How Low Porthole Preheating Temperatures Affect Mandrel Integrity

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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.

When using FEA simulations for die design, a primary task is predicting the peak stress of a porthole die. By accurately estimating the tool stress under load, it is possible to predict whether or not a mandrel might be subject to permanent plastic deformation. For this kind of analysis engineers may make use of Altair SimLab™ to accurately analyze the performance of complex assemblies. In the SimLab environment, an elastoplastic analytical model is available, which provides the behavior of hot working steel at different temperatures. This is critical when looking to accurately predict the tool stress.

Case Study

The AA6063 rectangular pipe shown in Figure 1 is a hollow section that would likely be extruded using a 9 inch container press in order to offer a large contact surface between mandrel and billet. This profile would likely be produced using spreading, which allows for the extrusion of a profile that is wider than the container. When implementing spreading for a profile, it is important that the extruder take special care with their die filling practices, including controlling the preheating temperatures of die and billet in order to avoid damage to the die during first billet breakthrough.

In this case study, the influence of die preheating temperature, aluminum alloy, and billet preheating temperature were investigated in terms of mandrel stress for a Butterfly Die™ type die design (Figure 2). This is a self-containing die without backer made from H11 steel hardened at 48 HRC. It is 21 inches in diameter and 12 inches thick. The 21 x 9 inch bolster is of a rigid design and was preheated together with the die, therefore, it was not included in the FEM model. Coupled simulations were performed with the Mechanical Engineer Suite from Altair. The ram speed was set at 24 ipm, billet length at 39 inches, and liner temperature at 800°F.

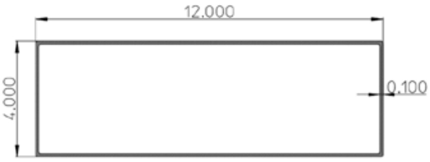

Figure 1. AA6063 section extruded using a 9 inch billet container press (values in inches). The profile has a nominal weight of 3.7 lbs/ft and extrusion ratio of 23.

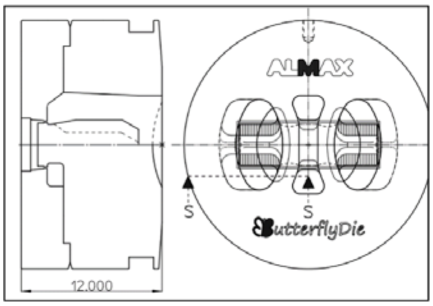

Figure 2. Butterfly Die design under investigation with front view and vertical cutaway-section (values in inches).

Based on the pressure and thermal loads coming from the coupled steady state simulations, an element tool stress analysis was performed using Altair SimLab for the combinations of die and billet temperatures (Table I). Starting with a die preheated to 932°F and a billet preheated to 842°F (precautionary conditions A), different intermediate situations were investigated, concluding with the theoretically most unfavorable conditions (combination D). In addition to considering AA6063 alloy for the profile, combinations A and D were also considered for AA6082 alloy billet.

Combination	Die (°F)	Billet (°F)
A	932	842
B	932	752
C	752	842
D	752	752

Table I. The four combinations of die and billet preheating temperatures investigated.

Numerical Results

Figures 3 through 6 show the predicted tool stress for the mandrel bridges in the AA6063 profile along the cutaway section shown in Figure 2. Figure 3 shows that the original die has been properly engineered. This demonstrates that, if the preheating temperatures are ideal, then the mandrel works within the elastic field and neither tip of the bridge section show a peak stress close to the plasticity limit of 850 MPa.

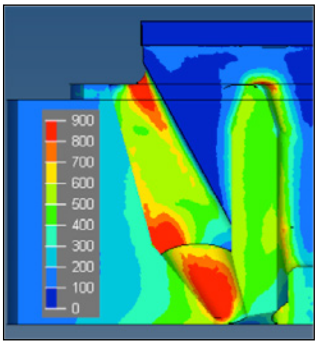

Figure 3. Von Mises stress simulation (MPa) for preheating combination A along the main bridge section (AA6063 alloy).

