Reducing gas porosity in high pressure die castings

Larry Winkler
Awintech Inc.
Plymouth, Minnesota

Abstract

The issue of reducing gas porosity associated with high pressure die casting has been one of the major challenges for die casters since the advent of the process. Various techniques to remove gas from die cavities have been discussed, researched, and applied over the years with varying degrees of success. This paper provides a review of the basic problems and compares several methods currently being utilized to reduce gas porosity via cavity evaluation in high-pressure die-casting.

The reality of the issue with gas porosity in the die-casting process is not if there will be porosity, but how much and where.

Introduction

The benefits of adding a means of evacuating air, gas and residue from a die cavity has long been acknowledged by most die casters.

Approaching the problem from a basic scientific prospective, air makes up the space in a shot sleeve, metal feed system, and cavity detail in the cold chamber process. Additional air and gases are created during the injection of the molten metal. This increase can be due to improperly designed runners and gates and from the reaction of the molten metal when the metal comes in contact with release agents sprayed on the surface of the die. The total volume of air and gases must be evacuated in the short time available during the injection phase of the die casting machine cycle in order to reduce porosity in the casting being produced.

Figure 1 illustrates the spaces containing air in the cold chamber process.

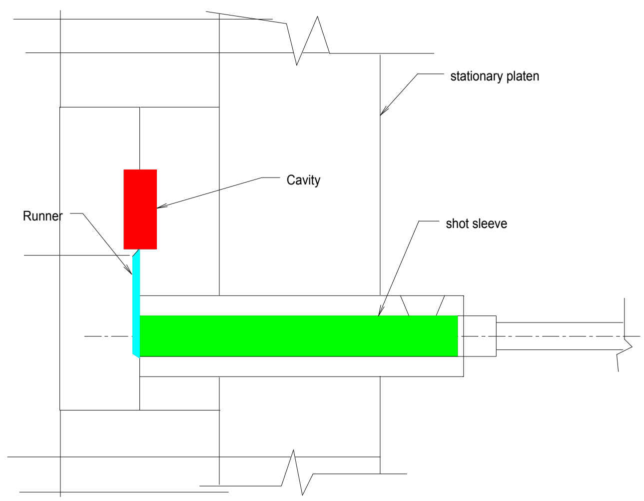

Figure 1

Even though some of the air in the shot sleeve is displaced with metal prior to injection, a great deal of the sleeve space still contains air. It is reasonable to venture that if most die casters were to check the percent fill within their shot sleeves they might find that the sleeve contains approximately 30% metal. This means that the remaining 70% of space contains air and poses a challenge to evacuate.

Figure 2 illustrates the spaces containing air and metal in sleeve.

