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Simulation Analysis of Extrusion Process of Equilateral L-shaped Aluminum Profiles Based on Deform-3D

Guangchen XU*, **Wenwu ZHANG, Sisi CHEN, Mantong WANG**

Yingkou Institute of Technology, Yingkou, Liaoning, 115014, China

***Corresponding Author:** *Guangchen XU, E-mail: kanu012@163.com*

Abstract:
The extrusion deformation process of L-shaped aluminum profiles was numerically simulated using the finite element program Deform-3D. The simulation findings revealed that the deformation of the profiles was mostly caused by unequal material flow velocity, which resulted in the profiles bending. Determine the impact of extrusion parameters on the bending deformation of the profile after studying various parameters that may affect the material flow mode (hole position, extrusion speed).
Keywords: *Deform-3D; extrusion processing; bending*

1 Introduction

Extrusion processing is a vital technique in the metalworking industry. The metal is normally heated to the temperature of plastic formation during the extrusion process, and then various shapes of goods are extruded using extrusion molds. Because the material properties of aluminum alloys vary at high temperatures, the flow mode of the material varies, affecting the quality of extruded products. Aside from temperature, mold design, friction conditions, and product form all influence material flow patterns. As a result, the aluminum alloy extrusion process is extremely complex, and the majority of mold design processes are empirical in nature, relying entirely on the experience of mold workers to construct the trial mold. There is no effective formula or criterion for reference.

Numerous academics both domestically and internationally have made great strides in their studies of the extrusion process of aluminum profiles in recent years by using numerical simulation methods. FANG et al. [1] used Deform-3D software to perform numerical analysis on the extrusion of a typical industrial profile, and they investigated the effects of extrusion speed and working strip length on the material's temperature distribution, the profile's dimensional accuracy, surface quality, and extrusion pressure over the course of the extrusion process;JO et al. [2] conducted numerical simulations on the production process of 7003 aluminum alloy pipes and obtained the influence of billet preheating temperature, extrusion ratio, working strip length, and aluminum pipe wall thickness on extrusion pressure, maximum temperature of profiles, surface quality of profiles, and dimension accuracy of the profile.SuperForge was utilized by WU et al. [3] to investigate the metal flow that occurs during the extrusion of rectangular hollow aluminum tubes. The shape and size of the diversion hole as well as the path shape from the diversion hole's inlet to the working zone were found to be the main factors affecting the flatness of the end face of the extruded rectangular hollow tube by comparing the results; Yan Hong et al. [4] used numerical methods to analyze the extrusion process of angle aluminum profiles and combined neural networks and genetic algorithms to optimize the extrusion process parameters.Mooi et al.[5] employed the finite element method to simulate profile flow and mold deformation during extrusion. Imamura et al.[6] provided a simple design solution for a guide plate to assure uniformity in plastic flow velocity at the exit of the mold, addressing the problem of expanding extrusion when the breadth of the profile is greater than the diameter of the original embryo; Jo et al.[3] investigated the influence of welding length on extrusion pressure for pipe fittings with numerous hole molds, as well as the link between extrusion pressure and temperature variations; In order to improve the extrusion condition of products, Ulysse and Johnson[7] proposed applying mathematical models to forecast plastic flow properties such as changes in flow velocity at the departure of extrusion molds. The majority of the preceding research focus on the flow plastic analysis of the early embryo in the mold, with little examination of the impact of mold elastic deformation on product size [8-13].

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This article investigates the extrusion process of equilateral L-shaped aluminum profiles, investigates the effects of mold design and extrusion parameters on extrusion forming characteristics during the extrusion process, and provides a theoretical foundation for improving the quality of profile extrusion forming.

2 Design of Extrusion Processing Process

2.1 Selection of extrusion molds

Create the appropriate model for simulation using Solidworks program and save it in STL format. Figures 1 and 2 demonstrate profiles and mold models created with the finite element simulation program DEFORM-3D for extrusion forming simulation analysis.

