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RESEARCH ON METAL REFLOW LAW OF THREE ROLL SKEW ROLLING (TRSR) HOLLOW AXLE

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In the process of TRSR hollow axle, there is metal reflow on the surface of the rolled piece, which greatly reduces the forming accuracy of the rolled piece. To solve this problem, it is necessary to study the metal reflow law of axle body. First, the flow law of metal on the surface of rolled piece is obtained by point tracking method. Moreover, the effects of process parameters on the metal reflow degree of axle body are carried out, and the influence law of process parameters on the metal reflow degree of axle body is obtained. Finally, by comparing the results of the experiment and the simulation, the reliability of the simulation is proved.

Keywords: LZ50 steel, TRSR, hollow axle, metal reflow, process parameters

INTRODUCTION

TRSR is an advanced technology in the production of shaft parts. It has the advantages of small rolling force, strong university of die, low equipment cost and so on. Scholars at home and abroad have done a lot of research on TRSR axle. Pater [1] proposed to use TRSR technology to produce axle, and determined the rolling process parameters through finite element simulation. Then a TRSR mill is designed and completed, and the feasibility of TRSR axle is verified by experiments. By carrying out rolling experiment, Pater [2] found that TRSR technology has some defects. The influence of these defects on product quality is determined by experiment and numerical analysis. Zhang [3] obtained the forming mechanism and control method of spiral mark defect of TRSR axle. Wang [4] determined the best process parameters to control the uniformity of microstructure through orthogonal test, and then obtained the evolution law of microstructure.

In addition to the above macro and micro quality research, the research on metal reflow defects is missing. The metal reflow in the rolling process will greatly reduce the forming accuracy of the rolled piece and lead to the waste of materials. Therefore, this paper will carry out the research on metal reflow.

PRINCIPLE OF TRSR HOLLOW AXLE

The working principle of the TRSR hollow axle is shown in the Figure 1. The first is the structure, three identical rollers are equally spaced along the circumference of the rolled piece, and the roller axis is inclined by 5 ° relative to the blank axis, which is also called the feed angle. The second is motion, mode: 1. The three rollers rotate in the same direction and drive the rolled piece to rotate in the opposite direction, mode 2. The three rollers move synchronously in radial direction to drive the rolled piece to compress radially, mode 3. The fixture drives the rolled piece to move in the axial direction, which drives the rolled piece to extend in the axial direction.

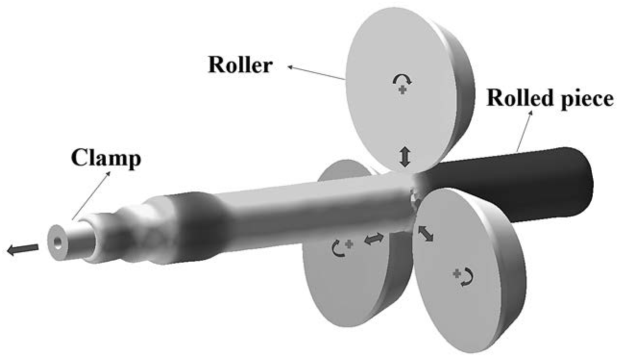

Figure 1 Principle of TRSR hollow axle

ESTABLISHMENT OF FINITE ELEMENT MODEL

To explore the metal reflow law of the rolled piece, the simulation model of TRSR hollow axle was established. In the process of TRSR hollow axle, the following parameters were set. The feed angle α (angle between roller axis and blank axis) is 5 °. The roller rotation speed n is 60 rpm. The axial velocity v of the fixture is 20 mm/s. The friction coefficient μ between roller and blank is 0,9. The rolling temperature T is 1 150 °C. The forming angle β (cone angle of the roller) is 20 °. The length L of roller forming zone is 12 mm. The roller diameter D is 150 mm. In addition, the diameter of rolled piece is shown in Figure 2.

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The material of the blank is LZ50 steel, and its constitutive relationship is as follows [5]:

$$\dot{\varepsilon} = 1{,}34 \times 10^{18} \left[\sinh\left(8{,}198 \times 10^{-3} \sigma\right)\right]^{8{,}1434} \times$$

$$\times \exp\left(-\frac{4{,}6334 \times 10^{5}}{RT}\right) \quad (1)$$

In the formula:

Where $\dot{\varepsilon}$ is the strain rate /s^{-1}; σ_p is the peak stress; R is the gas constant with a value of 8,314 J·mol^{-1}·K^{-1}, and T is the temperature /K;

ANALYSIS AND DISCUSSION ON METAL FLOW LAW OF AXLE BODY

Before the start of simulation, 18 feature points are selected radially in the middle of the blank for point tracking. The metal reflow of axle body is divided into four stages. as shown in Figure 2. In addition, the dimension of rolled piece is shown in Figure 3.

