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SIMULATION AND FORMING MECHANISM ANALYSIS OF MULTI-PASS SPINNING PROCESS OF DEEP CYLINDER PARTS

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In this paper, the forming mechanism of 3103 aluminum alloy forming deep cylinder part under ten passes spinning is studied. The forming process of each step is simulated by finite element method. The distribution characteristics of equivalent stress field and strain field in forming were analyzed in detail. The influence of feed ratio on spinning force is obtained. By measuring the thickness and circularity of the final forming deep cylinder part, the final forming effect of multi-pass spinning is obtained.

Key words: 3103 aluminum alloy, deep cylinder part, forming mechanism, spinning force, forming quality

INTRODUCTION

Spinning, as a kind of plastic processing technology, integrates the characteristics of extrusion, deep drawing, bending, ring-lashing, cross rolling and rolling [1]. It can easily produce a variety of symmetrical seamless rotating body parts. Therefore, there is a wide range of demand in many industries.

The manufacture of deep cylinder parts generally adopts multi-pass spinning technology. Li et al. [2] studied the influence of drawing and spinning process parameters on workpiece wall thickness, outer diameter and forming performance through experiments. Wang et al. [3] analyzed the influence of process parameters such as pass thinning rate, feed ratio, forming angle of spinning roller and fillet radius of inner spinning roller on roundness, straightness and wall thickness difference of thin-wall cylindrical spinning parts by using finite element method. Du et al. [4] obtained the influence law of the spinning roller feed ratio, the spinning roller fillet radius and the relative clearance value between the spinning roller and the core die on the uniformity, straightness and roundness of the wall thickness distribution of the spinning parts. Zeng et al. [5] found that the most uniform wall thickness of the spinning parts was obtained when convex and concave arcs were used to feed back and forth to the spinning roller track without pass sticking die propulsion.

On the basis of the above research, the stress and strain changes and the final forming quality of deep cylinder parts are studied in this paper.

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FE OF DEEP CYLINDER PARTS SPINNING

In this paper, 3103 aluminum alloy is used for spinning simulation. Figure 1 shows the cylindrical part formed by the target. The wall thickness of the bottom part is 3,5 mm, and the wall thickness of the straight cylinder part is 1,8 mm. Multi-pass spinning forming is carried out by spinning deep drawing. The 3 d model is shown in Figure 2. The blank rotates with the core die under the pressure of the top block, and the spinning roller moves along the preset path and passively rotates around its own axis. The blank is gradually formed under the pressure of the spinning roller while rotating.

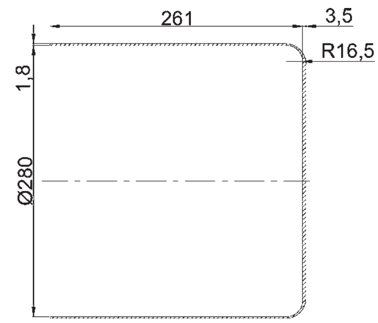


Figure 1 Target part drawing

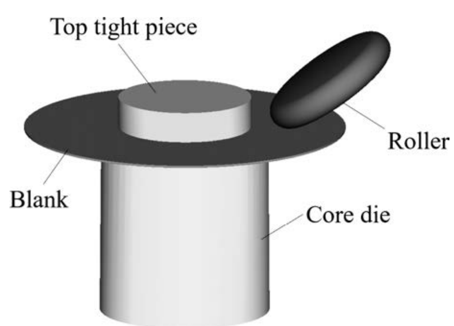
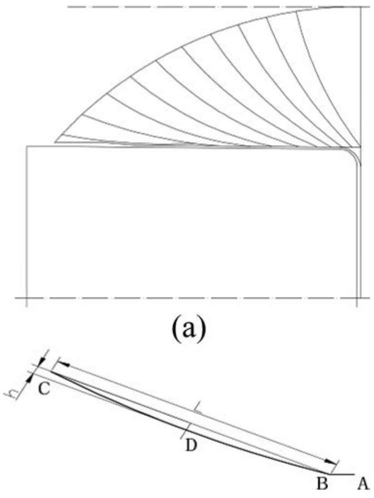


