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STUDY ON ROLLING FORMING MECHANISM AND INFLUENCING FACTORS OF BLANKS WITH ARC-SHAPED

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In this paper, the influence law was analyzed, the effective parameter range was determined. Based on the significance analysis of the orthogonal experiment with three factors and three levels, the order of the influence degree of each parameter on the forming quality of the end is obtained. According to the optimized simulation analysis in the effective scheme, the optimal forming process parameters were determined. The results show that the order of the influence of various factors on the diameter of the roll cut is as follows: roll cutting speed> friction factor> baffle gap; the best combination of process parameters is A2B1C1, the friction factor is 0,5, the roll cutting speed is 1/$rad \cdot s^{-1}$and the baffle gap is 0,1/mm.

Key words: cross wedge rolling, blank, arc-shaped end, process parameters

INTRODUCTION

Cross wedge rolling technology is a near-net shape processing technology for shaft parts, which is widely used because of its high production efficiency. However, during the forming process, the surface layer of the rolled piece and the core metal have the problem of asynchronous flow in the axial direction, which makes the end of the part concave after the end of the rolling [1]. Studies have found that processing the ends of the blanks into special-shaped ends can have a better effect on suppressing the end recesses [2].

In order to realize the forming of the special-shaped end billet Shu X. D. et al. [3] proposed a roll-cut billet process, which is mainly based on the principle of the cross wedge rolling process, using a pair of upper and lower rolls to rotate around their axes at the same speed and in the same direction. Wang Y. et al. [4] proposed a hot-shearing blank-making process. Its advantage is mainly to keep the blank in place when the end is preformed. Due to the cumbersome movement of the tool in this process, the equipment structure is complicated. Wang R. et al. [5] combined the above two process principles and proposed a roll forming process. However, there are still small cavities in the tapered end billet after rolling, and there are fracture and stacking problems in the quality of the tapered end roll forming.

This article analyzes the influence of three main structural parameters. The orthogonal test scheme was designed, and the range method was used to evaluate the significant influence of friction factor, roll cutting speed and baffle gap on the forming quality. Finally, with the smallest deviation of the diameter of the roll cut as the evaluation index, the process optimization design of the arc-shaped end roll forming is carried out, and the best combination of process parameters is obtained.

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Rolling forming mechanism of arc-shaped end blank

As shown in Figure 1, the middle is the circular blank held by the clamp. The symmetrically arranged roll cutters revolve around the blank, and at the same time, the roll cutters rotate around the axis to make an arc. In the roll cut area, the blank roll cut contact zone produces radial compression, tangential expansion and axial extension deformation.

The material is 42CrMo steel, the blank is set as a plastic body, and the roll cutter is set as a rigid body, and a rigid plastic model is established.

In the tapered wedge into the widening section, the wedge width and wedge height are continuously increasing, so that the blank continuously undergoes radial com-

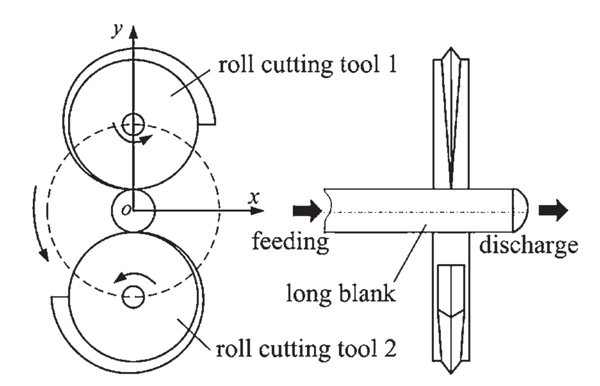

Figure 1 Principle of roll forming

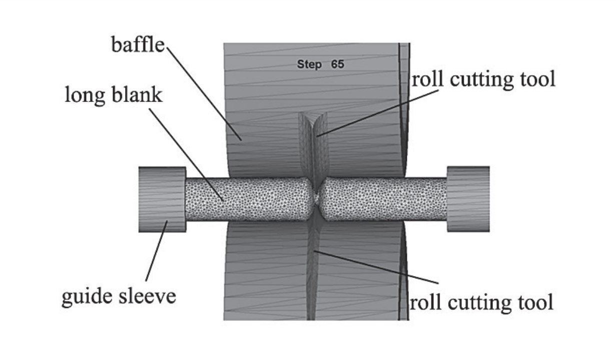

Figure 2 Finite element model

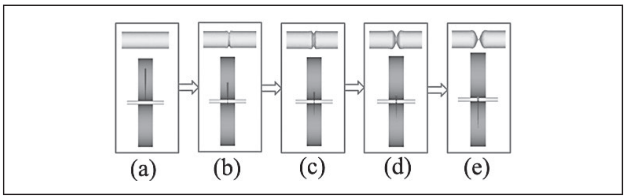

Figure 3 Roll forming process of blank with curved end (a) Initial stage; (b) Conical wedge into the widening section; (c) Conical flat section; (d) Arc wedge into the widening section; (e) Arc finishing section

pression, tangential expansion and axial extension in the roll cutting area. And then enter the conical flat section. Next, the blank enters the arc-shaped roll to cut the widening section. In the final finishing section, the blank no longer has a large amount of axial extension, and the roll cutter rounds the end to make it a preset cone.

