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Parameters Optimization for Milling of 7075-T6 Aluminum Alloy Based on Cutpro9.0

Parameters Optimization for Milling

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***Abstract*—In recent years, parts of aluminum alloy have been widely used in aerospace manufacturing. High speed milling is the most common processing method for the parts of aluminum alloy. Therefore, the parameters optimization for improving the processing quality and processing efficiency attracts more attention. The parameters optimization for high speed milling of 7075-T6 aluminum alloy is carried out based on Cutpro9.0. The frequency response function of the system is obtained by the hammer test. Then, the optimization parameters are selected based on the flutter stability domain, and the dynamic simulation of cutting process is carried out. Finally, the feasibility of parameters optimization is validated by milling experiment. The optimization parameters are that the spindle speed is 11950r/min and the depth of cut is 0.6mm. The result of milling experiment shows that the processing quality is effectively improved, and the processing efficiency is increased by 3 times.**

***Keywords*— Parameters Optimization; 7075-T6 Aluminum Alloy; High Speed Milling; Flutter Stability Domain; Dynamics Simulation**

I. INTRODUCTION

In recent years, with the development of processing technology and aerospace technology, the product performance is improving. The processing quality of parts is also improving. In the modern aerospace industry, the parts of aluminum alloy are widely used in the field of aerospace. High speed milling is the most common processing method for the parts of aluminum alloy. However, the problems of chip bonding and processing deformation are easily appeared in the processing of aluminum alloy, which causes the low processing efficiency and processing quality. The reasonable cutting parameters can decrease the cutting force and tool vibration, and effectively improve the processing quality and processing efficiency. Therefore, the study of parameters optimization for high speed milling attracted more attention.

In 1998, Budak et al. [1] improved the calculation formula of chatter stability in milling, and set the coefficient of cutting force into a constant. In 2003, Weng et al. [2] established a three-dimensional dynamic model of the machining system, and the practicability of the model was verified by the turning experiment. In 2004, Altintas [3, 4] conducted a detailed study and summary on the stability of high speed cutting. In 2005, Liu and Yin [5] developed a dynamic simulation system based on Matlab-Guide. In 2006, Peng et al. [6] developed a NC milling chatter stability domain simulation system based on the Web. It obtained a remote simulation tools and methods of parameter optimization, which was verified in the actual production. The system can accurately predict the instantaneous milling force, spindle power and other physical quantities. In 2009, Liang et al. [7] established the dynamic frequency response model of the milling. The accuracy of the model was verified by experiment, and the stability was predicted. In 2010, Li and Liu [8] optimized the processing parameters of some machine materials in a large degree based on the Cutpro. In 2012, Li et al. [9] carried out experimental research on the milling vibration, and realized the control of the vibration by the adaptive technology of cutting parameters. Lin et al. [10] researched the law of limit cutting width of regenerative chatter varying with the speed of spindle, and the diagram of cutting stability of thin cylindrical shell was obtained. Furthermore, the area of strict stability was proposed compared with traditional stability. In 2013, Jiang et al. [11] established the dynamic model of vibration for high speed milling, and verified the accuracy of the model by experiment. Wang et al. [12] established a finite element model of high-speed spindle system, the influence of the cutting parameters on stability was analyzed based on the three-dimensional lobes. Parameter optimization of thin-wall parts in aerospace was realized based on Cutpro, because it can effectively avoid the damage of tools and machine tools [13], in 2014. The stability charts with different feed directions and spindle positions were investigated based on the modal test, and the machining stability performance along different feed directions was analyzed according to the sound signals collected during machining [14]. In 2015, Li et al. [15] optimized the parameters for the chip removal and burr in the drilling of aerial laminates. Jiang et al. [16] carried out the end milling experiment of TC4 titanium alloy, and the system vibration of metal machining was studied.

At present, most of the studies for parameters optimization are carried out based on the cutting experiments. This method is more reliable, but the period of study is longer, and a large amount of resources and effort are needed. 7075-T6 aluminum alloy is widely used in the field of aerospace as a result of the high strength and good corrosion resistance. The chemical composition of 7075-T6 aluminum alloy is listed in TABLE Ⅰ. The parameters optimization for high speed milling of 7075-T6 aluminum alloy is carried out based on Cutpro9.0 in this paper. The frequency response function of the system is obtained by the hammer test. Then, the optimization parameters are selected based on the flutter stability domain, and the dynamic simulation of cutting process is carried out. Then, the feasibility of parameters optimization is validated by milling experiment.

