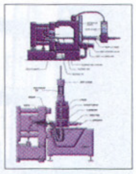

That Fateful Four Thou

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Four thousandths of an inch. This miniscule but critical distance should be indelibly etched in the mind of every light metal die caster. It is the optimum gap between the plunger tip and the shot sleeve during the casting process. If at any time during the shot, the gap exceeds .004, the alloy is likely to penetrate the space, and flash or blowby will occur. This will inevitably cause excessive wear.

If the gap becomes much less than .004, there is a constant danger of interference and inconsistent shot velocity. Scrap will result. It is essential, therefore, that a gap of very close to .004" be maintained at all times during the casting cycle.

The Problem

When metal is heated, it expands. If both the shot sleeve and the plunger remained at a constant temperature, maintaining a consistent gap would be no problem. However, when molten alloy at about 1300°F is poured into the shot sleeve, then pushed out the other end, unless effectively controlled, the temperature of both the plunger tip and the shot sleeve will increase considerably, and they will expand.

If the ID of the shot sleeve is no greater than about three inches, the potential problem is minimal, and can likely be ignored. The coefficient of thermal expansion, however, is a constant. The same increase in temperature of a six-inch shot sleeve, for example, will cause it to expand twice as much as a three-inch sleeve. The market for larger light metal castings is increasing. Shot sleeves are getting bigger, but whatever the size of the sleeve, that critical gap of .004 of an inch unfortunately remains unchanged.

Cooling the Plunger Tip

Controlling the gap between the plunger tip and the shot sleeve is complicated by the fact that the plunger tip is usually made of copper, for better conductivity, while the shot sleeve is made of steel. The coefficient of thermal expansion for copper is about 50 percent greater than for steel. This means that if the temperature of both plunger tip and shot sleeve increases by the same amount, the plunger will expand much more than the shot sleeve. In a large machine, if the plunger tip is not adequately cooled, the gap between plunger and shot sleeve can easily disappear.

Die casters usually reduce the temperature of their plunger tips with water. The most common cause of excessive plunger tip expansion is insufficient coolant. Even experienced die casters often neglect this.

Rate of flow is easily determined, and should be monitored constantly. Maintaining an adequate flow of water is vital to controlling plunger tip expansion.

There are some proprietary cooling-intensive plunger tips available that utilize the cooling water much more effectively than conventional tips.

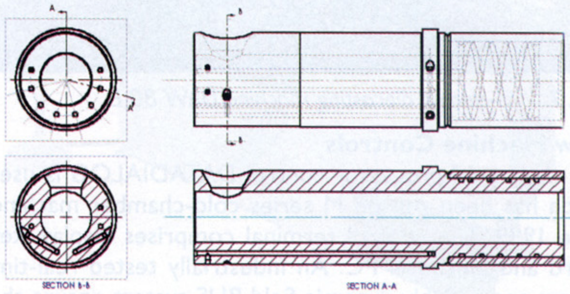

Fig. 1 – *Shot sleeve cooling jacket.*

The unique plunger tip illustrated above is of forged beryllium copper. This facilitates the heat transfer from the body of the plunger to the coolant. The stainless steel holder is in full contact with the face of the plunger, and absorbs the total pressure of the shot. The face can then be quite thin, for improved heat exchange.

The water flow is from the center of the shot rod, through the holder and directly to the inside face of the plunger tip. It is then distributed through four channels to the circular external coolant channel. These channels are designed to create a turbulent flow, which makes for maximum heat transfer.

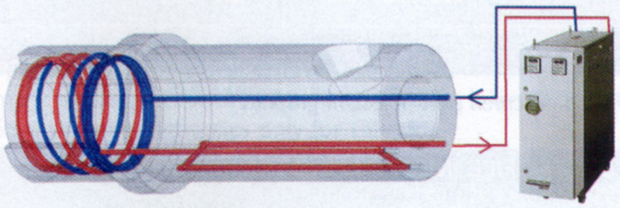

Fig. 2 – *Oil regulated shot sleeve.*

Controlling Shot Sleeve Temperature

Nearly all die casters cool their plunger tips. Effectively controlling shot sleeve temperatures, however, is a more difficult challenge. The most common method of water cooling shot sleeves, is with a pattern of cooling ducts which are an integral part of the sleeve.

The pour end of the shot sleeve is where the temperature is highest. This is obviously where cooling is most necessary. Accordingly, another method of temperature control is the pour end cooling jacket. This effective and economical device puts shot sleeve cooling where it is needed most, directly below the pour spout. The cooling jacket can also be re-used when the sleeve is replaced.