The influence of process parameters on the forming quality of arc-shaped end roll

The friction factor between the roll cutter and the blank is one of the important factors to control the axial displacement of the blank.

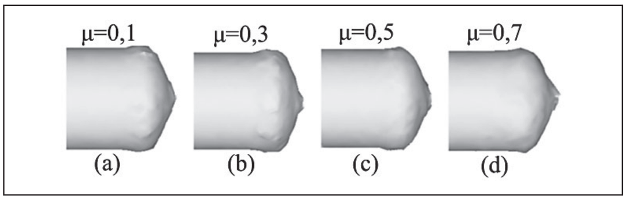

Figure 4 Forming results of arc-shaped ends with different friction factors

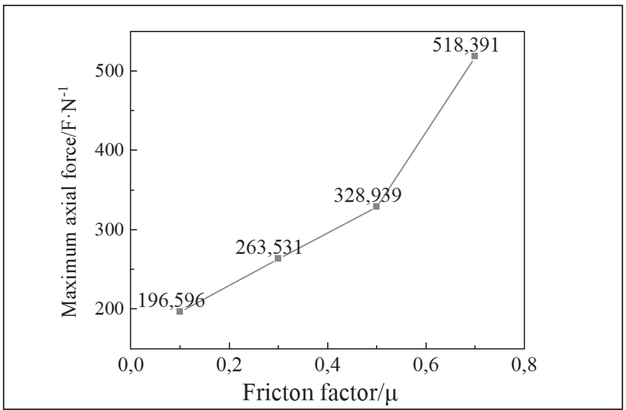

Figure 5 The relationship between the maximum axial force and the friction factor

It can be seen from the figure, the maximum axial force of the blank shows a gradually increasing trend.

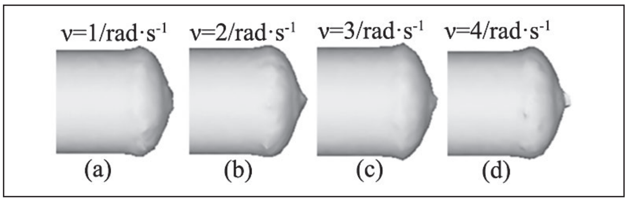

Figure 6 Curved end forming results at different roll cutting speeds

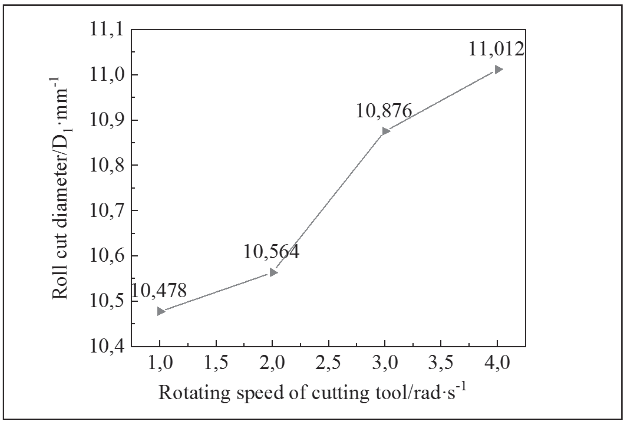

Figure 7 The relationship between the diameter of the roll cut and the roll cut speed

As the figure shows that the diameter of the roll cutting position gradually increases with the increase of the roll cutting speed.

