# Deflections of Critical Die Tongues

## *How to Avoid Them with AMVICO Cut*

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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 to the die design and its behavior under load. It describes the physical origin of those defects including the ones related with poor mechanical properties and provides design practices to minimize them.*

### Introduction

The fourth article in this series deals with flection and deflection of die plates due to complex profile geometry and critical die tongues. During extrusion, the press load on the tool stack accounts for an average of 60% of the breakthrough force. This load generates flections, deflections, and plastic deformations of the dies, which becomes more significant in the case of flat dies with critical tongues like the ones used to extrude heat sink profiles.

Tolling "best practices" recommend using die sets with feeders that are capable of adsorbing stress from the billet and, therefore, are able to deform rather than the cap itself. Industry also recommends the adoption of tool steel qualities with superior toughness in order to improve the mechanical properties of the die plates. Finally, pre-heating practices and die filling operations are of extreme importance for the successful extrusion of such products.

The deflection of the die and the flection of its tongues can have a big influence on the wall thickness of the extrudate and may lead to tool failure (Figure 1). Die bending cannot be avoided completely and can only be reduced. Therefore, attention should be dedicated to design and manufacturing. In particular, assuming a state-of-the-art die design, the technology used to machine the back release of the dies is what makes a difference.

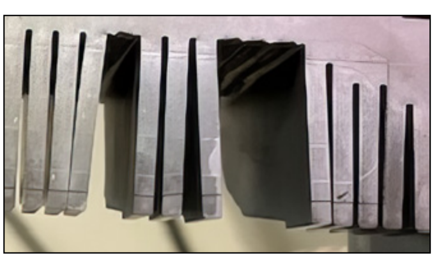

Figure 1. Example of cracked tongues, permanent flections, and deflections in a die cap. These die failures can be caused by several factors, including process, die design, and manufacturing.

### Case Study

In this article, the influence of different manufacturing practices over the ability of the die to withstand the workload given by the aluminum was quantitatively investigated, with the aim of minimizing flections and deflections, thus offering a tool capable of extruding a profile without tongue failures. The section in Figure 2 is a typical solid shape used to dissipate heat. Due to the complex geometry, the die used to extrude this shape is characterized by critical tongues that require proper support. From the quoted dimensions it can be noticed that the ratio between the length of the tongues and their base is 8, while the contact surface offered by each individual tongue to the workpiece is 50 sq mm.

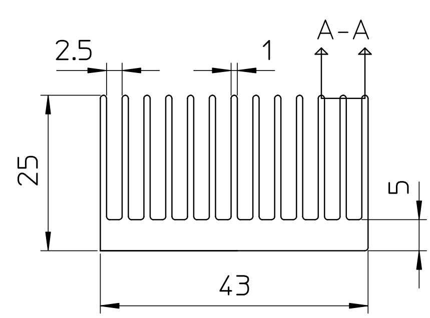


Figure 2. Schematic of the profile under investigation (AA6063), with values in millimeters. These types of heat sink profiles are among those most subject to die failure. It can be noticed that the tongue ratio is 8, while the contact surface offered by each individual tongue to the aluminum flow will be 50 sq mm.

Figure 3 shows the die design under investigation, including a three-set die made of a feeder plate, a cap section, and a backer. Figure 4 presents the different milling technologies widely used in the manufacturing of the die back release that were investigated. All of them present a back release step, but different relief angles and therefore increasing support to the tongues. The chosen extrusion tool has a 7 inch diameter and an 8 inch thickness. The die is supposed to be pressed using a 6 inch billet container press with the liner sealing over the die. All die sections are supposed to be made of H11 steel and preheated at 500°C. The 3D models used for the simulations did not include the bolster, which has been considered a rigid entity. Pressure and thermal loads come from steady-state flow simulations performed using Click2Extrude® software.

