The Influence of Die Design on Productivity and Recovery for an AA7020 Hollow Section

By Tommaso Pinter, Almax Mori

Editor's Note: "FEA in Extrusion Die Design" is an ongoing series dealing with the opportunities that finite element analysis (FEA) offers to the extrusion industry. Topics will include addressing extrusion defects through die design, the effect of die design on aluminum microstructure, novel approaches to prototyping, and more.

Introduction

Finite element (FE) codes are important tools for process and product optimization for the aluminum extrusion industry. Using numerical simulation, process parameters and die designs can be optimized in order to enhance product properties and to increase productivity at a relatively low cost. When considering the defects typically encountered by extruders, die makers can choose a die concept that helps to minimize those defects as well as further optimizing the design using FEA. This third article in the series will look at how a die maker can use FEA to evaluate charge weld evolution in different die designs in order to increase productivity and reduce scrap generation.

Different from other inherent defects of the extrusion process, such as seam or longitudinal welds that only affect hollow profiles, charge welds affect both hollow and solid profiles. Seam welds as such are unavoidable defects of the extrusion process. The portion of the profile containing the charge welds needs therefore to be discarded from the commercialized length if the final application requires a structural resistance.

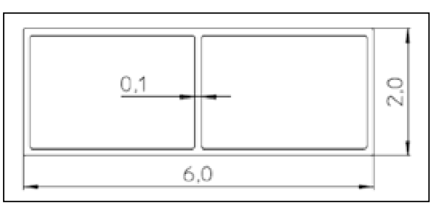


Figure 1. The AA7020 hollow profile under investigation (dimensions in inches).

Ram Velocity (in/s)	Billet Diameter (in)	Billet Length (in)
0.08	10	39

Table I. Extrusion parameters for FEA of the profile.

Case Study

Alloys such as AA7020 are characterized by low production and high scrap rates during extrusion, which is partially due to the fact that this alloy is difficult to extrude through porthole dies. A case study was conducted using FEA analysis to measure and compare different die designs for a hollow section in AA7020 (Figure 1). The extrusion parameters used for the FEA of the profile are listed in Table I.

Two different porthole die geometries were created in order to quantitatively evaluate the effect of different design practices on charge weld extension—a Butterfly design (Figure 2) and a Caterpillar design (Figure 3). The Butterfly design is a solution widely adopted by the extrusion industry. It consists of four legs and a central rib used to link the two cores, thus controlling mandrel deflection during extrusion. The Caterpillar design employs two vertical legs that are not connected by any beam, the result of which is an apparently less stable structure with much smaller ports. The aluminum needed to fill the die is 322 in^3 in the case of the Butterfly design and 192 in^3 for the Caterpillar. Finally, if Figure 2 and 3 are compared, it can be seen that the legs of the two mandrels have the same height and thickness. All the die plates and bolsters were made of H11 hot work tool steel at 48 HRC.

For both designs, flow simulations were performed using HyperXtrude software and tool stress analyses using the Altair SimLab multiple physics approach. Transient simulations have been performed using HyperXtrude software with identical pre-heating temperatures.

Results

Numerical results are summarized in Figure 4 in terms of charge weld evolution for the two die geometries investigated. The Caterpillar design showed a significant reduction of the charge weld extension (Table II). The onset of the

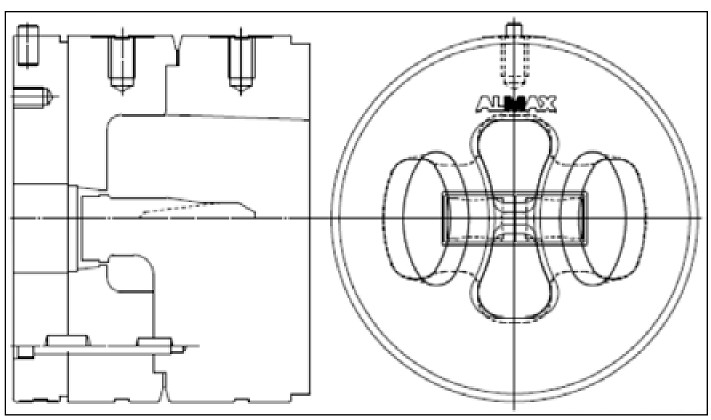


Figure 2. The first design investigated is a Butterfly-type die (350 x 250 mm).