The first stage in shown in Figure 2-1, when the roller is far away from the tracking point, the tracking point position is basically remains unchanged and are distributed in a straight line along the radial direction.

The second stage is shown in Figure 2-2, as the rolling progresses, the position of the tracking point changes as the roller begins to shape tracking point area, and the straight line formed by the tracking point begins to tilt slightly clockwise. This is because when the rollers are pressed down in the radial direction, the metal on the surface of the rolled piece flows faster than the metal at the core, resulting in a larger axial displacement of the metal on the surface of the rolled piece than the metal on the core.

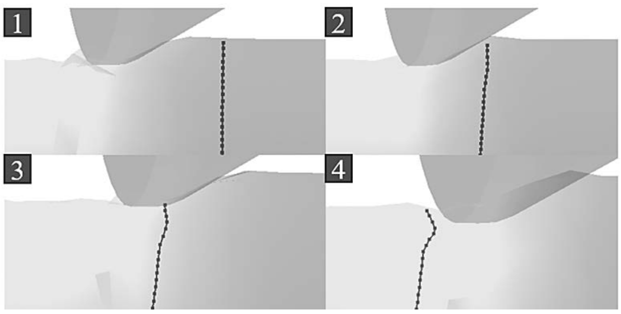

Figure 2 Metal flow law in axle body

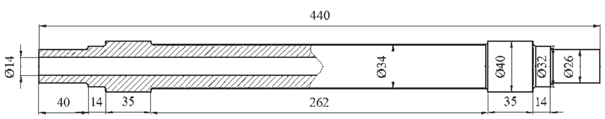

Figure 3 Dimension of rolled piece

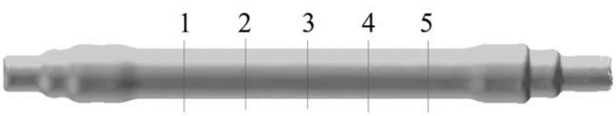

Figure 4 Research location of axle body

The third stage is shown in Figure 2-3, when the roller appears just above the tracking point, the metal at the contact area between the roller and the workpiece begins to flow back. The reason is that the feed angle and rotation direction of the roller will bring a reverse force to the metal on the surface of the rolled piece, which will cause the metal reflow.

The fourth stage is shown in Figure 2-4, with the progress of rolling, the metal reflow phenomenon continues until the roller moves away. The reflow phenomenon will greatly reduce the accuracy of the rolled piece.

EFFECT OF PROCESS PARAMETERS ON THE DIAMETER OF AXLE BODY

As shown in Figure 4, five equidistant positions are taken in the axle body for research. Use the diameter measurement function of the software to measure the diameter of the axle body, and finally calculate the average value of the five positions.

It can be seen from the Figure 5 that with the increase of rotation speed of roller, the diameter of axle body is also increasing. The reason is that the increase of roller rotation speed will accelerate the reflow speed of metal on the surface of rolled piece, resulting in the reduction of rolled piece accuracy.

It can be seen from the Figure 6 that as the rolling temperature increases, the diameter of axle body is also increasing. The reason is that the softening of the rolled

