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Research on Coreless Neck Spinning Force of Tubular Parts based on Abaqus

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Abstract

Based on the commercial finite element analysis software Abaqus, the three-dimensional elastic-plastic finite element model of copper tube was established. The material mechanical properties of copper tube were obtained by tensile testing machine. The variation rule of the spinning pressure of the spinning wheel during the spinning process is analyzed and the relationship between the process parameters and the spinning pressure is studied.

Keywords

Copper Tube; Abaqus; Finite Element Method; Neck Spinning.

1. Introduction

TP2 is the abbreviation of phosphorus deoxidized copper, a kind of red copper with low oxygen content, good thermal conductivity, strong corrosion resistance, superior process performance and no hydrogen disease. TP2 copper tube necking parts are mainly used in air conditioning, refrigerator and other equipment, as the main heat exchange components, such as dryer, condenser, etc[1].

Common tube end reducing processes include stamping, impact and spinning. Metal plastic forming is a nonlinear process with high complexity. It is easy to produce instability, wrinkling, fracture and other defects in stamping and impact reducing process; Spinning necking has the advantages of high material utilization, high forming precision and wide processing range, which has a good application prospect [2].

In recent years, scholars have done a lot of research on tube spinning. Based on Abaqus, Liu Bin et al. [3] studied the forming law of double wheel stagger diameter reduction spinning of copper tube. Based on Abaqus, chi chen Huang et al. [4] studied the forming process of AISI 1020 steel tube high temperature reducing spinning. Xia Qinxiang et al. [5] studied the influence of process parameters on the forming of 1Cr18Ni9Ti stainless steel vessel based on spinning test. Based on the finite element simulation, Li Bo et al. [6] analyzed the influence of process parameters on the necking spinning forming of GH625 superalloy reducer. Based on Abaqus platform, Zhan Mei [7] and others studied the forming law of LF3 aluminum alloy bellows by neck spinning without mandrel.

Based on the commercial finite element analysis software Abaqus, a three-dimensional elastic-plastic finite element model of TP2 copper tube spinning without mandrel was established. The distribution of spinning force in the forming process was analyzed, and the influence of process parameters on spinning force was studied.

2. Forming programme

In the process of neck spinning, the forming scheme can be divided into single spinning wheel, double spinning wheel and three spinning wheels according to the number of spinning wheels. Due to the existence of radial spinning pressure, the symmetrical distribution of multiple spinning wheels can

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avoid the eccentricity caused by excessive radial force, which is conducive to improving the forming accuracy of the workpiece[8]. Usually two or three identical rollers are used. Considering the manufacturing and installation of the actual equipment, this paper adopts the forming scheme of symmetrical distribution of double rollers, as shown in Figure 1.

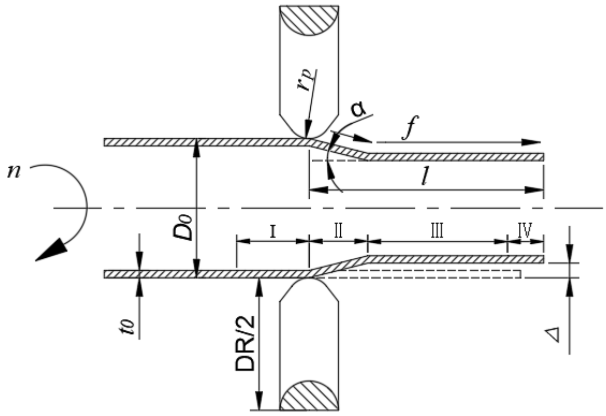

Figure 1. Schematic diagram of neck spinning for pipe-shaped parts

3. Material model

The stress-strain parameters of TP2 copper tube were obtained by tensile testing machine, and the real stress-strain curve was obtained by formula transformation, as shown in Figure 2. The density, elastic modulus and Poisson's ratio of TP2 copper tube are 8.94 g/mm^3, 115 GPa and 0.31 respectively.