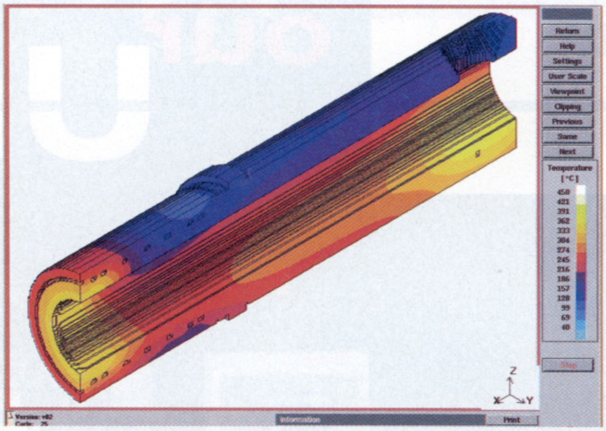

Fig. 3 – *Simulaton of shot sleeve, without temperature control.*

The Advantages Of Using Oil For Container Temperature Control

A common misconception is that the amount of thermal expansion of a shot sleeve is simply a factor of its diameter and its maximum temperature. If this were the case, temperature control would simply depend on cooling.

This is incorrect.

The amount of thermal expansion or contraction depends on the ID of the sleeve, and the amount of temperature change, up or down, not on the maximum temperature. This temperature differential, usually known as ΔT, will cause exactly the same amount of expansion at any point on the temperature scale.

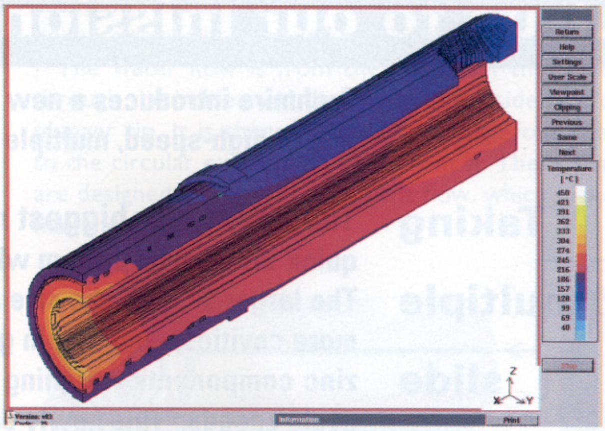

Fig. 4 – *Simulation of shot sleeve, with temperature controlled by oil.*

The maximum temperature in a shot sleeve occurs at the bottom, under the pour hole. If the shot sleeve has been preheated by circulating hot oil at 400°F, for example, ΔT will be reduced and consequently the amount of expansion. Also, all temperatures greater than 400°F as the pour continues, will also be reduced, as the oil then acts as a coolant.

A major advantage to preheating the shot sleeve is that start-up scrap is eliminated. When using more expensive alloys, this saving can be significant, as well as additional savings in costly production time.

When oil is used to control shot sleeve temperature, start-up scrap is eliminated, temperature variation both top to bottom and back to front very closely controlled and expansion minimized. The .004 gap can be maintained.

