Vacuum Assisted Casting Answers Today's Market Needs

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Vacuum Makes Possible the Bigger, More Complex Castings Now Wanted by Automakers

The Challenge of a Demanding Market

About 70 percent of all the light metal castings produced in North America are for the automotive industry. This figure will come as no surprise to any die caster, nor will the fact that the auto industry is extremely demanding. Vendors must provide products with perfect quality, in complete orders and on time ... every time. This is understood and accepted by all suppliers and would-be suppliers to the automotive industry.

The automotive market for light metal shapes continues to grow at an accelerating rate. This increase is driven mostly by the demand for lighter vehicles to reduce fuel consumption. Continued unrest in the Middle East has been less than reassuring with regard to the long-term availability of oil from that region. It can reasonably be assumed, therefore, that for the foreseeable future, the automotive sector of our market will continue to grow.

This is good news for light metal die casters, but satisfying the needs of automakers may require die casters to make use of technology which has been available for some time, but not universally employed, because it wasn't often absolutely essential.

A key factor in this market sector is that automotive design engineers today are in no way constrained by the previously accepted limits of the light metal cold chamber die casting production process. They simply decide what would be the best shape and size for the part they want. Their criteria are usually limited only to strength and weight. They now want die cast products that are larger, thinner, more complex and stronger than have ever been commercially produced before. If they cannot be satisfactorily provided by existing die casters, the automakers will simply make these large near net shapes themselves.

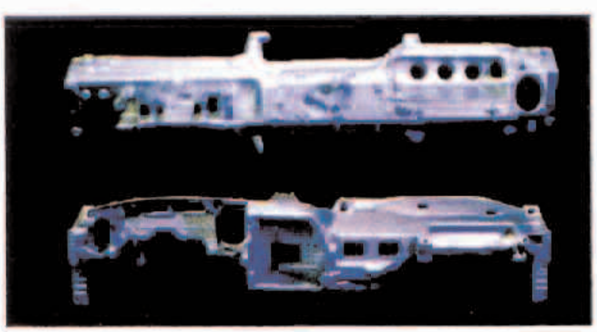

Figure 1: Die cast auto dashboard.

Consider the dashboards of several new cars. They are light metal castings and they are huge, complex and incredibly thin. They are proof that with vacuum assistance, this type of product really is possible.

This is the challenge facing North America's light metal die casters today.

The Problem

More castings are rejected due to porosity than any other reason.

In cold chamber die casting of light metals, because of the turbulence of the alloy as it is forced at a high pressure into the die cavity, and the complex shape of many casting molds, air and other gases are often trapped in the metal. This, of course, results in porosity in some parts of the casting.

If the casting is to be chromed, painted, or powder coated, or if any part of the casting is very thin, any air or gas inclusions usually result in rejection. Porosity also affects the mechanical properties of the product. In structural applications, porosity can act as a stress concentrator and therefore create a site where cracks may occur.

An additional problem is the fact that porosity in a casting may not always be immediately apparent. If discovered after subsequent processing, customer dissatisfaction can be extreme.

Figure 2: Allper vacuum system.

Vacuum Assisted Casting is the Solution

Before the injection shot occurs, a vacuum is drawn in both the shot sleeve and the mold cavity. The vacuum is maintained until the injection cycle is completed. Almost all of the air is positively evacuated from the mold.

A good vacuum in the mold cavity enables the alloy to flow into blind recesses in complex shapes. It also allows the fronts of the molten metal to merge freely without forming shuts.

Whatever vacuum method is employed, if it works well, improved quality and reduced scrap can be guaranteed.

The benefits of vacuum assisted die casting are many:

- Rejections due to porosity are virtually eliminated.
- Rejections after secondary processing are greatly reduced.
- Excellent surface quality is practically ensured.
- Product density and strength are increased.
- Larger, thinner, more complex, castings are made possible.
- Less casting pressure is required.
- Tool life and mold life are extended.
- The die closes better.
- Flash is reduced.

Value Added

A metal die caster is not, by definition, really a manufacturer. He does not actually make anything. He simply converts metal from one form to another. He changes liquid metal into a solid casting. In doing so, he adds value. His success or failure therefore results entirely on the amount of added value economically generated by his casting process.

Product that is rejected is unusually costly to the die caster. The value of the machine time that was lost while producing the rejected product is never recovered.

Adding a vacuum system to an operating process benefits a die caster in several ways. First, it reduces the rate of rejection. Second, by lessening the force required on the plunger, it increases the life of almost all components of the DCM. But most importantly today, by allowing the die caster to produce thinner, stronger and more complex castings, it provides an opportunity to participate in a demanding, fast growing market sector.

The Essential Seal

It is an obvious fact that a vacuum can only be created in a totally enclosed space. This makes the seal between the plunger and the shot sleeve critical to effective vacuum-assisted die casting.

Figure 3: Allper plunger tip.