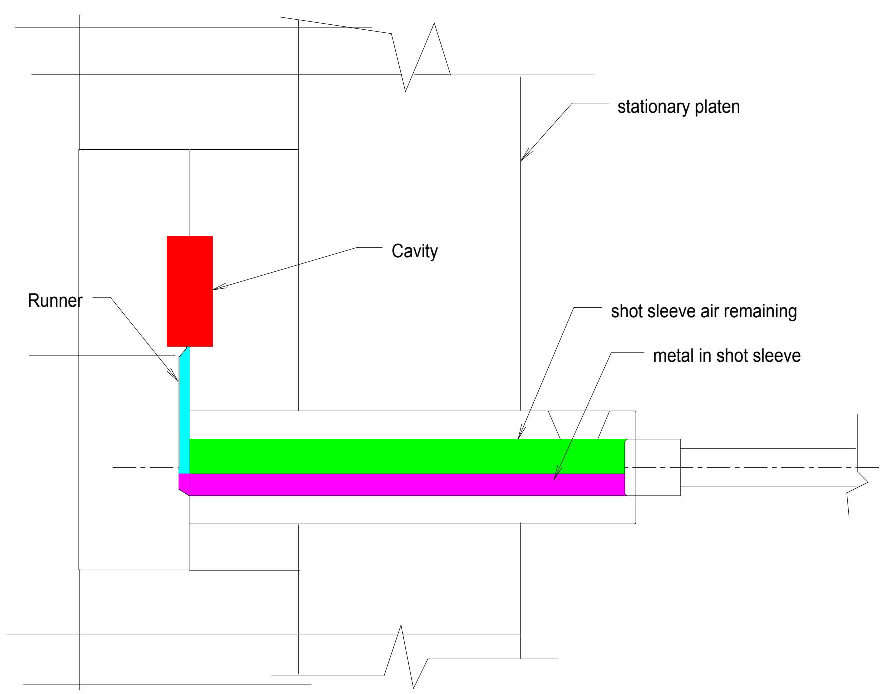

Figure 2

This volume of air has to go somewhere as the liquid metal is injected into the cavity. Much of the air will be compressed into the molten metal and thus into the casting during metal solidification. This event occurs even if the die casting machine is fully capable of attaining critical slow shot speed.

Figure 3 illustrates a complete shot at the end of fill

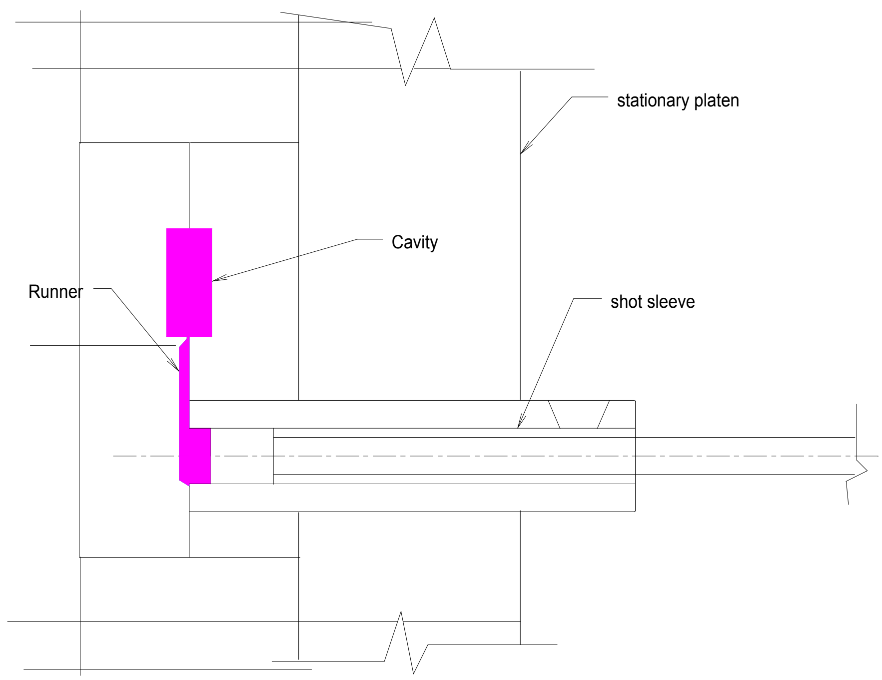

Figure 3

The other factor that must be addressed when attempting to remove trapped air from the shot sleeve is the time available to remove the air. This means that a specific volume of air must pass through a defined area in a given amount of time. If the time or vent area is not adequate to allow the entrapped air to escape, porosity will occur in the casting

Venting methods

Many methods have been devised and utilized to remove, or assist in the removal of gas from a die. One method often used by un-educated die casters is to reduce the locking pressure of the die-casting machine. This action causes the machine to lock up while allowing a very small air gap at the parting line of the die. As molten metal is injected into the die, air is pushed out of the shot sleeve into the die cavity and out through the die parting line to the atmosphere. This action serves to assist in evacuating air and may improve the surface appearance of the casting, however, it can also cause metal pressure loss and internal porosity may likely result in the casting.

