S. K. SHI, J. H. QIAO, L. N. CAO, J. CONG, S. GUO, H. C. JI

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RESEARCH ON HOT EXTRUSION FORMING OF 7075 ALUMINUM ALLOY WHEEL PROFILE

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Design the wheel mold according to the cross-sectional view of the lightweight aluminum alloy wheel profile, determine the length of its working belt and use HyperXtrude software to simulate it, verify the rationality of the working belt design, analyze the flow velocity and temperature of the mold outlet, and determine the 7075 aluminum alloy The alloy wheel profile is most reasonable to be produced on a 10 MN extruder. Finally, the optimized working belt length is used for production. The quality of hot extrusion profile is qualified, which proves the accuracy of the simulation.

Keywords: aluminum alloy; wheel profile; hot extrusion molding; finite element model (FEM); numerical simulation

INTRODUCTION

Aluminum alloys have excellent properties such as low density [1], high strength and stiffness, good corrosion resistance, easy processing and recycling [2], and are widely used in rail transit, construction machinery, military and other fields [3]. According to different extrusion principles, it can be divided into flat die extrusion and split die extrusion. Flat die extrusion is suitable for solid profiles, and split die extrusion is used with hollow profiles. Due to the existence of split flow and welding processes in the extrusion process, so the quality of welding directly affects the overall performance of the profile. The size of the wheel profile is small and the structure is complex. If the flow rate of the outlet profile is too large, the deformation heat will increase, and in serious cases, the alloy may be over-burned, which is more unfavorable for production. In order to solve the depression of the bottom in the extrusion of complex aluminum profiles. In order to solve the depression at the bottom of the complex aluminum extrusion, Yi et al [4]. analyzed the velocity difference at the exit of the profile and the pressure distribution in the welding room based on HyperXtrude software. By adding flow blocking blocks in the welding chamber where the velocity is larger, the exit velocity of the profile was reduced to obtain a more uniform velocity. The shunt die structure was optimized to improve the extrusion defects of complex hollow aluminum profiles. Bai et al [5]. carried out finite element simulation of magnesium alloy tube through Deform software, predicted and controlled extrusion temperature, also calculated the required extrusion load through numerical simulation, finally determined the process parameters, and used these optimized process parameters to carry out the mechanical properties of the extruded alloy tube were evaluated to verify the accuracy of the simulation.

In this paper, by designing the 7075 aluminum alloy wheel profile mold and importing it into the HyperXtrude software, it is analyzed that the flow rate and temperature of the outlet profile are within the allowable range, and finally put into production.

S. K. SHI, L. N. CAO, J. CONG, S. GUO, Tangshan Jinhengtong Bicycle Parts Co., Ltd J. H. QIAO, H. C. JI (E-mail: jihongchao@ncst.edu.cn) College of Mechanical Engineering, North China University of Science and Technology, Hebei, Tangshan, China.

MOLD DESIGN AND FINITE ELEMENT MODEL ESTABLISHMENT

7075 aluminum alloy belongs to Al-Zn-Mg alloy, which is the most common alloy in 7 series aluminum alloys. It is the alloy material with the best strength and hardness among aluminum alloys. It has the advantages of low density, corrosion resistance and oxidation resistance. Aluminum alloy has a small specific gravity, making it an important lightweight material, which is widely used in aerospace, construction, railway and other fields [6]. The main chemical components of 7075

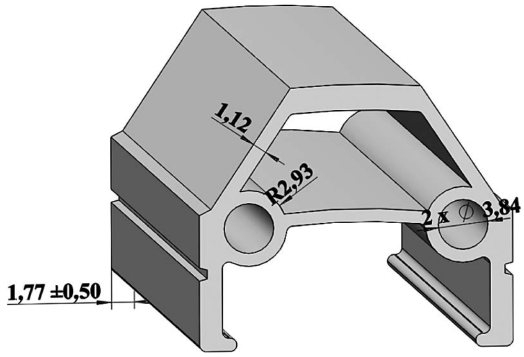

Figure 1 Schematic diagram of the wheel profile

Table 1 **Main structural parameters of the mold**

Mold structure parameters	Value
Shunt bridge angle	40°
Welding chamber height / mm	12
Welding chamber fillet radius / mm	5
Die outer diameter / mm	120

