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EFFECT OF 6061 ALUMINUM ALLOY WHEEL FORGING AND SPINNING PROCESS PARAMETERS ON FORMING QUALITY

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This paper mainly studies the influence of process parameters on the forming quality during the spinning process of 6061 aluminum alloy wheel forging blanks. The four parameters of spinning temperature, spindle speed, wheel feed and wall thickness reduction rate are selected for research, and the quality of the surface of the hub and the influence on the size of the hub are judged. Simufact software is used to simulate the influence of various process parameters on the forming quality of the hub. The results provide a certain reference for the reasonable selection of process parameters during the spinning forming process of 6061 aluminum alloy hub.

Keywords: 6061 aluminum-alloy, wheel, forge, process parameters, forming quality

INTRODUCTION

Forging spinning process is a relatively high-end forming process in the process of producing automobile hub. The hub manufactured by forging spinning is superior to the cast hub in terms of mechanical properties, weight and appearance. With the intensification of automobile lightweight [1], the forging spinning hub is bound to become the future of the hub market.

Many scholars have also done a lot of research on the forming mechanism, forming process and forming quality of aluminum alloy wheel hub. C. C. Wong et al. Explored the effects of the shape and feed rate of the spinning wheel on the spinning pressure and material flow during spinning. Huang CC established the spinning forming finite element model of tubular parts using ABAQUS platform, studied the effects of roller feed speed, fillet radius and friction coefficient on the forming quality of spinning parts, and verified the correctness of the finite element simulation through practical experiments [2]. In reference [3], Essa K and Hartley P analyzed the spinning of traditional cylindrical workpiece, determined the main factors affecting product quality, and optimized the spinning results. In reference [4], Lu Y J obtained the influence of main process parameters on the forming force of 6061 aluminum alloy hub during forging and spinning through simulation.

On the basis of what scholars have done before, this paper will explore the influence of process parameters on the forming quality of 6061 aluminum alloy hub.

Principle of hub spinning forming

The process principle diagram of spinning forming of aluminum alloy hub is shown in Figure 1. The main movement of the process is the rotary movement of the blank driven by the core die. At the same time, the rotary wheel feeds along the axial direction of the cylindrical blank and makes its own rotary movement due to the existence of friction. Through the radial and axial movement of the two rotating wheels, the rough embryo of the forging is locally deformed under the action of the rotating wheel, so as to reduce the partial thickness of the wheel rim, so as to meet the requirements of the wheel hub for its shape, size and various properties.

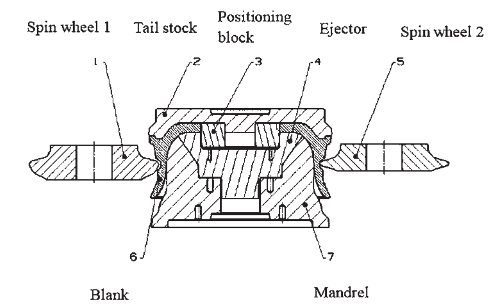

Figure 1 Principle of spinning

Due to the complex shape of the hub, when the thickness of the blank changes suddenly, due to the large flow of metal and defects, it is easy to flare or uneven boundary deformation at the end of the spinning workpiece. Therefore, in this paper, the forming quality of automobile hub is mainly judged from two aspects: the forming quality of hub surface and the size of hub. In terms of the surface forming quality of the wheel hub, it is mainly judged from whether there are wrinkles, peeling and other defects on the surface and whether the surface is smooth; In the analysis of the accuracy of hub size, it is mainly judged by the deviation of hub diameter and wall thickness. The inner di-

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ameter deviation refers to the clearance between the inner surface of the workpiece and the core die after spinning, which reflects the fit degree between the workpiece and the core die; Wall thickness deviation refers to the change between the actual rim thickness and the theoretical rim thickness after spinning. If the deviation is too large, it will have a great impact on the dimensional accuracy of the hub.