The mother mold used in this study is a pocket die, which has benefits for extrusion that traditional flat molds do not have. These benefits include: (1) simple control over material flow; (2) minimal direct impact of extrusion pressure on the mold, minimizing mold damage; and (3) the ability to form a pre-formed extrusion ingot at the pocket to improve extrusion processing precision.

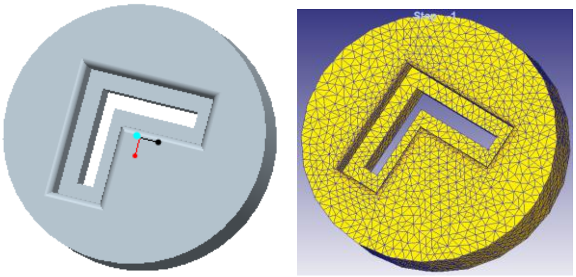


Figure 1 L-shaped profile diagram

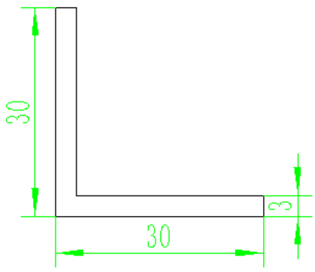


Figure 2 3D model and finite element model of pocket mold

2.2 Extrusion parameter setting

The secret to accurately simulating is to define boundary criteria. Because the extruded items in this study have a symmetrical shape, half of the models were chosen for examination and study. There is no deformation in the XZ and YZ planes of the DEFORM-3D finite element analysis because the extrusion direction is along the negative Z-axis direction. Consequently, the XZ and YZ planes' boundary conditions can be established by setting the displacement symmetric boundary to zero.

The simulation accuracy greatly depends on the calculation parameters that are established when the simulation analysis is initiated. Table 1 displays the primary extrusion simulation parameters based on the real extrusion production design.

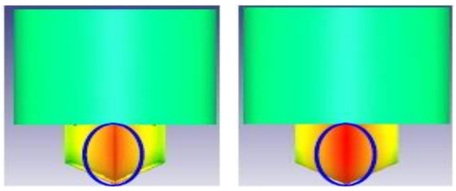
Table 1 L-profile extrusion simulation parameters

Embryo Material (mm)	Embryo diameter (mm)	Number of Meshes	Extrusion Ratio	Extrusion Velocity (mm/s)	Outlet Velocity (mm/s)	Initial Temperature (°C)	Heat Transfer Coefficient (W/m°C)
100	80	30000	30	2.2	32	300	10

3 Simulation of Extrusion Processing

3.1 Analysis of defects in profile extrusion forming

Figure 3 depicts the extrusion flow rate diagram of an aluminum profile blank. The flow rate of the substance can be seen in Figure 3. The flow velocity in the middle of the profile is faster than the flow velocity on both sides, resulting in the first velocity difference; the flow velocity behind the profile is faster than the flow velocity in front of the profile, resulting in the second velocity difference. Because the two speed variations lead the billet to bend from a high flow rate area to a low flow rate area, uneven material flow rate is the primary source of bending errors in profile extrusion molding.



(a) Front view (b) Rear view

Figure 3 Flow velocity diagram of L-shaped profile billet

3.2 Analysis of mold hole position

Firstly, introduce the bending angle - β, Define the degree of deformation during extrusion and bending of profiles.

$$\beta = \langle \vec{A}, \vec{B} \rangle = \cos^{-1} \frac{(A, B)}{|A| \cdot |B|} \tag{3-1}$$

A and *B* are vectors representing two places on the mold outlet and profile, respectively. The ideal bending defect indicator value is zero, and the clockwise direction is positive; The greater this angle, the more severe the bending defect.

