Sequential Filling of Mold Cavities

This new gating technique results in optimum pouring times for each cavity as well as increased riser efficiency. By allowing individual cavities in a multiple cavity mold to fill sequentially, optimum casting results may be obtained.

C. R. Loper, Jr., Professor
Dept of Metallurgical and Mineral Engineering
University of Wisconsin
Madison, WI

Proper design of gating systems has long been the goal of the foundryman and a variety of systems have been proposed to accomplish this. These systems may vary significantly but are usually based upon sound principles derived from the application of hydraulic flow to molten metals.

Gating systems may be pressurized or unpressurized, with the differences being related primarily to the location of the flow control orifice (the choke) within the system. Choke location at or near the base of the sprue renders the gating system unpressurized, and full control of the metal flow is achieved when the sprue is filled.

This type of gating system permits a low-velocity metal flow to be realized in the runners and gates, and slag or dross are separated in the runners before the metal enters the mold cavity. A variety of runner and gate locations have been advocated in this system. With the runner in the drag and the gate in the cope, the runner is filled prior to the entry of any metal into the mold cavity. Furthermore, this geometry insures that the runner will always remain full, regardless of the details of pouring e.g., interrupted pour or an inadequate pouring rate to keep the system full.

Pressurized gating systems have the choke at or near the casting ingate. In these systems full control of metal flow is not achieved until the entire gating system is filled. Entry of metal into the mold cavity is controlled by the respective gates.

The technique described here makes it possible to fill the individual cavities of multiple-cavity molds one at a time, or in a predicted sequence, in full accordance with the filling rates calculated using most of the well-known calculation methods. It also permits the orderly filling of pattern impressions where multiple inserts are used, and where it is desirable to isolate the filling of each impression. In those cases where the riser ingate is positioned above the normal parting line to effect sequential filling, riser efficiency is substantially improved.

Gating System Design

The selection of a suitable gating system, whether pressurized or unpressurized, is the result of a number of considerations that may be unique to a given casting e.g., casting geometry, yield requirements, space available in the mold, mold fed risers, etc.

Examples for the application of most gating systems first consider the production of a single casting with single or multiple ingates. When multiple ingates are involved, procedures have been developed so that the flow rate of metal through each ingate is the same. This entails the introduction of such procedures as tapering or stepping down the runner or adjusting the gate area.

When multiple castings are to be produced from a single gating system, the usual procedure is to design the gating system so that the flow rate of metal through each ingate is the same i.e., all the mold cavities fill at the same time and rate. However, calculation of the gating system where multiple cavities are involved usually results in filling times that are substantially longer than those determined for a single mold cavity. In fact, the foundryman often finds it impossible to deliver metal through the gating system rapidly enough to fill a multiple-cavity system to match the rate calculated for a single mold cavity. The result is often that the multiple-cavity arrangement yields defects related to slow pouring rates e.g., cold shuts, misruns, entrapped slag and dross, chilled edges in gray and ductile irons, etc.

To illustrate this, one procedure to calculate a gating system bases the pouring time for gray cast iron on the following formula (the results of which have frequently been presented graphically):

\[ t = K(0.95 + 0.85T) / W \]

where

- \( t \) = pouring time in seconds
- \( W \) = casting weight in pounds
- \( K \) = fluidity factor, and
- \( T \) = critical section thickness in inches.

Consider a 7.5-lb gray iron casting having a critical section thickness of 0.5 in. and a fluidity factor of 1.0. This results in a pouring time of 4.2 sec. (1.8 lb/sec.). As a first approximation this may be considered the time to fill the mold cavity.

Now consider the production of four of these same castings from a common gating system. The usual procedure is to multiply the casting weight by four. The resulting pouring time would then be 8.4 sec. (3.6 lb/sec.), or a doubling of the mold filling time. If eight castings were to be made from a common gating system, the same procedure results in a pouring time of 11.9 sec. (5.0 lb/sec.).

It can thus be seen that to maintain the same mold cavity filling time as for a single mold cavity requires a significant increase in the pouring rate.

Alternative Gating Designs

While the preceding figures are for a hypothetical casting, the change in pouring rates for each case is dramatic and
characteristic of a problem often experienced in the foundry. Since there are practical limitations to manipulating the pouring rate to obtain a constant mold filling rate, the foundryman may have to consider alternative gating designs.

As an example of the change that sequential filling of mold cavities can make, consider the same 7.5-lb. gray iron casting as above. The gating system design for pouring two castings from a common gating system calls for a pouring time of 5.9 sec. (pouring rate of 2.5 lb/sec). If eight cavities were to be poured in a single mold, it would be desirable to fill them in pairs, with a filling time of 5.9 sec. for each pair. The total filling would then be 23.6 sec. at a pouring rate of 2.5 lb/sec. To accomplish this requires that a runner dam, or weir, divert the flow of iron into two mold cavities at a time.

