Predicting Profile Wall Thickness Using a Multidisciplinary Simulation Environment

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

One of the important properties required for high quality extruded profiles is achieving tight tolerances all along the finished profile length. In this respect, one of the most challenging targets to hit during simulation is the prediction of wall thicknesses for solid profiles, because the deflection of the die and the reciprocal sliding of its sections can have a big influence on the linear weight of the extrudate. For this kind of detailed analysis, the engineers at Almax Mori in Italy use Altair SimLab™, a process-oriented multidisciplinary simulation environment designed to accurately analyze the performance of complex assemblies, such as a die-set made of different sections assembled using registers and pins and loaded together with its specific back-support. This article shows how using a multidisciplinary simulation approach can help to address the challenge of accurate wall thicknesses.

Case Study

An open section of a U-shaped profile was analyzed as part of the case study (Figure 1). U-shaped profiles are typically subject to die deflection and, as a consequence, to a variation of the linear weight of the extrudate in respect to the nominal wall thickness. If the linear weight of the profile is under tolerance after trial production, then the customer will require modification of the die using EDM wire erosion. Since the customer often cannot require an overseas die manufacturer to perform the modification, they will have to perform the work internally. On the other hand, if the linear weight of the profile is above tolerance, then the die will not be usable, which means it will be necessary to produce a new die

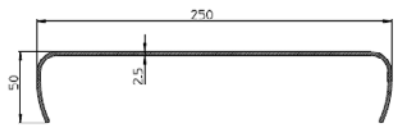

Figure 1. The U-shaped profile used in the investigation.

cap section in order to extrude the required profile. This second scenario is not good for the extrusion company, which would be forced to take a longer time to bring the profile to market. It also results in additional costs that are detrimental for both the die maker and extruder.

In the case study, the influence of widely adopted manufacturing practices on the behavior of the die under load was quantitatively investigated. The aim of the study was to find a means to control the die deflection, thus offering a tool capable of extruding a profile with nominal wall thicknesses.

Two die designs were analyzed in the investigation (Figure 2). Both are three set dies (feeder, cap, and backer) with four sealing pins between the cap and backer. Unlike Die A, Die B features a large sealing key between the feeder and cap and longer sealing pins between the cap and backer. All die sections, bolster, and pins are made of H11 steel and preheated at 470°C.

A multidisciplinary approach was used in the investigation, including

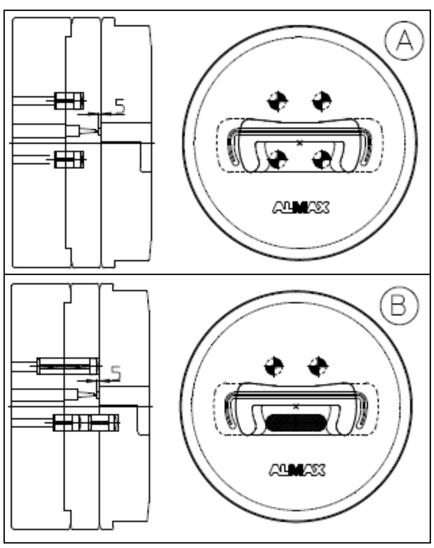

Figure 2. Schematic of the two die designs that were under investigation, showing a vertical cutaway-section (left) and a front view (right) of each die.

the use of 3D models and elasto-plastic analytical models, which describe the behavior of a metal under load (in the elastic and plastic fields). The 3D models used for the simulations also included the bolster, while the pressure ring was considered a rigid entity in order to reduce the number of nodes and, therefore, the amount of computation time. Pressure and thermal loads come from transient flow simulations performed using HyperXtrude software.

Numerical Results

Figure 3 shows the numerical results in terms of cap elastic deformation perpendicular to the bearings, showing a comparison of the cap absolute sliding for the two designs investigated. In both cases, the left part of the cap (tongue) closes, while the right part expands with an equal relative sliding of 0.05 mm. Therefore, the profile is expected to have a 5% thinner wall due to cap deflection. Despite that, thanks to the additional constraint introduced in Die B provided by both the longer pins and the key, the absolute sliding of the cap under load is reduced by almost 30%.