The gap between the plunger and the wall of the shot sleeve is necessarily very small ... only 0.004 in. If at any time during the slow part of the shot, the gap becomes much greater than four thousandths of an inch, air is likely to be sucked through the gap. During the fast part, with the sleeve full of metal, the alloy may penetrate the gap and flash or blowby will occur. With alloy on the plunger tip, rapid deterioration of the vacuum seal will result, as the tip becomes galled and the sleeve becomes soldered.

If the gap becomes much less than four thou, there is then a danger of interference. Inconsistent shot velocity will inevitably result. This gap must therefore remain virtually unchanged during the entire casting cycle to guarantee the secure seal that is necessary if an effective vacuum is to be drawn. If close control of this tip/sleeve gap is lost, a good vacuum can be easily destroyed in less than 1,000 shots.

A difficulty, of course, is that when metal is heated it expands. If the ID of the shot sleeve is no greater than three or four inches, expansion is minimal, and usually creates no great problem. But large castings require large shots and the coefficient of thermal expansion remains constant. The same increase in the temperature of a six-inch sleeve, for example, will cause it to expand exactly twice as much as a three-inch sleeve. Unfortunately, the critical allowable gap is still only four thousandths of an inch.

Another problem is that the shot sleeve is of steel and the plunger tip is usually of copper and copper has a much greater coefficient of thermal expansion than steel. This difference in coefficients makes close control of the gap, from the start of the shot to the finish, extremely difficult. At the start, the tip is coolest and the sleeve is hottest. At the end of the shot, the tip is hottest and the sleeve is often water-cooled.

To further complicate gap control there are other concerns, such as the differential in temperature from the top of the sleeve to the bottom.

The bottom of the shot sleeve directly below the pour spout is the place where flash most often occurs. Interference will occur when metal gets on the plunger tip from penetration of the gap that often results from the erosion of the steel beneath the pour. There is also the possibility of blow back of metal at the end of the fast part of the shot.

As well, the alloy being poured into the sleeve is at about 1300°F, while the annealing temperature of H13, the shot sleeve material, is only 1085°F. If the shot sleeve is not adequately cooled, it will likely lose some of its hardness. Soon wear will result from the abrasive action of any alloy that penetrates the gap.

With temperatures constantly changing throughout the stroke, the size of the gap doesn't depend on the actual temperature, but only on the differential in temperature between the plunger and the shot sleeve at any point. For larger castings, effective temperature management of both the plunger tip and the shot sleeve is therefore absolutely essential, if a consistent gap and a secure seal is to be maintained.

Controlling Plunger Temperature

Almost all plunger tips are made of copper, because its excellent thermal conductivity expedites the transfer of heat from the plunger to the cooling medium. Copper, however, is not a strong metal. Therefore, the face of the tip that carries the full force of the shot is usually fairly thick. This reduces the rate of heat transfer from the molten metal to the cooling water circulating within the tip.

A plunger tip, developed by Allper in Switzerland and produced in North America by Castool, provides a method of maximizing the rate of cooling without sacrificing strength.

This unique tip is not directly attached to the plunger rod. Screwed to the end of the rod is a stainless steel tip holder. The BeCu tip is attached to the holder with a bayonet-type coupling that provides a firm and dependable connection plus quick and easy replacement. This steel holder lies in full contact with the inside face of the plunger, and absorbs the total shot pressure. This allows the face of the plunger tip to be very thin, and so improves the heat exchange. The tip holder is cross-drilled with four water channels that produce a high velocity turbulent flow and maximize the cooling efficiency of the tip.

The Allper plunger tip also has a tool steel wear ring, which floats in a groove machined in the tip. Easily replaceable, the flexible ring expands to make continuous contact with the inside of the shot sleeve. Providing the temperature of the shot sleeve is also well controlled, the possibility of the tip/sleeve gap becoming too large is virtually eliminated, and the seal necessary for an effective vacuum can be successfully maintained. As the producers of large castings learn to control the gap with the Allper plunger tip, the number of shots with a good vacuum increases from a few thousand, to tens of thousands. In some cases the Allper plunger tip is also the enabling technology that makes a new product feasible to produce.

A Holistic Process Adds Synergy

Cold chamber die casting is a good example of a holistic production process. No single component of the DCM operates in isolation. Effective and profitable productivity depends on all parts of the process functioning at close to maximum efficiency at all times. Synergy really can result. This is an achievable goal for any die caster.

Many of the large and complex near-net shapes that are now required, can only be competitively produced with vacuum assistance. The efficiency of any cold chamber casting process will be improved by the addition of vacuum. But the maximum benefit of vacuum can only be approached when the temperature of both the shot sleeve and the plunger tip are closely controlled throughout the injection stroke, and a secure seal between plunger and sleeve maintained at all times.

A Challenge and an Opportunity

The need for light metal castings by automakers is really just beginning. It will continue to grow rapidly. Castings of a size and complexity never before envisage will be required.

This is a challenge to die casters, but also an opportunity of unmatched magnitude. With the aid of vacuum assisted casting, this challenge will be met. The opportunity will be seized. Our industry will prosper.