The quasi-static tensile simulation was carried out on the 6061 aluminum alloy round bar specimen, and the tensile specimen model was drawn. Three sets of simulation with uniaxial tensile velocity of 10 s\(^{-1}\), 15 s\(^{-1}\) and 20 s\(^{-1}\) were set at normal temperature, and the numerical simulation of the tensile process was carried out by using ABAQUS software. The experimental data were imported into the model, and the relevant parameters such as damage model were set. The derived simulation results are in good agreement with the experimental results, indicating that the established simulation model can simulate the uniaxial tensile behavior of 6061 aluminum alloy well.

**Keywords:** 6061 aluminum alloy; static drawing; mises stress; stress-strain curves; numerical simulation

## INTRODUCTION

6061 aluminum alloy is a high quality aluminum alloy product produced by heat treatment and predrawing process\[1\]. Its chemical composition is shown in Table 1. Because of its good formability, weldability, machinability, at the same time has moderate strength, after annealing can still maintain good operation, become the metallurgical industry commonly used metal materials\[2\]. 6061 aluminum alloy is mainly used for high-load parts and component materials, such as skeleton parts on aircraft, skin, space rocket storage box, etc.

As a kind of ductile material, the uniaxial stress-strain relationship of 6061 aluminum alloy is the basic physical relationship for structural analysis and engineering design by using continuum mechanics method, which plays a key role in the design and safety evaluation of engineering samples\[3\]. After necking occurs in the iso-straight specimens, the load gradually decreases\[4\], and the material element in the necking zone is in the strengthening stage of complex deformation. In this paper, the real stress-strain relationship after necking is obtained by traditional uniaxial tensile test, and the finite element model of 6061 aluminum alloy bar is established by using ABAQUS finite element software, whose style parameters are shown in Figure 1. The stress-strain relationship of ductile metal of 6061 alu-

## ESTABLISHMENT OF FINITE ELEMENT MODEL

ABAQUS finite element simulation software was used to draw bar material, and 6061 aluminum alloy material properties were introduced. The density was 2700 kg/m\(^3\), elastic modulus was 50 GPa and Poisson’s ratio was 0.33. The effective stress-strain relationship of 6061 aluminum alloy material should be input in the plastic section (Figure 2), and the value of flexible damage is shown in Table 2.

The three-dimensional model of uniaxial tensile simulation sample of 6061 aluminum alloy was established according to the sample size in Figure 1, as shown in Figure 3(a). C3D8R was used for the grid unit, and the global seed distribution and medial axis algorithm were used for grid division, as shown in Figure 3(b). A reference point RP-1 was established at the top end of the model and coupled with the top surface, as shown in Figure 3(c), to facilitate subsequent loading of boundary conditions. In order to simulate the stretching process, completely fixed boundary conditions were applied to one end of the model, and different constant stretching speeds were applied to the other end along
Table 2 Values of flexible damage

<table>
<thead>
<tr>
<th>Serial number</th>
<th>Fracture strain</th>
<th>Triaxial stress</th>
<th>Strain ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0.9</td>
</tr>
<tr>
<td>2</td>
<td>0.5</td>
<td>0.4</td>
<td>0.9</td>
</tr>
</tbody>
</table>

Figure 2 Stress-strain curve of 6061 aluminum alloy.

Figure 3 Construction process of tensile finite element model (a) three-dimensional sample model (b) mesh division (c) coupling setting (d) boundary condition setting.

Figure 6 Uniaxial tensile simulation of 15 s\(^{-1}\) Mises stress at normal temperature (a) when the specimen begins to draw (b) during the tensile process (c) when the specimen breaks.

SIMULATION PROCESS

In order to illustrate the simulation process and model effectiveness, the tensile speed of 10 s\(^{-1}\), 15 s\(^{-1}\) and 20 s\(^{-1}\) were selected as three working conditions to demonstrate and illustrate.

Figure 4 shows the Mises stress change in 10 s\(^{-1}\) uniaxial tensile simulation at normal temperature. From Figure 4(a), it can be seen that only the middle part and the fillet transition and the upper part of the sample are stressed at the beginning of tensile. The Mises stress at the upper and middle ends increased significantly when the Mises was stretched to the point of necking (Figure 4(b)). When the specimen was about to be broken (Figure 4(c)), the Mises stress region was mainly concentrated at the fracture and the upper end.

Figure 5 shows the comparison of true stress-strain curves between simulation and experimental uniaxial tensile tests in 15 s\(^{-1}\). The simulation curve is taken from one of the elements at the fracture. As can be seen from Figure 5, the two curves fit well, indicating that the established 10 s\(^{-1}\) uniaxial tensile simulation model can simulate the real tensile experiment well.

Figure 6 shows the change of Mises stress in the uniaxial tensile simulation of 15 s\(^{-1}\) at normal temperature. As can be seen from Figure 6(a), only the middle part of the sample is subjected to a large tensile force at the beginning of stretching, and the lower part of the middle part has the largest force. When the Mises stress in the middle part was increased significantly and the Mises stress in the upper part was increased when the elongation reached the threshold of necking (Figure 6(b)). When the specimen was about to break (Figure 6(c)), the Mises stress region was mainly concentrated in the middle part.

Figure 7 shows the comparison of true stress-strain curves between simulation and experimental uniaxial tensile tests in 15 s\(^{-1}\). The simulation curve is taken from one of the elements at the fracture. As can be seen from Figure 7, the simulation data is larger than the experimental data at the maximum stress, but in general the two curves are in good agreement, indicating that the...
established 15 s\(^{-1}\) uniaxial tensile simulation model can simulate the real tensile experiment well.

Figure 8 shows the Mises stress change under normal temperature in 20 s\(^{-1}\) uniaxial tensile simulation. As can be seen from Figure 8(a), at the beginning of tensile, almost only the middle and upper sections of the sample were stressed. The Mises stress at the upper and middle ends increased significantly when the Mises was stretched to the point of necking (Figure 8(b)). When the specimen was about to break (Figure 8(c)), the Mises stress was mainly concentrated in the fracture and the middle section.

Figure 9 shows the comparison between simulation and experimental stress-strain curves of uniaxial tensile in 20 s\(^{-1}\). The simulation curve is taken from one of the units at the fracture. As can be seen from Figure 9, the simulation data at the last and last sections are smaller than the experimental data, but generally the two curves are in good agreement, indicating that ABAQUS simulation has high accuracy in predicting fracture displacement and stress-strain, and the established model can be used to predict the tensile behavior of 6061 aluminum alloy.

CONCLUSION

Through the above experiment and simulation analysis, the following conclusions can be drawn:

1) Stress increases with the increase of tensile rate at room temperature;

2) Through the above experiments and simulation analysis, it can be concluded that the stress-strain curves simulated by ABAQUS are in good agreement, indicating that ABAQUS simulation has high accuracy in predicting fracture displacement and stress-strain, and the established model can be used to predict the tensile behavior of 6061 aluminum alloy.

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Note: The responsible translator for English language is H. C. Ji-North China University of Science and Technology, China