BIGGER CASTINGS – BIGGER PROBLEMS

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INTRODUCTION

The cautionary title of this paper might better have been “Bigger Castings - - Greater Opportunities”, because the market for light metal die castings is expanding more rapidly than ever before, and much of this opportunity lies in large castings. This escalating market is primarily in the automotive sector.

Oil is not a renewable resource. It is finite, and most of the world’s remaining supply is found beyond the direct control of the industrialized Western nations. Its long-term availability, therefore, cannot be assured.

It is an accepted fact that for an average-sized car, a 10% reduction in weight will result in a 5% reduction in fuel consumption. Automakers are naturally anxious to reduce the weight of their vehicles by replacing steel components with aluminum, wherever it is economically feasible. Some of these will be quite large castings, engine blocks, gear boxes, dashboards, and so on. Since about 20 million vehicles are produced in North America each year, the potential for the light metal die casting industry is considerable.

Anticipating this market, some diecasters who previously used only 3” to 4” diameter shot sleeves X 24” to 35” in length, are adding 3,000 to 4,000 ton machines with shot sleeves that are 6” to 7” diameter X 50” to 55” in length.

For its suppliers, the automotive industry is extremely demanding. Automakers insist on 100% guaranteed quality, with just-in-time delivery. The size of their long-term orders allows them to negotiate very low prices. The potential volume of business is certainly attractive to a diecasters, but to profit from it, their productivity must be outstanding. A number of problems such as uncontrolled thermal expansion, lubrication, and porosity due to incomplete air evacuation, which are easily resolved in smaller machines, are seriously magnified when producing large castings. Possible solutions to these several problems arising from the production of large alloy castings will be addressed.

COOLING SHOT SLEEVE

To attain maximum productivity, and also maximum operating life for both the shot sleeve and the plunger tip, the plunger must move smoothly and at a constant speed through a perfectly round, straight, shot sleeve. The clearance between plunger and shot sleeve cannot exceed 0.004" (0.10 mm). If the clearance becomes greater than this, the alloy can penetrate as flash or blow-by. This will cause excessive wear.

The problem is that when metal is heated it expands. The amount by which each metal will expand or contract with changes in temperature, is expressed in terms of its coefficient of thermal expansion. Plunger tips are commonly made of copper, and shot sleeves of H-13 steel or its equivalent. H-13 expands at the rate of 0.0000061/F° (0.000011/C°) and copper at 0.0000094/F° (0.000017/C°). Since these coefficients are constants, they represent both in/in and mm/mm. These figures may appear to be extremely small, but if the temperature of a 6" copper plunger tip increases by 200F°, the diameter will increase by more than 0.011".

Slide 1. Thermal distortion of sleeve and tip.

The clearance between plunger and shot sleeve never remains constant. At the pour end, at the start of the casting cycle, the sleeve is very hot, and the plunger tip quite cool. As the plunger moves forward toward the die end, the tip becomes hotter. At the end of the stroke, the sleeve dissipates heat to the platen and the die, and cools. The tip therefore expands, while the shot sleeve contracts. If the initial clearance at the pour end is small enough to prevent penetration of alloy past the tip of the plunger, the plunger may seize in the sleeve before reaching the end of the stroke. The chance of this happening increases with the length of the shot sleeve.

Typically, a shot sleeve may become 270F° (150C°) 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 that at the top, unequal expansion will cause it to become oval instead of round. This will also cause the sleeve to become slightly bowed instead of straight. Either or both of these conditions will cause premature wear of both plunger tip and sleeve. The extent of ovality and distortion is directly related to both the diameter and length of the shot sleeve. To avoid too much variance in thermal expansion, the bottom of the shot sleeve should be cooled so that the difference in temperature, bottom to top, does not exceed 90F° (50C°).

For small diameter shot sleeves, 3.5" (9 cm) or less, thermal distortion is usually so small that temperature control is seldom necessary. For large sleeves, however, cooling is always necessary.

Slide 2. Water cooling, with M- Loop

Cooling shot sleeves may be done with either water or oil. One method of cooling with water is by machining grooves in the outside wall of the sleeve, then inserting copper tubing. The system has an "M" shaped loop which extends up the side walls of the sleeve. To determine the best location for the cooling tube, a comprehensive temperature audit is required.

Slide 3. Water cooling, with reusable water jacket.

Recently, Castool has started using a reusable cooling jacket with internal plumbing as an alternative to the M-Loop. The cooling jacket uses water as the cooling medium. It is more durable, promotes more uniform sleeve temperatures and does not obstruct current filling methods. The result being increased tooling life and further reduced scrap.

Slide 4. Oil cooling, showing internal coolant passages.

A more advanced method of regulating the temperature of the shot sleeve uses oil instead of water. The advantage of oil is that it can be used for heating as well as cooling. By preheating the sleeve, the diecaster can minimize the tip and sleeve wear, and reduce the scrap which normally occurs while the sleeve is heating up to operating temperatures.