Figure 2 Simplified model of spinning processing



(a)

(b)

Figure 3 Track of movement of spinning roller

Table 1 **Main spinning parameter setting**

Friction coefficient	0,1
Installation angle of spinning roller / °	35 °
Corner radius of spinning roller / mm	12
Feed ratio / mm s^{-1}	1,6

In terms of spinning path setting, the arc line in the concave curve is used to design the spinning wheel track in Figure 3 (a). The single track is divided into two sections, as shown in Figure 3 (b). The *AB* bonding section makes the blank form a cylindrical shape, and the *BDC* feeding section promotes the flow of aluminum alloy material to produce a deep drawing effect. The arc *BDC* segment can be determined by connecting the line *BC* as the central perpendicular line, and taking point *D* on the central perpendicular line to form the arc *BCD*, and generally $H = 0{,}04\ L$ to $0{,}05\ L$ [6]. See Table 1 for Settings of other parameters.

ANALYSIS OF MULTI - PASS SPINNING PROCESS

After ten passes of spinning, the equivalent stress distribution of each pass is shown in Figure 4. The equivalent stress at the end of each pass is distributed uniformly along the axial direction. And the maximum is located at the position where the spinning roller contacts with the workpiece along the spinning path. Through comparative analysis, it can be seen that the equivalent stress of the workpiece in the clamping section tends to be stable after the spinning roller is pressed down with the continuous progression of passes. The closer to the tail of the spinning path, the greater the equivalent stress is.

The maximum value of equivalent stress on the workpiece surface at the end of each pass was plotted in Figure 5. It can be seen that the value increases first, then decreases and then increases with the passing. At

