L. B. LI, J. B. ZHENG, X. D. SHU, J. ZHANG, W.W.SHEN

ISSN 0543-5846
METABK 62(3-4) 383-386 (2023)
UDC – UDK 669.715:531.717:539.376:658.562=111

STUDY ON COLD SPINNING DEFORMATION BEHAVIOR AND LOAD MECHANISM OF CONICAL THIN-WALLED ALUMINUM ALLOY PARTS

Received – Primljeno: 2023-03-01
Accepted – Prihvaćeno: 2023-04-30
Original Scientific Paper – Izvorni znanstveni rad

Aiming at the problem that the wall thickness uniformity of conical thin-walled aluminum alloy parts formed by single-pass spinning is difficult to control, this paper systematically studies the influence of different spinning parameters on the material evolution law and load mechanism during the forming process of 1070 thin-walled aluminum alloy. The effects of slab thickness, roller gap and feed ratio on the macroscopic forming quality and mechanical load of 1070 thin-walled aluminum alloy conical parts were simulated by Simufact.forming software. Finally, the optimal spinning parameters of 1070 thin-walled aluminum alloy conical parts were obtained. The final results show that increasing the diameter-thickness ratio of the blank can prevent wrinkling, and reasonable spinning parameters can improve the uniformity of the wall thickness of the product.

Key words: aluminum alloy, thin-walled, spinning forming, forming quality

INTRODUCTION

Aluminum alloy is widely used in the structure of various thin-walled conical parts due to its low density, high specific strength and good plasticity [1]. As a special forming process method, spinning is a branch of plastic processing technology. Compared with other processing technologies, spinning process has the advantages of small spinning deformation force, simple mold, high material utilization rate and short production cycle. The thin-walled aluminum alloy conical parts are a kind of spinning parts used in aviation, aerospace and other fields. Due to the interaction of many factors in the spinning process, the forming mechanism is complicated, which seriously restricts the output of this kind of spinning parts. Therefore, it is necessary to deeply analyze the forming mechanism of this kind of thin-walled aluminum alloy conical parts, grasp the causes of defects and solutions in the simulation process of this kind of parts and the influence of main process parameters on the quality of spinning forming, and provide theoretical basis for the improvement of product quality in actual processing[2].

Lu Yanlin et al.used the finite element analysis method to simulate the spinning process of 1060 aluminum alloy cylindrical parts, and analyzed the changes of stress and strain during the spinning process[3]. Mostafa A et al.studied the formation and migration of grain dislocations in plastic deformation of 1070 aluminum alloy[4]. M.D. Chen et al. predicted the shear spinning force and surface roughness of the spinning cone by establishing a regression model[5].

L.B. Li, X.D. Shu Healthy & Intelligent Kitchen Engineering Research Center of Zhejiang Province; X.D. Shu (Email: shuxuedao @nbu.edu.cn)

Based on the above research, after studying the influence of spinning parameters on the forming quality of 1070 aluminum alloy thin-walled conical parts, this paper deeply analyzes the causes of defects in spinning parts by studying the variation law of roller force and energy parameters during spinning. The research results provide theoretical guidance for the actual production of 1070 aluminum alloy conical parts.

POWER SPINNING FORMING PRINCIPLE

The principle of power spinning forming process of conical parts is shown in Figure 1. The slab rotates with the mandrel, and the roller feeds along the direction of the mandrel generatrix at the same time. The roller rotates passively due to the effect of friction. Thin-walled conical parts with specific wall thickness are formed by controlling the roller gap.

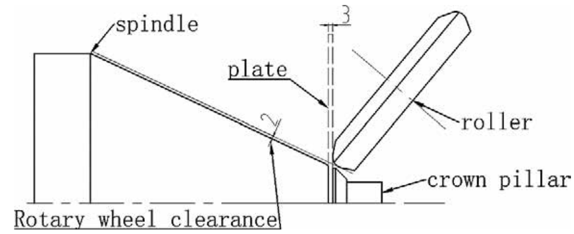

Figure 1 Power spinning schematic diagram

ESTABLISHMENT OF FINITE ELEMENT SIMULATION MODEL

The parameters of the mold and the roller are shown in Figure 2, where the half cone angle of the mandrel is 25° and The fillet radius of the roller is 4mm.

