Die function – what really happens when the alloy passes through the die?

Paul Robbins of Castool, Toronto suggests that the die itself is not the most critical factor in the production of high quality extrusions, but that just as important are other components, such as die ovens, container, and dummy block, all of which contribute to passing alloy through the die at, or close to, uniform optimum temperature and speed.

Castool Tooling Systems is a global provider of today's most advanced production tooling and equipment for the light-metal extrusion industry. Always a leader in research and development, Castool pioneered the fixed dummy block and thermal controlled tooling. The Author has been actively involved in all aspects of the industry for more than 20 years, coining the phrase "Temperature, Temperature, Temperature" in a 1996 article, The Superextruders.

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 the perfect die is actually a myth. Extruders 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.

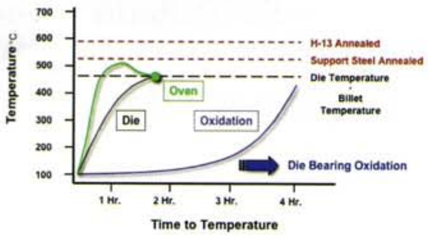
The die is often called the heart of the extrusion process, because the die is where so much of the added value which the extruder creates is actually generated. Unfortunately, this has led some people to believe that the die makes the extrusion. Of course it doesn't. The die aperture is simply one part of the total shape conversion process. But that mindset, that the extrusion is made by the die, causes many extruders to considerably underestimate the real rate of productivity that could be achieved by the production system they are using. The extruder should avoid focussing on the word "die", and think in terms of the "die function".

What really happens when the alloy passes through the die? If the die is well-designed and well-made, the shape that leaves it should meet all the required dimensional tolerances, have a good surface finish, and be moving at a profitable speed, from the first billet to the last. This can only happen, however, if three specific conditions are satisfied.

- The alloy must enter the die uniformly at or near its optimum operating temperature
- The die must be completely and uniformly at the operating temperature of the alloy being used
- The temperature of the die and the exit temperature of the extrusion must remain almost unchanged from the beginning to the end of each cycle

To meet these conditions, all parts of the extrusion production process must interact together as a system, and the temperature of the alloy must be effectively controlled from start to finish. In the past several years, partly as a result of technological advances in measuring capability, both physical and thermal, the extruders real understanding of all aspect of the extrusion production process has grown significantly. This allows the practitioner to predict with much greater accuracy the results of changing temperatures, pressures, and speeds. As a result, it is now possible for the extruder to operate with confidence much closer to maximum limits in several areas than ever before, and to increase productivity.

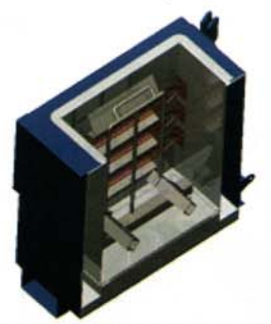
Many extruders, however, are unaware of the significance of the fairly recent improvements in thermal control that have made it possible to manage more effectively the die function. The die may be the most overrated and under-utilised component of the extrusion production system. If the extruder simply assumes that his die is well-designed and well-made, and concentrates on the die function and the three principal factors that facilitate its effective operation, an increased rate of productivity is sure to follow.



Dies are heated by initially increasing the chamber temperature above the die target temperature, usually 475°C. Care must be taken to prevent drawing back the die and supporting tooling steel, and harming the nitride layer. The die should be removed from the oven shortly after reaching the target temperature to reduce oxidation of the die bearing

Improving the die function

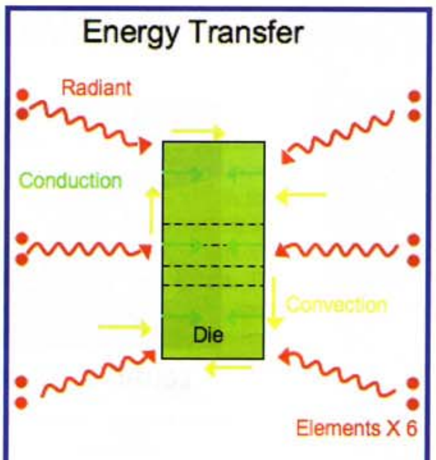
The extrusion die, by itself, cannot unconditionally correct the results of the less than perfect function of other complementary components, whose basic purpose is to help to present the alloy to the die in such a way that the critical shape conversion can most easily and accurately take place. A good die corrector may be able to make the die operate effectively, but the life of the die is usually compromised, and repeatability is difficult. The die function can therefore be best improved by enhancing the operation of these other components. Good examples of this are the Castool single-cell die oven and QR container.