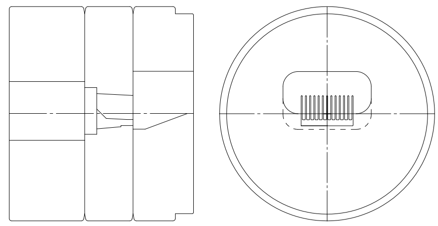

Figure 3. Die designs under investigation with front view (right) and vertical cutaway-section (left). The die has a diameter of 7 inches and a thickness of 6 inches. Design is a standard three-pieces die set comprised of a feeder, die, and backer.

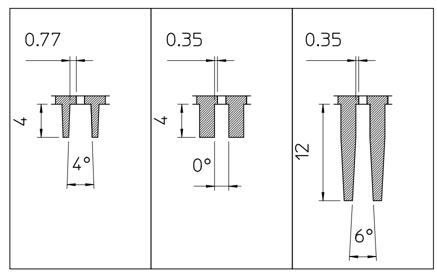


Figure 4. Different die back releases—2° conical cut (left), cylindrical cut (center), and 3° relief with conical cut (right)—investigated along the cutaway section A-A shown in Figure 2, with the extrusion direction from top to bottom (values in millimeters). All three solutions offer a release step after the bearings. The cross sectional area of the tongue support is increasing from 6 sq mm (left) to 10 sq mm (center) to 20 sq mm in the case of 3° relief with cylindrical cut (right).

### Numerical Results

Figure 5 shows the numerical results in terms of tool stress (Von Mises) for the different milling solutions of the back release presented in Figure 4. The adoption of a 3° relief in combination with a cylindrical cutter (right) significantly improves the cross-sectional area of the tongue; however, the pre-


Figure 5. Numerical results in terms of Von Mises stress along the cutaway section A-A shown in Figure 2. Only the back release technology shown in the right section of Figure 4 looks acceptable; however, the bearings region is predicted to work over the plasticity limit of 850 MPa.

dicted stresses in the bearings region look excessive and that could lead to a die failure.

## Remedies

Based on the first set of simulation results, an evolute manufacturing technology has been investigated. Instead of using a back release step, the length of the bearings is defined by a 2° relief obtained thanks to a 4-axis wire cut, called AMVICO (Figure 6). With the adoption of this technology, the depth of the back support is increased significantly and the cross sectional area of the tongue becomes four times bigger in respect to the one obtained with the best free milling technology, shown in the right section of Figure 4.

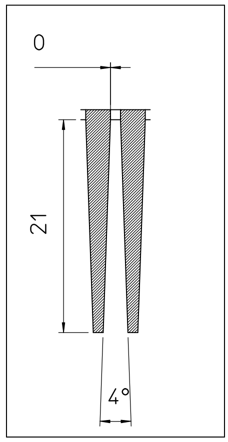


Figure 6. Cross sectional area of the tongue support (along the cutaway section A-A shown in Figure 2) obtained with AMVICO cut. Each individual tongue is supported by a section of 40 sq mm and, therefore, two times more in respect of the 3° relief with the conical cut shown in Figure 4. It can be noticed that, with this technology, only a release angle is given after the square bearings.

Figure 7 shows the numerical results for the advanced manufacturing solution presented. AMVICO provides a significant reduction of the stress at the tongue region thanks to an impressive increase of back support. The improved die back release obtained significantly increases the chances of the die to produce the required shape without failures.

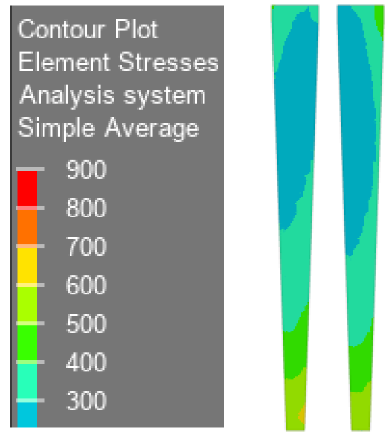


Figure 7. Numerical results in terms of Von Mises stress for the support obtained with AMVICO cut. The increase of the cross-sectional area of the support significantly improves the capacity of the die to absorb the stress generated by the workpiece over the tongues.

## Conclusions

In the case of critical tongues, like the ones described in Figure 2, a successful die does not only require a good design and a superior quality steel, but also an advanced manufacturing technology like the AMVICO cut. ■