A Study on Effects of Design Parameters on Extrusion Product Quality Using Comsol LiveLink for Inventor

Van-The Than, Jin H. Huang, Chi-Chang Wang, Tat-Tai Truong, and Thi-Thao Ngo

Abstract An investigation of some design parameters in hollow extrusion die by Comsol LiveLink Inventor is presented in this paper. Three-dimensional extrusion die of a rectangle profile is designed by Autodesk Inventor. This model is then linked to Comsol for simulating extrusion process to obtain temperature, velocity, stress etc. Some design parameters will be automatically changed to consider their effects on the extrusion process. Results provide useful information for designer during the constructing extrusion die which can improve product quality.

Keywords Aluminum extrusion · Design parameters · Comsol software · Autodesk inventor

1 Introduction

Aluminum alloys with advantages of corrosion resistance, recyclable, low density etc. have been used in the aerospace and automotive industries. Aluminum extrusion method is being applied to produce high-yield profiled aluminum alloy products. During the extrusion process, hot aluminum is pressed through the die with the same shape as the product. However, during the extrusion process may occur some defects such as unbalanced flow, too high mold temperature which are ultimately affect the product quality and mold life. In particular, the defects are common appeared with aluminum products having complex profiles. In the past, designers had to use many tests to correct die designs to improve product quality. However, this process often takes a lot of time and costs for manufacturing and testing. Fortunately, numerical simulation with high accuracy is a useful solution. Many researchers have simulated to predict the product quality for the extrusion process. Lee et al. [1] used a 3D FEM

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to simulate and consider extrusion process of cooling tubes in automobiles. Variation of chamber shape on porthole die was performed to find its effects on material flow, welding pressure, extrusion load, and. An optimal structure of the die used for extrusion of a rectangular hollow pipe was obtained based on numerical analysis software Msc/SuperForge by Wu et al. [2]. A more uniform velocity distribution has been acquired by modifying porthole and bearing lengths. Numerical method was also utilized to investigate the correlation between die design and process parameters after multiple-cycles to extrusion welds prediction and die deformation [3]. HyperXtrude software was applied in their simulation. Chen et al. [4] considered effects of pyramid angle on evaluation parameters of extrusion by using finite element simulation. Three modifications for the porthole die were proposed by Liu et al. [5] to achieve a uniform flow velocity and enough die strength. The optimal porthole die was then validated by experiment. From above analysis, it is clear that the numerical simulation method is widely applied and effective in optimizing the design of aluminum extrusion molds.

In this study, a synchronous solution from extrusion mold design to extrusion analysis is performed through Inventor link software with Comsol software. In this way, the design parameters will be easily changed to consider their effect on the temperature as well as the balance of the flow during extrusion.

2 Modeling Extrusion Die

2.1 Die Design

In this study, a rectangle hollow product is considered and its geometry is displayed in Fig. 1. It is clear that thickness of the product is constant and equals 2 mm. Based on theory and experiences, a porthole die type is chosen and designed as shown in Fig. 2.

From Fig. 2, it can be seen that there are many dimensions which need to be set during design. In this study, effect of bridge angle and bearing length (see Fig. 3) on extrusion process will be analyzed.

2.2 Modeling Extrusion Process

Aluminum Alloy 6063 (AA6063) common used varying application will be chosen for simulation. Properties of AA6063 and die materials (H-13 tool steel) are listed in Table 1.