The stainless steel liner is surrounded by hard board ceramic insulation. Inexpensive quick-change resistance elements are positioned to direct radiant energy at the die faces. A stainless steel die carrier is custom made to suit the dies being heated

The single-cell die oven

Often, the product from the first billet at the beginning of a production run must be scrapped, as the die needs to be brought uniformly to operating temperature by the heat of the alloy. With a Castool single-cell die oven ensuring that the die is properly and uniformly heated, good product is as achievable from the first billet as from the last. As the name indicates, a single-cell oven has a single heating chamber and heats only one die at a time. A computerised controller calculates the necessary heating time required to bring the die safely and completely to the optimum extrusion temperature for the alloy being used. This calculation is based primarily on the mass of the die, its surface area, the thermal conductivity of the steel that the die is made from, the known heat loss of the oven, and the number of kilowatts of energy being used. In a fraction of the time taken by chest ovens, the die is then individually brought to temperature. Maximum production requires that the next die is always ready to put on the press, as soon as the previous run is finished. The most usual reason why the next die is not ready is that it is not completely at operating temperature. With the Castool single-cell die oven, the operator can see when the next die is ready to put on the press from the status indicator light on the oven. Downtime is reduced.

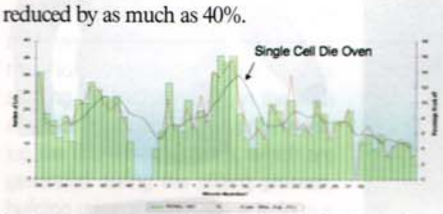


Energy is transferred to the die mainly as radiant energy in a single cell die oven. Energy is transferred through the die by conduction. Convection energy plays a minimal role in heating the die

Radiant heat is generated in the single-cell oven by high performance sheath heaters. Thermocouples monitor the temperature in the heating chamber which is designed to reflect the heat to the surface of the die with maximum efficiency. The steel outer shell is lined with high-quality rigid ceramic insulation. To heat a die rapidly, the surface of the die must initially be heated considerably above the target operating temperature. Care must be taken, however, to avoid exceeding the critical temperatures for the die and support steel. Overheating is prevented by locating a temperature-controlling thermocouple at the hottest point in the oven chamber, close to the heating elements. This is conservatively set well below these temperatures. At the expense of a shorter time to temperature, this safety margin positively protects the die from overheating.

To harden the surface and extend the life of an extrusion die after it has been manufactured, the die is usually nitrided. If the die is then overheated, this nitrided layer on the surface of the die is soon destroyed, and its operating life shortened considerably. This is avoided in the Castool single-cell oven.

A common cause of scrap is that, if left too long at or near operating temperature, die bearings will oxidise and need to be re-polished. This is a difficult problem because usually the extruder's first indication of bearing oxidation is surface deterioration of the product. Tests have shown that quite rapid oxidation begins after a die has been held at temperature for only about three hours. This also is avoided with the single-cell oven. The extruder then monitors his savings in reduced scrap loss and downtime, before adding additional units as their investment proves to be justified. By reducing both scrap and unscheduled downtime, single-cell ovens almost immediately increase profit, and also the break-through pressures of dies preheated in single-cell ovens versus chest ovens are often reduced by as much as 40%.



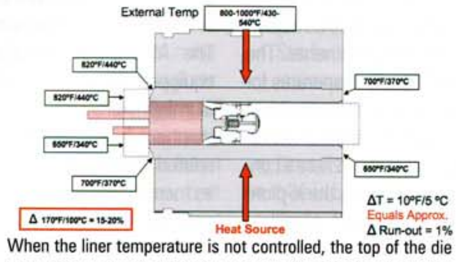
Knock offs, dies not meeting planned production demands are usually reduced when using a single cell dies oven versus multiple die ovens

Transition

Many extruders have had experience of installing a large multi-hole die that has been uniformly heated to the correct operating temperature, and are pleased to discover that the first billet produces good material. However, after a few billets, the run-out lengths begin to differ, and dimensional tolerance and shape start to deteriorate. The container liner and die slide have begun to alter the temperature of the die. This is immediately reflected in the run-outs.

