Three-dimensional finite element simulation of high-speed cutting of 7055 aluminum alloy based on ABAQUS

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Abstract

In order to fill the shortcomings of 7055 aluminum alloy high-speed cutting and so on. In this paper, 7055 aluminum alloy is used as the research object. First, the three-cutting finite element model of 7055 aluminum alloy and the "three high characteristics" The simulation results show that there is a reasonable agreement between the simulated values of the cutting force and the experimental values, and the simulation results of the cutting temperature are in agreement with the experimental results. The maximum error between the experimental values is 15%, within the allowable range, and the friction between the cuttings has an important effect on the cutting temperature, and at any cutting condition the predicted maximum cutting temperature always occurs before the tool The side of the blade face near the main cutting edge.

Keywords

7055 aluminum alloy; High speed cutting; Cutting force; Cutting temperature; Finite element simulation.

1. Introduction

With the development of aerospace industry, the continuous progress of science and technology, aircraft and aircraft performance requirements continue to improve, in addition to the requirements of materials with excellent mechanical properties, but also requires excellent mechanical properties of the alloy[1]. As a result of many aircraft and aircraft aluminum alloy parts are used to directly emptied the blanket processing, and in the cutting process, the thermal energy occupies more than 95% of the proportion of power, that is, the energy conversion process is basically in the form of heat If the heat is not released in time, the cutting zone temperature will suddenly increase the trend [2]. In the field of metal cutting, cutting temperature measurement has always been a hot topic of concern to domestic and foreign experts, early, domestic and foreign experts and scholars on the low-speed cutting process of cutting temperature and cutting heat measurement has been relatively large progress. However, there are still no feasible theories and models for the measurement of cutting heat and the effective control of cutting heat. At the same time, in the cutting heat problem, the finite element simulation method came into being. Through the finite element simulation can be intuitive to see the cutting layer of metal stress, strain and the basic shape of the chip, which makes cutting heat and cutting temperature problems can be resolved, but the current application is not wide, mostly in the conventional two-dimensional cutting finite element Analysis on. Until today, domestic and foreign experts on the cutting force and cutting temperature finite element simulation were studied. Outside John T. Carroll studied the finite element simulation of single point diamond turning[3], T.I.El-Wardany studied the finite element simulation of cutting temperature for difficult machining of ceramic cutting tools [4]. In this paper, the application of two-dimensional finite element analysis in orthogonal cutting 7075 aluminum alloy [5]; Wang Dianlong's finite element software Deform simulation Study the cutting process[6]. Most of the above studies focus on two-dimensional finite element simulation, the limitations are relatively large, only in the orthogonal test to verify, but can not simulate the actual processing situation. In this paper, three-dimensional finite element simulation of ABAQUS is used to study the cutting force and cutting temperature of 7055 aluminum alloy.

2. Finite element model of cutting process

The finite element model is established by combining the production of the actual workpiece geometry, tool geometry and angle reduction, and given the material parameters and load conditions[7]. Geometric shape is the tool and the workpiece according to the actual situation of the proportion or a certain proportion of scaling; application of the constitutive equation of material instead of material properties; processing load through the load and boundary conditions control to complete.

2.1 The establishment of geometric model

The geometry of the tool and the geometry of the workpiece are simplified, but the geometric angle and size are scaled according to the actual situation. The bottom of the workpiece is all fixed, limits all degrees of freedom, the tool is set as rigid, counterclockwise, Milling. The 3D cutting finite element modeling of 7055 aluminum alloy is shown in Fig.1.