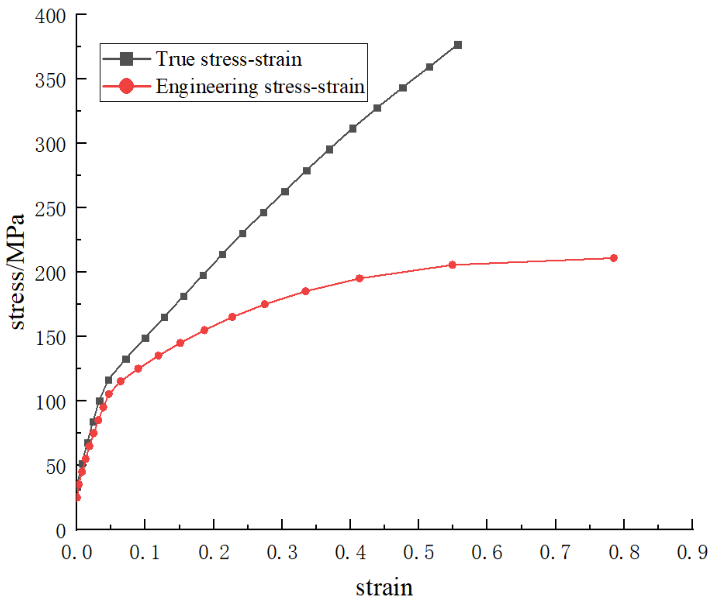

Figure 2. Stress-Strain curve of TP2 copper tube

4. Finite element model

Based on Abaqus/Explicit platform, the numerical analysis model of TP2 copper tube necking spinning is established, as shown in Figure 3. The tube blank part is a deformable body with an outer diameter of D_0=19mm, thickness t_0=1mm. The stiffness of the spinning wheel is large, and it is set as analytical rigid body type.

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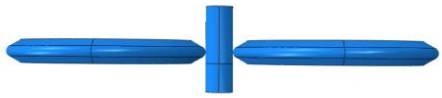

Figure 3. Finite element model of copper tube neck spinning

The shape of the tube blank is regular, and the hexahedral element of C3D8R is used for mesh generation [5]. As the main analysis area, I ~ IV area of tube blank is divided into fine mesh to ensure the accuracy, and the unit size is 0.8mm × 0.8mm × 33mm, the remaining part of the billet is divided into coarse grids, and the unit size is 4mm × 0.8mm × 33mm, as shown in Figure 4.

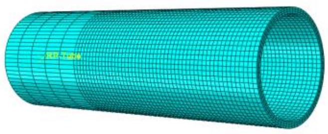

Figure 4. Finite element mesh generation

The Coulomb friction model is selected to define the contact properties, and the friction coefficient is μ= 0.1. In the finite element analysis, the influence of temperature on the forming process is not considered, and the material is assumed to be isotropic.

5. Model reliability verification

When the linear reduced integral element c3d8r is used in Abaqus/Explicit analysis, there are numerical problems of "Hourglass Model" and Quasi-Static analysis. In the "History Output" results, if the ratio of artificial strain energy (ALLAE) to internal energy (ALLIE) is stable within 5% - 10%, it can be considered that the hourglass control effect is good; If the ratio of kinematic energy (ALLKE) to internal energy (ALLIE) is stable within 5% -10%, it can be considered as quasi-static analysis [9].

In this paper, hourglass control selects "enhanced" control and the quality scaling factor is 25. The curves of pseudo strain energy, kinetic energy and internal energy with time are plotted as shown in FigURE 5. It can be seen that the ratio of kinematic energy to internal energy is gradually stabilized within 1%, and the ratio of artificial strain energy to internal energy is gradually stabilized within 5%. Both of them meet the requirements, which proves that the simulation results are highly reliable.

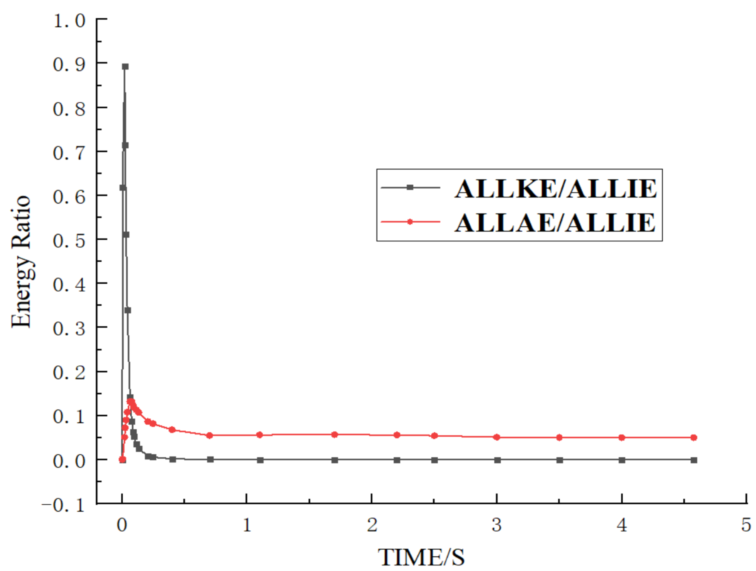

Figure 5. Reliability verification of finite element model

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6. Analysis of numerical simulation results

