Determining the Effect of Preheating Bolsters on Die Performance

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.

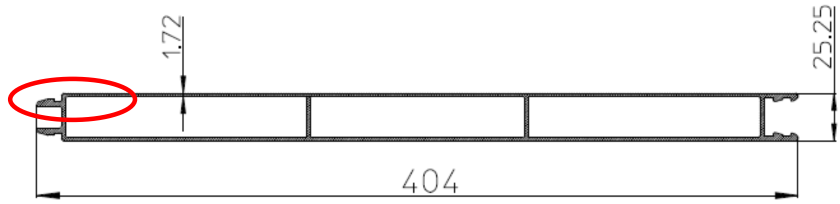

Figure 1. An AA6063 profile extruded using a 9 inch press (values in mm). Nominal weight is 4.4 kg/m with an extrusion ratio of 27. The red circle represents the cutaway-sections of Figures 4, 5, and 6.

When using FEA simulations for die design, one important target is considering the peak stress of the tool during extrusion. Accurately estimating the die stress under load makes it possible to predict whether or not the die will be subject to incipient cracks and, therefore, to a short operating life.

For this kind of detailed analysis, the engineers at Almax Mori in Italy use Altair SimLab™, a process-oriented multidisciplinary simulation environment, 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 a specific back-support. Last but not least, in the SimLab environment, an elastoplastic analytical model is available for the behavior of hot working steel at different temperatures. This is critical when looking to provide accurate predictions of the tool stress.

Case Study: The hollow section in Figure 1 is a wide shape extrusion produced using a relatively small die diameter. As a consequence, the cap might be subject locally to high peak stresses. In this case study, the influence of a "cold" bolster on the behavior of two different die design solutions was quantitatively investigated, with the aim of comparing the peak stresses in the cap section. Figure 2 shows the two die designs under investigation. Both designs include a self-containing die set (mandrel, cap, and bolster). Design B differs from design A in that a shrinking-ring has been applied to the cap in order to contain its thermal expansion and deflection. All die sections, bolster, and pins are comprised of H11 steel.

Thermal simulations were performed with three different bolster temperatures, including a bolster preheated to 450°C, a bolster at 20°C (room temperature), and a bolster preheated to 300°C. The 3D models used for the simulations considered a bolster in which the pressure ring is a rigid entity in order to reduce the number of nodes and therefore the computational time. Pressure and thermal loads come from steady state simulations performed using HyperXtrude software. In this respect, the ram speed has been settled at 10 mm/s, the billet length at 1,000 mm, the billet temperature at 460°C, and the porthole preheating temperature was fixed at 450°C.

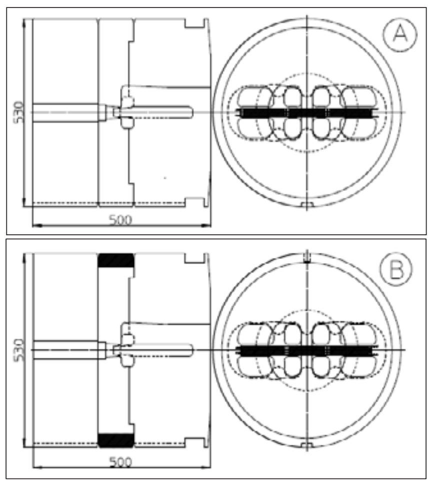

Figure 2. Die designs under investigation with front view and vertical cutaway-section. Design B features a shrinking ring on the cap section (dashed).

Numerical Results: To reduce the computational time the author assumed no heat exchange between bolster and pressure ring. This hypothesis looks to be optimal in the case of the bolster at room temperature (with the extrusion press front-plate most likely operating at room temperature). In the case of the bolster preheated at 300°C, this boundary condition is probably underestimating the cooling of the die cap due to the big mass of the pressure ring in comparison with the bolster (in reality the bolster would be cooled by the pressure ring and not only warmed-up by the die cap).

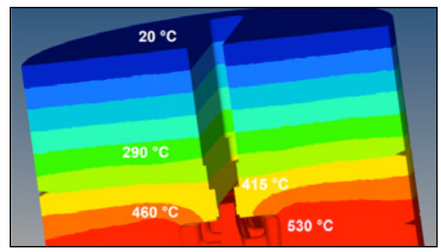

Figure 3. Results of the thermal simulations showing the dramatic cooling effect of a cold bolster (room temperature) on the die cap (values in °C). The cap, mandrel, and bolster sections are visible.

Figure 3 shows a comparison of the thermal equilibriums reached by design A with a 20°C bolster. The simulations demonstrate that, as expected, a non-preheated bolster significantly cools down the die cap, thus influencing its mechanical properties under load. Figure 4 shows the results in terms of Von Mises stress for design A, with specific attention to the cutaway region marked with a circle in Figure 1, while Figure 5 shows the same for design B.

In Figure 4, it can be seen that using a bolster at room temperature implies an increase to the peak stress up to 60% in respect of pressing the die with a bolster preheated at 450°C. FEA predicts a peak stress of close to 800 MPa. Reaching the plasticity field on the corner detail results in a crack appearing on the cap, causing a defect to form on the aluminum profiles after extruding only a few billets. Therefore, using a cold bolster should be avoided in order to preserve the die and to extrude a profile without defects.