FE OF HUB SPINNING

In order to explore the influence of process parameters on the forming quality in the spinning process of aluminum alloy hub, spinning temperature T, spindle speed n, roller feed F and wall thickness thinning rate φ are selected in this paper. The four factors that have a great influence on the forming quality are analyzed. Five groups of data are selected for each factor, and a total of 20 groups of single factor experimental parameters are shown in Table 1.

In this paper, 6061 aluminum alloy is selected as the raw material of forgings, which has low density. Aluminum alloy is divided into cast aluminum alloy and deformed aluminum alloy by forming process. 6061 aluminum alloy used to manufacture wheel hub in this paper belongs to 6-series deformed aluminum alloy, and 6-series deformed aluminum alloy belongs to aluminum magnesium silicon alloy. This kind of aluminum alloy takes Mg2Si phase as strengthening phase, which has good workmanship, good corrosion resistance and medium strength, and is not easy to deform after processing, It has many advantages, such as easy coloring, good surface finish of processed workpiece and so on. It is widely used in the production and processing of automobile hub. According to the research of Xiang Zhang et al. in the literature [5], the constitutive equation of 6061 aluminum is as follows:

$$\varepsilon - 1{,}34742\times10^{23}\left[\sinh\left(0{,}02104\sigma\right)\right]^{7{,}23209}\exp\left(\frac{-314{,}304\times10^{5}}{RT}\right)$$

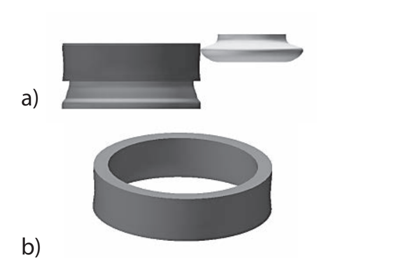

Figure 2 (a) Simplified model of spinning processing
(b) Simplified model of blank

Table 1 **The process parameters selected in simulation**

Section / Parameters	Reference section	Change section
T / C°	350	300 / 350 / 400 / 450 / 500
n / r/min	400	300 / 350 / 400 / 450 / 500
f / mm/r	1	0,5 / 1 / 1,5 / 2 /2,5
φ / %	40	30/ 35 / 40 / 45 / 50

Where ε is is the strain rate /s^{-1}; σ_p is the peak stress; R is the gas constant (8,314 J·mol^{-1}·K^{-1}), and T is the temperature /K.

The simplified model of spinning processing and the simplified model of Forging blank are shown in Figure 2. Considering that the spinning analysis is only carried out for the rim in the spinning process, if the real blank is directly used for analysis, it is very time-consuming. In order to save time and reduce the amount of calculation, the hub blank that does not need to be analyzed is simplified, and then the proportion is reduced to the original 10 %, At the same time, change the number of spinning wheels from two to one.

INFLUENCE OF PROCESS PARAMETERS ON FORMING QUALITY

Spinning temperature is an important parameter in aluminum alloy spinning deformation. As shown in Figure 3, 300 C° to 500 C° is selected. It is concluded from the figure that when the spinning temperature is 400 C°, the inner diameter deviation and wall thickness deviation of aluminum alloy hub are the smallest. The larger or smaller the temperature, the deviation will gradually increase. The wall thickness deviation at 500 C° is 34 % higher than that at 400 C°, and the inner diameter deviation at 300 C° is 32 % higher than that at 400 C°. It can be seen from the simulation results in Figure 4 (a) that when the temperature is 300 C° and 350 C°, due to the insufficient thermoplastic of the workpiece, the spinning pressure will increase significantly when the spinning wheel acts on the rim, and the workpiece will vibrate slightly during processing, resulting in uneven surface of the workpiece. At 450 C° and above, the strength of the surface of the workpiece is obviously reduced due to the high temperature. Under the action of tensile stress, there will be adhesion on the metal surface and extrusion wrapping in the deformed area. At 400 C°, the surface of spinning workpiece is smooth and flat. Therefore, from the simulation results, when the spinning temperature is 400 C°, the forming quality of hub is the best.