Examine how the location of the mold hole affects the profile extrusion forming's degree of bending. The locations of holes in L-shaped profiles are depicted in Figure 4. The origin (X=0) is defined as the position of the center on the symmetry axis, and the centroid position of the L-shaped profile hole in the figure is at the center of the circle. In order to mimic a total of five positions at the circle's center, the study approach involves choosing two locations in the positive X direction and two positions in the negative X direction. The centroid position of the L-shaped hole is displayed in Table 2. Figure 5 displays the flow velocity of the L-shaped profile blank at these five locations. The profile moves upward to its maximum when X = 8 mm, as Figure 5 illustrates; the profile moves downward to its maximum displacement when X =-12 mm. Furthermore, it was discovered through simulation that every profile had severe bending situations, and Figure 6 illustrates the bending situations of profiles at various centroid points. found using the graph β The angle is between 20° and 35 °, and the profile's bending is greatly affected by the hole's location.. Therefore, changing the position of the holes can effectively improve the bending defects in the extrusion forming of profiles.

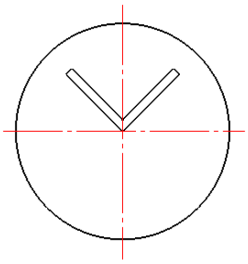


Figure 4 L-shaped profile hole location diagram

Table 2 Location of L-shaped hole centroid

location	1	2	3	4	5
X(mm)	8	4	0	-6	-12

(a)X=8 (b) X=4 (c) X=0 (d) X=-6 (e) X=-12

Figure 5 Flow velocity diagram of L-shaped profile billet

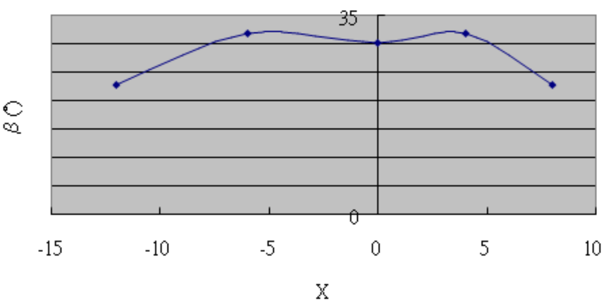
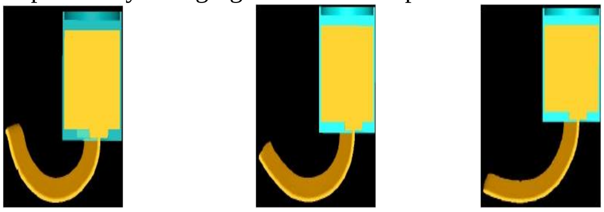


Figure 6 Bending trend of profiles at different centroid positions

Analyze the effect of extrusion speed on the bending degree of profile extrusion forming, and Figure 7 shows the bending situation of profiles at different extrusion speeds. As shown in the figure, the bending degree is most severe when the extrusion speed is 1.1mm/s. Table 3 shows the results under different extrusion speeds β The angle calculation results can be seen from the table β The angle decreases as the extrusion speed increases. Therefore, the bending degree of profile extrusion can be improved by changing the extrusion speed.



(a)v=1.1mm/s (b) v=2.2mm/s (c) v=3.4mm/s

Figure 7 Bending degree of profiles under different extrusion speeds

Table 3 Profile under Different Extrusion Speeds β horn

Extrusion Velocity(mm/s)	β(°)
1.1	30.2
2.2	23
3.4	18

4 Conclusion

In this work,two extrusion parameters—hole position and extrusion speed—are analyzed through simulation research on the extrusion process of L-shaped profiles.Through the use of bending indicators, the degree of extrusion bending deformation of profiles is assessed using the β Angle.The degree of bending of profiles is influenced by the position of the mold holes, and bending flaws can be efficiently rectified by repositioning the holes.The bending degree of the extruded profile can be enhanced by varying the extrusion speed,which can also affect the extrusion pressure.

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