The Black and White of Automotive Die Casting

Paul Robbins, General Manager
Castool Tooling Systems
Uxbridge, ON, Canada

Introduction

Just now, in selected new models, some automotive companies are beginning to replace a few steel structural components, such as engine cradles, with unusually strong aluminum alloy castings. These castings are quite large, convoluted, and very thin. This is something the die casting industry has been looking forward to for many years, and it will add a large volume of new business which is then expected to increase at an almost exponential rate, as other automakers also turn to aluminum to remain competitive.

Black and white fairly describes aluminum die casting for the automotive sector, because in this unforgiving discipline there are no shades of grey. Every action or interaction in the die caster's production process is either flawless or it is disastrous.

In automotive die casting, there are no minor problems. The potential volume of new business is so great that no die caster can afford to jeopardize his share for any avoidable reason.

A Holistic Process

In serving this exacting market, no single component of the die casting production process should be examined or evaluated individually. Each interacts with at least one other complementary element of the process. If the interacting elements are equally efficient, they will reinforce and enhance the function of each other. Only if the entire process is considered as an integrated system, with all parts working together in common cause, can maximum efficiency be approached.

Success depends primarily on a philosophy of anticipation and prevention rather than correction. Also, it is absolutely essential to have complete, constant, and precise thermal control throughout the entire production system.

The automakers will negotiate very large blanket orders with independent established die casters or their own die casting divisions. They will carry very little inventory of finished parts at any time. All releases must be shipped complete. Of course, the quality of the castings must be certified as 100%. In the automotive industry, "almost perfect" is completely unacceptable. After all, a car is really designed to run forever.

The Vacuum

It is an accepted fact that to meet the challenging standards of quality required by the automotive sector, vacuum assistance is a prerequisite. When vacuum was introduced in die casting several years ago, the die caster needed an extreme application to justify its use because, at that time, the vacuum valve required so much maintenance. Today the Castool valve is stronger, thermally/dimensionally stable, and has very few moving parts. Accordingly, we have customers making 20-40,000 castings before performing routine maintenance. The vacuum valve is, of course an important component in the production system, but only one link in the chain of interacting components that must function flawlessly if the die caster intends to serve the automotive industry.

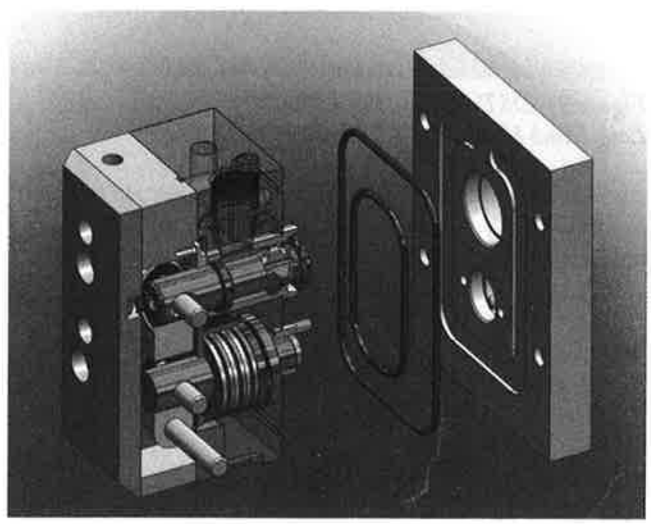

Figure 1 – The Castool Thermally Controlled Vacuum Valve.

Obviously 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. This is accomplished by Castool by very close temperature and thus dimensional management of both the shot sleeve and of a special plunger tip.

There are three main requirements for an effective vacuum system:

1. A vacuum tank with a large volume relative to that of the die cavity to ensure rapid evacuation.
2. A high level of vacuum in the die, and effective elimination of impurities, dirt and so on after the shot.
3. The vacuum in the tank should be at least one millibar.

