THE ULTIMATE EXTRUSION TOOLING SYSTEM
FOR MAXIMUM RAM SPEED AND
MINIMUM UNSCHEDULED DOWNTIME

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Abstract
In the practical science of light metal extrusion, the single uncontrollable limiting factor in the quest for maximum productivity is the maximum speed at which the metallurgy of the alloy being used will permit it to form saleable product with the required profile. All else in the entire production system is controllable. Maximum saleable product with minimum unscheduled downtime is the goal of every extruder because he is not motivated by perfect product, just by profit. In the past decade, as a result of our increased knowledge of the actual extrusion process and the digitization of controls, much more improvement has been made in the tooling available to assist the extruder in this regard than in any similar period in the history of the extrusion industry. Three examples of new or improved extrusion tooling components will be discussed.

The single cell die oven
In the ongoing evolution of light metal extrusion, the impact of the single cell die oven can be compared only with the introduction of the fixed dummy block. It is so rapidly becoming a standard in our industry globally, that in a competitive market any extruder not using single cell ovens may find it very difficult to remain profitable.

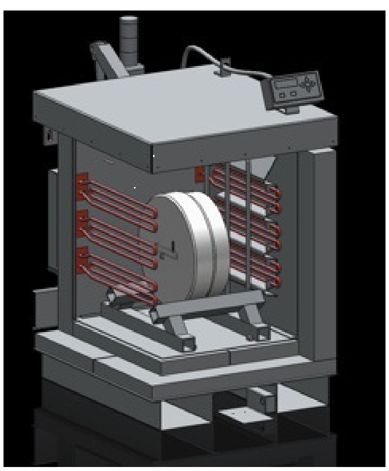

Figure 1
Single Cell Die Heater

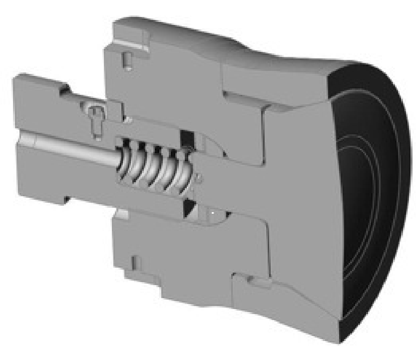

Figure 2
RRB Fixed Dummy Block

As with any other major component in the extrusion tooling system, the single cell die oven has evolved over time. Contemporary models reflect the influence of improved temperature measurement and subsequent increase in pertinent knowledge of the extrusion process. Today, with a good single cell oven, saleable product is as achievable from the first billet as from the last. The necessary heating time required to bring the die safely, uniformly and quickly to the optimum extrusion temperature for the alloy being used has been accurately estimated. In a fraction of the time taken by a chest oven, the die is then individually brought uniformly and completely to operating temperature.

Using the best of today's technology, Castool minimizes the time required to bring the die to the required temperature. Radiant heat is generated by six high performance Incalloy sheath heaters. Two "K" type thermocouples monitor the temperature in the stainless steel heating chamber which has been designed to reflect the radiant heat to the surface of the die with maximum efficiency.

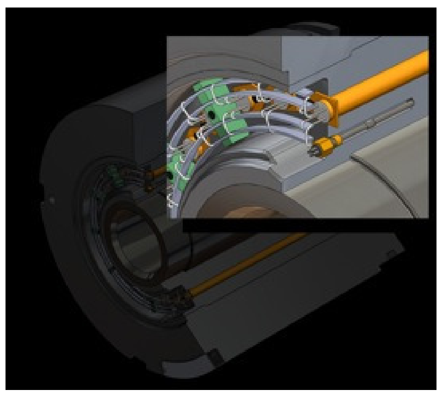

Figure 3
QR Container Thermocouples

To heat the die rapidly, the surface of the die must initially be considerably above the target operating temperature. Care must be taken to avoid exceeding the critical temperature above which the die steel begins to soften and the nitride layer starts to degrade. This negative affect of overheating will be first apparent in the deterioration of the die bearings. Overheating is, however, positively prevented by locating one temperature-controlling thermocouple at the hottest point in the oven chamber i.e. close to the heating elements. This is conservatively set well below the annealing temperature of the die. At the cost of a shorter time at temperature, this safety margin absolutely protects the die from overheating.

When the heating cycle starts, a yellow indicator light comes on. The controller shows "Time to temperature." and begins to count down.