The extrusion is a complex process combining heat transfer, fluid flow and structure analyses. Therefore, Comsol Multiphysics has been chosen for modeling and analyzed the extrusion process. Figure 4 presents the model extrusion process; each

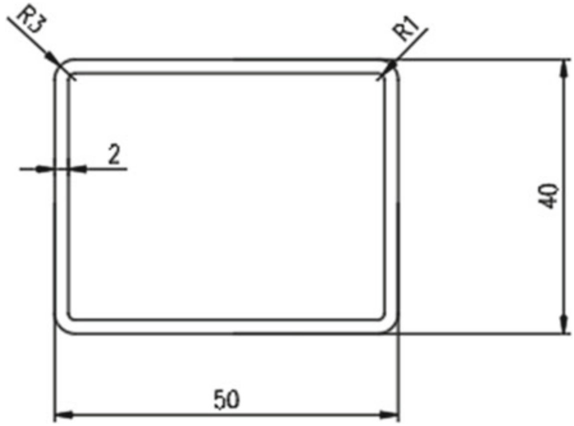
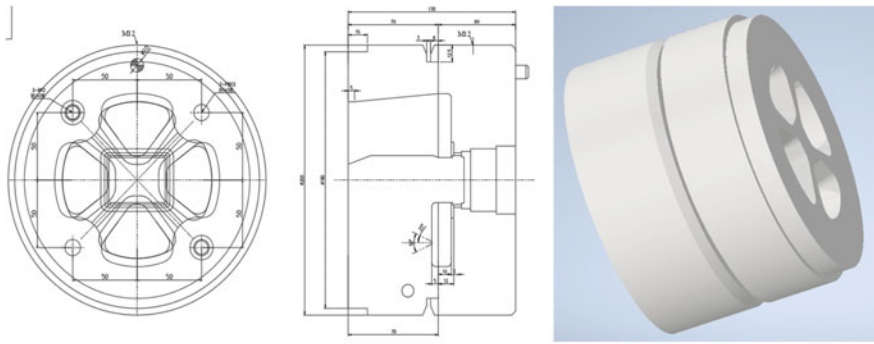


Fig. 1 Geometry of rectangle hollow product



a. Die deign in 2D

b. Die design in 3D

Fig. 2 Porthole die

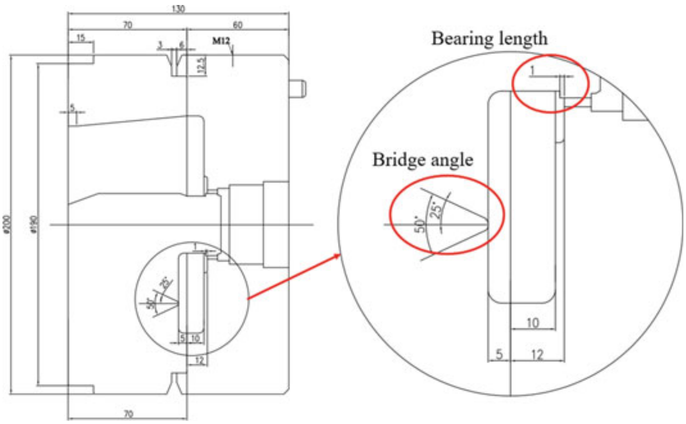


Fig. 3 Some investigate dimensions

Table 1 Materials properties

Name	AA6063	H-13 tool steel
Density (kg/m^3)	2700	7760
Young Module (MPa)	68,950	210,000
Poisson ratio	0.293	0.3
Thermal expansion coefficient (1/°C)	1×10^{-5}	1.2×10^{-5}
Specific heat [J/(kg K)]	900	460
Thermal conductivity (W/m K)	198	24.3
Emissivity	0.05	0.15
Yield strength (MPa)	260	1200

phenomenon will be set for corresponding to surfaces or regions. Meshing of the model is given in Fig. 5.

After solving, results of temperature, flow velocity, stress etc. will be obtained as displayed in Fig. 6.