The size of the high-speed valve is dependent on the smallest section that the exhausting gas passes through. The smaller the evacuation section, of course, the longer is the evacuation time.

Today, almost any product can be profitably made with a vacuum-assisted die casting system. The much improved valve is now working very profitably, while supported by a thermally controlled shot sleeve and plunger tip combination that create a secure seal, using a minimal amount of a special benign lubricant.

The Plunger Tip

Plunger tips were originally made of steel. Steel tips are still used, primarily for their durability and economy. A steel tip, of course, has the same coefficient of thermal expansion as the shot sleeve in which it slides. Since the plunger tip is exposed to more heat than the sleeve, the expansion of a steel tip is difficult to control very precisely. The next step in the development of the conventional plunger tip was to make it of beryllium copper which has a coefficient of thermal expansion more than 50% greater than that of steel. This made the expansion of the tip much easier to control. It was then possible to maintain the thermal, and therefore the dimensional, stability of the tip throughout the length of the stroke.

Excessive plunger tip expansion and wear is nearly always simply the result of insufficient coolant. Even experienced die casters sometimes neglect this. Rate of flow is easily measured, 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 that utilize the cooling water much more effectively than conventional tips. Castool's ARP plunger tip was developed a number of years ago by Allper of Switzerland. Allper was purchased by Castool in 2009. The water flow is from the center of the shot rod, through the stainless holder, and directly to the inside face of the plunger

Figure 2 – Castool AMP Plunger with Lubrication System.

tip where a turbulent flow is generated to maximize the heat transfer. It then goes through four channels to the circular external coolant return passage.

Beryllium copper is an ideal medium to dissipate heat from the plunger to the cooling water. It is, of course, not nearly as wear-resistant as the steel of the shot sleeve. Since the tip was then dimensionally stable, and the gap controllable, this problem was resolved with the development of a steel wear-ring. This tempered steel ring rests freely in a groove machined near the front of the plunger tip. It is split, and expands against the inside wall of the shot sleeve. Only the ring wears, and not the copper body.

Because the ring is flexible, it makes continuous contact with the inside of the shot sleeve. Flash, which is a major cause of wear, is essentially eliminated, and shot speeds are consistent. Since the expanding wear ring ensures a secure seal between the plunger and the shot sleeve, a better vacuum can be drawn. An additional advantage is that the face of the ARP is considerably cooler than that of other plunger tips. This cools the biscuit much faster, and reduces the cycle time significantly. It is not uncommon for die casters to attempt to reduce cycle time by cooling the die end of the shot sleeve. This unfortunately tends to shrink the sleeve at the point where the plunger tip is hottest, and is likely at its greatest diameter.

A New Plunger Tip

The demands on the plunger tip, particularly in strength and stability, outgrew the replaceable wear ring plunger. This led to the development of the Castool AMP plunger tip. As with the ARP, a steel holder screws onto the plunger rod. The beryllium copper body with its steel head is similarly connected with a quick-release bayonet fastener.

With the AMP, after a considerable period of incremental redesign and field-testing, the heat transfer to the coolant has become much more effective. The tip is more dimensionally stable and thermal control less dependent on the high coefficient of thermal expansion of copper.

Cycle times are reduced. Cost of consumables is reduced. Operating life of wear rings and tip bodies can now be fairly accurately estimated, and downtime for replacement scheduled, so production runs are never unexpectedly interrupted. The AMP high strength plunger tip responds to the demands of an increasing and changing market. It simply makes better castings.

Controlling the Shot Sleeve Temperature

Typically, a shot sleeve may become 100-150°C hotter at the bottom under the pour hole, than at the top in front of the hole. If the temperature of the sleeve is much higher at the bottom than at the top, unequal expansion will cause it to become oval instead of round. This will also cause the sleeve to become slightly bowed rather than straight.

If uncontrolled, the vertical temperature variance in the shot sleeve will result in distortion, which may allow some of the alloy to enter part of the gap between the plunger and the sleeve. This will cause the seal between the plunger and shot sleeve to be compromised, premature wear, and inconsistent shot velocity.