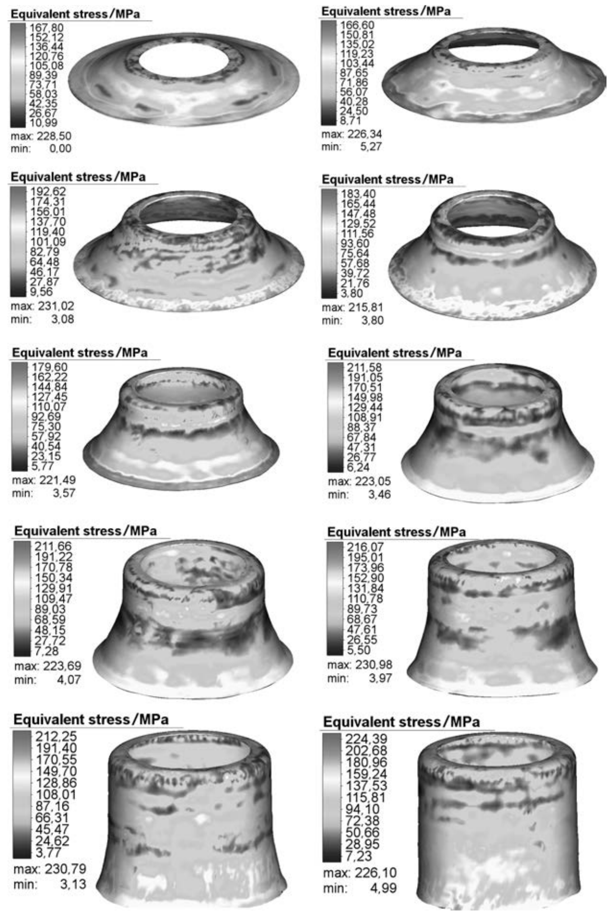


Figure 4 Equivalent stress of workpiece in each pass

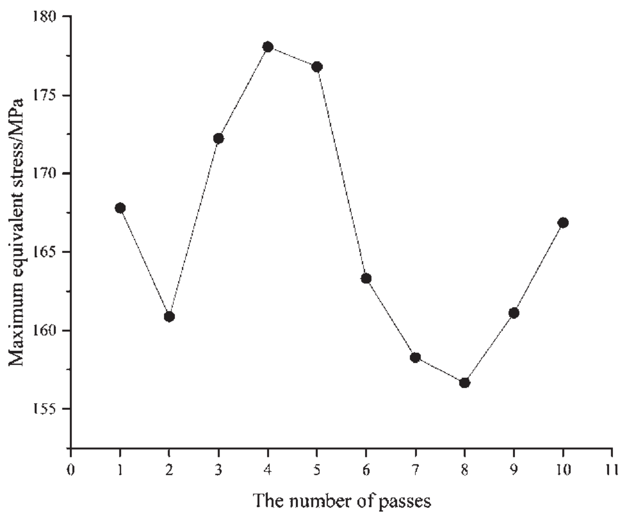


Figure 5 Equivalent stress changes at each pass

the fourth pass, the equivalent stress value of the workpiece surface reaches the maximum, then decreases successively, and begins to increase again after the eighth pass. This phenomenon is related to the path setting of the spinning roller. The spinning of the stick mold section will increase the surface stress of the workpiece, and the longer the path setting of the section, the farther away the workpiece tail from the core mold, the greater the surface stress.

After ten passes of spinning, the equivalent plastic strain of each pass is shown in Figure 6. When the spin-

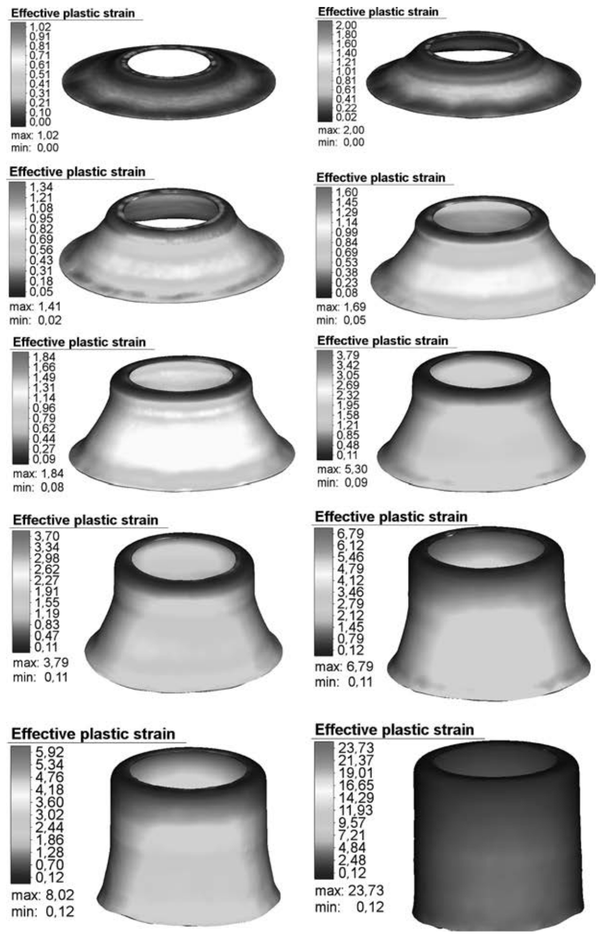


Figure 6 Effective plastic strain of workpiece in each pass

ning roller makes the feed movement, the blank in the die section is crushed. The material in contact with the roller flows to the edge of the blank along with the feeding direction of the roller, resulting in the increase of the equivalent plastic strain of the sticking section and the thinning trend of the rolled part. In addition, with the passing progress, the blank is pushed forward and begins to form a cylindrical shape, and the plastic strain is large at the position of the die sticking section through the spinning roller path.

By comparing the maximum value of the equivalent plastic strain on the workpiece surface between passes, it can be seen that the equivalent plastic strain shows a trend of increasing with the progress of passes, but the increasing trend becomes slow between the third and fourth passes, and then restores the previous increasing trend after the fifth pass, as shown in Figure 7.

In the multi-pass spinning process, the equivalent stress reaches the maximum at the fourth pass. Therefore, this passage is the one most prone to defects in actual production. Through analysis, it is found that the reason for this situation is that the spinning pressure reaches the maximum in the spinning process of this pass, as shown in Figure 8. Among them, the radial spinning component is the largest, and the fluctuation is also the largest, especially in the spinning process of the die section rises to the peak. The circumferential and axial spinning forces are relatively small and stable.