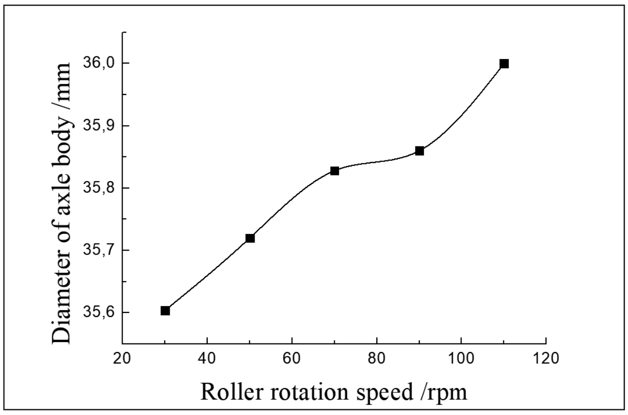

Figure 5 Influence of rotation speed of roller on axle body diameter

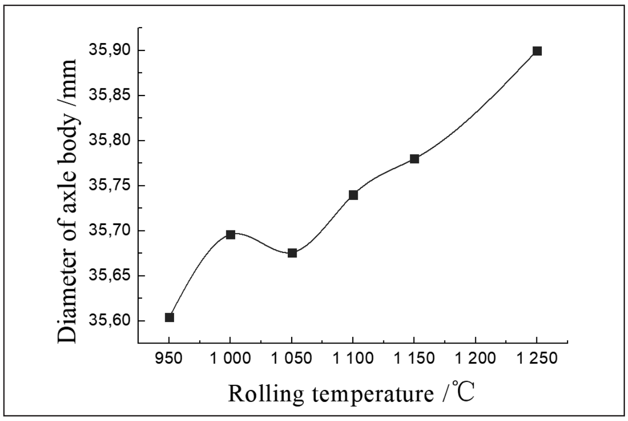

Figure 6 Influence of rolling temperature on axle body diameter

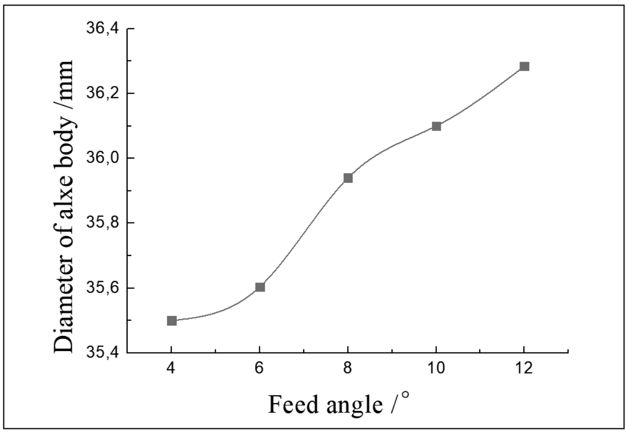

Figure 7 Influence of feed angle on axle body diameter

metal will aggravate the flowability of the metal and cause more serious reflow.

As shown in the Figure 7, as the feed angle increases, the diameter of the axle body is also increasing. The reason is that when the feed angle increases, more axial force will be distributed to the rolled piece, which will cause more serious metal reflow in the axial direction.

EXPERIMENT VERIFICATION

The experiment of TRSR hollow axle was completed at the Lublin University of Technology in Poland. Figure 8 shows the dimensional measurement of the axle body of the rolled piece.

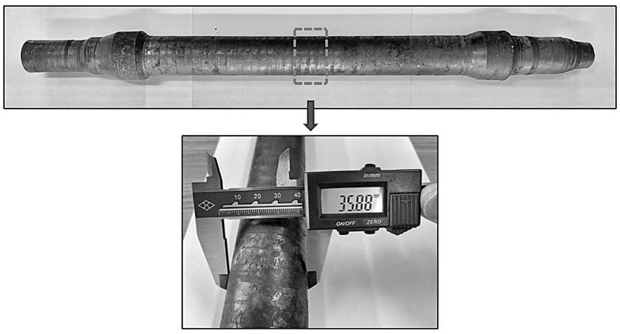

Figure 8 Dimension measurement of experiment workpiece

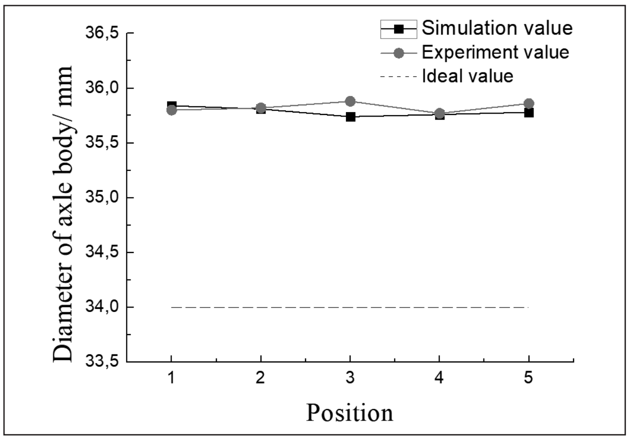

Figure 9 Comparison between test results and simulation results

As can be seen from Figure 9, by comparing the result of experiment and simulation, it is found that the difference between the two results is very small, which proves the reliability of the simulation results. However, both diameters are about 2 mm larger than the ideal value. Through the above research, it is proved that this phenomenon is caused by metal reflow.

CONCLUSION

1) Through point tracking, it is found that when the roller rolls a certain area, the metal will flow reversely and reduce the forming accuracy.
2) The increase of rolling temperature, feed angle and roller rotation speed will aggravate the metal reflow, and the three basically have a linear relationship with the degree of metal reflow.
3) By comparing the experiment and simulation results, it is found that the difference between the two results is very small, which proves the reliability of the simulation. However, both are about 2 mm larger than the ideal value, indicating that the reflow of metal will greatly reduce the accuracy of forming. The next work can consider improving the process parameters or repeated rolling to improve the forming accuracy of the rolled piece.

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Note: The responsible translator for the English language is J.T. Wang, Ningbo, China