^*-R}} \tag{12}$$

4. The Implementation and Experimental Verification of Efficient Machining Blisk CAM Module

4.1. Special Steps of Building Blisk CAD Module

Step1:creat hubs. Hub curve surface is produced by free-curve rotated with a axis. In UG/Open Grip, the function is represented as param/'enter the options; 'data1=','data2=', ' data3= ', 'are shown respectively as num1, num2, num3 to achieve human-computer interaction dialog. According to parameters input, establishing closed curve serves as rotation curves. Slew command solrev is used to make the curve rotated and establish a solid model modeling hub. Complete hub is shown in Figure11.
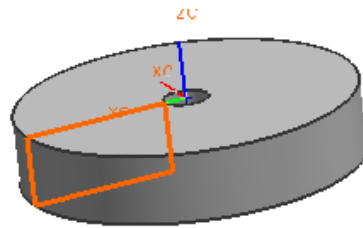

Figure 11. Hub Rotation Curve and Modeling

Step2: read data point file of blades. According to curve coordinates point obtained in section lists, data files, needed by modeling, are transformed into data forms.dat file, which is identified. It is convenient to store all of section curve points in a file, where customers input the number of lines and utilizes READ command in Grip to read file data points. In this paper blade model is given three data points of section lines.

Step3: optimization of data points and generation of b-spline curve. It is the main process of blisk modeling. According to designed requires of blades, the leading and trailing edge surfaces and the suction curve and the pressure surface curve are required far higher connection. By above algorithms, curve data points are inserted. In the meantime, adjusting the spline curve control points in the leading and trailing edge surfaces, especially increasing control points in the dramatic change of curve ratio, is to ensure smoothness of blade edge. The whole blade section curves are fairly fitted by spline curve command which is generated from approximation curve in Grip. B curves command is created in the grip and eventually generates optimal b-spline curves. As shown in Figure 12.

Step4: blade curve surfaces and generation of chamfer. Some of new generated curves make section lines fit blade entity in the "through the curve" command. In the Grip command, [, DEGREE, num] is the order of v direction in constructed curve surfaces. In this paper all values of degree are set as 3. In the intersection lines of hubs and blades, usually there is limited radius circular bead. By using the command of sheet chambered, hub surface and the line of the blade fillet are created by entering radius circular value. Curve specific function: obj=BSURF/CURVE, objlistl[,ENDOF,{,objlist2|, numlist}][,DEGREE, num[,CLOSED]][,IFERR,lable:] generating curve surfaces(as shown in Figure 13).

Figure 12. Data Points Fitted To Curve   **Figure 13. Fitting Curve Surfaces**

Step5: array of blade curve surfaces. Customers need have a circular array for the number of blades n (the angle between adjacent blades is m=360/n) and set blisk center axis as a rotation axis, having a average circular array to generate complete entity, which is used as machining blisk. Then building blade models are used to copy, rotate and move. Finally, it accomplishes array of blades (as shown in Figure 14).
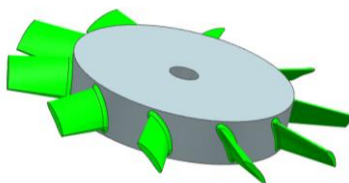

Figure 14. Blade Array Modeling About Blisk

Main functions of blisk CAD module: Input hub parameters, establish hub curve surfaces, insert the inputted original data, generate blade section lines, fit generated blade curve surfaces, input the number of blades and complete blisk modeling.

4.2. Special Steps of Building CAM Module of the Blisk

Step 1: Initialize the system

(1) Using the GPA function & MODULE = & MACH statements to make the system into UG processing programming module.

(2) Using the sentence of &OPTSET='/mydir/templates/mill_multi-axis.opt' configures the initial processing environment.

(3) Using the OPER function creates the processing operation. Processing methods for mode selection still uses 'mill_multi-axis' and 'VARIABLE_CONTOUR'. VARIABLE_CONTOUR is variable axis surface contouring for UG.

