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Research on the Cutting Process Simulation Based on Finite Element Analysis

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Abstract. The blade is a complex mechanical structure model which has two processing methods. One is making mold blade using the electrochemical methods and forming the blade molding using precision casting methods. But the cycle of this processing method is long and the process is complex and difficult to control. The second method is cutting the blade directly. The cutting force and the friction between tools and blanks can affect the machining accuracy of the machining. We should timely adjust the cutting parameters and cooling model to improve processing accuracy.

Introduction

The blade is a complex mechanical structure model. Its precision is difficult to ensure due to the presence of the cutting forces and the temperature. Thus we need to optimize the processing parameters process to ensure the precision in the process. This paper simulates the blade machining cutting process using the finite element method and CAD simulation software. The second part of this paper establishes finite element mathematical model of tools in three axial [1]. Finally, it gets cutting force curve by CAD calculation module which provides a theoretical reference for the study of finite element simulation of blade during the cutting process [2].

Introduction of blade machining

There are two commonly-used methods of blade machining. One is the electrochemical machining. Another is the direct mechanical cutting. The detail introduction of the two processing technique is described as follows: (1) Electrochemical machining: The principle of the electrochemical machining is putting the material which needs to process into the positive or negative pool of electrochemical decomposition pool[3]. (2) Mechanical cutting: With the development of CNC technology, mechanical cutting machining is the most commonly used processing method of machining.

Mathematical model of the finite element in cutting process of blade

The change of cutting force in the cutting process is mainly reflected in the change of the angle of the tool and cutting position. Finite element mathematical model of the cutting process can be modeled by coordinate micro-element method. The blade position in the process of movement can be expressed as:

$$\beta(a,b,c) = d \cdot \Delta\alpha - (a-1)\frac{2\pi}{M}[(e-1)dr + \frac{dr}{2}]\frac{\tan\theta}{z} \tag{1}$$

In formula (1), a is the position of blade; b is angle increment; c is the number of cutting tool; m is the number of tool's teeth; θ is the angle of knife; dr is the thickness of the cutting tool; z is the diameter of the too. The cutting force of tool can be expressed as [4]:

$$\begin{cases} dGx(a,b,c) = Jx1l(a,b,c)dr + Jx2\dfrac{dr}{\cos\theta} \\ dGy(a,b,c) = Jy1l(a,b,c)dr + Jy2\dfrac{dr}{\cos\theta} \\ dGz(a,b,c) = Jz1l(a,b,c)dr + Jz2\dfrac{dr}{\cos\theta} \end{cases} \tag{2}$$

In formula (2), $dGx(a,b,c)$, $dGy(a,b,c)$ and $dGz(a,b,c)$ are the force of the tool in the three axial directions; $Jx1$ is the shear stress coefficient of the three directions; $Jx2$ is axial stress coefficient of the three directions; $l(a,b,c)$ is the instantaneous cutting tool thickness; $l(a,b,c)dr$ is cutting area.

$$l(a,b,c)dr = \begin{cases} fr\cos(\beta(a,b,c)) \\ 0 \end{cases} \beta(a,b,c) \in [\psi 1, \psi 2] \tag{3}$$

This article transfers the space infinitesimal coordinate to the tool by coordinate transformation model. The transformation matrix can be expressed as [10]:

$$\begin{bmatrix} dGs(a,b,c) \\ dGd(a,b,c) \\ dGw(a,b,c) \end{bmatrix} = \begin{bmatrix} dGx(a,b,c) \\ dGy(a,b,c) \\ dGz(a,b,c) \end{bmatrix} \cdot T \tag{4}$$

We can substitute the value of T and get[11]:

$$\begin{cases} dGs(a,b,c) = dGx1(a,b,c)\cos\beta(a,b,c) + dGx2(a,b,c)\sin\beta(a,b,c) \\ dGd(a,b,c) = dGy(a,b,c)\sin\beta(a,b,c) - dGy2(a,b,c)\cos\beta(a,b,c) \\ dGw(a,b,c) = -dGz(a,b,c) \end{cases} \tag{5}$$

The finite element model of the whole tool can be expressed as[12]:

$$\begin{cases} Gx(b) = \sum_{i=1}^{M} \sum_{u=1}^{N} dGx(a,b,c) \\ Gy(b) = \sum_{i=1}^{M} \sum_{u=1}^{N} dGy(a,b,c) \\ Gz(b) = \sum_{i=1}^{M} \sum_{u=1}^{N} dGz(a,b,c) \end{cases} \tag{6}$$

In formula (6), $Gx(b)$, $Gy(b)$ and $Gz(b)$ are the total cutting force of three axles; N is the infinitesimal number of cutting.

CAD finite element numerical simulation in cutting process of blades

In the cutting process, CAD finite element simulation includes pre-processing and calculation process. Pretreatment process includes 3D modeling, parameter setting and the effect of cutting. The calculation process comprises the calculation of cutting force and the display of the effect of the calculation.

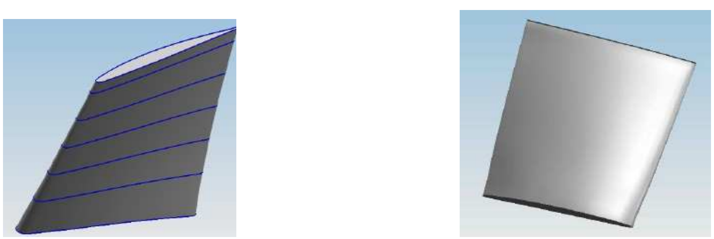

Figure 2. CAD finite element modeling

In Figure 2, it is blade model established in the CAD. The root and the corner of blade have been parameter optimized. The optimized blade is more in line with the curve and surface effect of real blade.