6.1 Analysis on the change of three-way spinning pressure

From the curve of the three directions spinning force of the roller in Figure 6, it can be seen that the numerical relationship of the three directions spinning force is: Radial spinning force Fr > Axial spinning force Fa > Tangential spinning force ft.

The II region is the initial stage of spinning, and the three directions spinning force is increasing steadily. This is because in the initial stage of spinning, the roller and the tube blank just began to contact, and more spinning force is needed to make the material of pipe blank enter the plastic strain stage.

After entering the III region, the axial spinning force continues to increase because of the accumulation of materials in front of the roller and the increase of the obstacles to the movement of the roller axial. Therefore, more axial spinning force is needed to push the stacking material to flow along the axial direction; The radial and tangential spinning force is stable at the beginning of III region, but with the continuous flow of tube blank materials along the axial and radial direction, the three directions spinning force is decreasing.

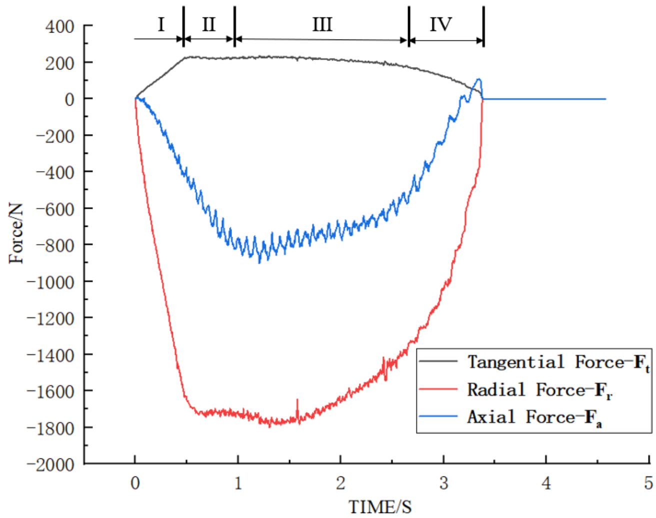

Figure 6. Time curve of three directions spinning force of roller

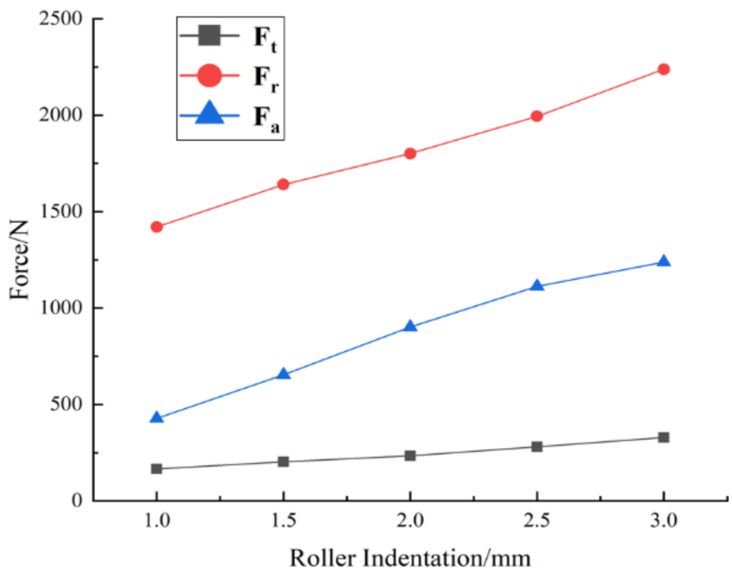

Figure 7. Effect of roller indentation on three directions spinning force

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6.2 Influence of roller indentation on spinning force

Figure 7 shows the curve of the influence of different amount of roller indentation on the three directions spinning force. It can be seen from the figure that with the increase of roller indentation, the three indentation spinning force Ft, Fr and Fa show an obvious increasing trend. The reason is that the radial and circumferential deformation increases with the increase of roller indentation, which makes Fr and Ft increase; According to the metal flow characteristics in spinning process, it can be known that the tube blank material will accumulate in front of the roller during the feeding process of the roller, and with the increase of the roller indentation, more material will accumulate in front of the roller, resulting in the increase of the axial force.

