The Case of Central Beams in Hollow Profiles: Influence of Die Design on Extrudate Temperature

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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 optimize the design using FEA. This second article in the series will look at how a die maker can use FEA to consider whether to include central beams in a die design for hollow profiles.

Case Study

Aluminum alloy 6082 is characterized by a solidus phase temperature of 590°C, and the alloy is subject to tearing and cracking if the metal reaches temperatures of 550°C or higher. For this reason, it is necessary for extruders to keep the temperature as low as possible while operating at the desired ram velocity in order to achieve the desired profile. In this context, the die can play an important role in keeping the extrudate temperature between 530°C (the solvus point) and 550°C.

A case study was conducted using FEA analysis to consider how the die design can impact extrudate temperature. A hollow profile (Figure 1) was used to identify the optimal die design concept in order to minimize the extrudate temperature. Flow simulations were performed using HyperXtrude software, while tool stress analyses used the Altair SimLab multiple physics approach.

Two different tool geometries, Design A (Figure 2) and Design B (Figure 3), were created in order to quantitatively evaluate the effect of different design practices on extrudate temperature. All die plates and bolsters were made of H11 hot work tool steel at 48 HRC.

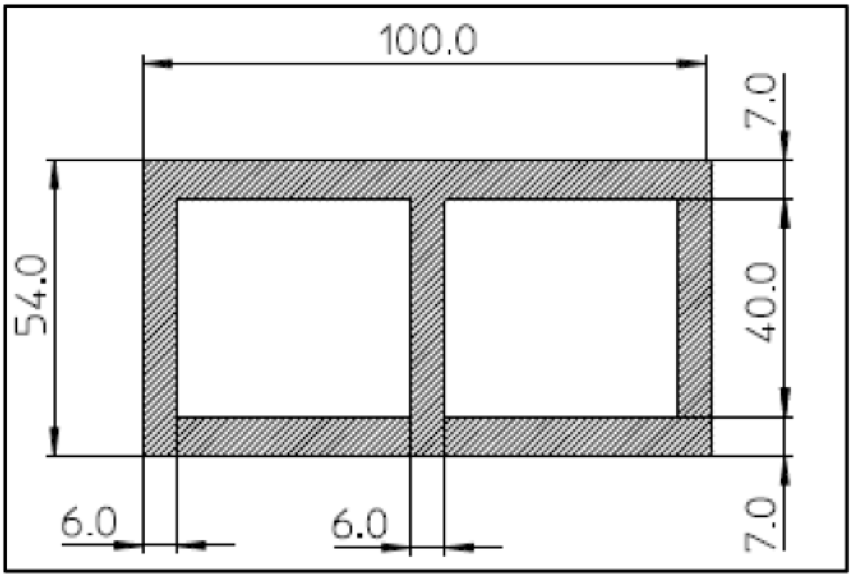


Figure 1. An AA6082 hollow profile was used for the investigation of central beams in die design (dimensions in mm).

Design A represents a typical solution widely adopted by the industry, which incorporates direct central feeding to properly feed the central beam in order to achieve a good seam-weld quality. The die has five ports, of which four are big and proportioned to the profile section they feed. The fifth direct port appears much smaller due to geometric issues that do not allow the die designer to properly dimension it.

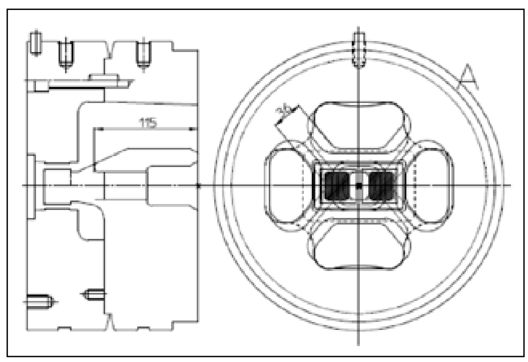


Figure 2. Design A incorporating direct central feeding (dimensions in mm).

Design B shows no direct central feeding. The result is a more balanced design with four ports that are comparable to Design A in terms of cross section area. The central rib is used only to link the two cores, thus controlling the mandrel deflection.