From Figure 5, the influence of spindle speed on wall thickness deviation and inner diameter deviation is similar to that of spinning temperature, but the effect is greater. The value of wall thickness deviation is 172 % higher than that of 300r / min when spindle speed is 400 r/ min, and the value of inner diameter deviation is 92 % higher than that of 300r / min when spindle speed is 400 r/min.

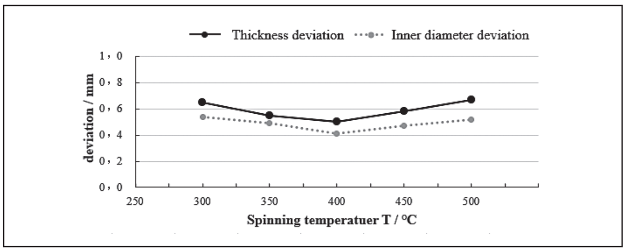

Figure 3 Effect of spinning temperature on forming quality

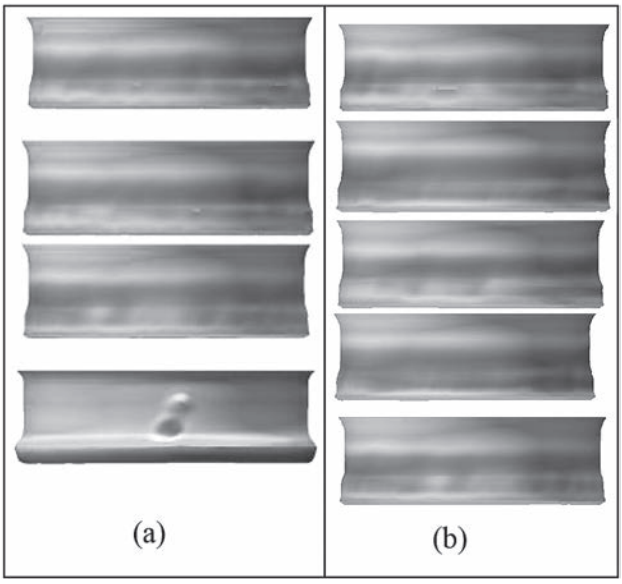

Figure 4 Surface quality under different process parameters
(a) Spinning temperature 300-450 C°
(b) Spindle speed 300-500 r/min

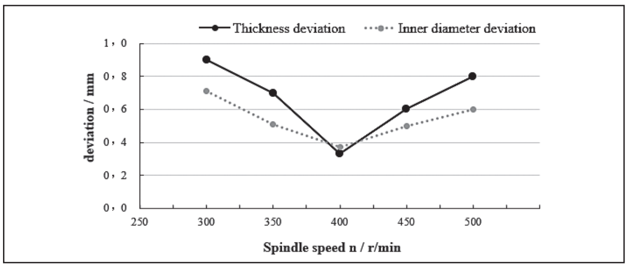

Figure 5 Effect of spindle speed on forging quality

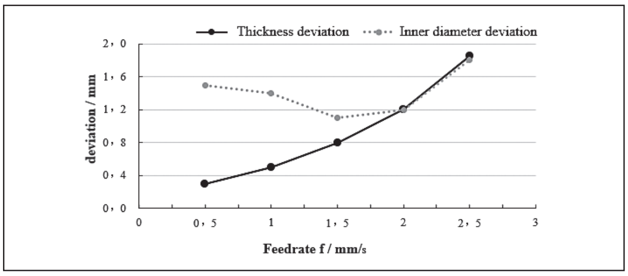

Figure 6 Effect of feedrate on forging quality

From Figure 4 (b), the strain value on the wheel hub and rim is higher when the rotating speed is low. When the rotating speed of the main shaft is greater than 400 r/min, the metal strain on the wheel rim becomes relatively uniform. Therefore, when the spindle speed is 400 r/min, the accuracy and surface quality of the hub are relatively good.