The application of conventional techniques in dies, such as metal overflows and venting allows a certain amount of air to escape to atmosphere or be displaced to an area outside the casting. This technique is defined here as the “push method”. As metal is forced into the die-casting tool, air is forced, or pushed through areas that have been provided in the tool as overflows or vents. When one considers that most vents are designed to a thickness of .005” to .006” one can begin to understand the degree of force required to “push” air from the tool to the atmosphere and the necessity to maintain vents and overflows in good condition. Under normal operating conditions vents are frequently prone to close off due to metal flash and die lubrication build-up. In addition, if vents are not maintained free of flash, the die steel around the edges of the vents can experience peening and may close off or reduce the effective area.

Another technique used by die casters to assist in air removal from dies deals with the installation of chill and vent blocks in die casting tools. Chill and vent blocks have proven to be additional assurance of functional venting is an improvement over conventional venting methods. (Reference figure 3a)

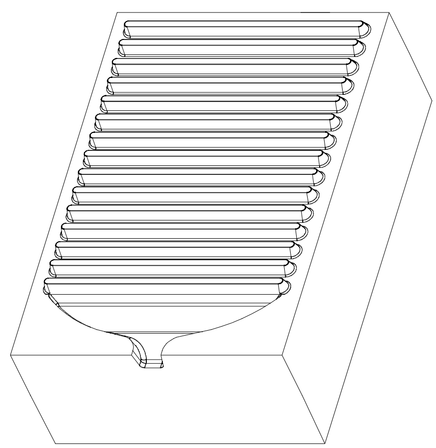

Figure 3a

Calculating Vent Areas

Calculating areas for proper venting of die casting dies has been a topic of discussion over the years and it seems everyone has their own theory. One common theory says that the vent area should be a percent of the total inlet gate. An example would be a casting that required a .100in2 inlet gate area and a die cast designer selecting a percent of 30 % or a vent area of .03 in2. The scientific method would say you have a container with a known volume of air and you have to evacuate it in a given period of time, what size should the area of the outlet be to allow the air to escape?

The calculations for the sizing of the vent area are made easier today through the use of computer software.

Vacuum methods

The introduction of vacuum assistance for die-casting in the 1950's gave die casters the ability to produce higher quality die-castings with better surface finish and less gas porosity.

The American Die Casting Institute (ADCI) became involved with the development of vacuum systems and blocks. These blocks were originally produced from beryllium copper because of its exceptional heat transfer capability. In addition, one major advantage of these blocks was that they were free of moving parts. Die casters utilized these vacuum blocks for a number of years-with varying degrees of success. However, because beryllium copper is relatively soft and its cost is high compared to other materials, the blocks were easily damaged and required frequent maintenance and replacement. In addition, licensing fees paid for using the block designs and systems were costly. As a result, this style of serrated vacuum block fell out of favor with many die casters.

During this same decade, valve style vacuum systems began to come into favor. Various valve style vacuum systems continue to be produced and utilized today. These valve style systems utilize a valve to stop the flow of metal and vacuum.