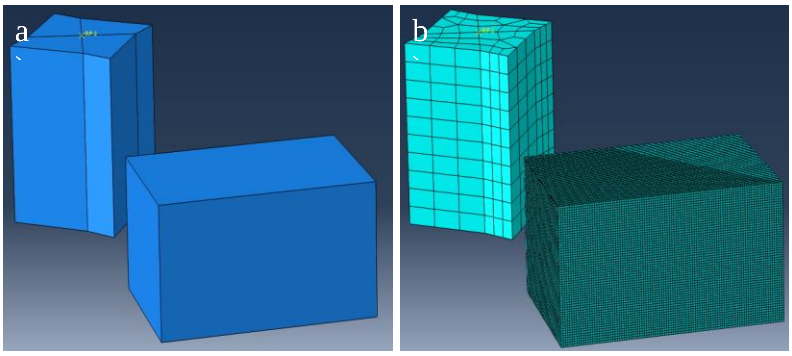

Fig.1 3D finite element model and mesh model

2.2 Constitutive model of materials.

The constitutive model of the material is the most intuitive description of the stress, strain, strain rate and temperature of the material. It is described in the form of a function expression, and the weight coefficient of each parameter is more intuitively displayed[8]. High-speed machining is a high-strain, high strain rate and ultra-high temperature of the "three high characteristics" of the processing process, only to establish a "three high characteristics" of the constitutive equation, in order to accurately describe the material processing. In this paper, the Johnson-Cook model is used to simulate the cutting process using the Johnson-Cook constitutive model satisfying the "three high characteristics". The Johnson-Cook model is shown in equation (1).

$$\bar{\sigma} = (A + B\varepsilon^{n})(1 + C\ln(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_0}))(1 - (\frac{T - T_{room}}{T_{melt} - T_{room}})^{m}) \tag{1}$$

In the formula, the first brackets describe the strain hardening effect of the material; the second bracket is the strain rate enhancement effect; the third term is the high temperature heat softening effect of the 7055 aluminum alloy [9]. Where A, B, n, C, m are the five parameters to be determined; A, B, n characterize the material strain enhancement coefficient; C characterize the material strain rate enhancement coefficient; m characterize the material thermal softening coefficient. The material parameters of the Johnson-Cook model in the 7055 aluminum alloy are shown in Table 1 below.

Table1 material parameters of Johnson-Cook Model

A/Mpa	B/Mpa	n	c	m
542.24	273	0.194	0.136	0.271
561.38	323	0.173	0.375	0.537

3. Simulation of cutting process

According to the three-dimensional finite element model established in Fig.1, the finite element simulation is carried out to obtain the simulation results of the three-dimensional metal cutting process. The three-dimensional milling stress cloud is shown in Fig. It can be seen from Fig. 2 that the plastic deformation of the cutting layer metal during the cutting process is stronger in the first deformation zone, and it can be seen that the stress in this region is the largest in the stress cloud.

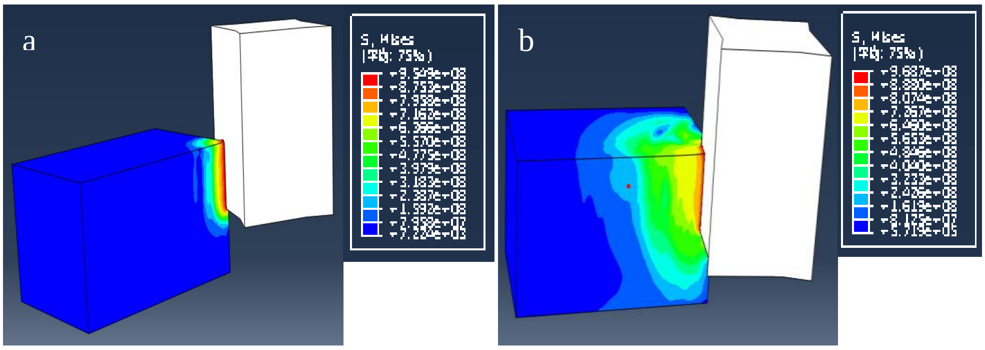

Fig.2 stress - strain contours

3.1 Cutting force forecast

In order to ensure the reliability of the experimental and simulation results, the three-dimensional finite element simulation of all parameters and experimental parameters are exactly the same[10], 7055 aluminum alloy workpiece parameters, 10mm10mm5mm, the milling volume includes milling depth ap, spindle speed and feed rate.

Figure 3 shows the tangential force obtained by the three-dimensional finite element simulation. It can be seen from Fig. 3 that the Z-direction cutting force is the largest in the three-way cutting force, the Y-direction cutting force is relatively stable and the value is the smallest. The X-direction cutting force fluctuates greatly.