In the actual processing process, in order to achieve high production efficiency, the feed rate should be as large as possible under the condition of ensuring product quality. The size of feed rate is closely related to the accuracy of parts, surface finish and the stress state of workpiece surface. Figure 6 shows the influence of different feed rates on the forming accuracy of aluminum alloy hub. With the increase of feed rate, the rim inner diameter deviation of the hub first decreases, reaches the minimum value when it reaches 1,5 mm/r, and then

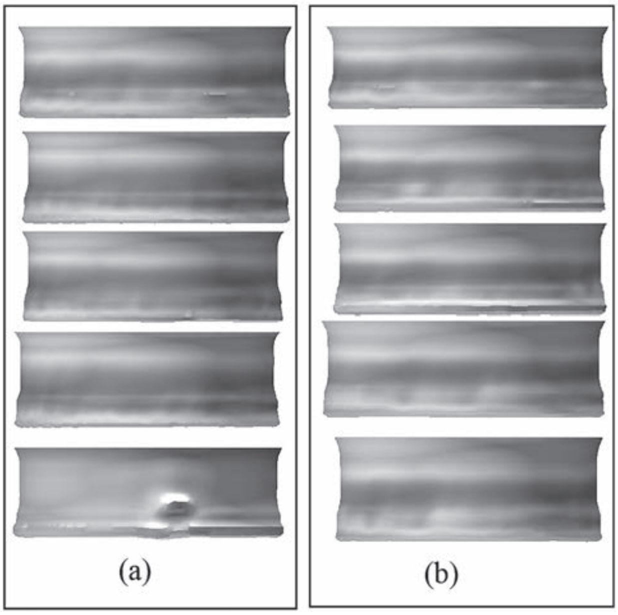

Figure 7 Surface quality under different process parameters
(a) Feedrate 0,5-2,5 mm/s
(b) Spindle speed 300-500 r/min

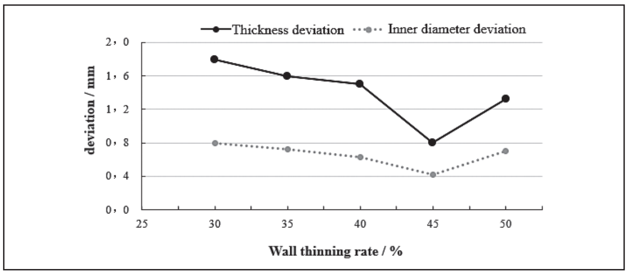

Figure 8 Effect of wall thinning on forging quality

increases. With the increase of feed rate, the wall thickness deviation also increases, which is due to the more and more serious metal accumulation in front of the contact part between the roller and the blank, and the more and more serious tensile deformation of the metal.

Figure 7 (a) shows the simulation results of five different feed rates. When the feed rate is selected as 2,5 mm/r, the surface contacted between the roller and the workpiece has large deformation and metal flow resistance, and there are wrinkling and peeling defects at the front end of the roller, which seriously affects the forming quality of the workpiece. When the feed rate is 0,5 mm/r, uneven wrinkling will also occur on the hub surface. When the feed rate increases to 1 mm/r to 2 mm/r, the hub surface will be smooth and uniform. Considering the comprehensive productivity, the feed rate can be appropriately increased under the condition of meeting the requirements of accuracy.

If the thinning rate is too large in the spinning process, the metal surface will be broken and seriously deformed, which will affect the processing quality; If the thinning rate is too small, it will not have a great impact on the processing quality, but it will waste a lot of time. As shown in Figure 8, when the thinning rate increases, the inner diameter deviation and wall thickness deviation first gradually decrease, while when the thinning rate is greater than 45 %, the inner diameter deviation and wall thickness deviation will increase rapidly. As can be seen from Fig. 7 (b), when the thinning rate is 45 %, the hub surface is uniform and smooth, and the others are provided with flash and burr. Therefore, the spinning forming quality of the hub with the thinning rate of 45 % is better

CONCLUSIONS

By comparing 20 groups of simulation results, the effects of different process parameters on the wall thickness deviation, inner diameter deviation and surface quality of 6061 aluminum alloy hub with forging and screwing are obtained. At the same time, the spindle speed and thinning rate have a great impact on the forming accuracy of the hub. This paper provides a reference for how to reasonably select the process parameters to ensure the forming quality of the hub.

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Note: The responsible translator for English language is S. Y. Chen, Ningbo, China