Figure 4 reveals that, even in the undesirable case in which a cold billet is pressed in a properly preheated die, the main mandrel stress at the bridge section does not increase significantly. Things are different if one tries to press a die preheated at only 750°F (Figure 5). Despite the properly preheated billet, the die stress increases dramatically and the risk of permanent mandrel deflections also seems likely. Finally the numerical results for the worst combination of preheating temperatures is shown in Figure 6, which are similar to those shown in Figure 5.

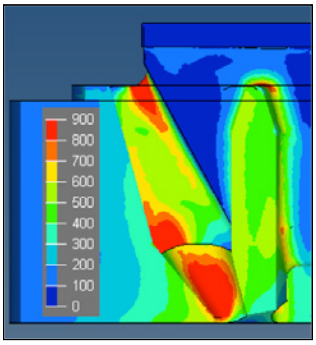

Figure 4. Von Mises stress simuluation (MPa) for preheating combination B along the main bridge section (AA6063 alloy).

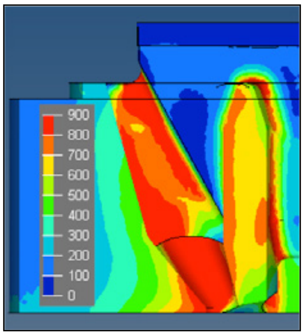

Figure 5. Von Mises stress simulation (MPa) for preheating combination C along the main bridge section (AA6063 alloy).

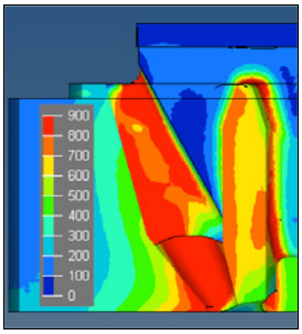

Figure 6. Von Mises stress simulation (MPa) for preheating combination D along the main bridge section (AA6063 alloy).

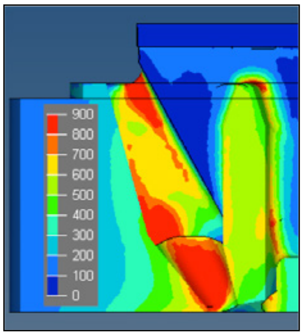

Figure 7. Simulation for AA6082 alloy profile, showing Von Mises stress (MPa) on the section of the mandrel legs using preheating combination A.

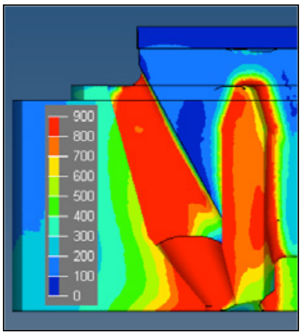

Figure 8. Simulation for AA6082 alloy profile, showing Von Mises stress (MPa) on the section of the mandrel legs for AA6082 using preheating combination D.

The results of the simulations (Von Mises) for AA6082 are shown in Figures 7 and 8, respectively. For the same process parameters, AA6082 significantly increases the tool stress in comparison with AA6063 (Figure 8). The simulation proves that a mandrel engineered for AA6063 should not be pressed with AA6082 without a preliminary analysis using FEA. In the case of when both die and billet are relatively cold (Figure 8), the mandrel will most likely be extruded together along with the first billet. This is due to the fact that mandrel bridges are expected to work in the plastic field for the majority of their section.

Conclusion

Using a multidisciplinary simulation environment, it is possible to predict with acceptable accuracy the stress of a mandrel under load at different temperatures. Mandrel stress increases more in the case of a low die preheating temperature (750°F) than with a relatively cold billet (750°F). Using AA6082 also significantly increased the stress on the mandrel, especially in the case of low preheating temperatures. The combination of AA6082, a relatively cold billet, and a cold die appears to be detrimental for the integrity of the mandrel and must be absolutely avoided in order to preserve the mandrel from early breakage.

Based on these results, the following best practices for preheating are recommended. If the die temperature is more than 20°C lower than the theoretical one, then abort the die trail/production and send the die back to the preheating oven. A die engineered for AA6063 should not be pressed with AA6082, unless a FEA is performed to check if the additional stress is acceptable. If an extruder would like to extend the lifetime of their die, they should not push them cold with a relatively cold billet, especially if it is made of AA6082 or harder alloys. ■