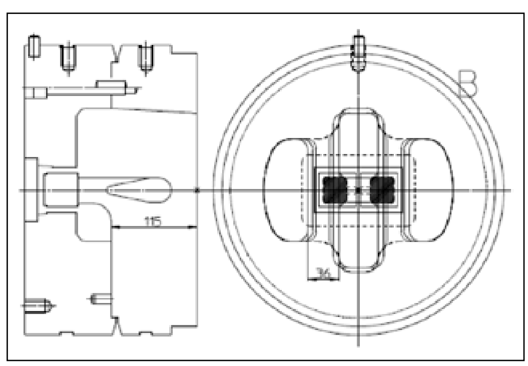


Figure 3. Design B incorporating a central rib instead of direct central feeding (dimensions in mm).

The aluminum needed to fill the die is the same for both Design A and B and equal to 3 dm^3. If we compare Design A with Design B, it can be seen that the legs of the two mandrels have the same geometry. This was done intentionally in order to avoid complications in the interpretation of the numerical results.

Careful attention was paid to the preparation of the 3D CAD models and an almost identical size of the tetra-elements was adopted for both the model of the workpiece and tool. Steady state simulations were performed, assuming a 9 inch billet container on a direct extrusion press, a 420°C liner, a AA6082 billet that is 1,300 mm length and preheated to 470°C (same as the die and bolster), and a ram speed of 10 mm/s.

Results and Conclusions

The numerical results for the two designs in terms of profile temperature at the bearings exit are summarized in Figure 4. As expected, Design B showed a significant temperature reduction in the central rib. Based on this data, it can be determined that, in order to reduce exit temperature and increase productivity, extruders should use dies without direct central feeding.

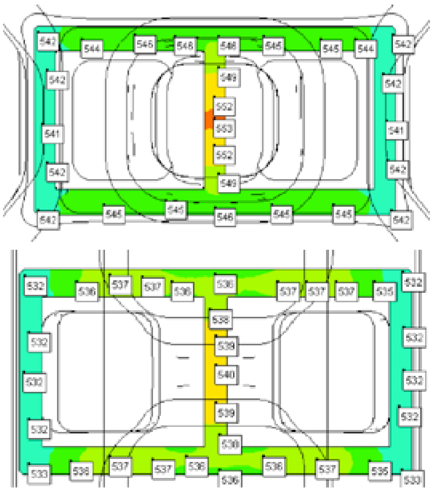


Figure 4. Numerical results in terms of extrudate temperature (°C): Design A (top) and Design B (bottom). The temperature for Design B is 13°C lower than Design A.

In terms of pressure in the welding chamber and on the bearings section, the numerical results are shown in Figure 5. This reveals that adoption of a direct central feeding (as in Design A) does not help to improve the feeding of the central beam between two cores, but rather it reduces the pressure and therefore could result in lower seam-weld quality.

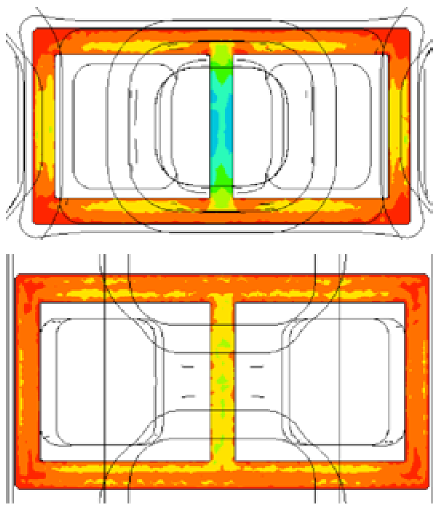
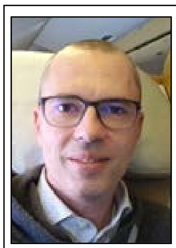


Figure 5. Numerical results in terms of pressure at the bearings inlet (MPa): Design A (top) and Design B (bottom). With a minimum value of 45 MPa at the central beam, Design B is shown to be preferable over Design A.

Further examination could be considered. A next step could be to perform transient simulations with the die designs meshed in order to take into account the non-uniform heating of the die mandrel. In such a case, the author would expect that Design A would show an even higher temperature of the extrudate than Design B due to the heat generation in the central direct feeding, which cannot be dissipated to the outer part of the mandrel. ■



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