How to Predict and Counteract Wall Thickness Contraction in Hollow Sections

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Editor's Note: Die-Related Extrusion Defects is an ongoing series dealing with the analysis of the defects encountered in extruded profiles that are related with die design and its behavior under load. It will describe the physical origin of those defects including the ones related with poor mechanical properties and provides design practices to minimize them.

Introduction

While reaching the maximum velocity in extrusion with dilute 6000 series alloys, in most cases, the surface finish becomes unacceptable before any tearing situations appear; the onset of pick-up and scoring are usually encountered first (Extrusion Defects series by Jerome Fourmann, *Light Metal Age*, 2014-2018). In the case of high yield 6063 alloys that require excellent crushability, and therefore ductility, wall thickness contraction is encountered first and tearing might not even occur (Figure 1). The second article of this Die-Related Extrusion Defects series deals with wall thinning, an extrusion defect that is also known as "wall thickness contraction."

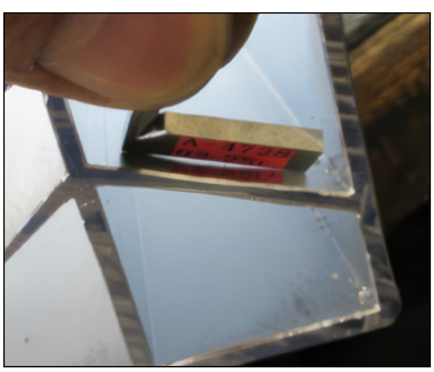

Figure 1. Wall thickness contraction (thinning).

Remedial measures for wall thickness contraction can be applied mainly in two areas—extrusion process optimization and die design. The case study presented here is investigating the latter; in particular, the study concentrates on wall thickness contraction related with the stresses imposed by the extrusion process that typically affect the internal walls of hollow sections made of high yield 6063 aluminum alloys.

Case Study

A 6063 aluminum alloy hollow section made of 13 voids has been used as a case study. The section, used to manufacture an automotive crush component (typically for vehicle crash management) has a C.C.D. of 9 inches. It is extruded using an 11 inch billet container press using a porthole die with a 19 inch diameter and 12 inch thickness. Due to intellectual property rights protected by a non-disclosure agreement with the OEM, the profile section and the extrusion conditions cannot be shared.

Experimental Results

At the required ram speed, one internal wall of the hollow section (fed by direct central feeding) showed severe wall contraction (Figure 2). With the wall thickness being well below minimum tolerance, the die shop repaired the die to obtain a profile within the tolerance at the second production trial. It is worth mentioning that the extrudate samples produced during the second production trial passed the crush tests performed by the OEM company.

Numerical Results

With the aim of predicting the appearance of the defect shown in Figure 2, a FEA campaign was performed. Two different dies were simulated using the same process parameters as the experimental trials. In particular, the FEA study looked at the pressure, flow stress, strain rate, equivalent strain, exit temperature, and disproportionate speed in the region of the wall thinning.

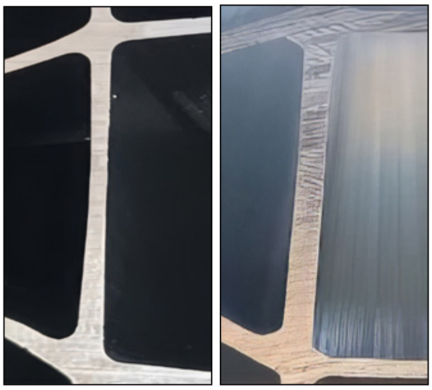

Figure 2. The wall thickness contraction experienced during first die test (left) and nominal wall obtained after die repair (right).

First of all, due to the presence of a die bridge over the problematic wall, the aluminum pressure (MPa) in the welding chamber has been investigated for the original die and the die after repair. The two dies studied both showed very similar results. Therefore, it can be determined that pressure alone is not enough of a parameter to understand whether the wall is going to be properly formed. In addition, flow stress (MPa) and strain rate for the original die and the die after repair were also found to be quite similar.

Figure 3 shows the distribution of equivalent strain in the welding chamber, with the simulation results of the die after it was repaired revealing that the welding chamber is now feeding better for the problematic wall.

Finally, Figure 4 shows the relative exit speed difference in the region of the wall subject to thinning. It is clear that after die repair, the problematic wall has accelerated significantly, which explains the higher exit temperature (Table I).

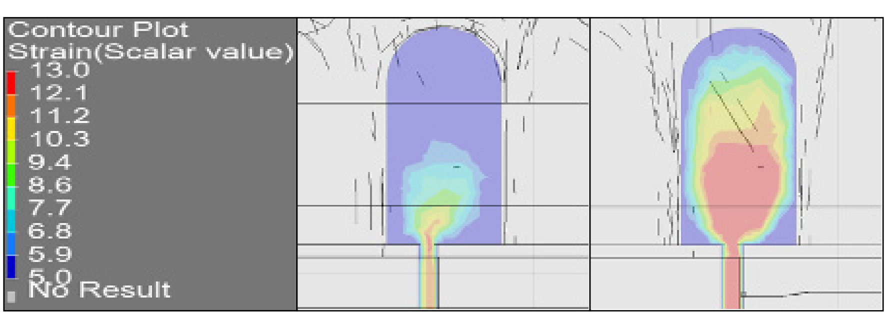

Figure 3. The numerical results in terms of equivalent strain in the bearings' region for the original die (left) and for the die after repair (right). It can be noticed that after repair the sticking layer over the bearings was reduced drastically.

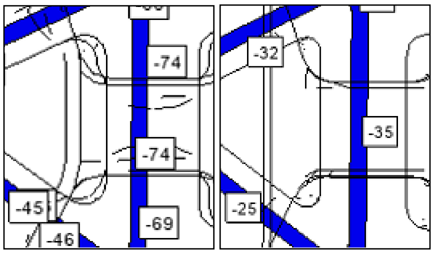

Figure 4. The numerical results in terms of relative exit speed (%) for the original die (left) and for the die after repair (right). The die repair significantly improved the exit speed of the wall that was subject to thinning.

	Thin Wall	Nominal Wall
Pressure (MPa)	29	30
Exit Temperature (°F)	1,067	1,079
Equivalent Strain (ε)	Low	High
Relative Exit Speed (%)	-74	-35

Table I. The correlation between predicted extrusion conditions at the bearings region and experimental results. Pressure at bearings and exit temperature appear to not be key factors.

Discussion

Despite the high number of parameters investigated, only a few of them show a correlation with the experimental results and consequently the focus was shifted to the equivalent strain and relative exit speed difference. After die repair, the deformation zone of aluminum in the welding chamber improved tremendously and the sticking layer of aluminum over the bearings reduced to a normal extent (Figure 3).

Table I summarizes the most significant numerical results. Results are telling us that extended sticking at the bearings together with significant exit speed differences might generate wall thinning. However, the improvements predicted by FEA after die repair look significant only if investigated in detail. Only the difference in the relative exit speed provided enough insights for the drawing engineer to make corrections without requiring cost consuming investigations.

Conclusion

The identification of wall thickness contraction in hollow sections can be challenging and cost consuming due to the fact that this defect often affects the hidden inner walls and usually becomes worse towards the end of an extruded length. Thanks to FEA, it seems to be possible to predict the appearance of this extrusion defect by looking for a combination of good pressure at the bearings' inlet, reduced sticking layer over bearings, and uniform relative exit speed difference. Nevertheless, because it was difficult to find a correlation between numerical predictions and experimental results, ensuring an accurate analytical correlation may be too ambitious at this time. Further analysis and/or developments are required. ■

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