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Research on Simulation and Experiment of Spinning Process of Ta-10W Liner

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Abstract. This paper mainly simulates the spinning process of tantalum tungsten alloy liner parts, simulates the spinning process with finite element analysis software, and obtains the stress and strain program in the spinning process. With the wall thickness difference of the spun parts as the analysis target, the influence law of the feed ratio, radius, and working angle of the spinning wheel on the wall thickness difference is obtained. The spinning experiment is conducted with the process parameters obtained from the simulation, and the experimental results are in good agreement with the simulation results, which shows that the method and means of simulation can guide the actual spinning process.

Keywords: Spinning; Finite element analysis; Wall thickness difference

1. Introduction

1.1 Research Background

At present, although there are other advanced processes, due to various reasons, such as immature technology, complex process conditions, high cost, and other problems, especially in the processing of large complex thin-walled shells, the disadvantages are very obvious, so the spinning process using traditional technology is the most suitable. The penetration performance of the spinning process on the drug type cover has been improved, which is of great help to improve China's military strength.

Due to the different process methods used in spinning forming due to the different materials and shapes required by the finished product, Li et al. [1] mainly analyzed the hemispherical shape and obtained the influence of spinning parameters on the wall thickness of the workpiece. Ma et al. [2] established a general rotational finite element model consistent with the actual situation, mainly to study the influence of the key parameters of spinning on the forming status of the first pass. Quigley and Monaghan [3] explored the meshing of workpieces, mainly analyzing the accuracy and efficiency of simulation calculation. Liu and Yang [4] summarized the multi-pass general spinning technology, indicating the complexity and diversity of spinning process trajectories. He and Cheng [5] mainly analyzed the influence of various influencing parameters of spinning on the accuracy of spinning forming. Song [6] mainly put

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forward suggestions on how to plan the multi-pass spinning trajectory and study the influence of different process parameters on the accuracy of the finished product. Chen [7] simplified the boundary loading conditions, established the corresponding elastoplastic numerical model, and studied the influence of the spinning process on forming quality to obtain high-precision thin-walled finished products. Han et al. [8] improved the establishment of the numerical model of the finite element model of internal spinning of cylindrical parts, the control of contact conditions and boundary conditions, and the calculation efficiency, and studied the flow stress of spinning material in cylindrical parts and the causes of cracks in the spinning process. Music et al. [9] summarized the current research status of multiple curve combination trajectories and suggested a trajectory form similar to involutes. Kang et al. [10] found that the first spinning during the general rotation process plays a decisive role in the final overall wall thickness change. Lin [11] studied the influence of different pass distribution methods on the final multi-pass spinning forming. In this paper, the corresponding results are obtained from the simulation and experiment of the general spinning process, tailless top, and synchronous fixture mode, and the change law of spinning forming is obtained through result analysis, to provide help for subsequent experiments.

1.2 Purpose of the Study

Thin-walled curvilinear generatrix parts single-pass spinning forming process, due to its core mold shape and workpiece forming curve restrictions, cannot use the tail top mode for spinning process, can only use the synchronous rotary fixture for circumferential fixing and fixed pin for axial workpiece clamping, but during the spinning process, due to the fixed pin clamping effect affected by the spinning vibration and deterioration, resulting in the workpiece forming accuracy is affected, the forming process is very easy to appear instability and other phenomena, forming quality is difficult to guarantee.

The synchronous rotary fixture and fixed tightening pin clamping method adopted in this paper studies the mapping relationship between various process parameters and environmental parameters on the forming accuracy of the workpiece through simulation experiments, explores the workpiece rebound effect caused by the disappearance of the spinning pressure of the bow and arrow after the spinning of the formed workpiece, selects the optimal solution of the parameter through the simulation results for practical experiments, and compares and analyzes the results of the two to verify the correctness of the simulation model and play the role of guidance.

2. Simulation Model Building

2.1 Selection of Materials

The choice of material for the drug-shaped cover is mainly related to the penetration ability of the formed metal jet or explosive-forming projectile, and the material selection of the drug-shaped cover has undergone a variety of changes since World War II, as shown in Table 1. After research, the penetration performance is inseparable from the sound velocity, density, and plasticity of the material, and the square root of the ratio between the total penetration depth and the jet density and the density of the target material is directly proportional, so the higher the material density of the drug-shaped hood, the deeper the penetration depth.

Table 1. Table of the evolution of drug-shaped hood materials.