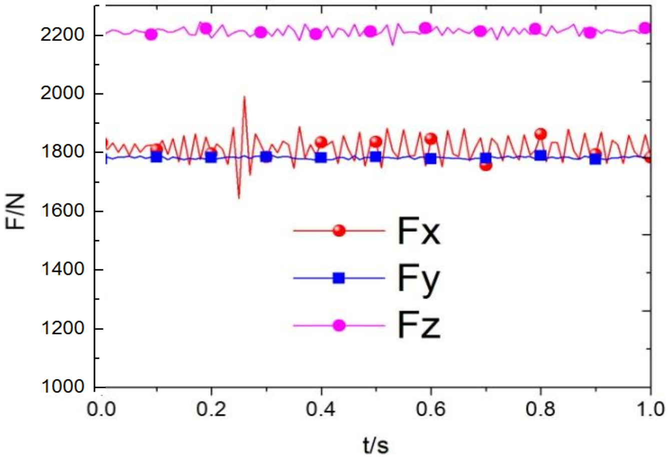

Fig.3 The results of finite element simulation on cutting force

3.2 Cutting temperature forecast

Figure 4 shows the cutting temperature of the cutting temperature at different milling speeds. As can be seen from Fig. 3, the cutting temperature increases with the increasing milling speed. When the milling speed is 1500 m / min, the cutting temperature is 355 ℃, cutting speed of 600m / min, the cutting temperature of 320 ℃ or so.

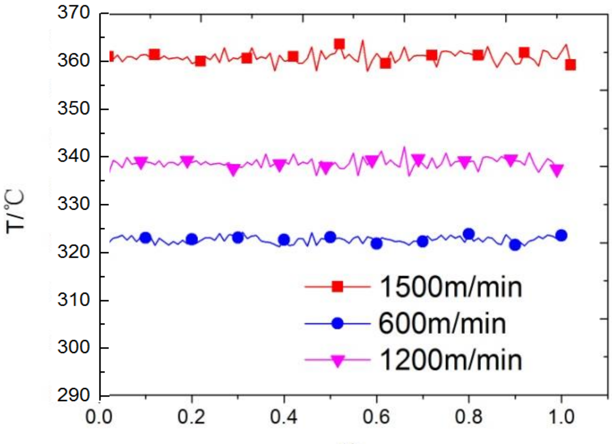

Fig.4 The results of finite element simulation on cutting temperature

Figure 5 shows the cutting temperature of the cutting temperature after the completion of the finite element simulation temperature distribution cloud map, can be seen through Figure 5, the rake face and the first deformation zone of the highest temperature, which is also consistent with the theoretical analysis of the formation of a consistent[11]. The reason is that the first deformation zone material subjected to high-speed load, resulting in severe plastic deformation, deformation of the heat can not be lost in time, eventually leading to the highest cutting temperature in this part .

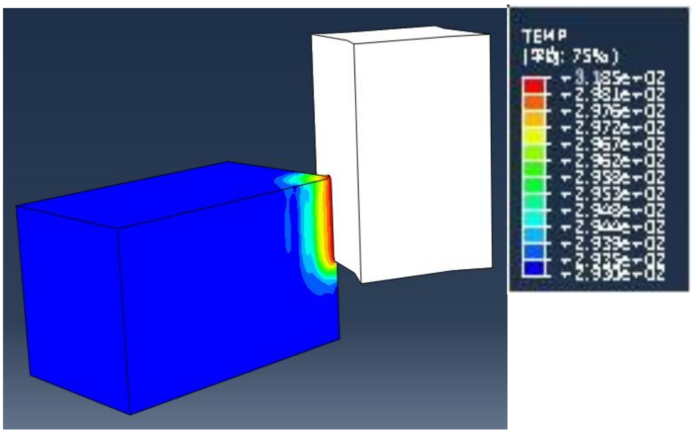

Fig.5 contours of cutting temperature distribution

4. Experimental verification

In order to verify the results of the cutting force simulation, the 7055 aluminum alloy was subjected to high speed milling test. The high speed milling experiment was carried out on a KVC800 / 1 vertical machining center. The tool used for the milling test was the carbide cutting tool CoroMill290. The test was carried out using a dry cut using a Kistler three-way piezometer to measure the three-way cutting force [12]. Here, the cutting speed of 1200m / min as an example to illustrate the three-way cutting force;

Figure 6 depicts the relationship between the experimental value of the three-way cutting force and the simulated value. It can be seen from the figure that the simulation value of the cutting force and the test value are reasonably consistent, the average error between them is 13.5%, the maximum error is 21.3%, the minimum error is only 2.57%, and the simulation value of the cutting force And the test value also has a common development trend.