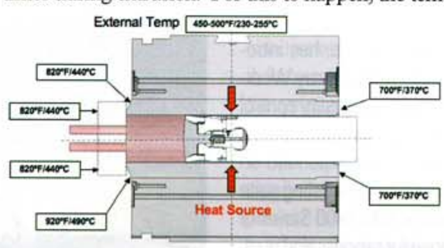
The quick response container

The temperature of the billet should be closely controlled from the time it is heated until it passes through a uniformly heated die. This is best done by immediately correcting any variations in the temperature of the container liner as soon as they occur. 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 Castool Quick Response or QR Container, with at least four temperature control zones, cartridge heaters are located close to the liner. Their purpose is to heat the liner, not the mantle, and thus maintain a consistent billet temperature as the alloy enters the die. Specially designed double thermocouples are used to monitor the temperature of both liner and mantle simultaneously. The heat elements are positioned close to the temperature sensors. The quick response that results ensures that the liner temperature will remain fairly constant. The risk of overheating, tempering, and softening the mantle is also practically eliminated.



When the liner temperature is not controlled, the top of the die is significantly hotter than the bottom. The alloy therefore runs through the top of the die aperture faster than the bottom and uneven run-outs occur

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. For this to happen, the temperature of the exit end of the container liner must be very closely controlled during the extrusion process, because the temperature of the die very quickly reflects that of the container. The thermal mass of the container is much greater than that of the die stack. Accordingly, as soon as the die is firmly sealed to the end of the liner, heat transfer by conduction begins, and continues rapidly until a thermal equilibrium is reached. Especially with large containers, unless closely controlled, heat lost from the bottom of the container mantle rises inside the housing, and increases considerably the temperature at the top. With conventional containers, the vertical temperature difference at the liner exit is typically 85 – 110°C (150 - 200°F).



When the liner temperature is controlled, the die temperature can be uniform. The alloy therefore can run through the die aperture evenly and run-outs controlled

Thermal measurements have proved 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 5°C or 10°F of vertical temperature variation, 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 with a high vertical component. 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 draw heat from the lower half of the die. Equalising 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 eliminate any vertical temperature difference at the die exit. The Castool Quick Response Container with total temperature control solves the problem of vertical temperature variations in the liner, and in the die, by employing at least four control zones, top and bottom, as well as horizontal. The velocity of the product leaving the top or bottom of the die will therefore be the same. Experience has shown that a Castool QR container, which is designed primarily to heat the liner, rather that the mantle, can reduce the amount of energy used by as much as 75%. In addition, long-term savings accrue from extended mantle life. By eliminating overheating, mantles retain their hardness. Extreme internal thermal stresses that can cause cracking are greatly reduced. The scrap resulting from vertical temperature difference in large dies is also eliminated. Large extrusions are now being produced to profile tolerances never before possible.

Cartridge heaters are positioned close to the liner. Double thermocouples are located between the heaters and the liner close to the container entrance and exit

Conclusion

Focusing on the die function is a logical progression of the 'Systems' approach to extrusion. 'Systems' advocates always considering extrusion to be a holistic system with all parts working in concert, and none in isolation. The major change in emphasis comes with the realisation that the die itself doesn't play nearly as large a part in achieving world-class extrusion than was previously thought.

The importance of the level of performance of other components such as the die oven, container, and dummy block, all of which contribute to passing alloy through the die at, or close to, optimum temperature and speed, has fairly recently become clearly apparent, along with the extruder's ability to manage the die function by enhanced and comprehensive temperature control.

It has also been found that by improving the effectiveness of each component in performing the basic function for which it is intended, it not only increases its life and contributes to increased productivity, but also has a positive affect on the other pieces of production tooling with which it interacts. For example, by enhanced thermal control of the container, the bore remains round and straight. This allows the dummy block to perform better. Its operating life is extended. It expands and contracts as it was intended to. The amount of billet impurities that enter the die is reduced.

In evolution of light metal extrusion, the impact of this major change in emphasis from the die itself to the function of the die, and the factors that improve it, may well prove to be one of the most important advances. Yet it does not depend on a new product or process. It simply requires better basic extrusion. The results are immediate and exceptional.

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