The Myth of the Perfect Die

By Paul Robbins, Castool

Extruders have long believed that the best way to increase productivity and profit lies with a better die. The perfect die is still their goal. But they expect too much from the die maker. Just now, the perfect extrusion die is impossible because dies must still be designed and produced for an imperfect production process. The die is made to be used at a less than optimum temperature, and for an uneven flow of alloy. Accordingly, it is much stronger than an ideal die would be for the alloy being used and the profile being extruded. It has a longer stroke, and often some manual machining or grinding to redirect the anticipated uneven flow. This strong die, of course, considerably increases breakthrough pressures and reduces the maximum speed of extrusion.

The Moment of Extrusion

The die is the heart of the light metal extrusion process. Most of the added value—that is, the basic purpose of extrusion—is generated in the instant that the alloy passes through the die. This is the essence of the extrusion process, and by definition may be referred to as the moment of extrusion.

To even approach maximum productivity, three conditions must be met.

1. The alloy must enter the die uniformly at the optimum operating temperature and the optimum rate of flow for the type of alloy being used, and the shape being extruded.
2. The die itself must be completely and uniformly at operating temperature.
3. The temperature of the alloy and the die, and the rate of flow, must all remain constant throughout the extrusion cycle.

If these prerequisites are met, theoretically maximum productivity can result. Today, the real key to better extrusion therefore lies not with the die, but with the effectiveness of the interactive components of the production system that impact the moment of extrusion.

Three of the components that have perhaps the most influence on the die function and the moment of extrusion are the die heater (die oven), the container, and the dummy block. Advantages of the efficient use of these components are described including user-certified results.

The Single-Cell Die Oven

Every extruder wants to get good product from the first push to the last in every run. The usual reason why this doesn’t always happen is that the first one or two billets bring the new die completely and uniformly to operating temperature. This results in scrap, lost production time, and the danger of unnecessary die correction. The basic problem is inconsistent die temperature. The traditional chest oven is an inefficient and often inaccurate way to heat dies. The answer is the single-cell die oven (Figure 1). Benefits of using a single-cell die oven include:

- Each oven heats only one die at a time—quickly, completely, economically.
- Scrap is reduced as the first billets are no longer needed to heat the die.
- The die is at optimum operating temperature for the alloy used and the profile being extruded.

![Figure 1. Five single-cell die ovens with 15 dies being sequentially heated.](image)

- Higher operating temperature reduces breakthrough pressure.
- Rapid heating minimizes oxidation of bearings and degradation of nitride layer.
- Ensuring that the die is completely at optimum temperature allows increased use of pre-filled dies.
- A status indicator light shows the operator when the die is ready to run. No time is lost.
- Acceleration time needed to reach desired speed is shortened.

**Reduced Die Failure:** When dies are preheated in a single-cell oven to a uniform operating temperature, breakthrough pressures are regularly reduced by 30 – 40%. Typical results shown here are from a large eastern U.S. extruder who compared the effect of single-cell ovens during September - November 2006 with a chest oven in the previous three-month period. Since last November, the number of die failures has continued to decline.

<table>
<thead>
<tr>
<th>Chest Oven</th>
<th>Single-Cell Oven</th>
</tr>
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<tbody>
<tr>
<td>Die Pushed In</td>
<td>Jun. – Aug./06</td>
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<tr>
<td>Mandrel Moved</td>
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<td>Bridge Pushed In</td>
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The Quick Response Container

The modern container is likely the most misunderstood component of the extrusion production system. In the past few years, more knowledge has been gained concerning the real function of the thermally-controlled container than in the previous 20 years.

For example, many extruders have long thought that the heat inflow from the billet could overheat the container. This is simply impossible. There is a massive imbalance between the thermal mass of the container (mass X specific heat) and that of the aluminum billet. The container mass will dissipate heat readily within its volume, then lose some to its surroundings within the housing.

The heat generated due to extrusion occurs primarily in the deformation zone, just before the alloy enters the die. Most of this heat is carried out through the die before it has time to heat the container.

The excess heat rises inside the container housing and increases the temperature at the top. With a conventional container, the higher temperature at the top of the liner
reduces the viscosity and therefore the flow stress of the alloy at that point. The alloy then flows through the die slightly more rapidly at the top than at the bottom. In a multi-hole die, the runouts from the top holes will be longer than from the bottom. Unequal tension on the pullers will then cause dimensional problems with the product.

The time taken to respond to a demand for heat is in direct proportion to the distance between the temperature sensor and the heat source. A contemporary Quick Response (QR) container has temperature sensors located near the liner. Cartridge heaters are positioned close to the sensors, instead of in the center of the mass of the mantle, as in most conventional containers. Their purpose is to heat the liner, not the mantle, and thus to maintain a consistent billet temperature as the alloy enters the die. Double thermocouples monitor both liner and heater temperatures simultaneously. Benefits of using a QR container include:

- Since the controlling heat, when needed, is focused on the liner and not the mantle, the cost of energy required is usually reduced by 50% or more.
- Vertical control zones can eliminate vertical temperature differences at the die end of the liner (Figure 2).
- Axial control zones assist the progressive upset of the billet to facilitate isothermal extrusion.
- Differing upper and lower runout lengths in multi-hole dies is virtually eliminated.
- Incidence of "knockoffs," i.e. dies that must be replaced before the production run is complete, is reduced.