(4) Define the machining coordinate system. The GRIP program is: & MCS = & WCS.

(5) Define the drive. Surface driving method is chosen as the drive.

Step 2: Define the tool. This paper sets two kinds of tool. They are spherical cone cutter and circular tool. PARAM function is used to establish the parameters input dialog shown in Figure 15. TOOL function is used to input parameters for modeling tool.

Step 3: Define the tool-axis. By GAP function initialized processing environment, practical experience shows that tilt angle between 75° and 85°, lead angle between 0° and 15°in a range, can well ensure the cutter not to interfere with both sides of the blade, and to have a better cutting performance at the same time. Specific functions are: & MNLEAD, & MNTILT, & MXLEAD and & MXTILT etc. and the parameter dialog box is established.

Step 4: Define cutting step. Feeding step length function &STEPTY is defined in inside and outside tolerance method. GRIP program is &STEPTY=&TOLS. Inside and outside tolerance function are &DRITOL and &DROTOL, which are established by the function parameter input dialog PARAM.

Step 5: Define cutting line distance. Using &CNSCAL will define type of cutting step as the Iso-scallop. Its GRIP program is: &STOVTY=&CNSCAL. After setting the

Iso-scallop method, value of Iso-scallop function &SCALLP need to be set. Initialize parameter input dialog by using the PARAM function.

Through the above steps to complete the establishment of the CAM system, its main functions: select the driving surface, select the machining surfaces, define the machining cutting tool, input cutter geometry parameter, define cutting tool axis, input tilt angle and lead angle, both inside and outside the tolerance parameters, input the Iso-scallop parameters, generate tool-path(as shown in Figure 16).
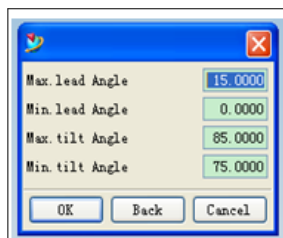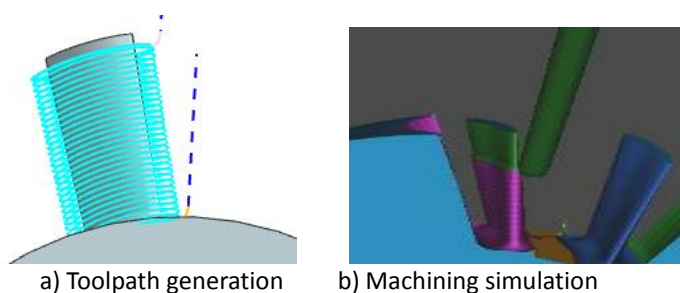

Figure 15. Input Lead Angle and Tilt Angle

| a) Toolpath generation | b) Machining simulation |

Figure 16.Toolpath Generation and Simulation

4.3. Experimental Verification of the Machining Module

This paper completed integrated system from building module to actual processing. In the process, using CAD module conducted modeling of blisk after inputting the given blade data and using CAM module realized side milling semi-finishing programming and actual machining by generating the cutter location file. In order to verify the practicability and accuracy of the relative technologies in the designed CAD/CAM system for blisks, blisk machining experiment is performed in MIKON HSM 600U five axis linkage processing center. Process parameters and process time are shown in Table1 and the machining process is shown in Figure 17. The workpiece material uses aerospace universal brand aluminum alloy 2024 (LY12), conical ball nose cutting tools used in the semi-finishing. Besides, use conventional milling machining blisk experiments to make a comparison.