6.3 Influence of roller radius on the spinning pressure

Figure 8 shows the curve of the influence of the fillet radius on the three-way spinning force. It can be seen from the figure that with the increase of the fillet radius, the radial spinning force Fr increases, the circumferential spinning force Fa decreases, and the tangential spinning force ft basically does not change. The reason is that with the increase of the roller radius, the contact area between the roller and the tube blank increases, the plastic deformation material increases, and the radial forming force increases. With the increase of the roller radius, the material flow in all directions of the tube blank is favorable, and the material accumulation in front of the roller is reduced, which makes the axial force decrease.

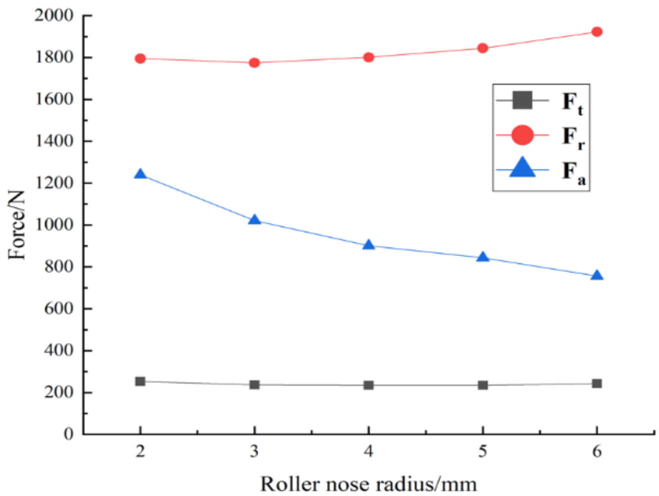

Figure 8. Effect of roller radius on three directions spinning force

6.4 Influence of feed rate on spinning force

Figure 9 shows the curve of the influence of the feed rate of the roller on the three directions spinning force. It can be seen from the figure that with the increase of the feed rate, the radial force Fr and the tangential force Ft show an increasing trend. This is because with the increase of the feed rate, the feed value of the roller increases when the tube blank rotates for one circle, and the tube blank material participating in the deformation increases, which makes the spinning force increase.

With the increase of feed rate, the axial spinning force Fa decreases first and then increases, and the increase of axial force occurs when the feed rate is 1.6 mm/r. This is because the plastic deformation of tube blank material is insufficient and the material accumulation in front of the roller decreases with the increase of feed rate.

When the feed rate is 1.6 mm/r, the axial force Fa increases because when the feed rate increases to a certain extent, the axial flow velocity is far greater than the radial flow velocity, and the accumulation of materials in front of the roller increases, resulting in the increase of axial spinning force Fa.

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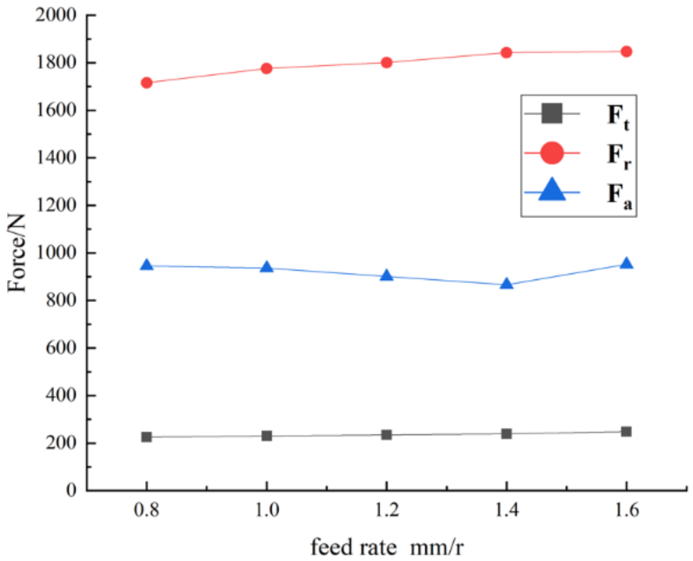

Figure 9. Effect of feed rate on three directions spinning force

6.5 Influence of roller diameter on spinning force

Figure 10 shows the curve of the influence of the diameter of the roller on the spinning force. It can be seen from the figure that the influence of the diameter of the roller on the three directions spinning force is very small. With the increase of the diameter of the roller, the radial force Fr and the axial force Fa are basically unchanged. Relatively speaking, the change of the tangential force Ft is slightly obvious, showing a decreasing trend. This is because with the increase of the diameter of the roller, the increase of contact length between the roller and the tube blank on the cross section, which is conducive to the tangential flow of the material and makes the tangential force Ft decrease.