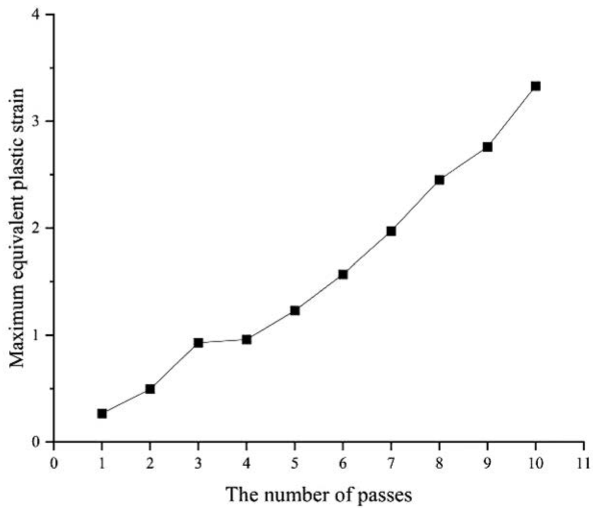


Figure 7 Effective plastic strain changes at each pass

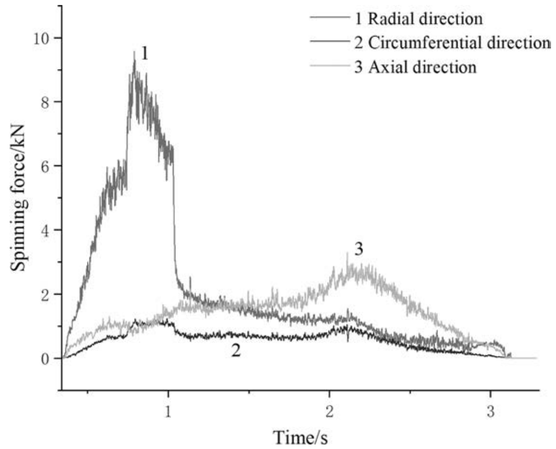


Figure 8 Spinning force of the fourth pass

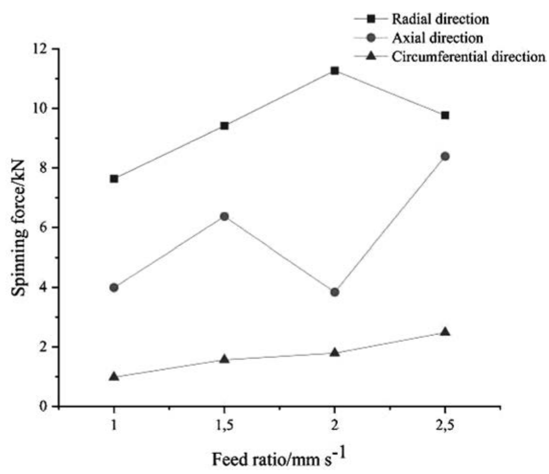


Figure 9 Effect of feed ratio on spinning force

The spindle speed is set as 400 rpm, and different feed ratios of 1 mm/s, 1,5 mm/s, 2 mm/s and 2,5 mm/s are adopted. The final rotary pressure obtained is shown in Figure 9. It can be seen that the circumferential rotational pressure increases with the increase of the feed ratio, because the contact time between the spinning roller and the workpiece surface decreases with the increase of the feed ratio. The axial rotational pressure decreases when the feed ratio is 2 mm/s, while the radial rotational pressure reaches the maximum when the feed ratio is 2 mm/s.

ANALYSIS OF FORMING QUALITY OF DEEP CYLINDER PARTS

The thickness distribution of the finally formed deep cylinder part is shown in Figure 10. Take 18 sections evenly from the top of the cylinder to measure the thickness. It can be seen that the thickness shows a trend of decreasing first and then increasing. At the bottom of the mouth, due to metal flow accumulation, the thickness is greater than the initial blank thickness, which plays a spinning thickening effect and makes the mouth more solid. The circularity of the deep cylinder part is shown in Figure 11. Nine sections are uniformly taken from the top down to show that circularity keeps increasing. The top is better due to multiple spinning forming and good circularity, while the bottom is higher due to metal flow accumulation.

