Study on the Time-varying Characteristics for Deformation and Stress of Turning Work-piece

Qiang ZHANG¹, Qian ZHU¹, Xiao-Jie WU¹ and Yu-Lin LUO²,b

¹Department of Air-material and Aerospace Ground, Air Force Logistics College, Xuzhou, Jiangsu 221000, China
²The Army of No.95133, Wuhan, Hubei 430000, China
a email: lsc20111213@163.com (corresponding author), b email: 215561271@qq.com

Abstract: Based on the orthogonal plane model theory, a two-dimensional finite element model of turning work-piece was established. Moving load was applied to work-piece by using APDL language. This paper carried out the simulation analysis on the Time-varying characteristics of the turning work-piece by using the birth and death element technology of ANSYS for the removal of the chip. The research shows that the work-piece is the most difficult to be cut in the initial stage of turning, and the stress value is the maximum at this moment. The stress obeys stress yield criterion of the work-piece after entering the stable turning stage. The deformation curve of the work-piece is nearly a half parabolic distribution.

1 Introduction

In the process of turning, the stress and deformation of work-piece will affect the machining accuracy. Research on turning theory has aroused the attention of many scholars. Merchant [1] established an early shear plane model and obtained the theoretical formula of cutting force, shear stress and strain in the cutting process. Based on the model developed by Merchant, Zorev [2] studied the high-speed cutting motion and found that the influence of cutting temperature on the shear flow stress was relatively small. The principle of chip formation in the metal cutting process was studied in literature [3]. A steady state orthogonal cutting mode was established in literature [4], and the stress and strain and temperature parameters were simulated. The shape of the chip was simulated in literature [5], and the temperature in the work-piece, tool and chip was predicted. The residual stress and strain of the machined surface were obtained in literature [6].

In this paper, based on orthogonal plane model theory and the birth and death element technology of ANSYS, the stress-strain field of the turning work-piece was simulated and the time-varying law of the stress and strain of the work-piece was obtained.

2 Orthogonal Plane Model in Turning Process

The actual metal turning process is a three-dimensional model. Due to the complex of turning process, scholars have studied the turning process based on the orthogonal plane model established by Merchant[1]. As shown in Figure 1, in the 3D turning process, the relative motion state between the tool and the work-piece is always the same, and the chip width is much larger than the chip thickness, which can be reduced to solve the plane strain problem in two-dimensional state. In the orthogonal cutting process as shown in Figure 2, the main movement is along the -x axis direction and the feed movement is the -y axis direction. The force in the axial x direction is the main turning force and the y direction force is the cut-depth resistance.

3 Finite Element Model of Turning Work-Piece

According to the orthogonal plane theory of turning machining, the finite element model of work-piece was established by ANSYS software, and plane element 42 of ANSYS was selected to simulate work-piece element model. The length of work-piece is 200 mm, the height of which is 20 mm, elastic modulus of which is 1.2×10¹¹ Pa and Poisson's ratio is 0.3. The mesh is divided by the way of mapping, and the left end of model is fixed constraint, the right end of which is free limiting. The finite element model shown in Figure 3, the total number of units is 1600 and the number of nodes is 1701.
4 Apply Constraints and Loads

According to the orthogonal plane model, the influence of the main turning force is mainly considered, and the influence of the secondary force is ignored. According to Merchant cutting theory, the main turning force is calculated as:

\[ F = \frac{\tau bh \cos(\beta - \gamma)}{\sin \phi \cos(\phi + \beta - \gamma)} \]  

(Eq.1)

where, \( \tau \) — the shear yield strength of work-piece, 
\( h \) — turning width, 
\( b \) — thickness of turning layer, 
\( \phi \) — shear angle, 
\( \beta \) — friction angle 
\( \gamma \) — rake angle

According to the literature, the main turning force remain the same in the stability state of turning process, so the turning force can be seen as constant value. Turning parameters were set as shown in Table 1, according to the main cutting force calculation formula (1), the main cutting force can be obtained. The moving load of the turning process was applied to the finite element model node through ANSYS APDL parameter language.

Table 1. Turning processing parameters.

<table>
<thead>
<tr>
<th>The shear yield strength of work-piece</th>
<th>200MPa</th>
<th>Turning thickness</th>
<th>1mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Turning width</td>
<td>3mm</td>
<td>friction angle</td>
<td>-2°</td>
</tr>
<tr>
<td>Shear angle</td>
<td>42°</td>
<td>rake angle</td>
<td>-5°</td>
</tr>
</tbody>
</table>

5 The Time-Varying Characteristics of Stress and Deformation in Turning Process

With general post processor of ANSYS, the stress and deformation maps of the work-piece during different turning stage shown in Figure 4. When the tool touches the work-piece, the maximum equivalent stress of the work-piece is 1033 MPa and the deformation displacement is 1.528 mm. With the work-piece cut in, the maximum equivalent stress of the work-piece rapidly decreases, and the maximum equivalent stress of the work-piece is reduced by about 44%. It indicates that the work-piece at the beginning turning process is the most difficult to be cut in, then the stress will reduce sharply. The maximum equivalent stress remained at 513MPa at the steady turning stage.

In order to study the maximum equivalent stress and deformation of the work-piece during the whole turning process, the change curves with time of the maximum equivalent stress and deformation were respectively fit as shown in Figure 5 and Figure 6. As can be seen from Figure 5, the stress value Figure reaches the maximum value 1033MPa at the beginning of turning process, then the stress decreases rapidly to 584.7MPa, and the stress was always stabilized on 513MPa at the steady turning stage. This shown that the work-piece is the most difficult to be cut in due to the work-piece has the ability to resist deformation, and the stress remain a fixed at stable turning stage.
because of the plastic deformation of the work-piece, which verified the stress yield criterion: the equivalent stress remains unchanged when the material enters the plastic state. As can be seen from Figure 6, the maximum deformation at the beginning of the work-piece is 1.528 mm. The deformation curve of the work-piece is nearly a half parabolic distribution, and the minimum deformation value at the whole turning process is 1.528 mm.

**Conclusion**

A two-dimensional finite element model of the turning work-piece was established by ANSYS software. Time-varying characteristics of the stress and deformation were obtained. The research shows:

1. The work-piece at the beginning turning process is the most difficult to be cut in. The maximum equivalent stress remained at 513 MPa at the steady turning stage, because of the plastic deformation of work-piece, which is coincident with the result of literature [7], and the result verified the stress yield criterion.

2. The deformation curve of the work-piece is nearly a half parabolic distribution.
References