During the heating period, the controller causes the heating elements to transmit as much energy as possible into the die without exceeding the maximum allowable temperature.

When the controller indicates that the die is uniformly at the desired temperature, the oven temperature is immediately reduced to the target operating temperature, and held there. A green light comes on, and the controller begins to indicate, “Time at temperature.” From the status indicator light on the oven, the operator can see at a glance that the next die is ready to go on the press.

A key to the most effective use of single cell die ovens is the optimizing of the heating program used for each die. It is based on the size and mass of the die, the thermal conductivity of the die steel, the amount of energy added by the resistance heaters, and the heat lost to the environment. Typically a new die oven customer will provide Castool with a die that will then have several thermocouples installed. Its heating cycle will then be fully documented. From the mass of pertinent knowledge now available to Castool from its user base of well over1,000 single cell die ovens in service globally, the algorithm used on its controller for each die is therefore now in fact a calculation rather than simply an estimate. The single cell oven is the most reliable means today to safely, accurately, quickly and economically heat a die.

The Quick Response Container

The thermal mass of the container is much greater than that of the die. Accordingly, as soon as the die is firmly sealed to the end of the container liner, heat transfer begins by conduction, and continues so rapidly that a thermal equilibrium is soon reached between the container liner and the die. In developing an improved container, therefore, the goal was to control the temperature of the liner as effectively and efficiently as possible, so that the die would remain at optimum temperature, and taper heated billets could optimize exit speed. This would require almost absolute temperature control at all times. The Quick Response Container by Castool approaches this ideal.

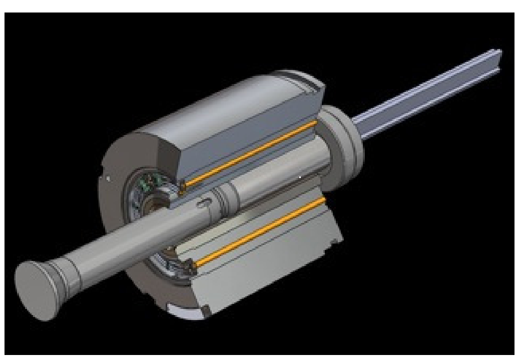

Figure 4
QR Container

The liner temperature is best controlled by correcting any variations as soon as possible. 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. In the QR container, cartridge heaters are located very close to the liner. Their purpose is to immediately summon heat to the liner when needed, not to the container mantle. Specially designed double thermocouples are used to monitor the temperatures of both the liner and the mantle simultaneously. Heating elements are positioned very close to the sensors. As a result, the quick response keeps the temperature of the liner and thus the alloy fairly constant.

Figure 5
Conventional Container Temperature

The energy required to control the temperature of the alloy is, of course, a function of the extent of the temperature variations. The QR container is therefore unusually cost effective. Think of smoothing ripples rather than waves. This is evidenced by the fact that when replacing conventional containers with QR containers, energy savings of as much as 75% are not uncommon. In addition, the risk of overheating, tempering and softening the mantle is practically eliminated.

The viscosity of the alloy being extruded is extremely temperature-sensitive. The die designer must, however, assume that the die will remain completely and uniformly at optimum operating temperature at all times during extrusion.

Primarily, the QR container differs from other smart temperature controlling containers in that its function is not to control the temperature of the container mantle, but the container liner. The real purpose of the QR Container therefore is to manage the temperature of the die during extrusion. The logic of this is irrefutable. Here follows a good example of this theorem.

Unless closely controlled, heat lost from the bottom of the container mantle rises inside the housing, and considerably increases the temperature at the top. With conventional containers, the vertical temperature difference at the liner exit is typically 55-110℃. (100-200˚F). Thermal measurements have proven that during extrusion the difference in temperature between the top and bottom of the die is approximately the same as between the top and bottom of the liner exit. Experience has also shown that for every 5ºC or 10ºF of vertical temperature variance, the runout length from the top apertures of a multi-hole die will exceed that of the bottom openings by approximately 1%. This presents a serious problem for both pullers, and cutting to length. It also makes it difficult to maintain required tolerances on a profile.