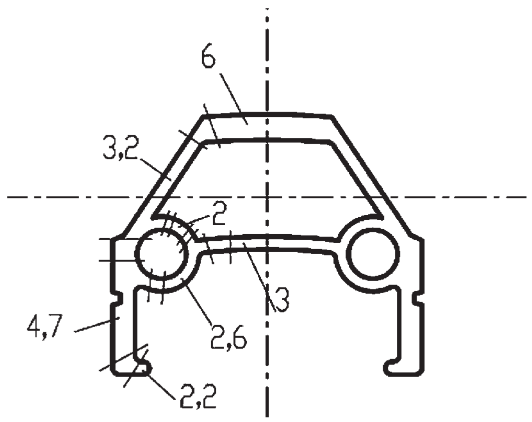

Figure 2 Work band length distribution

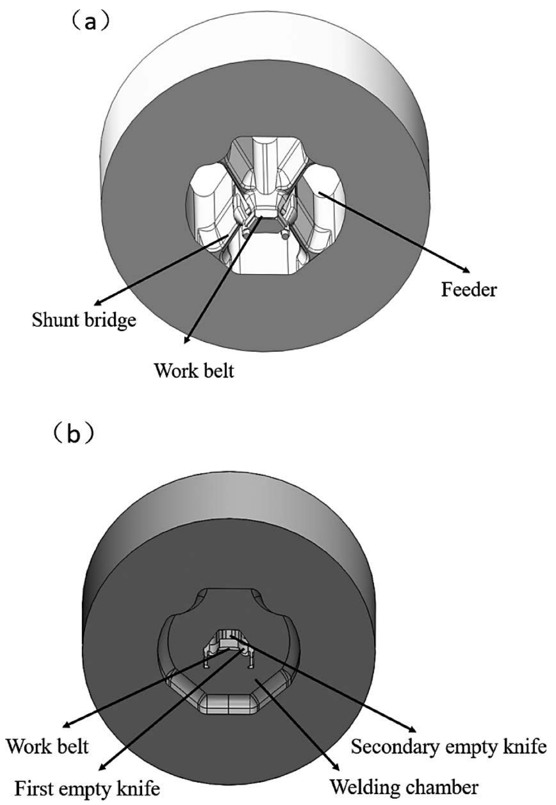

Figure 3 Die 3d drawing: (a) Male die; (b) Master mold

aluminum alloy are 0,4 % Si, 0,5 % Fe, 1,2 % Cu, 0,3 % Mn, 2,1 % Mg, 0,18 % Cr, 5,1 % Zn, 0,2 % Ti, and the rest are Al. Figure 1 is a three-dimensional view of an aluminum alloy wheel profile. As can be seen from the figure, the profile is a symmetrical structure and its wall thickness is relatively thin.

The main structural parameters of the die are shown in Table 1. The die adopts the second-order straight empty knife structure and the conical membrane core structure. The length of its working belt is shown in Figure 2. Then use SolidWorks to draw a three-dimensional drawing of the mold. As shown in Figure 3, the outer diameter of the mold is 140 mm, and there are four shunt holes. Since the threaded hole pin does not participate in the calculation in the finite element simulation, it is not drawn in the mold.

Numerical Simulation

First, build the 3D structure of the extrusion die with SolidWorks software, convert it into step format and import it into HyperXtrude software, carry out finite element modeling of the imported die, first orient and then establish a fluid model, and create a working belt to set the friction coefficient, then extract the surface of the established fluid model to distinguish the shunt hole and the welding chamber. The working belt to be generated next, the male mold has three membrane cores and a total of 3 closed working belts, and the female mold has a closed working belt. Subsequently, the establishment of the bar is carried out to determine the diameter of the bar, the diameter of the extrusion cylinder and the material of the bar, and then the heat transfer coefficient is set, and finally the speed of the extrusion rod, the temperature of the bar, the temperature of the die, and the temperature of the extrusion cylinder are set. A steady-state numerical analysis was performed.

During mesh division, in order to ensure the accuracy of numerical simulation calculation, the selected mesh size should be as precise as possible. The working belt and profile should have 5 layers of meshes in the direction of wall thickness, and then the welding chamber, the shunt hole and the embryo should be aligned in turn. The mesh is divided into meshes, and the mesh size can be sequentially reduced along the extrusion direction, which can shorten the time required for calculation. The final mesh is shown in Figure 4. The specific number of grids is shown in Table 2. The heat exchange coefficient between the bar and the extrusion cylinder,

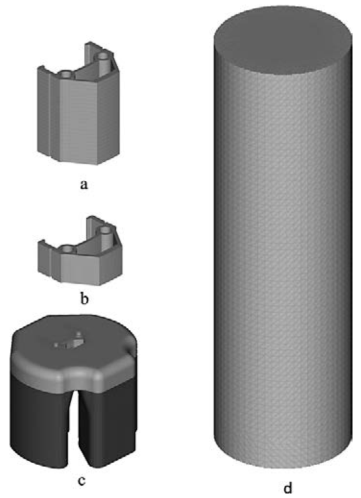

Figure 4 3D meshing: (a) Profile;(b) Work belt; (c) Welding Chamber and Shunt Holes(d) Bar stock

Table 2 **Number of grids**

Object	Volume / mm^3	Number of grids
Profile	3 468	58 212
Work belt	1 156	39 690
Welding chamber and shunt holes	147 470	600 173
Bar stock	4 743 000	138 919

Table 3 **Process parameters**

Process parameters	Value
Extrusion barrel temperature / °C	430
Bar temperature / °C	490
mold temperature / °C	440
Extrusion speed / mm / s	1,5
friction coefficient	0,3
bar material	7075 aluminum alloy
Bar radius / mm	45
Mold material	H13 steel

the bar and the die is set to 3 000 W/m^2 ·°C, the convection temperature between the extrusion outlet profile and the air is 20 °C, and the convection coefficient is 3 000 W/m^2 ·°C. The extrusion parameters and material selection are shown in Table 3 below.