Nearly all die casters cool their plunger tips. Effectively controlling shot sleeve temperatures, however, is a more difficult challenge. The pour end of the shot sleeve where the temperature is highest, is obviously where cooling is most necessary. Accordingly, one 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.

In most cases where vacuum is being used, it is necessary to use a thermally controlled (TC) shot sleeve. A series of gun drilled holes are located along the length of the shot sleeve under the pour spout, and are connected to similar

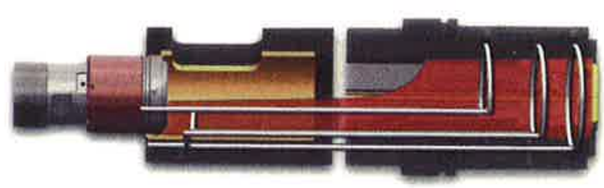

Figure 3 – Castool Total Control Shot Sleeve.

holes around the die end of the shot sleeve. A thermal control unit is used to manage the temperature and flow of a medium, usually oil to gain control of the shot sleeve temperatures and its dimensions during production.

Plunger Lubrication

The principal purpose of shot sleeve lubrication is simply to reduce the friction between the sleeve and the plunger, and to thus ensure the smooth passage of the plunger through the sleeve. This is essential for consistent shot velocities and to extend the operating life of both the shot sleeve and the plunger tip. The amount of lubricant used must be adequate, but care should be taken to avoid any excess. Lubrication should therefore be kept to an absolute minimum. It should be benign, and produce no toxic fumes.

Every care should be taken to eliminate the possibility of any non-metallic substance getting into the mold. Graphite-based lubricants, for example, can cause porosity in the casting.

Lubricant should be applied where it is needed... and only where it is needed. Any excess lubricant, not actually used, is an unnecessary cost and a workplace pollutant.

Boron Nitride is just now universally acclaimed as the most effective lubricant yet available for the aluminum die casting industry. Its unmatched lubricity far exceeds that of all other traditionally used lubricants. It is also completely benign, producing no toxic fumes.

A carefully measured amount of liquid lubricant is vaporized to form a fine mist. This is blown throughout the length of the shot sleeve, ensuring that the surface is completely and evenly coated with a thin film of lubricant. Any excess lubricant is wiped off when the ring returns through the shot sleeve bore at the end of each cycle.

The lubricant spray and air nozzle assembly is securely mounted just behind the plunger tip on the plunger rod. The nozzle technology effectively atomizes the lubricant to ensure total coverage and reduce overall consumption. A metered dosage injection pump provides the precise amount of lubricant required for each process cycle, with no danger of excess to contaminate the casting.

Caution

Be cautious of salesmen promoting a one-stop solution to your problems. Such a panacea simply does not exist. If possible, try to discuss your production process with the part designer to be sure that production is no more difficult than it really has to be. (Tolerances, finish, etc.)

Although improved steel may be metallurgically superior, its cost can seldom be justified. However, once design and process have been optimized, a better steel may help.

Triggering the closing of the vacuum valve more quickly with a vacuum controller adds to the complexity of the vacuum system, it may help to prevent alloy and pollution from entering the valve and causing downtime. But it is better to focus on the cause, and keep the valve as simple as possible.

Simply use the minimum amount of lubrication and put it in the right places. (Not in the casting.)

A Final Word of Advice

Any die caster knows how to produce large, thin, convoluted aluminum castings for the automotive industry. It is already being done quite satisfactorily and profitably in large quantities. There are no secrets. Knowing how to do it and actually doing it, however, are two very different things. When theory is finally replaced by reality, the most fundamental precept of die casting for the automotive industry can be found in the old adage, **a chain is only as strong as its weakest link.**

As long as you remain firmly focused on this, you are on the road to success. Ignore it and you will fail.