In order to verify the results of the cutting temperature simulation, the 7055 aluminum alloy was subjected to high speed milling test. The high speed milling test was carried out on a KVC800 -1 vertical machining center. The tool used for the milling test was the carbide cutting tool CoroMill290. The test was cut dry and the cutting temperature was measured. The cutting temperature is described below with cutting speeds of 600 m / min, 1200 m / min and 1500 m / min.

Figure 7 depicts the relationship between the experimental value of the cutting temperature and the simulated value. It can be seen from the figure, the cutting temperature simulation values and test values have a reasonable consistency[13]. When the cutting speed is 1200m / min, the error between the simulated value of the cutting temperature and the experimental value is within 10%. When the cutting speed is 1200m / min, the error between the simulated value and the experimental value is within 8%. When the cutting speed When 1500m / min, the error between the simulated value of the cutting temperature and the experimental value is the largest, but also within 15%. Through the above can explain the three-dimensional finite element milling model of the cutting temperature has a very accurate predictability, the actual production provides a means of guidance, but also to provide guidance for the optimization of cutting parameters.

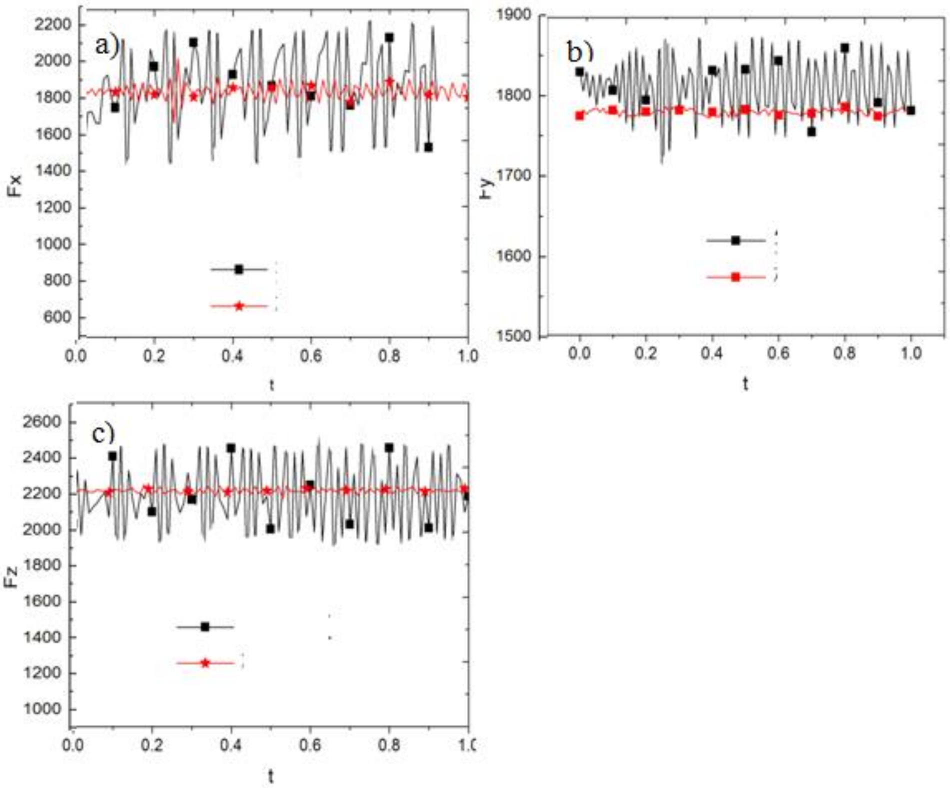

Fig.6 the simulation value and the experimental value of cutting forces

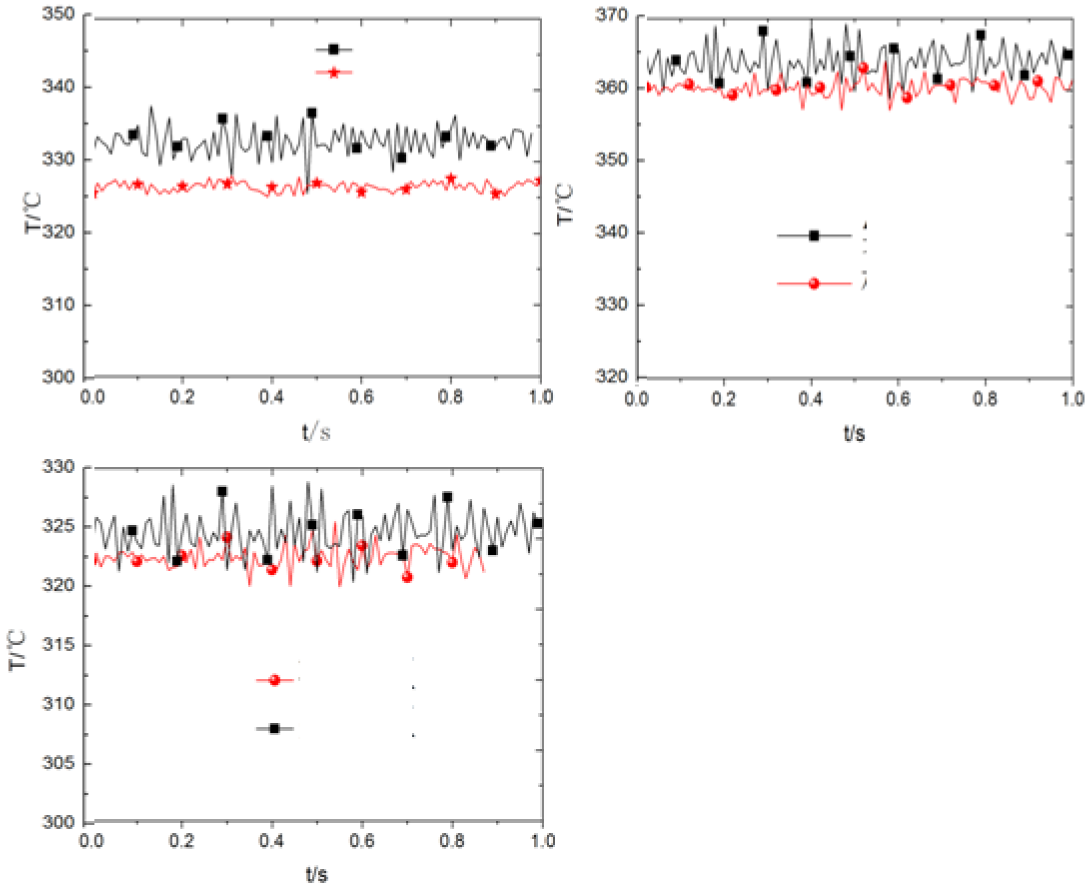

Fig.7 the simulation value and the experimental value of cutting temperature

5. Conclusion

(1) Three-dimensional milling finite element model simulation results show that the three-way cutting force simulation value and the test value between the reasonable consistency, the average error of 13.5%, the maximum error of 21.3%, the minimum error of only 2.57%.

(2) The maximum error between the simulation value of the cutting temperature and the experimental value is within 15%, and it is very accurate to predict the milling temperature within the allowable range, which is instructive for the actual production and cutting parameter optimization.

(3) It can be seen that the friction between the crumbs has an important effect on the cutting temperature, and at any cutting condition, the highest cutting temperature is always found on the tool nose face near the main cutting Edge of the blade.

Acknowledgments

The work was supported by the National Natural Science Foundation of China (No. 51575289) 、the Natural Science Foundation of Shandong Province (No.ZR2016EEP03) and Technology Project of Higher Education Shandong Province Science （No.J17KA0031).

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