

# The Comparative Study on Machining Deformation and Experiment of Integrated Frame Part

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**Abstract.** In aerospace equipment manufacturing, the machining deformation of the large integral structure is seriously influence on the machining efficiency and the accuracy of the parts. Based on the theory of elastic-plastic theory, the finite element analysis model of machining deformation of 3D integral frame is established, and the removal process of the material is simulated by using the technology of element birth and death. The deformation law of the initial residual stress release caused by the initial residual stress is studied, and the cutting experiment is designed, and the deformation of each milling is measured by using a three-dimensional coordinate measuring machine. Through the comparative analysis of the simulation data and the experimental data, it can make a conclusion that establishment of a correct analysis of the model can predict the machining deformation, and reduce the machining deformation.

## Introduction

In aerospace equipment, more and more integrated structural parts instead of the traditional assembly structure, improve production efficiency and reduce the probability of accidents [1-2]. For example: integrated frame, wing, and other parts.[3-4] The features of this kind of parts are large size, complex structure, high machining accuracy, large machining allowance and poor rigidity of parts. The residual stress in the blank affects the machining accuracy of the parts, which often leads to the deformation of parts and seriously affects the production schedule[5-6].

It has been successfully applied to analyze machining deformation by using finite element theory, but most researches are two-dimensional cutting. In recent years, with the progress of computer technology and the improvement of finite element theory, it lays a foundation for the study of 3D Cutting [7-8]. This paper establishes the overall frame parts milling 3D finite element analysis model based on finite element theory, the "element birth and death" technique material removal process simulation analysis, obtained the release of residual stress caused by the deformation of parts of the design and cutting experiments using 3D coordinate measuring instrument for measuring the time of milling deformation. By comparing the simulation data with the experimental data, the analysis model is validated.

## Analysis Model

The part drawing is shown in figure 1, The work-piece is positioned with the bottom plane as the locating surface, and the two ends are clamping positions. In order to improve the efficiency of analysis and reduce the time occupied by the computer hardware, half of the longitudinal part is analyzed. When the seed point is set and the mesh is finished, the outer surface of the part coincides with the boundary of the element. In this paper, a low order 8 node hexahedral element is used to divide the model into 188700 units and 200830 nodes.

The residual stress is firstly set up before simulation analysis. The number of parts according to the layered thickness direction, the discretization of the distribution curves of the stress test in the

residual, in accordance with the "force balance and torque balance" principle, the initial residual stress loading on the model. Fig. 2 is the distribution of the 7075-T7351 aluminum alloy pre-stretched sheet by layer by layer cutting method in the depth direction [9], the elastic modulus of the material is 73GPa, the Poisson's ratio is 0.35, and the material density is 2780 Kg/m<sup>3</sup>[10].

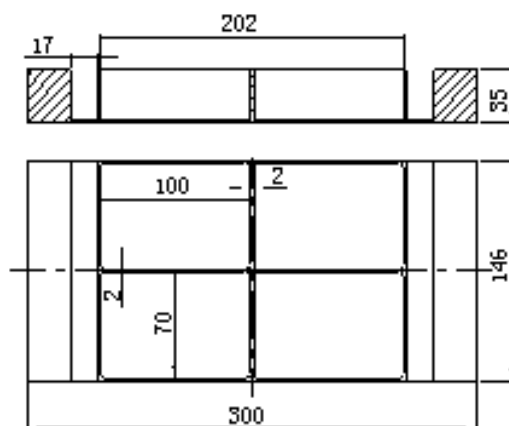


Fig.1 part dimension

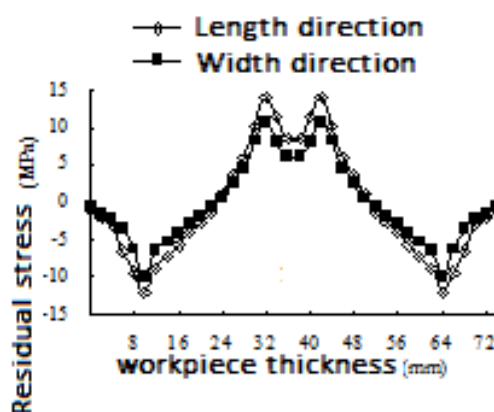


Fig.2 residual stress distribution

## Milling Process Analysis

The constraint condition of the model boundary condition is set up according to the clamping condition of the cutting experiment of the part. After each layer of machining simulation is completed, the deformation data of the part is obtained through the constraint transformation, and the steps are as follows: First remove cutting loads; and then release the displacement boundary condition; a point in the bottom parts non machining parts, limit three direction of rigid body displacement, while the other two parts of the bottom surface in different directions to limit rotational degrees of freedom, the free deformation of parts. In this paper, the cell life and death technology is adopted to simulate the removal process of materials. Unit to be "killed" in the post process is not visible, "die unit" is not removed from the model, but MARC software for element stiffness matrix multiplied by a factor of 10-6, the load associated with the "dead cell" is zero, and "dead cell" quality, damping, heat and other factors is zero, the element strain is zero. The analysis results are shown in figure 3-figure 4. From the figure we can draw deformation data, the cutting part for each layer, residual stress will release and redistribution of stress distribution will lead to deformation of parts, the parts material was removed to the side bending, bending degree with different cutting depth.