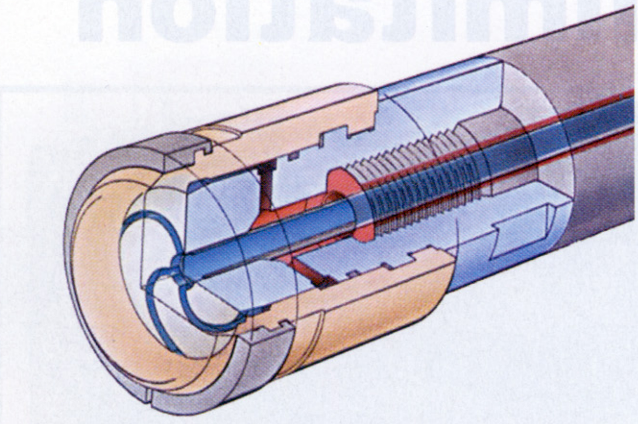

Fig. 5 *Cooling-intensive plunger tip.*

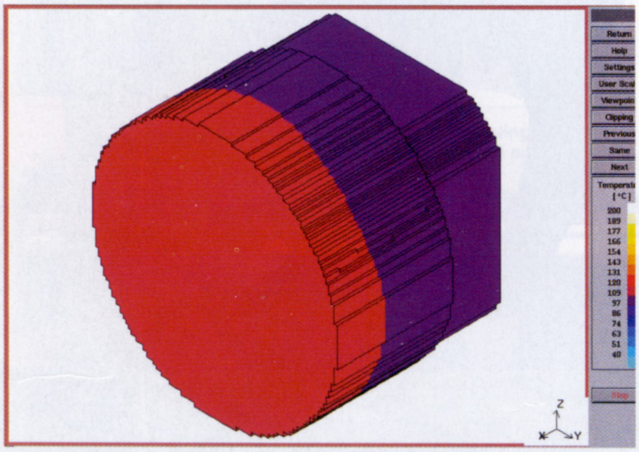

Fig. 6 – *Simulation standard plunger tip.*

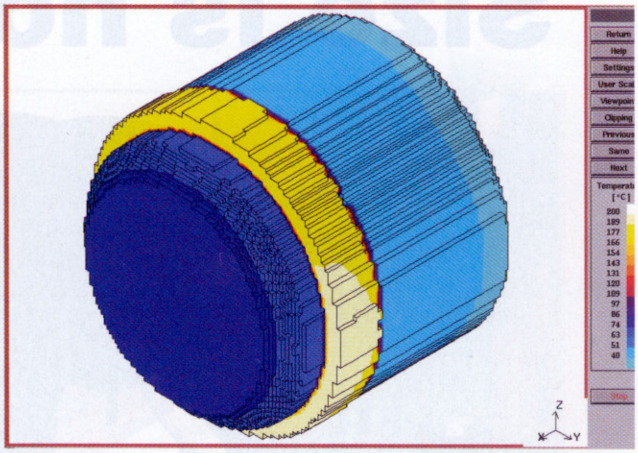

Fig. 7 – *Simulation cooling-intensive plunger tip.*

For large casting machines, controlling the amount of temperature change in the shot sleeve during the casting cycle is essential to a productive and profitable operation. This is clearly apparent in the 3-D computer simulations made by the R&D department. These compare the predicted temperature change in a shot sleeve with and without effective temperature control.

Numerical Simulations

If heat is applied to a particular point on a metal object, due to thermal conductivity the temperature will also increase at any other nearby point, but to a lesser extent. The closer these points are together, the more closely the temperature of the second point will be to that of the first. Also, if the heat is applied intermittently, but often enough that cooling is limited, the temperature at any location will soon stabilize, and remain fairly constant.

In preparing these numerical simulations, Castool basically used the law of conservation of energy, and a computational technique known as "The Finite Volume Method."

Using this method, you assume that the 3-D model of the object you are studying is broken down into a great number of very small discrete volumes, each of which surrounds a single point. For each of these points, the computer resolves the equation that predicts the effect that a slight change in temperature at that point will have on the next closest point.

The vast quantity of equations to be processed makes the Finite Volume Method practical only with the help of a specially designed computer program. Each of the simulations shown here required more than 2 million calculations.

In the simulations shown, where temperatures are represented by changing colors, there is a considerable margin of error due to inconsistencies in transmitting and printing exact shades of colors. Absolute temperatures therefore cannot be assumed. Relative values, however, are quite valid. The purpose of these simulations was merely to graphically demonstrate the need for temperature control in large shot sleeves. That is, the difference between controlled and uncontrolled temperatures.

Parameters

Shot sleeve: Length - 48" ID - 6.5"

Material: H13 steel

Coefficient of thermal expansion: 0.0000061/°F

Alloy being cast: magnesium (AM60B)

Alloy temp. while pouring: 1324°F

Dwell time (die closed onto biscuit): 20 seconds.

Total casting cycle time: 85 seconds.

Oil temp.: 400°F

Rate of oil flow: 6 USgpm.

Note: *The simulations shown were with the plunger in contact with the biscuit, after 25 casting cycles, when the temperatures within the shot sleeve were virtually stabilized.*

Observations

With no temperature control, (see figure 2,) the temperature inside the shot sleeve, just below the pour hole is about 650°F. The temperature then reduces gradually throughout most of its length until it reaches about 430°F. Near the die end, it increases rapidly to more than 600°F.

Using the coefficient of thermal expansion of H13, if the temperature of a 6.5" tube changes by 200°F degrees, the ID will change by about 0.008". The need for effective temperature control is obvious.

Consider now the pattern of the temperature change in a shot sleeve with its temperature controlled by oil entering the sleeve at 400°F, and a flow of 6 USgpm. (see figure 3).

You will note that the temperature beneath the pour hole is now about 430°F. The temperature soon drops to about 400°F, and remains fairly unchanged until close to the die end when it jumps to about 520°F. Only at the very end of the stroke, with the plunger tip in contact with the biscuit, does the temperature approach 570°F.

The Imperatives of Temperature Management

With no temperature management, the amount of expansion and contraction of a large shot sleeve is unacceptable.

When the temperature of the shot sleeve is regulated by preheated oil at about 400°F, its temperature before the pour is already about 400°F. The temperature differential, ΔT, throughout the shot sleeve, from beginning to end of the casting cycle, is quite small. The expansion and contraction is therefore limited.

If the temperature of a large shot sleeve is uncontrolled, particularly at the pour end, when partially filled with hot molten alloy, the shot sleeve will not only expand by an unacceptable amount, the vertical temperature variance will cause unequal thermal expansion. This will not only result in a considerable amount of ovality, but also some axial bowing. The inevitable wear will shorten the life of both shot sleeve and plunger tip. More importantly, it may interfere with the smooth and regular movement of the plunger. If this occurs, scrap will surely follow.

And in Conclusion . . .

At a time when the overall market for light metal castings is shrinking, but the automotive industry is increasing its demand for larger castings, for some die casters, survival may depend on improved productivity

Effective temperature control of both shot sleeve and plunger tip is essential to efficient extrusion. It will assist you in preserving that critical gap of 0.004".