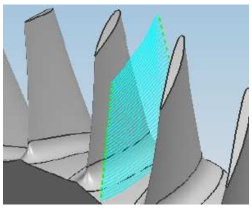

Figure 3. The locus of knife

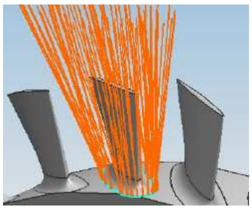

Figure 4. The cleared root locus of blade cutter

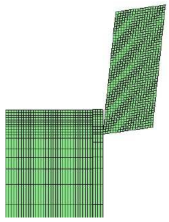

Figure 5. The local grid of tools and blades

In Figure 3, it is the locus of knife. The locus is spiral. In Figure 4, it is cleared root process of blade's root in the process of blade cutting process. Tool resects the root through directional coupling. In Figure 5, it is the grid schematic diagram of tools and blades.

Table 1. Cutting condition table

Condition	***Value***
Rotational velocity(r/min)	89
Feed rate(mm/r)	0 . 3
Cutting thickness(mm)	1.1
Cooling	Coolant

In table 1, it is tool parameter table. Cutting speed is 89 r/min. The cutting thickness is 0.3mm. We can substitute cutting parameters into the second part of the familiar model. We can get the neprogram of tool's attrition using the CAD calculation module which is shown in Figure 6.

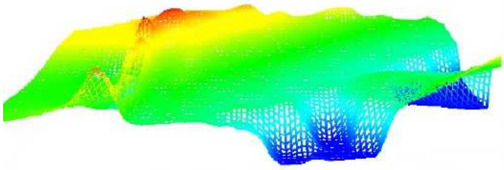

Figure 6. Fraying diagram of tool

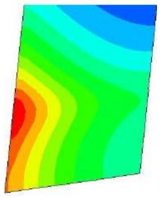

Figure 7. The stress nephogram of tools

As is shown in Figure 6, under the effect of the cutting force, tool has been abraded. As is shown in Figure 7, the stress of tools mainly concentrated in the top of the props under the effect of the cutting force. The stress of the end of tool is smaller.

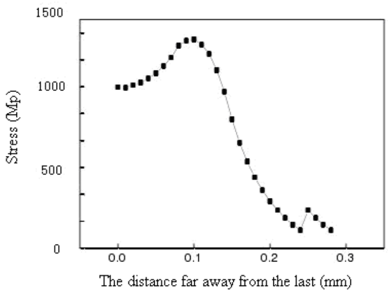

Figure 8. Stress curves of tool

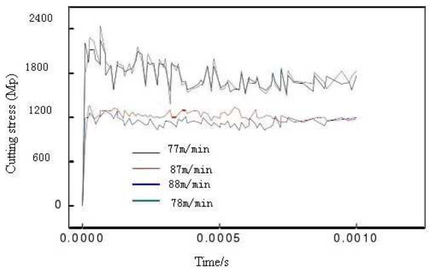

Figure 9. The cutting stress changes of different cutting speeds

As is shown in Figure 8, when The Cutting speed is 89m / s and cutting thickness is 0.3mm, the stress of tools mainly concentrated in the top of the prop. The stress of the tools decreases from the top to the end, and the maximum stress reached to 1450Mp. As is shown in Figure 9, at different cutting speeds, the cutting thickness is 0.3mm. From the Figure, we can see that when cutting speed is larger, the cutting force is smaller.

Data processing and optimization

5.1 Data processing

In data processing, we used regression analysis method, first establish a relationship formula.

$$\sigma = k \times a_p^{x_1} \times v^{x_2} \times a_e^{x_3} \times f_Z^{x_4} \tag{7}$$

σ is the maximum deformation value.
In the MATLABZ solution we derive results
$x_1 = 0.8695$; $x_2 = 0.012$; $x_3 = 0.6974$; $x_4 = 0.0342$; $k = 0.000815$
It can solve the problem into a linear problem after our regression algorithm, formula is:

$$\sigma = 0.000815 \times a_p^{0.8695} \times v^{0,012} \times a_e^{0.6974} \times f_Z^{0.0342} \quad (8)$$

5.2 Optimization

We use a genetic algorithm to optimize the amount of cutting; it is shown in Table 3.

Table 3. The results of optimization genetic algorithm

Iteration number	V m/min	a_p Mm	a_e Mm	f_z Mm	a_ε Mm	V Mm3/min
10	250	1.5	8	0.1	0.020	19853
20	285	1.58	8.9	0.1	0.030	20489
50	285	1.588	8.92	0.1	0.0380	20570
100	285	1.588	8.92	0.1	0.0386	20570

The method of finite element analysis is combined to study the entire cutting process, simulate the whole process, and the results were analyzed and optimized[5].

Conclusion

This paper simulated the blade machining cutting process using the finite element method and CAD simulation software. We got stress curve graph by calculation module CAD. From the curve, we can see that the maximum stress of tools reached 1450Mp. From the detection of a force point of different cutting speeds, we can conclude that when cutting speed is lower, cutting force is smaller.

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