Material	Density (g/cm^3)	Velocity (km/s)	Advantages
Cu	8.9	4.7	
W	19.25	5.2	Increased penetration
Mo	10.2		30% increase in penetration
Ni			15% faster
Al		5.32	Wide range
Ta	16.654		55% increase in penetration
U	19.1		Good armor piercing
Ni			The penetration far exceeds that of Cu
Ta-W	**16.930**	**4.7**	**Good penetration effect**

This experiment uses Ta-W alloy with the best penetration effect and the smallest environmental pollution for the spinning experiment, as shown in Figure 1, because its penetration ability far exceeds that of copper materials commonly used in China. However, since Ta-W alloy is a refractory material, the cost of billet preparation is too high compared with other materials. Besides, the spinning forming process is more difficult, due to its poor plasticity ability.

Figure 1. Schematic diagram of the blank

2.2 *Selection of Spinning Parameters*

The spinning experimental parameters include spinning process environmental parameters, a spinning wheel and a core die gap, and a lubrication method. The process parameters used in this experiment include the radius of the spinning wheel corner, the installation angle of the rotating wheel, the feed ratio of the rotating wheel and the temperature of the spinning parts. The plasticity of the billet changes significantly at -50 °C, so the temperature influence is included in the parameter selection, and the corresponding experiments are carried out in turn. The specific content is shown in Table 2. In addition, the gap between the rotary wheel and the core mold is set to fixed gap mode, the spinning method adopts the cold rotary double rotary wheel mode, and the lubrication method adopts the oil lubrication mode.

Table 2. Experimental Scheme design

	Corner radius (mm)	Mounting corner (°)	Feed ratio (r/mm)	Temperature (°C)
Scheme 1	R3	45	0.5	25
Scheme 2	**R3**	**45**	**0.5**	**--50**

2.3 Spinning Assembly

In this experiment, a double rotary wheel spinning structure is used, and the molds used are a double rotary wheel, synchronous fixture, mandrel, and a fixed pin**.** In the process of spinning forming, the temperature of the core mold, the rotating wheel, the tail top, and the synchronous rotary fixture is set to 25 °C at room temperature, and the initial temperature of the blank is set at 25 °C. The contact conditions include contact and bonding. The rotation of the rotary wheel belongs to passive rotation. Driven by friction, the direction of rotation is opposite to the direction of the rotation of the embryo. The contact condition can only be contacted. There must be a gap in the spinning process of the core mold and the embryo. To be consistent with the actual situation, the contact condition must also be set as a contact, and the assembly drawing is shown in Figure 2.

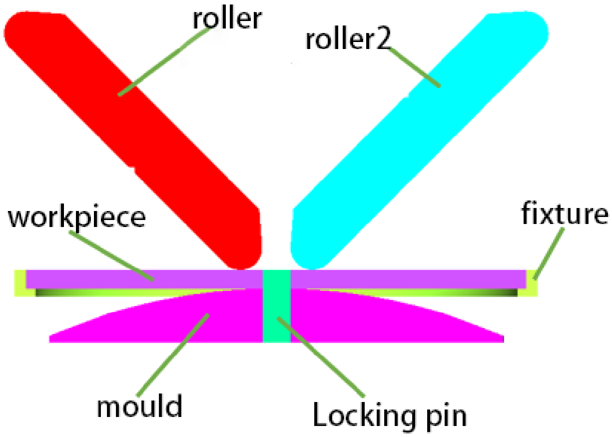

Figure 2. Schematic diagram of spinning assembly

2.4 Simulation Results

The analysis figures of the finite element simulation results (wall thickness) of Scheme 1 and Scheme 2 are shown in the figure below. The wall thickness distribution along the radial distribution is obtained by extracting the nodes on the symmetry plane. The minimum wall thickness at 25° and -50° in Figure 3 is 3.946 mm and 3.966 mm, respectively, and the corresponding maximum thinning rates are 5.7% and 6.0%, respectively. It can be seen that the overall wall thickness thinning rate is low at -50 °C, and the wall thickness thinning rate is improved at low temperatures.