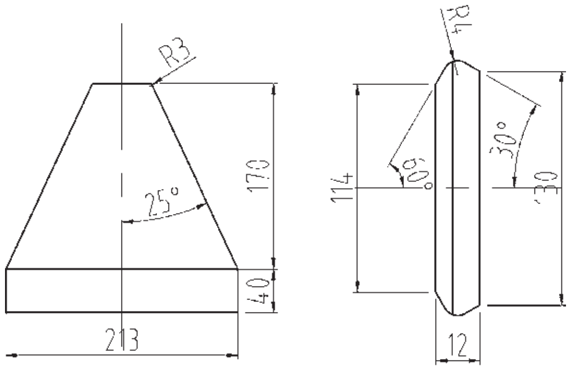

Figure 2 Mold size diagram

The model parameters are imported into the simufact software. In order to shorten the calculation time, the model is reduced to 1/10 of the original. (Note: Due to the use of 1:10 model, the spinning pressure results are also reduced, and the results are only used for research trends)

In order to study the influence of process parameters on the forming quality of thin-walled conical parts, in this paper, the spindle speed is 300 r/min, and the three factors of the roller feed ratio *f*, the roller gap t_f and the blank thickness t_0 are selected for analysis. Among them, three parameters are selected for the feed ratio, three parameters are selected for the spinning wheel gap, and four parameters are selected for the blank thickness. A total of 10 sets of single factor simulation experiments are performed. The spinning parameters are shown in Table 1.

Table 1 **Parameters of spinning model**

The parameter name	The numerical
blank thickness/ mm	2/3/3,5/4
roller feed ratio/ mm/r	0,4/0,6/0,8
roller clearance/ mm	1,6/1,8/2,0

INFLUENCE OF ROLLER GAP ON SPINNING FORMING QUALITY

The roller gap is the distance between the roller R angle and the core die bus, which can also be understood as the thinning rate of the blank. The roller gap is selected as 1,6 mm, 1,8 mm, 2,0 mm, and the parameters are imported into the software for finite element simulation analysis. On the surface line, 40 points are selected evenly, and their wall thickness values are derived respectively. The final results of comparative analysis are shown in Figure 3. It can be found that with the decrease of the clearance rate of the roller, the wall thickness at the end and tail of the workpiece shows a significant decrease. Therefore, if the wall thickness uniformity of the workpiece is required, the roller gap rate can be appropriately reduced to control the wall thickness uniformity. However, if the workpiece is required to thicken the tail to enhance the local strength, the roller clearance rate can be appropriately increased.

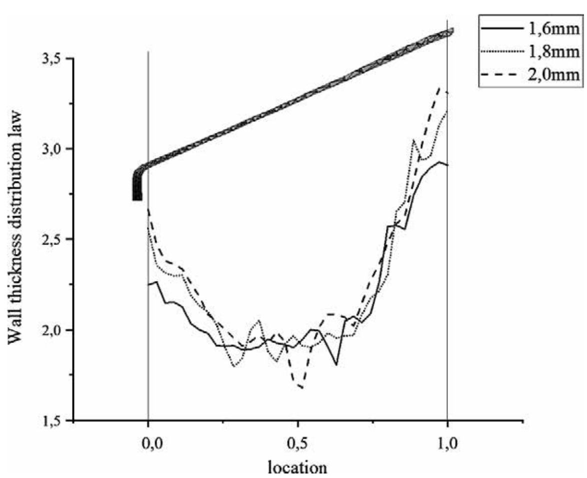

Figure 3 wall thickness distribution diagram

THE INFLUENCE LAW OF ROLLER FEED RATIO ON WORKPIECE WALL THICKNESS

The slab thickness is 4 mm, the spindle speed is 300 r/min, and the roller gap is 2 mm. The finite element simulation analysis is carried out. Finally, the relationship between the wall thickness and the feed ratio is shown in Figure 4. As the feed ratio decreases, the wall thickness of the tail of the workpiece also decreases. However, for the wall thickness of the waist of the workpiece, if the feed ratio is too high or too low, there will be a large fluctuation. So the size of the feed ratio has no obvious effect on the wall thickness uniformity of the waist of the workpiece. However, it can be seen from the figure that a lower feed ratio can reduce the wall thickness of the tail of the workpiece, so in general, a lower feed ratio can improve the overall uniformity of the workpiece.

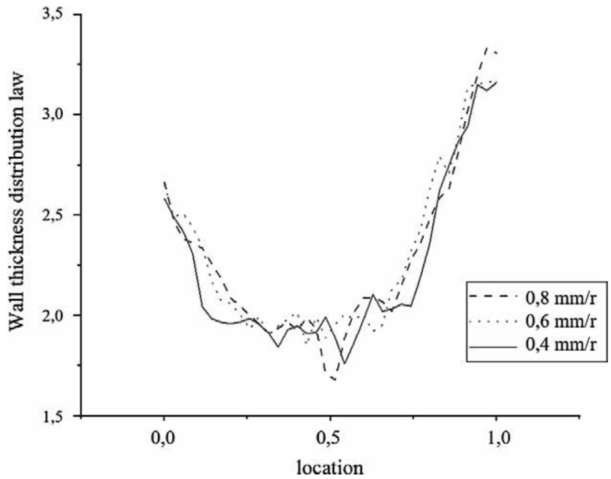

Figure 4 Effect of feed ratio on wall thickness

WRINKLE PHENOMENON AND CONTROL OF PRODUCT TAIL

The wall thickness of 3mm, 3,5 mm and 4 mm was selected for analysis under the feed ratio of 0,6 mm/r. The final equivalent strain diagram is shown in Figure