The results shown in Figure 5 are surprising. A shrinking ring can significantly reduce the stress on the cap and compensate partially for a cold bolster. The peak stress shown for design B pressed with a cold bol-

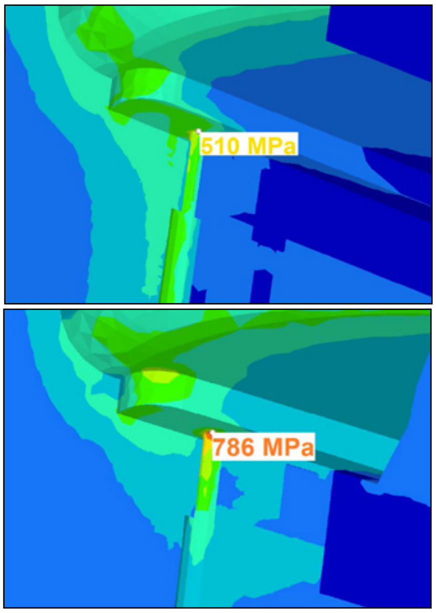

Figure 4. Peak stress for design A, when the bolster is preheated to 450°C (top) and 20°C (bottom).

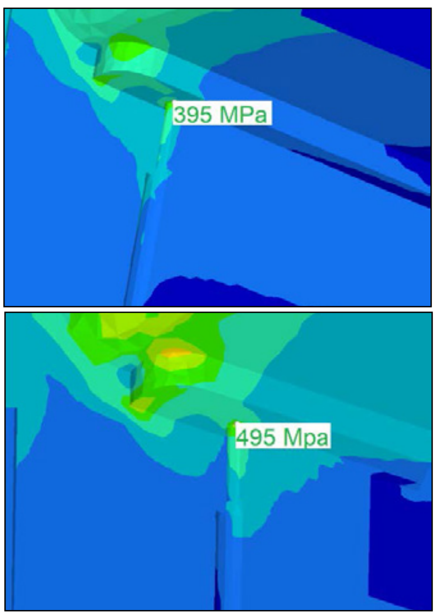

Figure 5. Peak stress for design B, when the bolster is preheated to 450°C (top) and 20°C (bottom).

ster is only 15% higher than the one predicted for design A with a bolster preheated at 450°C. Even if this result cannot be generalized (each die is different and backer would for sure protect the cap from the cooling effect of the bolster), it reveals that with FEA it is possible to engineer solutions in order to address observed problems and overcome technological limitations (e.g., preheating ovens not available for bolsters).

A third situation was investigated in which the bolster was preheated to 300°C. The advantage of this practice is that hot work tool steel will not lose hardness. This implies that standard bolsters can be located inside multi-chamber ovens at 300°C for an unlimited time period without their performance and operating life being affected. The results of the simulations for design B are shown in Figure 6, showing that the die cap has a very similar working stress compared to the results in Figure 3. This thus confirms the value of this specific preheating practice.

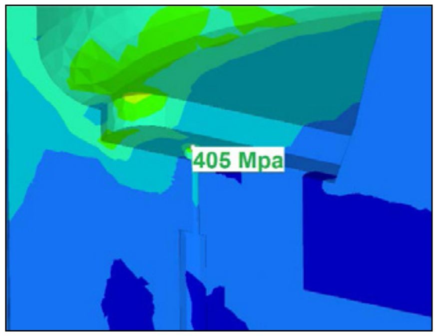

Figure 6. Peak stress for design B when the bolster is preheated to 300°C.

Conclusion: Using a process-oriented multidisciplinary simulation environment, it is possible to predict with acceptable accuracy the peak stress of a die cap under load at different temperatures. The results of these investigations showed that a cold bolster can significantly cool down the cap section, thus increasing dramatically the stress of the tool during extrusion. The die stress appears to be similar when the bolster is preheated to 300°C or when it is preheated to 450°C. The mandrel temperature/stress during extrusion seems to not be dependent on bolster preheating temperature. The adoption of a shrinking-ring can significantly reduce the stress on a cap under load, thus compensating partially for a cold bolster

Based on these results, the following best practices are recommended when dealing with bolsters. Always preheat bolsters (especially when the die has no backer). It is good practice to preheat standard bolsters to 300°C. In the case of critical profiles and hard alloys extrusion, the bolsters should be preheated to match the die temperature. If it is not possible to preheat the bolsters, then it is important that the die have a backer. ■

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Anti-Dumping Duties on Chinese Extrusions

On March 31, the European Commission published a regulation imposing definitive anti-dumping duties on aluminum extrusions originating in China. The anti-dumping duties imposed range from 21.2–32.1% and will be in place for the next five years. These duties are the result of an investigation opened in February 2020 following a complaint lodged by European Aluminium.

Preliminary Duties: In September 2020, the European Commission first announced its intention to impose provisional anti-dumping duties on extrusions originating in China with a duty rate varying from 30.4–48%. According to European Aluminium, Chinese imports of semi-fabricated aluminum had more than doubled during the prior five year period (2014-2019). The destructive impact of dumped imports led to a decrease in production and a loss of market share for European producers across the entire value chain, which forced several companies to restructure or close plants with significant job losses. Gerd Götz, director general of European Aluminium, said of the measure, "With this proposal, the Commission shows it is walking the talk when it comes to increasing the EU's trade defense against unfair trade practices. These anti-dumping duties are crucial for the survival of the European aluminum value chain, which is critical to Europe's transition to a digital and green economy."

Additionally, certain aluminum flat rolled products originating in China are also subject to an EU anti-dumping investigation. Earlier in March of this year, the EU announced its intention to impose provisional anti-dumping duties on flat rolled aluminum, ranging from 19.6-47.3%

Definitive Duties: The European Commission's investigation into unfair trade practices was finalized and definitive duties put in place beginning April 2021. As a result of the investigation, definitive anti-dumping duties (from 21.2–32.1%) have now been imposed.

Götz implored, "We call on the Commission to work with its counterparts in the U.S. and Canada to address the root cause of China's market distortive behavior: overcapacity. Anti-dumping duties offer protection against dumping in the short term, but we need a structural and global solution to address subsidized Chinese overcapacity in the long term." ■