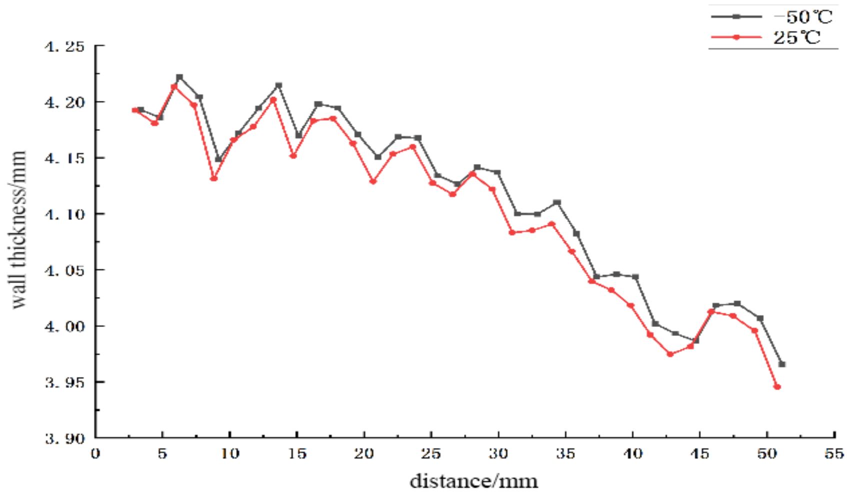

Figure 3. Wall thickness distribution diagram

3. Experimental Conclusions

The billet spinning was carried out under the above experimental conditions, and the formed workpiece was finally obtained, and the forming result of scheme 1 is shown in Figure 4. It can be seen from the figure that the shape of the workpiece is formed, but the surface of the workpiece has a peeling phenomenon, and the peeling phenomenon is serious, resulting in poor surface roughness of the workpiece. The wall thickness distribution of spinning parts was measured, and the wall thickness results and simulation results are shown in Table 3.

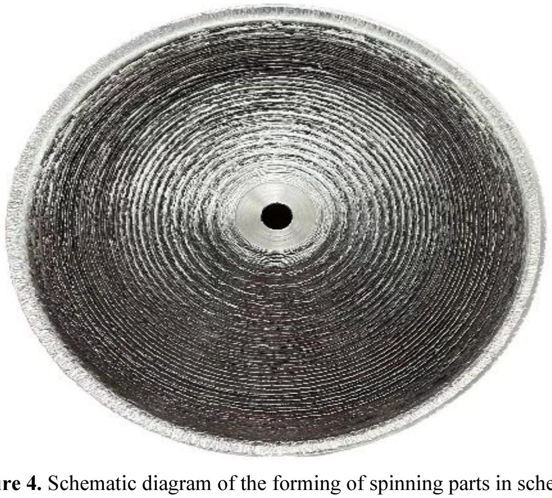

Figure 4. Schematic diagram of the forming of spinning parts in scheme 1

According to the wall thickness distribution in the table, the wall thickness distribution of the two busbars is not much different, which ensures the uniformity of the wall thickness of the spinning parts, but the wall thickness value of the spinning parts thickens. The main reason for its formation is that the surface quality of the spinning parts is too poor, and the peeling phenomenon is serious resulting in deviations in the measurement process. The height of the spinner parts is 13.1 mm, which meets the experimental requirements (13.1 mm). The above results show that the height of the spinner parts meets the requirements in the case of scheme 1, but the wall thickness results of the spinning parts are seriously biased and the accuracy is poor.

Table 3. Scheme 1: Wall thickness distribution of spinning parts

Experimental value (mm)		**Emulation values (mm)**	
Generatrix A	Generatrix B	Generatrix A	Generatrix B
4.3	4.32	4.22	4.21
4.41	4.42	4.18	4.17
4.36	4.42	4.18	4.18
4.38	4.41	4.16	4.15
4.45	4.42	4.15	4.12
4.43	4.45	4.10	4.10
4.08	4.12	4.00	3.99
3.98	**3.95**	**4.02**	**4.01**

It is found that the plastic deformation of the workpiece material is easily affected by the temperature, and the material flow capacity is improved as the temperature decreases. Therefore, the workpiece is treated at a low temperature by Scheme 2, where the workpiece is frozen to -50 °C and kept warm for half an hour, and then the spinning experiment is carried out. The actual spinning parts obtained are shown in Figure 5. The wall thickness distribution of spinning parts is shown in Table 4. The maximum deviation between the experimental value of the wall thickness of the spinning parts and the simulation value is 0.2 mm, and the uniformity of the overall wall thickness value of the spinning parts is good, indicating that the experimental and simulation results are in high agreement. The accuracy of the simulation is also verified. The height of the spinning parts is 13.1 mm. The above results show that the workpiece obtained by Scheme 2 spinning is the best quality and more in line with the requirements of the experimental results.

Figure 5. Schematic diagram of the spinning part of Scheme 2

Table 4. Scheme 2: Wall thickness distribution of spinning parts

Experimental value (mm)		**Emulation values (mm)**	
Generatrix A	Generatrix B	Generatrix A	Generatrix B
4.26	4.28	4.22	4.21
4.3	4.32	4.19	4.18
4.35	4.3	4.18	4.18
4.28	4.27	4.16	4.15
4.20	4.18	4.13	4.14
4.24	4.22	4.09	4.11
4.08	4.12	4.02	3.99
3.98	**3.95**	**4.00**	**4.01**

Based on the above, multiple sets of experiments were conducted, and the experimental results are shown in Figure 6. The results show that the surface quality of the workpiece at - 50 ℃ is better than that at normal temperature, which proves that using low-temperature means can greatly improve the molding and accuracy of the workpiece.

(a) Workpiece at 25 ℃ (b) Workpiece at -50 ℃

Figure 6. Experimental result

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