5. When the thickness of the slab increases to 4 mm, when the feed ratio of the roller is 0,6 mm/r, the workpiece does not wrinkle. When the slab is 2 mm, the workpiece has a large instability wrinkling when the spinning process reaches 55 %. When the thickness of the slab increases gradually, the wrinkling position is also gradually backward. When the slab is 3 mm, it wrinkles at 76 %, and when the slab is 3,5mm, it wrinkles at 91 %. Therefore,if the phenomenon of wrinkling still occurs after adjusting the feed ratio, it should be considered to reduce the diameter-thickness ratio of the billet, or directly increase the thickness of the billet to prevent the wrinkling of the billet.

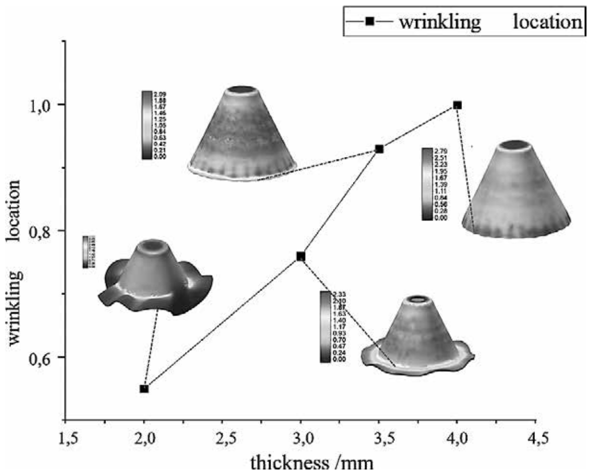

Figure 5 Wrinkle of different wall thickness

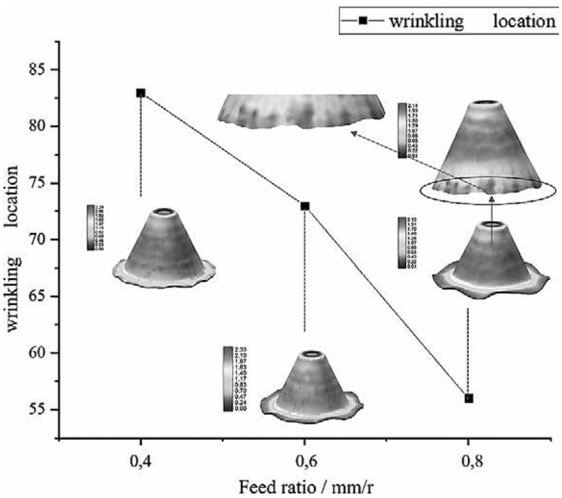

Figure 6 Wrinkles with different feed ratios

In the wrinkling phenomenon, the feed ratio is a very important factor, as shown in Figure 6.As the feed ratio decreases, the wrinkling position of the workpiece gradually migrates to the tail. When the feed ratio reaches a lower level, the wrinkling phenomenon can be avoided. Although the workpiece can still continue spinning and finally forming after wrinkling, it will affect the final quality of the product, which is concentrated on the tail of the workpiece.

ANALYSIS OF LOAD MECHANISM IN SPINNING WRINKLING PROCESS

The case of blank wall thickness of 3 mm and feed ratio of 0,6 mm/r is selected to analyze the relationship between spinning force and wrinkling. The results are shown in Figure 7.

As shown in Figure 7, the relationship between the spinning pressure in each direction during the spinning process is shown. It can be seen that the radial and axial spinning pressures are relatively stable throughout the spinning process, and the tangential spinning pressure fluctuates the most. The peak is concentrated in the second half of the spinning process (spinning tail area). Another peak of spinning pressure is in the early stage of spinning. When the roller just bites into the blank, the spinning process tends to be stable. The reason for the peak value of tangential spinning pressure should be that in the final finishing spinning process, the tail of the workpiece is instantaneously transferred from the horizontal position to the cone of the mandrel, and the angle changes greatly. Because the blank at the tail is not much left, there will be a large torque to hinder the deformation, which will eventually lead to the peak value. The existence of the peak will affect the quality of the spinning parts, and will also affect the life of the spinning machine. Therefore, it is necessary to select the appropriate spinning parameters to minimize the spinning pressure. Therefore, the feed ratios of the rollers with feed ratios of 0,4 mm/r, 0,6 mm/r, and 0,8 mm/r were selected for analysis. The thickness of the spinning slab was 4 mm, and the roller gap was 2 mm. The final tangential spinning pressure results are shown in Figure 8.