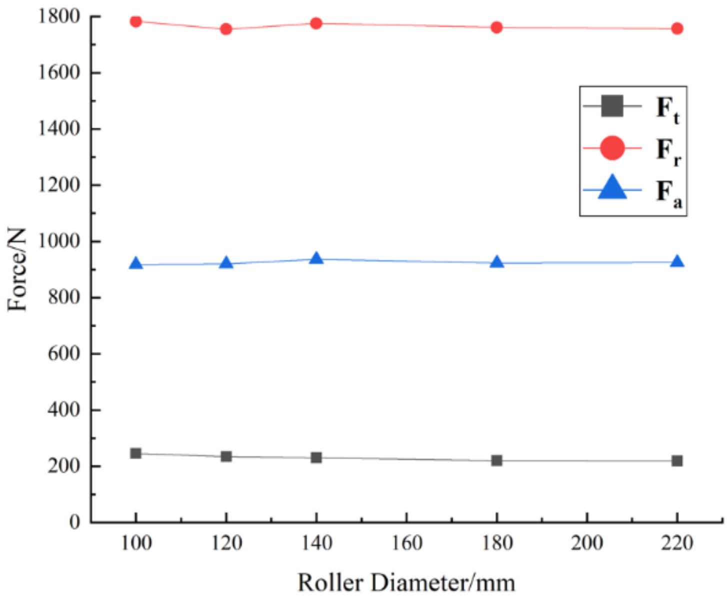

Figure 10. Effect of roller diameter on three directions spinning force

6.6 Influence of rotation speed on spinning force

Figure 11 shows the curve of the influence of rotation speed on the three directions spinning force. It can be seen from the figure that the three directions spinning force basically does not change with the change of rotation speed.

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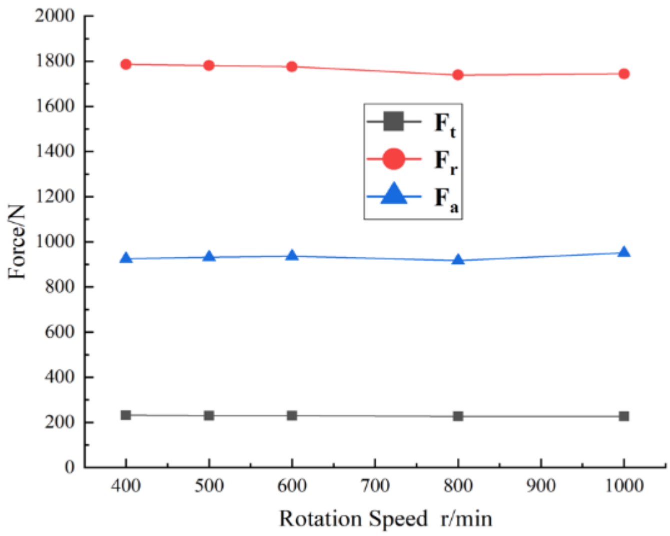

Figure 11. Effect of rotation speed on three directions spinning force

7. Conclusion

Based on Abaqus, a three-dimensional elastic-plastic finite element model of TP2 copper tube neck spinning without mandrel was established. The change trend of three directions spinning force was analyzed, and the relationship between process parameters and spinning force was determined. The following conclusions are drawn:

(1) In the initial stage of spinning, in order to make more tube blank plastic deformation, the three directions spinning force shows a stable growth trend. In the front of section III, the axial spinning force Fa increases continuously due to the accumulation. With the continuous flow of the material, the three directions spinning force decreases.

(2) From the curve of three directions spinning force with time, we can see the relationship between three directions spinning force: radial force Fr > axial force Fa > tangential force Ft;

(3) Relatively speaking, the feed rate, roller radius and roller indentation have a greater impact on the three directions spinning force, and the roller indentation has the greatest impact, while the rotation speed and roller diameter have less impact on the three directions spinning force.

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