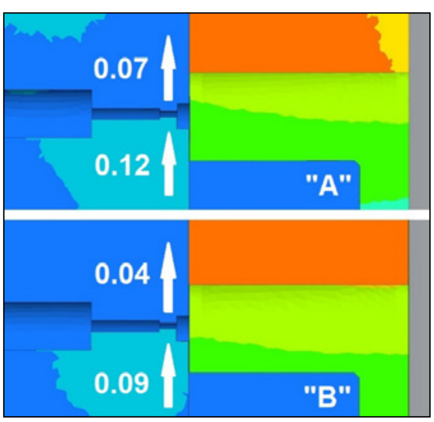

Figure 3. Deformation of the cap under load for Die A (top) and Die B (bottom) along cutaway-section (values in mm).

When a cap slides over a backer it accumulates elastic deformation that will be released sooner or later; this is the mechanism at the base of the surface defect known as a "pressure mark." For this reason, Die B is preferred over A in order to reduce the possibility of a pressure mark defect occurring.

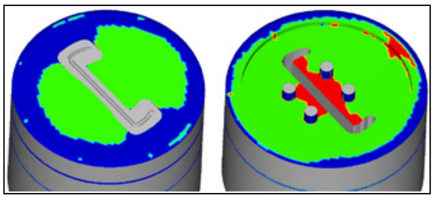

Figure 4. Results for Die A, between cap and feeder (left) and between backer and cap (right). Blue represents areas of no contact, green represents sliding surface, and red represents sticking surface.

Figure 4 (left) shows the sliding of the feeder-plate over the cap for Die A. This is a confirmation of the excellent design, in which the register and pins between cap and feeder were not considered, thus allowing the feeder to slide over the cap without dragging it. However, Figure 4 (right) is probably the most interesting, as the image shows the areas between caps and backers in Design A where sticking and sliding occurred. The pins reduced the sliding area, which concentrated the sticking around them. This explains why their adoption generally reduced the deflection of cap over backer.

Solution

Aiming to produce a die that minimizes sliding and, therefore, variations of wall thickness, a third die design was investigated (Figure 5). The geometry of the pocket in Die C was engineered in order to reduce the sliding of the cap over the tongue. In addition, a shrinking ring was applied to the cap in order to contain its thermal expansion. The result is a die with a more stable cap under load, since it neither deflects nor expands significantly (Figure 6). Therefore, Die C is expected to produce a profile with a near nominal wall thickness, as well as likely reducing the occurrence of pressure mark defects.

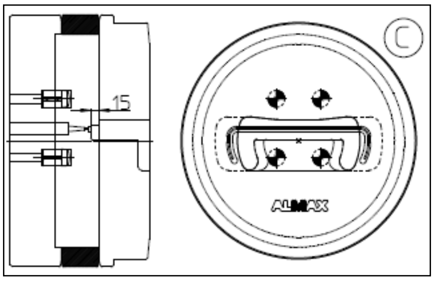

Figure 5 Schematic of Die C, showing a vertical cutaway-section (left) and a front view (right) of the die.

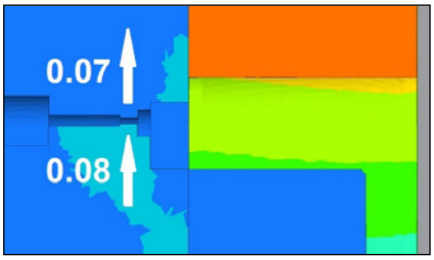

Figure 6. Deformation of the cap along cutaway section in Die C (values in mm).

Conclusion

Using an advanced elastoplastic approach, it is possible to predict in detail the behavior of an extrusion die made of different sections. The case study of an open U-shaped section shows that with FEA it is possible to minimize cap deformation, thus minimizing the variation of the profile wall thicknesses. In particular, the author recommends the adoption of a 15 mm deep pocket in the cap combined with a shrinking-ring in order to achieve the most stable die. ■

__Tommaso Pinter__ graduated in Industrial Engineering from Università di Trento nearly two decades ago 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. Contact Pinter at: www.linkedin.com/in/tommaso-pinter-460a8619.