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TABLE I. CHEMICAL COMPOSITION OF 7075-T6 ALUMINUM ALLOY

Chemical composition	Cu	Si	Fe	Mn	Mg	Zn	V	Zr	Ti
Content (%)	5.8-6.8	≤0.2	≤0.3	0.2-0.4	≤0.02	≤0.1	0.05-0.15	0.1-0.25	0.02-0.1

TABLE II. GEOMETRIC PARAMETERS OF TOOL

Diameter	Diameter of handle	Cutting edge length	Total length	Number of teeth	Helix angle
10mm	10mm	25mm	75mm	4	35°

II. HAMMER TEST

In order to obtain the frequency response function of the processing system, the hammer test was carried out on Makino S56. A carbide end milling cutter was used, and the diameter is 10mm. TABLE Ⅱ lists the geometric parameters of tool. Fig. 1 shows the device of the hammer test. During the test, the effects of static, noise, cutting tool materials and some human activities should be excluded for ensuring the reliability of the hammer test. The hammer test should be carried out on two orthogonal directions of *x* and *y*, and 5 data is needed in each direction. Besides, the system will receive the perfect signal automatically. Therefore, the frequency response function of the processing system in directions of *x* and *y* can be obtained.

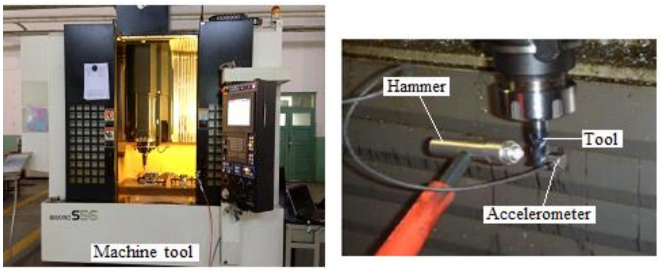

Fig. 1. Device of hammer test

III. SIMULATION OF FLUTTER STABILITY DOMAIN

Simulation of flutter stability domain was carried out based on the frequency response function. A series of parameters should be set in module of Milling 2.5 Axis, including tool parameters, blank parameters and cutting parameters. In particular, the frequency response functions of two directions of x and y must be selected correctly.

Fig. 2 shows the flutter stability curve of the processing system. It shows that the area above the curve is the resonance region, and the area below is the region of parameters optimization. The black dot means the initial parameters of milling and the black squares in red ellipse mean six selections of optimization parameters. It can be seen that the initial parameters is also in the flutter stable region, but the processing efficiency is low. In order to improve the processing efficiency, the spindle speed *n* is selected ranging from 9000r/min to 12000r/min, and the depth of cut a_p is below 4mm. TABLE Ⅲ lists the values of the parameters selected.

TABLE III. SELECTED PARAMETERS

Number	1	2	3	4	5	6
n (r/min)	11950	11950	11600	10560	9800	9215
a_p (mm)	0.8	0.6	3.344	3.7	3.344	3.6

IV. DYNAMIC SIMULATION OF CUTTING PROCESS

For further study the stability of milling, the dynamic simulation of cutting process is carried out based on the frequency response function and the cutting parameters in TABLE Ⅲ. The optimization parameters can be determined by analyzing the effect of cutting parameters on the processing quality and processing efficiency. TABLE Ⅳ shows the results of dynamic simulation. Where, F_y is the maximum value of main cutting force; R_{max} and R_{avg} means the maximum and average value of the surface roughness. It can be seen that the cutting force, the spindle power and the spindle torque increase with the increase of a_p, and decrease with the increase of *n*.