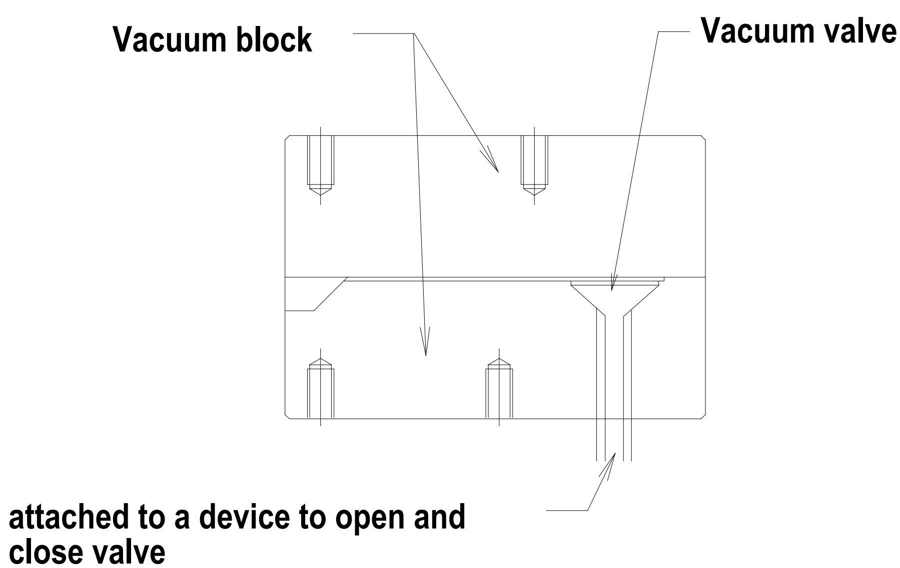

Figure 4

Figure 4 illustrates a "valve style vacuum block".

Several methods have been developed for closing metal flow through the vacuum vent system to prevent the molten metal from contacting and plugging the shut off valves.

These methods may utilize timers, metal position indicators and the actual metal stream itself to activate the closing of a valve. If the valves are properly maintained, the vacuum blocks will function adequately. There is a “price” to pay for these valve style methods however. First, the initial cost for purchasing and installing the vacuum system on a die casting machine and the die-casting tool. The system includes pumps, tanks, controls, associated utilities and other materials required for installation on a machine. Next, there are the on-going expenses associated with maintaining the systems. I am not aware of licensing fees associated with the use of the valve style systems.

Let us look at a couple of areas that deserve consideration when selecting a valve style block system. This style of system requires that the valves be shut off some specific time during the injection phase of the cycle. If the shutoff does not occur precisely, a vacuum will not be properly executed and, the gases will not be completely evacuated from the die cavity. If an error is made in properly setting the vacuum valve timer and position indicator, or the valve sticks due to excessive wear, the valve will be plugged with metal. The resulting effect will be machine down time. The solution to this problem is either to ensure that the timing is properly set, the valve is maintained in proper operating order or there might be a need to install a system containing a larger valve area.

Another method for shutting off the flow of vacuum and metal in a system is to utilize the liquid metal stream traveling through the vacuum block to close the vacuum valve. See Figure 5. Again, this system as with the timed system, has high initial investment cost and requires maintenance to keep it operating properly. This method has an advantage over the timer, and /or position systems in that the vacuum is pulled during the entire injection phase of the cycle. The down side is that the components associated with accomplishing the vacuum and metal shut off are high wear components as they are exposed to hot liquid metal and wear during each shot.

