The Case of Channel Profiles: The Influence of Die Design on Cap Deflection

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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

In recent years, finite element (FE) codes have become important tools for process and product optimization for the aluminum extrusion industry. The current state-of-the-art of numerical simulations applied to the extrusion process has been presented through past editions of the International Conference on Extrusion Benchmark (ICEB) conference.[1-2] By means of 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 while producing certain types of sections, die makers can choose a die concept that helps to minimize those defects as well as further optimize the design using FEA. This first article in the series will look at how a die maker can use FEA to address geometry defects in channel profiles.

Case Study

Extruded channel profiles (also named U profiles) have shown similar geometry defects since the industry first developed in the mid 20^{th} century. These defects typically occur when the tips of U profile legs are being pulled while the base side is simultaneously running, which causes the gap to close. Extruders can combat this by improving the temperature management of their process (isothermal extrusion can reduce the differences between the beginning and the end of the push) and by providing the die with the best support possible in order to reduce die deflection. Regardless of these efforts, die caps can still deflect under the load, thus causing the bearings to not work flat and producing the geometry defect described. In this context, the die maker can make his own contribution to minimize the defect by selecting a design concept that minimizes cap deflection without unbalancing the metal flow.

A case study was conducted to consider how FEA analysis could help solve this problem. Figure 1 shows the channel profile used to identify the optimal die design concept in order to minimize cap deflection. Flow simulations have been performed using HyperXtrude software and tool stress analyses using the Altair SimLab multiple physics approach. All of the die plates and bolster were made of H11 hot work tool steel at 48 HRC.

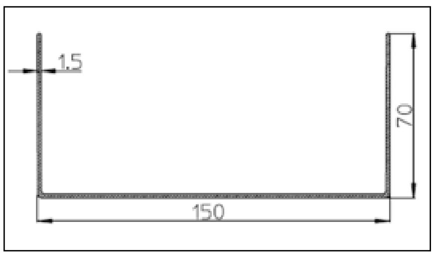

Figure 1. Channel profile under investigation (measurements in mm).

Figure 2 shows the basic die design investigated (design A), which is comprised of two pieces with a cap that has a 0.6 inch deep pocket used to balance the flow and to allow for continuous billet-to-billet production. The die is supported by a bolster at a thickness of 150 mm with the internal shape being an offset of the backer. Numerical results are shown in Figure 3 in terms of cap displacement in the extrusion direction. Despite the big support available to the tongue, design A showed a significant tongue deflection of 0.65 mm close to the bearings. The aim of the FEA was then to change the die design in order to minimize the cap deflection, thus reducing the geometry distortions caused by the relief on the bearings.

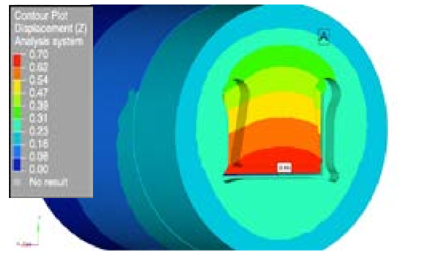

Figure 3. Predicted cap displacement (mm) in the extrusion direction for the basic design A.

An additional set of tool geometries (designs B-E) were created in order to quantitatively evaluate the effect of different design practices on the tool deflection (Figure 4). Starting from the basic design A (Figure 2), modifications were made. For design B, the tailored 15 mm deep pocket over the tongue was removed. For design C, a rectangular-shaped 70 mm thick feeder plate was added in the front, reducing the backer thickness accordingly. For design D, a tailored 70 mm thick feeder plate was added at the front of the A cap design, and for design E, a 35 mm recess was added in the front of the design D feeder plate. Attention was paid to the preparation of the 3D CAD models and an almost identical size of the tetra-elements was adopted for each model of the workpiece and tool. Steady state simulations were performed assuming a direct extrusion press with a 7 inch container, a 420°C liner, a 700 mm long AA6063 billet preheated at