**Figure 2.** Die end of QR container.

*Return on Investment:* To profit from the benefits of a QR container in the production process, an obvious question from any extruder is, "Can I afford it?" For most extruders, the answer is, "Yes."

Recently, a major European extruder made a very detailed calculation of return on investment (ROI) based on actual results of using QR containers of four different sizes. Factors used in the calculations included the following: Energy cost/yr based on 24/7, 350-day operation; life expectancy of liner, and reline costs/yr; life of mantle, and cost/yr; cost of control system; cost of knockoffs/yr, and savings assuming min. 25% reduction. The calculated payback period if a QR container is installed is as follows:

Calculated ROI: 7*-1.3 yrs 8*-0.94 yrs 9*-0.92 yrs 10*-1.32 yrs

*The Expanding Dummy Block*

The function of the expanding fixed dummy block initially appears to be quite straightforward. It is the extension of the ram and stem that actually pushes the softened alloy through the die. This is, of course, its main purpose. If the extruder is aiming for maximum productivity, however, there are a number of additional advantages to an effective contemporary expanding dummy block (Figure 3), which include:

- Reduces scrap
- Reduces unscheduled downtime
- Improves press speed
- Expands quickly under load and maintains a secure seal with the container wall, leaving only a thin film of alloy on the liner
- Separates cleanly from the billet at the end of the stroke
- Contracts immediately and returns through the container without stripping the film of alloy from the liner
- Causes no gas entrapment that can result in blistering
- Accommodates minor press misalignment
- Is quickly and easily removed and replaced

*Figure 3. Three piece expanding dummy block.*

**Increased Recovery:** When a Japanese extruder changed to expanding dummy blocks, which have a mandrel spring to ensure immediate contraction at the end of the push, his ram speed was more consistent. Because of the bayonet-type coupling, unscheduled downtime to replace dummy blocks was reduced. The most easily measured benefit, however, was scrap loss that primarily resulted from blisters due to gas entrapment. With an average production of about 1,000,000 lbs per month, this extruder had been consistently averaging 84.2% recovery. After upgrading his dummy blocks, his recovery increased to 84.6% which translates to a saving of 4,000 lbs of aluminum per month.

*Knockoffs*

A problem that is shared by most extruders is the unscheduled downtime that is caused when a die must be replaced before the production run has been completed. Usually known as knockoffs, this can be caused by many factors.

The incidence of knockoffs has proven to be greatly reduced and often eliminated by the adoption of single-cell die ovens, QR containers, and controlled expansion dummy blocks. Each contributes to improved productivity. Combined, these three interactive components can combat a number of costly problems that have been traditionally considered inevitable.

*The Die of the Future*

Today, the focus is no longer on designing and manufacturing better dies, it is on the moment of extrusion. It is on improving the function of the excellent dies now available, with better components that support the die and enhance its performance.
At some time in the future, when Superextruders are approaching maximum efficiency in all the components of their production system, the focus will again revert to the die. The challenge will then be to design a die that will improve the moment of extrusion without the constraint of assuming less than maximum efficiency from supporting components.

Today, assisted by accurate multi-axis CNC machining, a die maker can repeatedly produce a reliable and consistent die. This reduces the need for pre-production trials and bench correction. The die of the future will not be simply an open die that allows a faster ram speed. The advent of larger port entries for hollow dies, and thinner webs, has enabled lower extrusion pressures, lower billet temperatures, and higher extrusion speeds. However, the tendency to increase the port circle diameter close to the ID of the container liner increases the risk of billet skin entering the die and causing an unacceptable surface finish on the extrusion. Die makers now recognize the impact of their designs not only on extrudability and productivity, but also on the surface finish of the product.

The perfect die of the future will reduce extrusion pressures, meet closer tolerances in response to increasingly stringent demands of the market, and avoid problems of surface finish, and improve productivity through improved understanding and control of metal flow. The absolute maximum productivity of any well-run extrusion plant cannot be estimated. However, it is certain that productivity will increase as a result of increased knowledge of the moment of extrusion and understanding of the effective interaction of components that support the die.

Editor's Note: Paul Robbins has contributed a number of articles to Light Metal Age (LMA) that have struck a chord with extruders. He offers the perspective of the seasoned tool maker who can provide fresh insights into improving the extrusion process. His articles have emphasized how to achieve higher levels of productivity through understanding all the components of the extrusion process and their optimal interaction. Some recent articles of his in LMA that have garnered industry interest include: “Top 10 Worst Extrusion Practices (And How They Can be Avoided),” April 2005; “Precise Alignment (Physical and Thermal) is Key to Extrusion,” December 2004; “Superextruders: Improving Container Life Through Temperature Control,” April 2003; and “Who are the Superextruders?”, April 1997.

Paul Robbins, born in 1956, the son of a leading Toronto die maker, was educated at Upper Canada College and York University. He received a postgraduate degree at the Schulich School of Business. He has worked in the light metal extrusion industry for more than 25 years. He is general manager of CASTOOL Tooling Systems, a Canadian company serving a global market with the most complete line of extrusion production tooling and equipment available today. Paul holds several patents for improvements to extrusion technology that he has developed over the years, and is well-known internationally for the many technical papers he has presented at extrusion industry conferences.