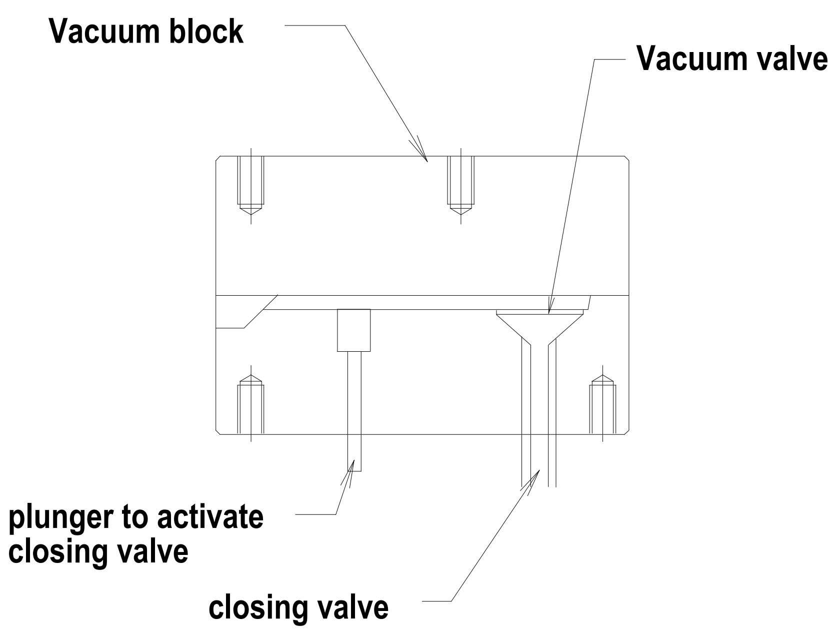

Figure 5

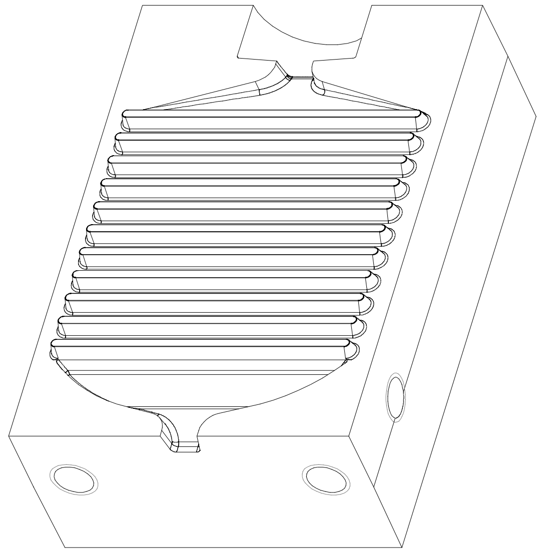

Figure 6 illustrates a “Valve-less vacuum block”

One other method that is being widely accepted by more and more die casters is a take off of the original chill block concept. This method uses resistance to metal flow and the solidification of the metal to shut off the vacuum and metal flow. There are no moving parts associated with this system, thus the degree of maintenance required to keep the system operating properly is minimal. This method has been termed “valve-less vacuum”. Unlike the original beryllium copper chill blocks these vacuum blocks are produced from tool steel and posses longer life. An added advantage with the “valve-less vacuum” blocks is the application of central vacuum systems. The vacuum activation valve, control and filter are all located at the die-casting machine. The vacuum pump and tank are located in a central area of the die casting plant and piped to each die casting machine. This reduces the cost of the system by utilizing one tank and pump. A back up pump may be added if desired.

The key to the successful application of each style of vacuum system is in the correct sizing of the vacuum block area, design of the vacuum gate/runners systems and proper installation.

Determining the area that will provide adequate evacuation is the initial step in designing a vacuum system. This determination may be performed using a computer program configured to utilize the total volume of air to be evacuated, and the cavity fill time. Once the suggested vacuum area is determined the vacuum gates and runners must be designed. Next, it is necessary to determine the number and location of the vacuum outlet gates, based upon the total calculated vacuum area. These vacuum outlet gates should be located in the areas of the die that are the last to fill. The outlets should be grouped in pairs and extend far enough from the cavity to prevent back filling of the cavity. A degree of resistance in the vacuum runner system is also needed to assure that the metal does not blow through the blocks during injection into the die cavity. The runners should be designed to reduce metal velocity as they approach the vacuum block main runner.

The two most critical items to consider when installing blocks is the alignment between the die halves and the pre-load on the blocks. A key is provided in the blocks to assume alignment and retention in the mold base. The blocks are installed at the same height as the cavity inserts to assist in shut off from atmosphere leakage. Seals may be installed on the surface of the die to further improve the shut off.

A number of computer programs are commercially available for use in calculating vacuum area and block selection. One such is "Vacuum Calc" and is available from Blue Ox Software at www.blueoxsw.com. The program can be used for both hot and cold chamber applications and there respective alloys.

Conclusion

Today, even more than in the past, reducing gas porosity poses a major challenge to the die caster. Customer's ever-increasing requirements for high quality, near free porosity castings demands improved evacuation of air from the die cavity. The die caster must be aware of this problem and select the proper corrective action and equipment for reducing porosity, and improving yields. Conventional vents and overflows may be adequate for attaining average die casting quality; on the other hand the average castings are not saleable in today's worldwide marketplace.

Vacuum assist, properly applied and utilized, can be one of the answers to the challenge of producing higher quality castings

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