Table 1. Process Parameters and Process Time

n （r/min）	v_f (mm/min)	a_p （mm）	t （min）
6000	1800	0.2	32

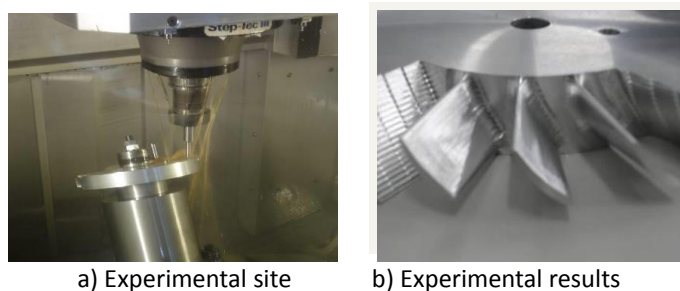| a) Experimental site | b) Experimental results |

Figure17. Processes and Experimental Results

The experimental results show that the design of blisk CAD/CAM system achieves seamless integration from three-dimensional modeling to programming and programming and greatly reduces unnecessary additional time and improves the processing efficiency (as shown in Figure 18). The CAM module uses a particular algorithm to program and there is no interference, over-cutting and other phenomena. Through the contrast test it can be seen that blade fairness is good, the surface quality is higher in the system processing（as shown in Figure 19）. The test verified CAD/CAM system of blisk had better actual machining performance, high surface quality, greatly improving the efficiency of blisk from design to processing.
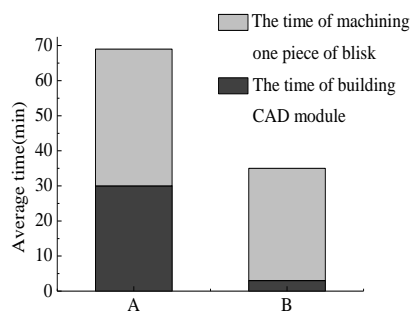
A: The design and machining time of
ordinary software in blisk
B: The design and machining time of special
CAD/CAM system in blisk

Figure 18. Comparing Time of Special CAD/CAM System and Ordinary Software in Blisk
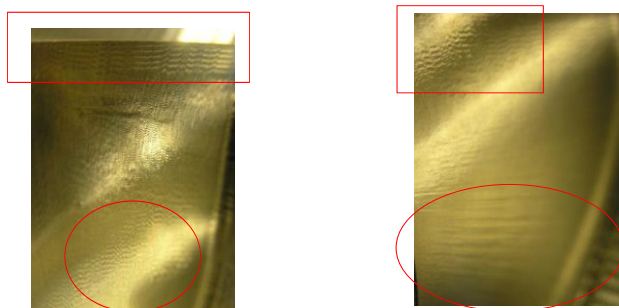
| (a) Blade surface quality after machining in CAM module | (b) Blade surface quality in comparing algorithm |

Figure 19. Blade Surface Quality of Semi-Finishing

5. Conclusions

In this paper, aerospace typical piece blisk CAD modeling is difficult, original data points provided is insufficient or defective points and other issues. The node of interpolation technology and NURBS principle based on the UG platform are used to construct a special blisk CAD modeling module. And CAE module of blisk blades are constructed to complete semi-finishing, the conclusions are as follows:

(1) By analyzing the blisk structure and modeling methods, the idea of overall application plan is put forward in order to make software program versatility. This paper has developed an automatic modeling and automatic machining programming of blisk based on UG/Open Grip, and the module is embedded into the UG in the menu bar. The establishment of human-computer interaction menu makes users convenient and high efficient.

(2) NURBS interpolation techniques are used to optimize original data points of the blisk and solve the problem of blade insufficient data points or defective point. Besides blade's 3rd order NURBS surface modeling is implemented based on the GRIP programming techniques to improve model accuracy. Hub generation technology is combined to complete the establishment of automated parameter CAD blisk module.

(3) Using GRIP language conducts secondary development based on the UG platform. Both inside and outside of the tolerance algorithm and residual height algorithm are respectively used to calculate the feeding step length and step feeding distance. And then, setting top rake and roll angle generates the machining tool path of integral blade. Finally, it realizes the CAM function of blisk. This system can ensure the processing without overcut and the interference. It can also reduce the workload, realize the rapid generation of location files for cutting tools and eventually improve the design and manufacture efficiency of the integral blade.

(4) The processing experiments for the development of the CAD/CAM system prove the efficiency and accuracy of the module. The running of the system is of great value for the processing of blisk production and processing.

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