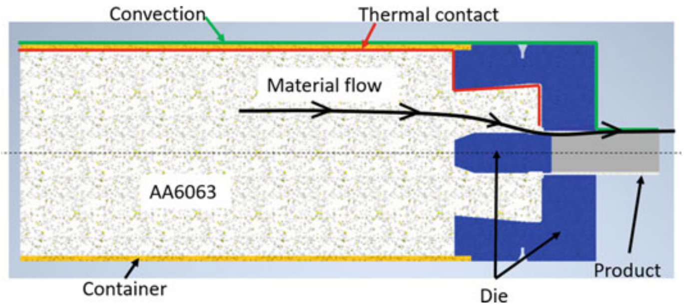
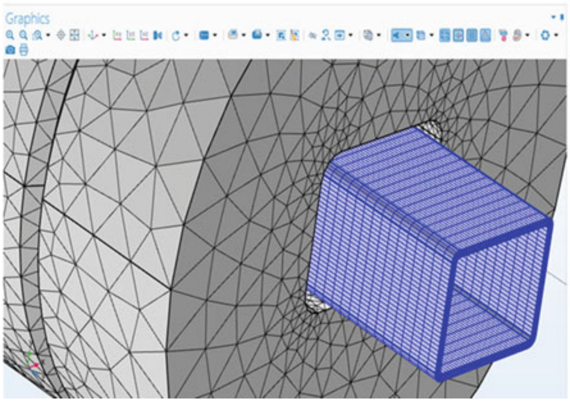
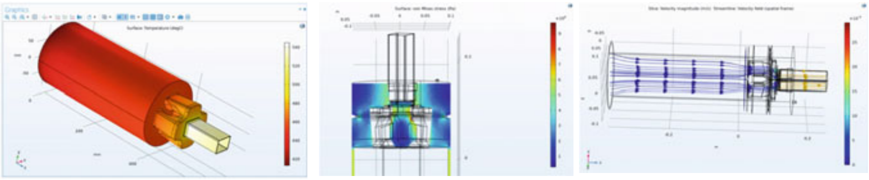


Fig. 4 Modeling extrusion process

Fig. 5 Meshing





a. Temperature b. Von Miss tress c. Velocity

Fig. 6 Simulation results

3 Results and Discussions

In the previous section, the extrusion analysis model was established and solved to obtain the results. In this section, some geometrical parameters of the mold will be changed to consider their effect on the extrusion process. The LiveLink tool between Inventor and Comsol will be applied to support the parametric design process on Inventor synchronize with Comsol. Figure 7 shows the synchronize tool in Inventor which allows user can select parameters for simulation process.

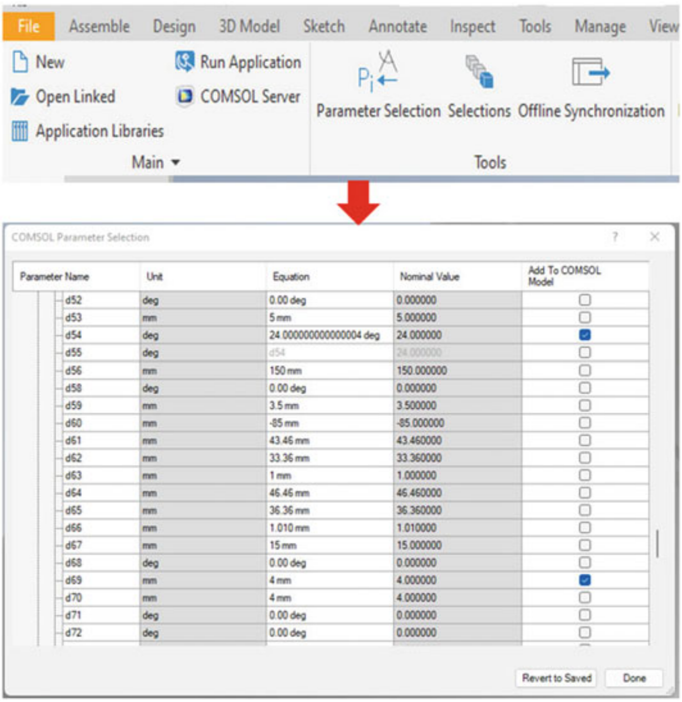
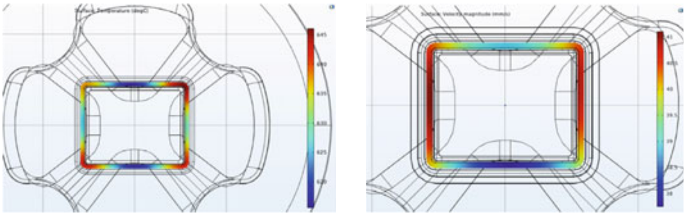