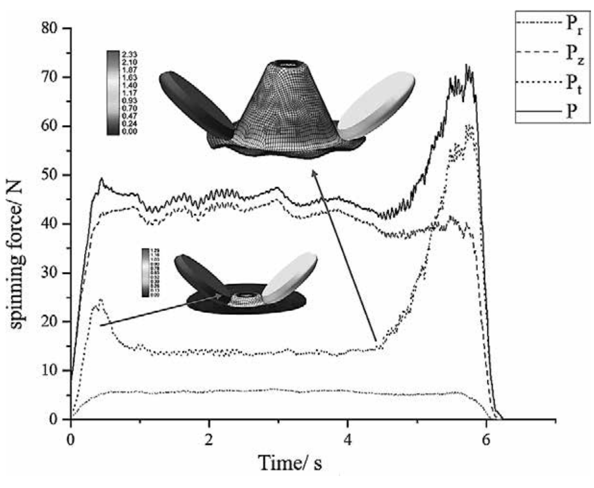

Figure 7 Spinning pressure change diagram

The results show that as the feed ratio increases from 0,4 mm/r to 0,8 mm/r, the tangential spinning pressure also increases, especially at the peak. The peak results increased from 70,1119 N in 0,4 mm/r to 98,846 N in 0,8 mm/r, and the increase was also very obvious. This is also one of the reasons for the uneven wall thickness of the final workpiece caused by the increase of the feed

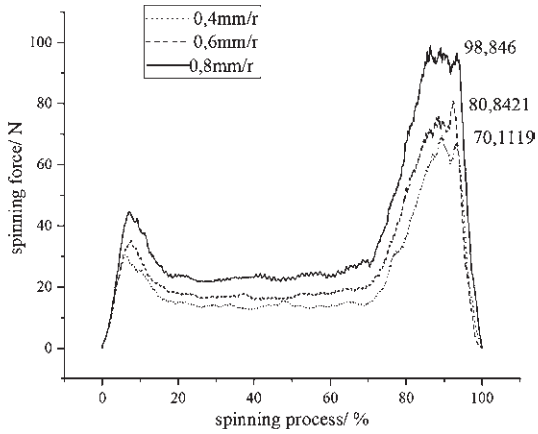

Figure 8 Relation diagram of spinning pressure and feed ratio

ratio. Therefore, the feed ratio of the workpiece spinning is selected as low as possible.

CONCLUSIONS

When the roller gap is 1,6 mm, the wall thickness distribution of aluminum alloy thin-walled conical parts is more uniform, because the equivalent stress is also evenly distributed.

The wrinkling phenomenon of workpiece is often related to the diameter-thickness ratio of blank and the feed ratio of roller. Increasing the diameter-thickness ratio of blank and reducing the feed ratio of roller can improve the wrinkling phenomenon.

When the feed ratio increases from 0,4 mm/r to 0,8 mm/r, the tangential spinning pressure also increases, especially at the peak. This is one of the reasons for workpiece wrinkling and uneven wall thickness. Therefore, in the actual production process, a lower feed ratio should be selected as much as possible.

Acknowledgments

This study was funded by the Natural Science Foundation of Zhejiang, China (Grant Num-ber:LZ22E05 0002), the National Natural Science Foundation of China (Grant Number: 51975301),and the Major Project of Science and Technology Innovation 2025 in Ningbo City, China (Grant Number: 2022Z064, 2022Z002).

REFERENCES

[1] J. Z. Zhao. Research on spinning forming equipment and process parameters of thin-walled 1060 aluminum alloy conical parts [D]. Shanghai University of Applied Sciences, 2021.

[2] Z. G. Xing. Research on spinning forming technology of thin-walled aluminum alloy cylinder [D]. Changchun University of Technology, 2020.

[3] Y. L. Lu, H. Q. Wang.Based on the numerical simulation of spinning processing of 1060 aluminum alloy cylindrical parts [J].Machine and hydraulic.2018,46(10):39-42.

[4] Mostafa A , Ibrahim H , Salah M , et al. Formation and Migration of Dislocations Produced by Plastic Deformation in 1070 Al-alloy A R T I C L E I N F O.2018.

[5] M.D. Chen, Hsu R Q , Fuh K H .Forecast of shear spinning force and surface roughness of spun cones by employing regression analysis[J]. 2001, 41(12): 1721-1734.

Note: The responsible translator for English language is J. B. Zheng, Ningbo, China