The problem of the vertical temperature difference which, if uncontrolled, will occur at the die end of the container liner, is further compounded by another vertical temperature difference in the die itself. The die slide in which the die sits has enough mass to act as a heat sink and leech heat from the lower half of the die. Equalizing the temperature at the top and bottom of the end of the liner will therefore not completely eliminate unequal runouts. The liner temperature must therefore be made slightly hotter at the bottom than the top to completely eliminate any vertical temperature difference in the die.

Properly designed temperature controlled containers solve the problem of vertical temperature variance in the liner, and thus in the die, by having vertical as well as horizontal temperature control zones. The velocity of the product leaving the top or bottom of the die will therefore be the same.

The Robotic Die Expediter (RDX)

The Castool RDX System is an innovative process designed to assist the operator in improving productivity by making best use of the knowledge gained during Visual Optimization when an optimum formula for heating the die was established.

It is essential that both billet and die are at the same temperature when extrusion begins. This does not always occur. Left unattended in the ambient air of the shop floor, a heated die will cool at the rate of about 50C in 10 minutes. Sitting in the die slide which acts as a heat sink, this rate of heat loss will be doubled.

Once a number of functions in the extrusion procedure have been digitized and an optimized production formula prepared for heating dies, it is then possible to use RDX, a robotic system which expedites the scheduling and heating of the die from the time of its arrival from the die shop until its installation on the press.
Although the die will be heated and moved according to a prepared formula, the press operator will continue to have complete control at all times. and will make all necessary decisions during every step in the process.

First, the die man brings the die and places it in an empty cradle. The die will remain in this cradle and be moved robotically until it is placed in the die slide by the operator.

Using a key punch, the operator enters the die number. If there is an existing production formula from the Visual Optimizing System, it will be activated. If not, the operator will prepare an initial formula and activate it. The die is then automatically moved into the scheduling area by a gantry robot.

The operator chooses which die is to be placed in an empty die oven. The robot places the die in the oven where it is heated to the temperature required by the formula.

When the operator requests the next die to be run, the robot moves the die from the oven to a heated holding area. Maintaining the temperature of the heated die while waiting to be used is critical.

After it leaves the heated holding area, the operator moves the die from its cradle to the die slide using eye bolt/crane previously employed. The RDX system requires no change to existing handling equipment.

There are a number of benefits to the use of the RDX system. The first, of course, is operator safety. Time spent moving dies in and out of hot die ovens is eliminated; Once a die production formula is entered in RDX, human error is eliminated; The die is held at operating temperature until use, and valuable floor space required for die ovens and dies is considerably reduced.

The Future

The technology of light metal extrusion has improved considerably in the past few years. Even the best extruders, however, are not yet able to make best use of the technology now available. The reason for this is because the variety of leaner hard alloys now being made that provide better strength, physical properties and surface finish as well as increased ram speed, does not nearly match the variety that would benefit extruders whose improved temperature measurement and control would now make their use possible. The trend towards leaner and faster alloys is a very positive development in our industry, but leaner alloys by nature demand more in terms of temperature monitoring and control, if the benefits are to be fully realized.

In the future**,** the extruder will have a broad spectrum of Designer Alloys to choose from. He can then take full advantage of the fact that he has very close control of the alloy temperature from the time the billet is heated until the alloy exits the die in the desired profile.

The extruder will then first negotiate the required section with his customer. He will discuss the application in some detail to determine the shape, the physical properties, surface finish, tolerances and so on that are actually necessary, not merely what the customer thinks he would like, with a view to modifying the original specification in any way he can to improve his productivity. As the technology is constantly improving, customers are very often unaware of what can actually be done by a good extruder. He will then talk with his billet supplier to determine the

alloy that will best fit his actual requirements and allow maximum ram speed. Then he will present the revised specification to his die maker saying something like, “This is the shape, these are the tolerances, and this is the alloy we’ll be using. Give me a die that will provide saleable product, and allow the fastest ram speed.”
Only then will the extrusion system really approach maximum productivity, and the light metal extrusion industry will approach maturity.

Epilogue
Every light metal extrusion production system can be improved. There are no exceptions to this rule. Because of this, any knowledgeable and efficient extruder will be understandably reluctant to install a closed-loop system, because once the production loop is closed, no further improvement is possible.

None of the state-of-the-art contemporary tooling discussed here is intended in any way to replace the press operator. It is designed simply to assist him in his quest for increased productivity.

In terms of improving productivity, a talented and experienced press operator is worth infinitely more to the extruder than the most sophisticated tooling system yet devised.