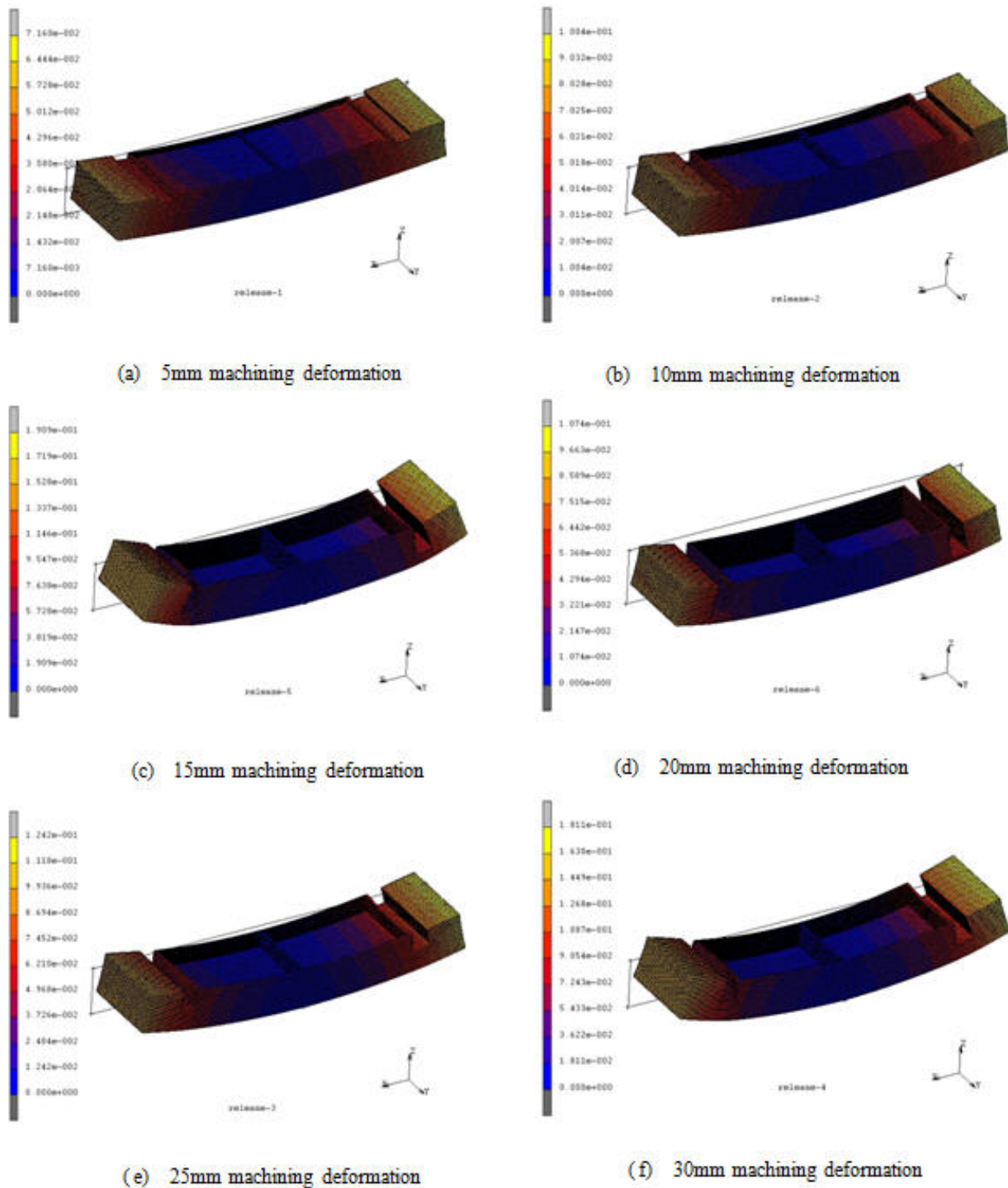


Fig.3 machining deformation

Fig. 4 is the finite element simulation of the deformation curve of the specimen. As can be seen from the diagram, the deformation in the first 4 layers of milling increases gradually, and when the milling depth reaches about 60%, the deformation amount of the specimen reaches the maximum value. From the fifth layer milling, the deformation of the specimen decreases gradually. Because the milling depth is more than 60%, the residual stress in the pre - removal part of the bottom of the specimen is tensile stress, so the deformation at both ends decreases gradually. It can be used for reference in the actual processing, when the milling depth reached 60% after machining, the work-piece from the fixture should be removed, the free deformation after keep free clamping, can greatly eliminate the work-piece deformation and subsequent processing.