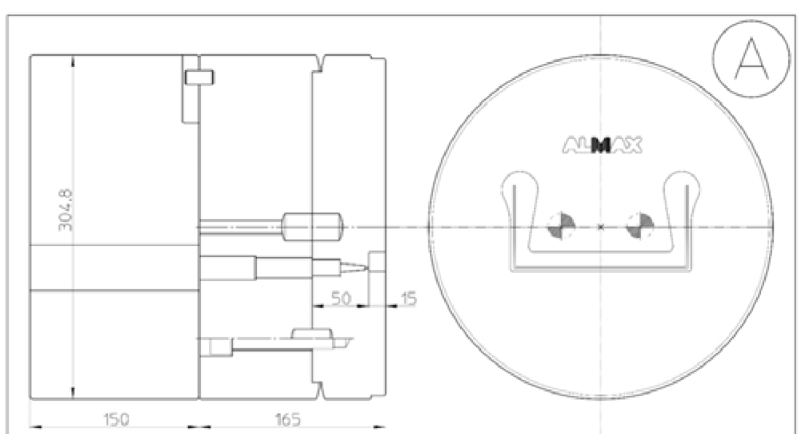

Figure 2. Basic die design investigated for design A (measurements in mm).

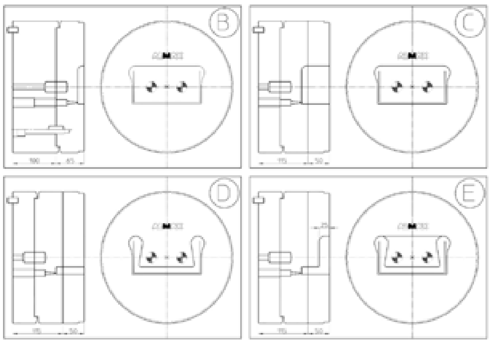

Figure 4. Additional set of die designs investigated by means of FEA (measurements in mm).

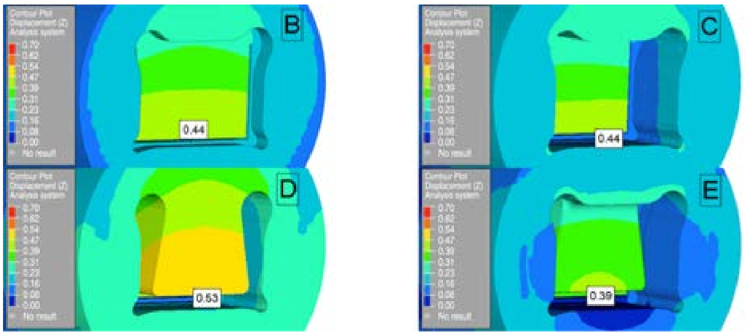

Figure 5. Numerical results for the four additional die designs in terms of cap deflection in the extrusion direction (measurements in mm).

480°C (like the die and bolster), and a ram speed of 10 mm/s.

Results and Conclusions

Numerical results are summarized in Figure 5 in terms of cap displacement in the extrusion direction for the four additional die geometries investigated. Some numbers were expected, while others were surprising. As expected, design B showed a significant reduction of the tongue deflection, down to 0.44 mm. Meanwhile, the adoption of a rectangular shaped 70 mm thick feeder plate (design C) did not demonstrate any reduction of the deflection with respect to design B. Design D showed the same deflection as the B and C designs, reducing recovery for extruders and, thus, revealing design mistakes for die vendors to avoid. Surprisingly, design E was the best performer with just a 0.39 mm cap deflection, which is 40% less than the deflection predicted for design A.

Results in this study should be generalized with care, as they are suited to a channel shape with a circumscribing circle similar to that of the billet diameter. It is likely that design C would have performed much better in the case of a design featuring small tongue with legs longer than the base.

This study provides further proof that FEA offers extruders and die vendors a big opportunity in the continuous improvement of the extrusion process they are pursuing. Finally, this contribution strengthens the universally adopted design rule for the tongue in an extrusion die: "take out from the die all that is not needed."

References

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2. Pietzka D., N.B. Khalifa, L. Donati, L. Tomesani, and A.E. Tekkaya, "Extrusion Benchmark 2009-Experimental Analysis of Deflection in Extrusion Dies," *Key Eng. Mat.*, Vol. 424, 2009, pp. 19-26. ■