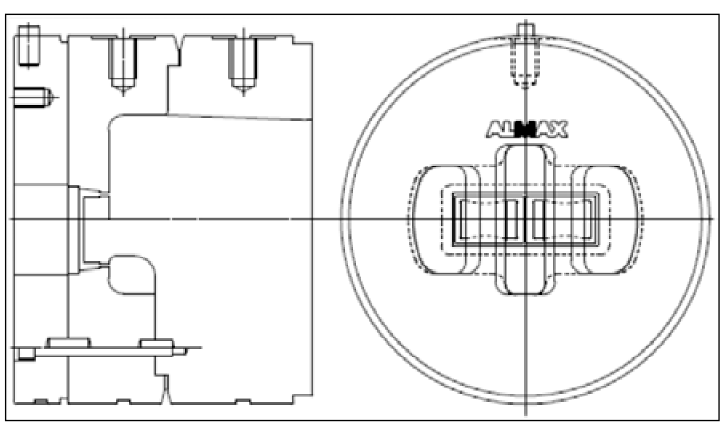


Figure 3 The second design investigated is a Caterpillar-type die (350 x 250 mm).

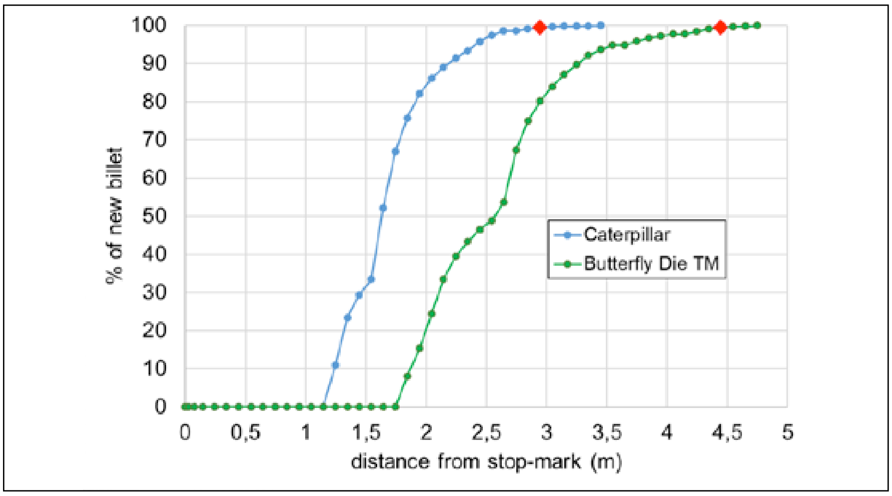


Figure 4. Numerical results in terms of charge weld extension and exhaustion. The Caterpillar design shows a significant reduction in the charge weld extension. The red point refers to 99% new billet material in the profile section.

Die Design Type	Ports Volume (in³)	Charge Weld Extension (in)	Break-Through Force (MN)	Exit Temperature (°F)
Butterfly	322	177	27.0	968
Caterpillar	192	118	27.5	970

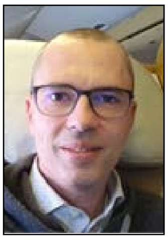
Table II. Comparison of numerical results for Butterfly and Caterpillar dies.

charge weld for the Caterpillar die design happens 0.6 m before the Butterfly, resulting in a charge weld extension that is 1.5 m shorter.

Table II also shows the numerical results in terms of estimated break-through force and exit temperature. Despite the huge difference in ports area and volume, both designs show a very similar behavior in terms of the load required to deform the aluminum in the die and extrudate temperature. The similar exit temperatures are most probably due to the low production rates, which give the die time to dissipate the heat generated. Regarding the very similar ram force at the break through, more investigations are needed to identify the driving factor.

Conclusion

For low production rates like the ones that characterize the extrusion of AA7020, a design with ports that have a reduced volume can give a significant reduction of the front-end defect. Being press load and exit temperature comparable, the adoption of a "reduced ports" die design seems to be the best choice to improve recovery without compromising press productivity. ■



Tommaso Pinter graduated in Industrial Engineering from Università di Trento and later studied metal forming processes at Bologna University. He is currently the CTO of Almax Mori & Alumat, an Italian networked organization of die vendors. He is the author of several aluminum industry publications.