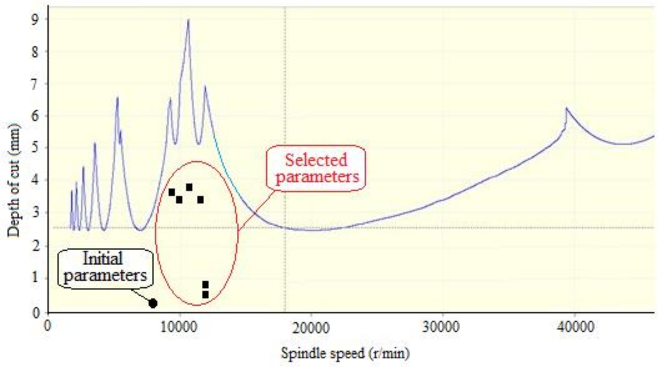

Fig. 2. Stable domain curve

Fig. 3 shows the prediction results of the dynamic simulation of NO.2. It can be seen that the spindle torque, the spindle power and the tool vibration are smaller. In addition, the surface roughness is within 0.0316mm. Therefore, the optimization parameters for high speed milling of 7075-T6 aluminum alloy are that *n* is 11950r/min and a_p is 0.6mm.

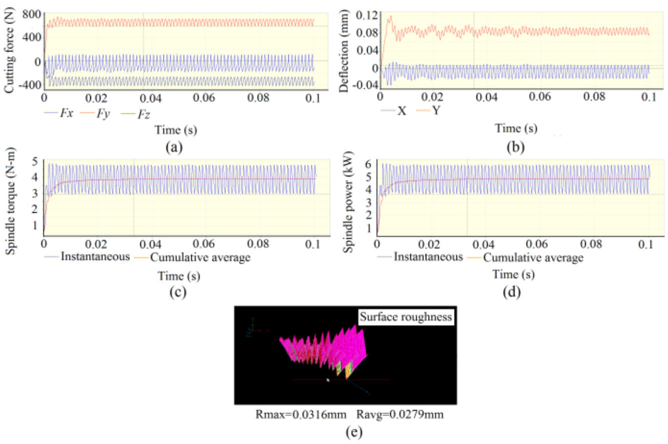

Fig. 3. Result of dynamic simulation (*n* = 11950r/min, a_p = 0.6mm)

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TABLE IV. RESULTS OF DYNAMIC SIMULATION

Number	F_y (N)	Spindle power (Kw)	Spindle torque (N-m)	R_{max} / R_{avg} (mm)
1	683.85	4.896	3.91	0.0985 / 0.0866
2	343.32	2.583	2.064	0.0316 / 0.0279
3	883.38	6.134	5.050	0.1289 / 0.1147
4	988.99	6.201	5.609	0.1454 / 0.1353
5	876.08	5.172	5.040	0.1281 / 0.1188
6	979.93	5.260	5.477	0.1330 / 0.1241

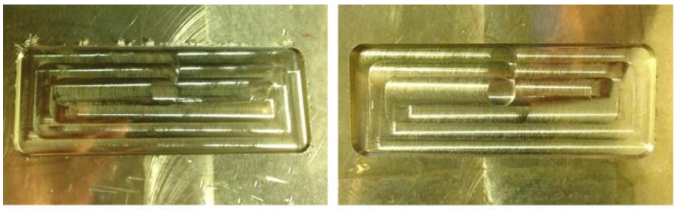
V. VALIDATION

In order to verify the feasibility of the optimization parameters, the milling experiment was carried out on Makino S56. The initial parameters and the optimization parameters are listed in TABLE Ⅴ.

TABLE V. EXPERIMENTAL PARAMETERS

Experimental parameters	n (r/min)	a_p (mm)	f (mm/min)
Initial parameters	8000	0.3	2000
Optimization parameters	11950	0.6	2000

Fig. 4 shows the comparison of experimental results. It shows that the processing quality is effectively improved by the optimization parameters, and the processing efficiency is increased by 3 times.



(a) Result of initial parameters (b) Result of optimization parameters

Fig. 4. Result of optimization parameters

VI. CONCLUSION

In order to improve the machining efficiency and processing quality of high speed milling of 7075-T6 aluminum alloy, the study of parameters optimization is carried out based on Cutpro9.0. The optimization parameters are obtained, and verified by milling experiments. The optimization parameters are that the spindle speed n is 11950r/min and the depth of cut a_p is 0.6mm. The result of milling experiment shows that the processing quality is effectively improved, and the processing efficiency is increased by 3 times.

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