An example of such a sequential filling system is shown in Fig. 1, where a 7.5-lb. gray iron shaft is being poured with eight patterns on a plate. An unpressurized gating system is shown using a drag runner and cope ingates. Flow control is established by the sprue.

It is evident that mold cavities 1 and 2 will fill completely before the level of metal in the runner rises to pass over runner dam A. When the metal runs over A, mold cavities 3 and 4 will be filled. Similarly, cavities 5 and 6 will fill only after the metal runs over runner dam B, and so on with cavities 7 and 8. By this technique the mold cavities are filled sequentially in pairs so that each set can be filled rapidly enough to minimize the occurrence of slow mold filling problems.

The runner dams must be molded well to prevent the washing away of molding sand, though it is possible that a core could be used to form the runner dam. In that case it may be possible to reduce the spacing between mold cavities considerably.

Note that while the individual mold cavities fill in 5.9 sec., (based on the first approximation calculations discussed above), the total mold filling time for this system is about 23.6 sec. This is considerably longer than the 11.9 sec. pouring time calculated above for eight castings on a common gating system where they are considered as a single mold cavity. While the total pouring time for a given mold may be extended as a result of the sequential filling procedure, a pouring rate that is reproducible can be realized, and a filling rate for an individual mold cavity can be obtained that gives optimum casting results.

Use of Multiple Insert Patterns

The sequential filling of mold cavities is particularly attractive when multiple insert patterns are used in the production of large molds. The technique can be applied to control the filling of the individual impressions, thus eliminating the problems often experienced with this pattern arrangement, where the filling of one impression depends upon the other insert patterns mounted with it.

For example, consider the hypothetical arrangement presented in Fig. 2, where the pattern plate is equipped with a fixed sprue location and a fixed “master runner.” Various inserts can be mounted in this pattern, and a variety of runner systems may result, depending on the number of inserts and the number of individual mold cavities.

Figure 2 presents a simplified combination of insert patterns, one of which is located primarily in the drag, and the other split between the cope and drag. It is preferable to pour these individual castings in such a way that the filling of one mold cavity does not adversely affect the filling of the other.

The common master runner involved in this case would normally result in filling the two mold cavities somewhat individually until one cavity was filled to the level of the gates. The filling of that cavity would then cease until the

**Fig. 1. Example of sequential filling of a small gray cast iron shaft using runner dams (A, B, and C) to control the metal flow into pairs of mold cavities (1 and 2, 3 and 4, 5 and 6, and 7 and 8).**

**Fig. 2. Example illustrating the application of sequential filling to a situation where pattern inserts are used.**
has been designed for this application and is now produced in a three-impression dump box. The core is two inches high, with one inch in the drag coreprint and one inch to serve as a runner dam in the cope.

An example of the application of this technique to a ductile iron casting is shown in Fig. 3. Originally the gating system was similar to that shown, but without the runner dam. Severe problems were experienced with cold shuts and misruns, and scrap levels at various times were at 41, 55, and 54%. Since applying the sequential filling technique, scrap rates for misrun and cold shut are negligible.

When first experimenting with the system, each section of the mold was not treated as a complete gating system. As a result, the casting ingates were acting as the choke, and misruns were still found. Adjustments to the ingate size resulted in successful casting production.

Conclusion
Application of the sequential filling procedure requires that an appropriate gating system be used. Note that in the examples set forth above the system was unpressurized. A pressurized gating system (where flow control is established at the gates) results in a back-up of metal in the runner, thereby causing metal to flow over the runner dam prior to the complete filling of the mold cavity or cavities designated.

APPENDIX
Terry L. Forshey, Metallurgist
Sperry New Holland
Belleville, PA

In the Belleville Foundry of Sperry New Holland, the sequential filling of mold cavities has been applied with considerable success to a number of jobs. An oil sand core other mold cavity reached that level. Further filling of the mold cavities would then occur at a rate dependent on the combined mass of those casting sections and the ability of the gating system to deliver metal. However, inclusion of a runner dam, or wall, in the master runner causes one mold cavity to be filled completely before filling of the other is initiated.

In a similar manner, a variety of other mold cavity combinations can be filled in an improved fashion. Multiple insert mold cavities often involve castings that would best be treated individually e.g., one casting that should be poured rapidly and another that should be poured slowly; or one that is chunky and another that is heavily cored. Modification of the gating system using the principles of sequential filling of mold cavities enables a solution of these problems.

A second example is shown in Fig. 4. This gray iron lift pivot had experienced a substantial amount of cold shut in the 5/8-in. wall between cored holes. The sequential filling technique allowed the filling of these castings in series: first eight castings; then sixteen castings; then final sixteen. Scrap due to misruns or coldshuts has been virtually eliminated.

Presently the sequential filling method is being used on five different jobs, and there is sufficient confidence in its success that a number of new jobs are being rigged with it. More impressions can often be placed on a plate with this method, since each section can be treated as a separate mold, thus increasing the yield.

The system is not a cure-all, but it may be applied to those jobs where problems are being experienced with the filling of the mold. When applied properly, the results have been encouraging.

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