Letter to the Editor...

Isothermal Extrusion?

October 22, 2008

Dear Sir,

The ultimate goal of any light metal extruder is to achieve isothermal extrusion. That is, to operate at a constant optimum exit temperature at maximum speed. This has seldom been done with consistency. The August 2008 issue of *LMA* contained a major article entitled "The Evolution of the Smart Container: Achieving Isothermal Control in Extrusion." In this, you imply that by using a smart container, isothermal extrusion can be assured.

This is simply not true.

It has been found that in most commercial extrusion situations the effect a container has on billet temperature is insignificant, and is certainly insufficient to create or adjust to provide the required thermal gradients necessary for successful isothermal extrusion. (See paper by Johannes and Jowett ET '96.) In limited cases where the extrusion cycle is very extended (hard alloy extrusion and high ratio indirect extrusion) there can arguably be some influence on billet temperature from the thermal surround of the container. However, the majority of commercial extrusion occurs with live cycle times between 50 to 100 seconds, and in these instances the billet is barely influenced by the temperature of the liner.

Success with isothermal extrusion can only be achieved with a consistent temperature taper from front to back of the billet. This allows constant speed, constant exit temperature, and consistent dimensional compliance of the product. Setting the front billet temperature to achieve exit temperatures toward the upper end of the allowable range for the alloy being used, and applying an appropriate temperature taper along the length of the billet is generally accepted as the best approach to isothermal extrusion for most commercial applications. However, many commercial systems available today attempt to achieve this by varying ram speed in response to exit temperature input, to compensate for variation in incoming billet temperature. The consequences of loss of shape and dimensional control under such inconsistent extrusion speed conditions imply the benefits from this approach are indeed limited. A fair question then is, "If a smart container doesn't ensure isothermal extrusion, what good is it?"

Obviously, the goal is to control the temperature of the liner as effectively and efficiently as possible, so that the alloy exits a preheated die uniformly at, or close to, optimum temperature and maximum speed. Traditional containers with radiant heat applied to the outside of the mantle are incapable of having significant influence on the liner temperature. Energy is wasted in these containers heating the container housing and outer diameter of the container mantle. In most cases, smart containers with well-managed internal elements reduce energy consumption by 50% or more.

A properly designed smart container will extend the life expectancy of the container mantle, the liner, and the dummy block. Container mantles usually fail because of thermal fatigue and localized annealing. This in turn causes the liner to belly and dummy block to fail.

The flow stress 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. Accordingly, as soon as the die is firmly sealed to the end of the liner, heat transfer begins by conduction, and continues rapidly until a thermal equilibrium is reached between the container liner and the die. The container's function therefore is really to manage the temperature of the die during extrusion.

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 100–200°F (55–110°C). 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 10°F or 5°C of vertical temperature variance, the run-out 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 leach 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 run-outs. The liner temperature must therefore be made slightly hotter at the bottom than the top to eliminate any vertical temperature difference in the die.

Properly designed temperature controlled smart containers solve the problem of vertical temperature variance in the liner, and in the die. The velocity of the product leaving the top or bottom of the die will therefore be the same

Your comments will be appreciated.

Paul Robbins, GM Castool

Dear Mr. Robbins,

Thank you for your letter.

Although the quest for the ideal isothermal conditions in aluminum extrusion seems to be never ending and wide open to innovations in billet heating (specifically taper heating/cooling), extrusion process control (ideally with online extrusion temperature feedback), control of container temperature ala the Smart Container® is an innovation that also promises to improve productivity not only from longer container life but also in achieving temperature control in extrusion tooling, i.e., a major factor in attempting to achieve isothermal extrusion. As you indicate, "The container's function is really to manage the temperature of the die during extrusion." Isn't that important in controlling isothermal conditions in extrusion?

In the ET '96 paper you cite by Johannes and Jowett, "Temperature Distribution in Aluminum Extrusion Billets," the authors essentially make a case for temperature control in containers, showing how contact between containers and billet significantly changes radial temperature distributions in 6xxx billets. In analyzing a run of six sequential billets on a press with a 200 mm diameter cylinder, a contact time of 32 seconds alternating with 20 second cycles with no billet in the container they wrote, "Here we see the container temperature rising, resulting in different temperature distributions in all the billets" (p. 241). In their conclusions, they point to the importance of external boundary conditions, billet-container being one, as a major factor in control of temperature distribution in aluminum extrusion billets.

The subject of isothermal extrusion was extensively reviewed by Bryant, Dixon, Fielding, and Macey in the April 1999 issue of LMA*, pp. 8-36. This article presented the state-of-the-art at the time for implementing isothermal extrusion, specifically by control of billet temperature gradient, continuous profile temperature measurement, optimizing heat transfer conditions in tooling and dies, improvements in equipment to facilitate isothermal extrusion, and closed loop automatic controls. With regard to container-billet heat transfer, they cite work by Biswas, for example, who reports thermal equilibrium in a uniformly heated container is only reached after 30-70 billets after the start of production. This is a strong case for the Smart*

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