Fig. 7 Synchronize tool in inventor



a. Temperature distribution *b. Velocity*

Fig. 8 Case of 22° bridge angle

Table 2 Results for different bridge angles

	T_{max} (°C)	Δ_T (%)	V_{max} (mm/s)	V_{min} (mm/s)	Δ_V (%)
22°	647	4,5	41.5	36.5	12.05
23°	**604**	**3**	**40.4**	**39**	**3.46**
25°	645	4,3	41.2	37.8	8.25
27°	647	4,5	41.8	36.1	13.6

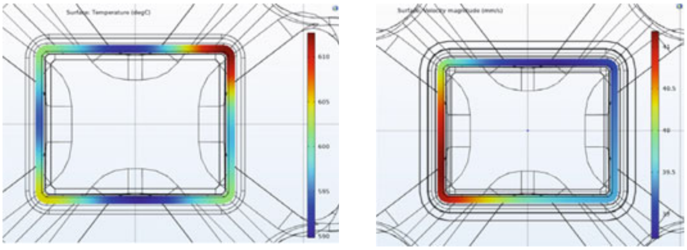
4 Effects of Bridge Angle

In this case, other parameters are selected as V_{ram} = 0.5 mm/s, T_{billet} = 460 °C; difference between feeder and bearing equaled 1 mm; P_{press} = 180 bar. The temperature and velocity results at out gate are presented in Fig. 8 for case of 22°. Similarly, simulate results of temperature and velocity for other angles are carried out and collected in Table 2.

From Table 2, results indicate that under bridge angle in range of 22° to 27°, the maximum temperature is 647 °C. At 23°, the maximum temperature is only 604 °C. Results also show that different velocity (ΔV) get minimum (3.46%) and maximum (13.6%) at 23° and 27°, respectively. Through analysis, it is clear that the appropriate bridge angle is 23°.

5 Effects of Difference Between Feeder and Bearing

Similarly, effect of difference in feeder and bearing will be anlyzed with fixed some other parameters as V_{ram} = 0.5 mm/s, T_{billet} = 460 °C, bridge angle = 23 °C P_{press} = 180 bar. The simulation for three levels of difference between feeder and bearing is performed and results are given in Fig. 9 and Table 3. As seen, varying the difference between feeder and bearing, the maximum temperature of all cases has a slight difference. Moreover, the difference in extrusion velocity is in range of 3.46% and



a. Temperature b. Velocity

Fig. 9 Difference between feeder and bearing equaled 1 mm

Table 3 Results for variation of feeder and bearing

No	T_{max} (°C)	T_{min} (°C)	Δ_T (%)	V_{max} (mm/s)	V_{min} (mm/s)	Δ_V (%)
0.5	612	590	3.6	41.2	38.7	6.07
1	**604**	**586**	**3**	**40.4**	**39**	**3.46**
1.5	615	589	4.23	40.9	37.9	7.33
2	618	593	4.45	41.2	38.3	7.04

7.33%. Based on the obtained results, using the difference of 1 mm between feeder and bearing will have the lowest temperature and velocity variation.

6 Conclusions

Comsol LiveLink to Inventor has been applied to model and analyze extrusion of the rectangle hollow profile in this paper. With dimension of the product, a three-dimensional die was designed by Inventor software which can parametric dimension. Choosing parametric dimension will be synchronized to Comsol. Extrusion process including heat transfer, fluid flow and static structure phenomenon is then constructed and solved by Comsol software. Results indicate that bridge angles and variation of feeder and bearing have affected on temperature and velocity of the extrusion process. Based on considering some values of these dimension design, the appropriation of bridge angles and difference between feeder and bearing are sequently 23° and 1 mm. Herein results provide useful method and information for optimal design for the extrusion die.

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