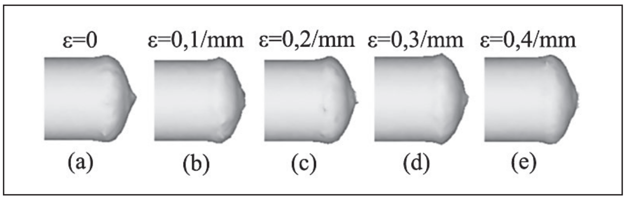

Figure 8 Forming results of arc-shaped ends with different baffle gaps

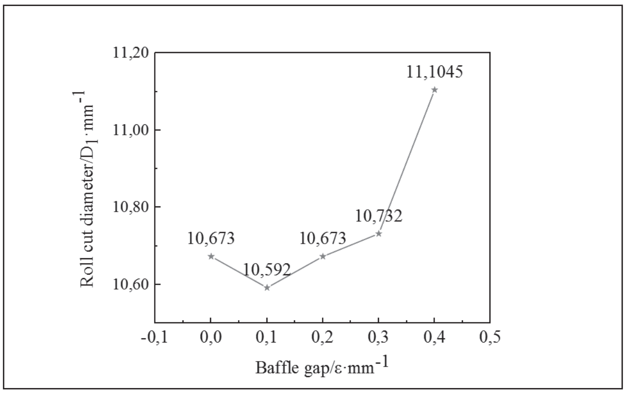

Figure 9 The relationship between the diameter the gap of the baffle

It can be seen from the figure that the diameter of the roll cut first decreases and then increases with the baffle gap. Because when there is a gap between the blank and the baffle plate, the overflow metal accumulates in the gap and reaches a certain height.

ANALYSIS OF THE BEST PROCESS PARAMETERS FOR FORMING

An orthogonal experiment with three factors and three levels is set up, and the interaction between the factors is not considered, and the influence law of a single factor on the forming quality is analyzed, and then the appropriate level is selected. Table 1.

Table 1 **Orthogonal test factor level**

Level	Factor of test		
	Friction factor /A	Roll cutting speed /B/ $rad \cdot s^{-1}$	Baffle gap /C/ mm
1	0,3	1	0,1
2	0,5	2	0,2
3	0,7	3	0,3

According to the level of each factor, the test plan is formulated, and the simulation results are obtained, as shown in Table 2.

As shown in Table 2, the arc shape of corresponding to each factor and each level. The surface did not undergo large uneven deformation, and the stacking at the roll cut was also within a reasonable range.

As Tables show, the order of the influence of various factors on the diameter of the roll cut is as follows: roll cut speed> friction factor> baffle gap. It has a certain effect on the diameter of the roll cut. The order of the influence of each factor on the axial displacement is: friction factor> roll cutting speed> baffle gap. The best combination is A2B1C1. The smallest axial displacement, the best combination is A1B2C2.

Table 5 **Results of optimize simulation**

Friction factor /A	Roll cutting speed /B/ $rad \cdot s^{-1}$	Baffle gap /C/ mm	Roll cut diameter	Axial displacement
0,5	1	0,1	10,132	0,152
0,3	2	0,2	10,211	0,161

According to Tables 3, 4, 5, the cutting diameter and axial displacement of the forming roll of the two schemes are all within a reasonable range, but in comparison, scheme 2 has some piles, and the forming result of scheme 1 is better than scheme 2.

CONCLUSION

The axial displacement decreases with the increase of the friction factor, the diameter of the roll cut increases with the increase of the roll cutting speed, and the diameter of the roll cut increases with the gap of the baffle. The order of the influence of the process parameters on the diameter of the roll cut is: friction factor> roll cut speed> baffle gap. The optimized simulation scheme is used, the best parameter combination is

Table 2 **Orthogonal experiment scheme and simulation results**

	Friction factor /A	Roll cutting speed /B/rad·s-1	Baffle gap /C/ mm	Roll cut diameter /mm	Axial displacement/ mm	Forming state
1	0,3	1	0,1	10,012	0,135	Has a small fracture
2	0,3	2	0,2	10,231	0,230	Obvious stacking
3	0,3	3	0,3	10,106	0,231	Well formed
4	0,5	2	0,3	10,232	0,301	Obvious stacking
5	0,5	3	0,2	10,012	0,225	Uneven arc surface deformation
6	0,5	1	0,1	10,100	0,321	Well formed
7	0,7	3	0,1	10,322	0,310	Uneven arc surface deformation
8	0,7	1	0,2	10,025	0,145	Uneven arc surface deformation
9	0,7	2	0,3	10,036	0,124	Uneven arc surface deformation

Table 3 **Analysis of range 1**

Index	Roll cut diameter		
	Friction factor /A	Roll cutting speed /B/ $rad \cdot s^{-1}$	Baffle gap /C/mm
Mean 1	10.112	10,213	10,201
Mean 2	10,092	10,124	10,124
Mean 3	10,101	10,210	10,031
Range	0,0452	0,0720	0,0316
Significance	More significant impact	Significantly affected	Certain influence

Table 4 **Analysis of range 2**

Index	Axial displacement		
	Friction factor/ A	Roll cutting speed/ B/ $rad \cdot s^{-1}$	Baffle gap /C/mm
Mean 1	0,212	0,223	0,101
Mean 2	0,102	0,134	0,144
Mean 3	0,131	0,310	0,236
Range	0,295	0,226	0,113
Significance	Significantly affected	More significant impact	Certain influence

A2B1C1, the friction factor is 0,5, the roll cutting speed is 1 $rad \cdot s^{-1}$, and the baffle gap is 0,1/mm.

Acknowledgements

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Note: The responsible translator for English language is X. Y. Zhang, Ningbo, China