Simulation results and analysis

According to the above modeling method, the finite element simulation is carried out according to the initial scheme of the selected process parameters, and the flow velocity distribution of the wheel profile is obtained after post-processing, as shown in Figure 5. In this section, the uniformity of the outlet velocity, the uniformity of the temperature and the extrusion load are used as the response values, and the optimal combination of process parameters is determined. The calculation formula of VRD to measure the uniformity of the outlet velocity is as follows.

$$VRD = \frac{\sum_{i=1}^{n} \frac{\left| v_i - \overline{v} \right|}{\overline{v}}}{n} \tag{1}$$

In the formula, ${}_i$ - the flow velocity of the ipoint at the outlet of the profile $\overline{v}$ - Average flow velocity at all points - Number of selected profile section nodes. Its outlet velocity VRD = 0,000164, the maximum outlet velocity is 101,87 mm/s, the minimum outlet velocity is 101,80 mm/s, and the range is only 0,07 mm/s. The maximum extrusion force is 8,50041 MN, so a 10 MN extruder is used for extrusion.

The more uniform the flow velocity of the profile outlet is, it directly reflects the deformation of the profile outlet. The deformation of the profile outlet can measure the quality of the extruded profile. If the deformation is too large, it can directly cause the scrap of the profile. The exit displacement is shown in Figure 6. The maximum deformation of the profile is 2,8 mm, the deformation of the profile is small within a reasonable range, and the appearance and forming effect is good

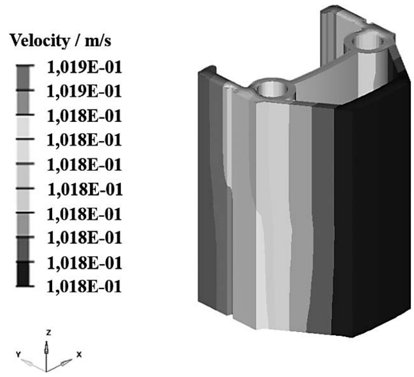

Figure 5 Outlet metal velocity distribution

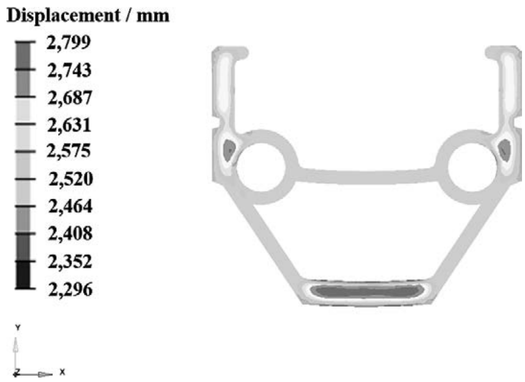

Figure 6 Profile exit displacement

and the two-dimensional map of the wheel profile is basically consistent to meet the production requirements. The outlet temperature during the extrusion process of the profile is shown in Figure 7, and the outlet temperature difference is within the allowable range.

EXPERIMENT

After numerical simulation, the mold was tested for production. The selected hot extrusion process parameters are shown in Table 3, and the actual extrusion production was carried out on the 10 MN forward extrusion machine. The extruded profile was shown in Figure 8 The surface quality of the profile was qualified, and the flatness, straightness and mechanical properties all met the quality requirements. Shorten the production cycle and reduce the production cost.

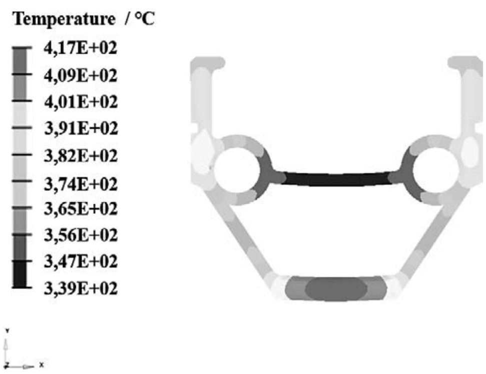

Figure 7 Profile outlet temperature distribution

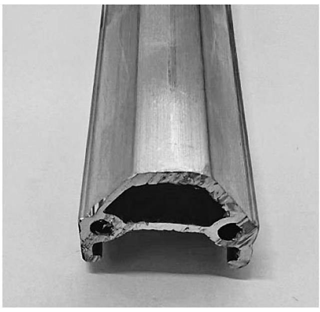

Figure 8 The profile obtained by mold testing

CONCLUSION

After the design of the working belt, the VRD of the profile outlet is only 0,000164, the deformation of the profile outlet is only 2,8 mm, the flow velocity uniformity of the profile is improved, and the temperature difference at the profile outlet meets the production standard. The profile obtained is not much different from the designed profile of the wheel, and the molding effect of the profile is good. The maximum extrusion force required for extrusion is 8,5 MN, which can be hot extruded on a 10 MN extruder, and the mechanical properties of the profile obtained are good.

Acknowledgments

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Note: The responsible translator for English language is W Q Wu-North China University of Science and Technology, China