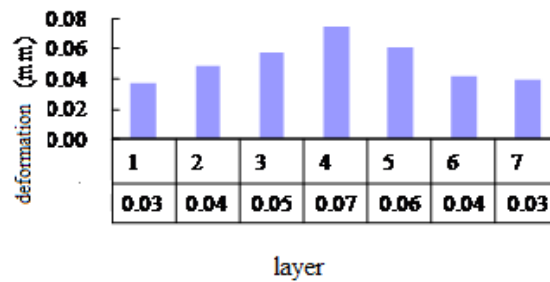


Fig.4 simulation deformation analysis

### Data Comparison Analysis

Experimental conditions: the diameter 10mm carbide coated end mill, spindle speed 4000rpm, feed F200mm/min, milling width of 5mm, using cutting fluid, as shown in Figure 5. Each of the milling depth after 5mm (seventh times the milling depth is 3mm), remove the parts from the bench, using three coordinate measuring instrument for measuring work-piece set on the feature point deformation along the depth direction, as shown in Figure 6, the measurement data are shown in table 1. The data comparison is shown in figure 7.

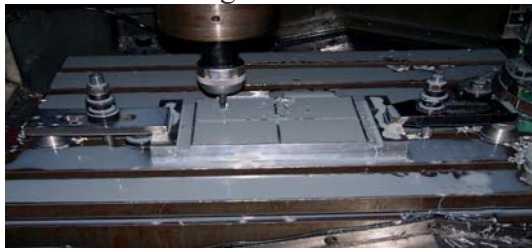


Fig.5 cutting experiment

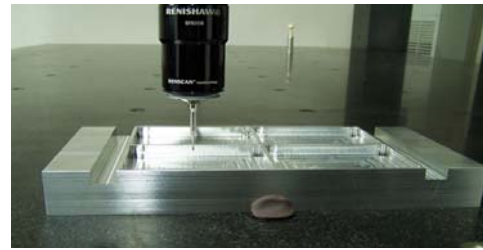


Fig.6 machining deformation measurement

According to the simulation results of the finite element machining and the measured results of the work-piece after cutting, the deformation tendency of the parts is the same. When the parts are machined to 60% of the thickness of the parts (fourth layers of milling), the processing deformation of the parts reaches the maximum value, and the deformation of the work-piece will gradually decrease when the work-piece is continued to be machined. When the cutting depth is more than 80% of the work-piece, the deformation of the work-piece changes little.

Table 1 The upper surface deformation of the work-piece after each milling (mm)

Milling depth	X Y	102	0	-102	planeness
5	72	0.013	0.011	0.011	0.018
	0	0.009	0.001	0.005	
	-72	0.024	0.014	0.019	
10	72	0.011	0.003	0.009	0.021
	0	0.020	0.015	0.018	
	-72	0.029	0.016	0.025	
15	72	0.026	0.017	0.018	0.026
	0	0.020	0.007	0.011	
	-72	0.040	0.022	0.027	
20	72	0.059	0.031	0.036	0.038
	0	0.068	0.033	0.039	
	-72	0.089	0.046	0.048	
25	72	0.059	0.031	0.036	0.044
	0	0.068	0.033	0.039	
	-72	0.089	0.046	0.048	
30	72	0.063	0.046	0.042	0.041
	0	0.072	0.043	0.048	
	-72	0.094	0.051	0.062	
33	72	0.088	0.086	0.089	0.028
	0	0.081	0.072	0.088	
	-72	0.115	0.088	0.110	

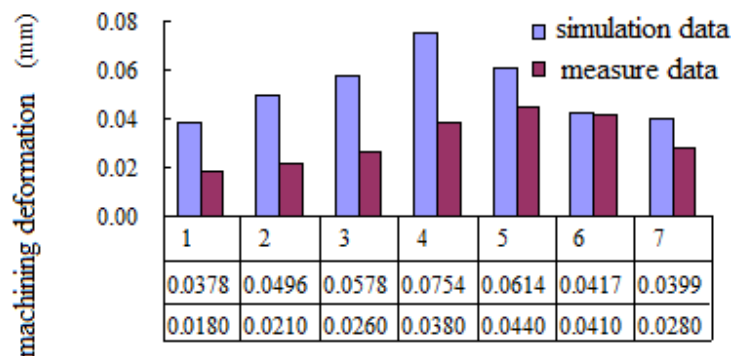


Fig.7 data comparative analysis

## Conclusion

This paper establishes the overall frame parts milling 3D finite element analysis model based on finite element theory, the "element birth and death" technique material removal process simulation analysis, obtained the release of residual stress caused by the deformation of parts of the design and cutting experiments using 3D coordinate measuring instrument for measuring the time of milling deformation. Through the simulation and experiment data analysis, validate the analysis model, the overall structure of box parts machining deformation law, in order to develop is conducive to the rational processing technology provides the basis for reducing machining deformation.

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