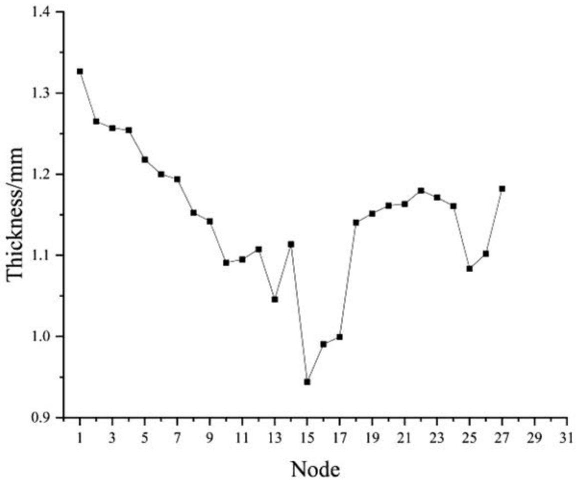


Figure 10 The thickness of the workpiece

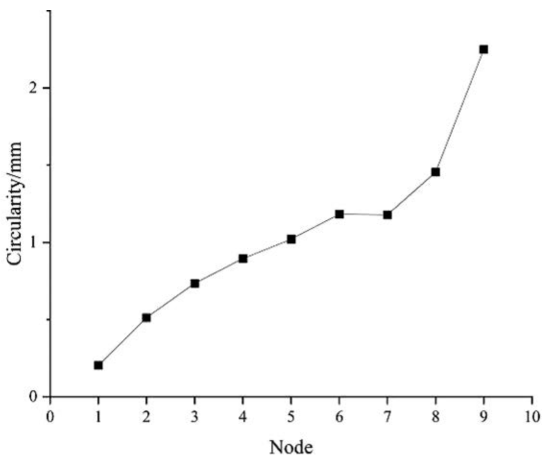


Figure 11 The circularity of the workpiece

CONCLUSIONS

In the process of multi-pass spinning, the workpiece surface stress reaches the maximum after the initial die attaching and spinning passes. In the same order, the smaller the feed ratio, the smaller the spin force, the more stable the spin. In actual production, the feed ratio of intermediate passes can be appropriately reduced to make spinning more stable.

The thickness of the deep cylinder part is thin in the middle and thick at both ends after multi-pass spinning. The thickness and circularity at the opening part reach the maximum, and the circularity at the bottom is the minimum.

Acknowledgments

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REFERENCES

[1] Yin Z.W., Zhang X.H., Zhou X.J., Chen Y.L., Han D.F., The spinning process of large-scale thin-walled aluminum alloy hemisphere shell [J]. Materials Science & Technology 21(2013)4, 127-130.

[2] Li X.M., Xiao S.H., Experimental research on one-step drawing and spinning of thin-walled cup [J], Die & Mould Industry 40(2014)10, 46-50.

[3] Wang D.L., Guo Y.M., Li Y.N., Huang T., Gao W.L., Zheng H.W., Xu H.Q., Numerical simulation and forming precision analysis on counter-roller spinning for large thin-walled cylindrical parts [J], Forging & Stamping Technology 45(2020)3, 47-55.

[4] Du F., Xia Q.X., Xiao H., Shi L., Analysis on forming quality of high strength steel DP600 cup-shaped part [J], Forging & Stamping Technology 42(2017)1, 54-59.

[5] Zeng C., Zhang S.J., Xia Q.X., Xie H.X., Research on effect of roller-races and process parameters on multi-pass drawing spinning quality [J], Forging & Stamping Technology 39(2014)1, 58-63.

[6] Han Z.R., Li L., Xiao Y., Jia Z., Effect of feed rate on wall thickness distribution in multi-pass deep drawing spinning [J], Light Alloy Fabrication Technology 47(2019)1, 67-71.

Note: The responsible translator for English language is Q.Y. Lu, Ningbo, China