Unusually high shot sleeve temperatures often result from short cycle times, high filling ratios, and thin sleeve walls. The wall thickness should be at least 1/3 of the inside diameter of the sleeve. The size of the pour spout should be less than 70% of the bore of the sleeve. The unsupported portion of the sleeve should be as short as possible to avoid bending.

The crux of the problem with thermal expansion in large casting machines, is that for the same increase in temperature, a shot sleeve or a plunger in a 6" machine will expand twice as much as in a 3" machine. But the size of the gap between them, which will allow the alloy to penetrate, still remains the same.

For large casting machines, effective cooling of the shot sleeve is essential.

Slide 5. Lubrication with oil mist.

LUBRICATION

To get maximum production from any cold chamber die casting machine, effective lubrication of the shot sleeve is necessary. Insufficient lubrication will result in inconsistent shot velocity, premature sleeve and plunger tip wear, and unnecessary scrap. Long, large sleeves require sufficient lubricant to coat the entire bore. The problem is that the most commonly used lubricants such as powder, wax, or oil, which are quite satisfactory in smaller machines are often inadequately applied when the shot sleeve is large and long. The lubricant itself may be effective, but if a 6" diameter (15 cm) sleeve is 50" (130 cm) long, when the plunger has traveled about 35" (90 cm) the lubrication is often gone.

For large machines, a method which ensures complete coverage over the entire length of the sleeve, is the high pressure injection of an oil mist. The spray nozzle can be inserted through the die side of the sleeve, or through the pouring spout.

For large casting machines, effective lubrication of the shot sleeve is essential.

Slide 6. Plunger tip designed for cooling.

COOLING PLUNGER TIP

The diameter of the plunger tip is much greater than the thickness of the shot sleeve. Also the coefficient of thermal expansion of the copper tip is greater than that of the steel sleeve. Unless the plunger tip is adequately cooled as it moves forward, it will expand much more rapidly than the sleeve. Binding may result.

Most problems in satisfactorily cooling the plunger tip result from an inefficient transfer of heat to the cooling water, and often simply an insufficient flow of water. A plunger tip designed for maximum cooling is shown in this slide.

This forged beryllium copper tip is supported by a stainless steel holder which lies in full contact with the inside face of the plunger, and absorbs the total shot pressure. This allows the face wall of the plunger to be very thin, which makes for an extremely efficient heat exchange. This exchange is assisted by cooling channels in the holder. These channels are designed in such a way that the flow of coolant becomes turbulent. This turbulence prevents filming or stratification, thus improving the transfer of heat to the coolant.

The flow of water is introduced through the centre bore directly to the insider face of the plunger. It is then distributed via four channels to the circular external channel.

For large casting machines, effective cooling of the plunger is essential.

Slide 7. Expanding Wear Ring

PLUNGER TIP WITH EXPANDING WEAR RING

To further ensure a consistent seal between plunger and shot sleeve, a plunger may be used which has a replaceable expanding wear ring mounted near the front of the tip. This ring, made of tool steel with a wear-resistant coating, is split so that it can be easily and quickly installed and replaced. Because of its flexibility, the ring automatically adjusts to the inside diameter of the sleeve during the shot. It will also compensate for some ovality of the sleeve.

Slide 8. Vacuum system for air removal

VACUUM AIR REMOVAL

When producing large castings for the automotive industry, a conventional venting system in the die is no longer adequate. Porosity and poor surface finish are absolutely unacceptable. Superior quality is demanded in this market sector, and the price level is such that any appreciable scrap loss will make the die caster uncompetitive. Air, and gases produced by burning lubricant and die release agents, should therefore be positively removed from the die cavity by vacuum technology.

By using a vacuum, almost all the air from both the die cavity and the shot sleeve can be extracted soon after the plunger tip closes off the pour hole. By practically eliminating air resistance in the die cavity, vacuum eliminates many problems related to excessive build up of pressure. In addition to reduced porosity, improved surface finish facilitates further treatment of castings such as chroming.

When producing high quality large castings, effective air removal by vacuum technology is essential.

CONCLUSION

To even approach the ultimate goal of efficiently and economically producing a large, perfect, light metal casting, the plunger, perhaps aided by an expanding wear ring, must first seal, and then pass through a round, straight, completely lubricated shot sleeve. Both shot sleeve and plunger will be adequately cooled to control thermal expansion and maintain the necessary gap. Air will be positively removed from the die cavity and the shot sleeve by an effective vacuum system.

The quality of the product will be consistently excellent. Delivery will always be on time. The price will be competitive. The customer will be satisfied. The die caster will make a profit.

Note: The plunger tip, oil mist lubrication, and vacuum system described and illustrated in this paper, are all proprietary to ALLPER AG of Dudingen, Switzerland. www.allper.com