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Preserving Profitability, Quality & the Environment: How Plunger Lubricants can help

G.Natesh
Business Development Director (Die Cast), Chem-Trend L.P, Howell, Michigan

ABSTRACT

Given the turbulent economic scenario, many casters are looking at creative options to survive profitably. With the increasing use of die cast components in critical applications in automotive and other heavy machinery, the quality requirements of the castings are becoming more stringent. At the same time there is growing pressure to reduce the impact that die casting operations have on the environment. This paper discusses some of the issues and the role that proper plunger lubrication can have on improving profitability, quality and the environment in a die cast operation..

INTRODUCTION

The recent turmoil in financial markets and the steep rise and fall in the prices of various commodities including crude oil has placed renewed challenges on today's die casters. The automotive sector is facing bankruptcy and has been forced to take cost-cutting measures to new levels. At the same time they are being challenged to produce products demanded by today's customers. Improved fuel efficiency has assumed an even greater importance for the auto industry, yet at the same time, growing environmental consciousness is also spurring the drive for alternatives. The die casting industry is directly impacted by all these issues, as automakers seek to increase the use of light metal cast components in vehicles at lower costs and regulatory agencies impose increasingly stringent regulations on air and water pollution..

QUALITY

Quality can mean different things to different people. In the context of die cast components, one of the most important parameters is porosity. Porosity can reduce the strength of a component, and while replacing steel with aluminium, strength is one thing we cannot afford to lose!

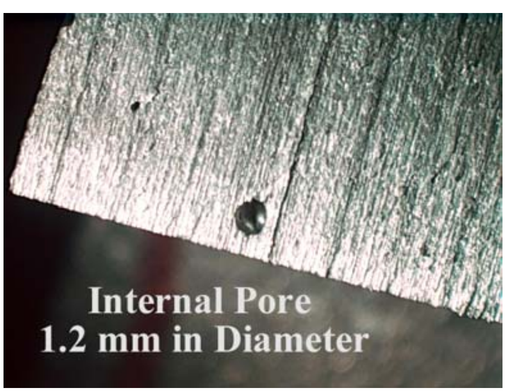

Fig 1: Gas porosity

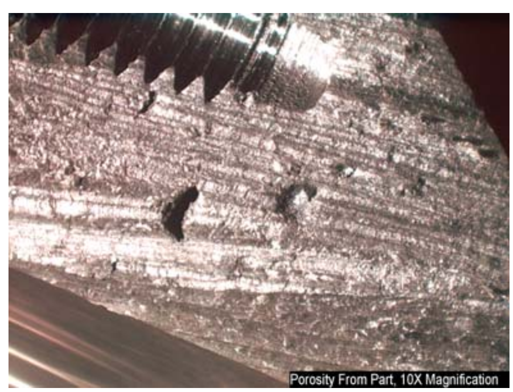

Fig 2: Shrinkage porosity

Porosity can be caused by many factors. Molten aluminium dissolves hydrogen from the atmosphere. Much of this is removed from the melt during the degasification step, but it is very difficult to remove it all. The die casting process itself operates at high speed and can contribute to porosity. Molten metal is turbulently sprayed through a narrow gate into the die cavity. Fine drops of molten metal are intimately mixed with the air in the sleeve and the cavity. Some of these can cause bubbles, which do not have time to migrate to the vents before the metal solidifies, contributing to porosity.

Solidification and contraction of the metal after the shot intensification is complete can lead to shrinkage porosity. This is particularly common when the casting has areas of different cross-sectional thickness.

Another quality parameter that is growing in importance is surface appearance/ paintability. Until now most die cast parts were not utilized in visible area of an automobile. However, increasingly, we are seeing structural members and external body components made from die cast components. This requires that the surfaces be free of blemishes and be able to take on the paint requirements of today's customers. If stains are present, they can affect the appearance of the final color of the part. In extreme cases, they can interfere with the adhesion of the coating to the casting.

Fig 3: Stain on casting

Another requirement is to ensure that parts can be glued together. Gluing is gaining ground as a way of joining parts together. The presence of a stain can interfere with the adhesion strength of the joint and lead to failures.

Many die casters make active efforts to reduce the porosity in their castings. The use of vacuum to evacuate gases during the injection phase, improved die design to minimize choke points, and enhanced ladling and degasification methods have all led to improvements in part quality. Another area that has now been recognized as having an important effect on casting quality is plunger lubrication.

PLUNGER LUBRICATION

Plunger lubricants are applied on the plunger tip or into the sleeve, before molten metal is introduced. As the shot fills the sleeve and enters the cavity, it is possible to entrain some of the lubricant into the molten metal. The very high velocities in the gate promote turbulence and facilitate intimate mixing of metal droplets and vaporized plunger lubricant. This can result in porosity or form a stain on the surface of the casting. Both these are to be avoided.

The effect of plunger and sleeve operations on casting quality has been studied by various practitioners. Early studies focused on the longitudinal waves that are setup in the molten metal during various stages of the shot.(1, 3) This led to the establishment of the critical velocities to avoid excessive entrapment of the gases above the molten metal in the sleeve. Other studies talked about the need to maintain uniform temperatures across the sleeve, to minimize sticking.(2) Plunger lubrication is an essential part of this process but the effects of different lubricants on casting quality have not been studied extensively.

Plunger lubricants can also contribute to pollution in the working environment of a die cast machine. Most plunger lubricants contain organic materials that will decompose or burn when they encounter the molten alloy in the sleeve. This is usually seen as a puff of smoke or a flame rising from the pour hole. (Figure 4) The amount of air available for combustion is usually low resulting in incomplete combustion. This results in the formation of carbon monoxide and soot in addition to carbon dioxide, which is a greenhouse gas that contributes to global warming. The soot escapes as smoke which also contributes to the pollution. Many plunger lubricants contain graphite, which is difficult to burn under the conditions found in the sleeve. Some of this also escapes contributing to the problem. This can also cause stains and/or inclusions in the casting.

Fig 4: Flames from shot sleeve

PLUNGER LUBRICANTS

Plunger lubricants can take many different forms. Oil based lubricants are very common and some of these may contain solid lubricants like graphite. Water based lubricants with suspended solid lubricants are also available. Wax based pellet lubricants have gained popularity in recent years and these are available in both graphite-containing and graphite-free versions. Finally, specialized solid powders are also used as plunger lubricants.

The selection of the appropriate plunger lubricant for a given application is a complex process and depends on a number of factors including the mechanical design of the system, the metallurgy of the sleeve and tips, the operating conditions, and shot weight among other factors. Increasingly, the potential to contribute to the cleanliness of the die casting environment, is playing a bigger parting the selection process.

The form and chemical composition and the method of application of a plunger lubricant can all have a significant impact on the amount of smoke or flame that is generated during the application. In most cases the plunger lubricant is applied on to the tip or the sleeve through a nozzle or by a brush, usually through the pour hole. Pellet lubricants are usually dropped into the sleeve through the pour hole using a moving shuttle. When the molten metal is introduced into the sleeve, it ignites the organic components of the plunger lubricant, creating a flame and smoke. The working area near the plunger is not well ventilated and therefore, the combustion is not complete, producing a lot of carbon residue. With smaller pistons, the liquid lubricant is dropped on the tip at the back end of the sleeve. Excess lubricant usually forms a pool below the sleeve and this can catch fire if hot metal or a spark lands on it. Even with pellet lubricants, it is difficult to ensure that all the material enters the sleeve. Excess pellets can collect on the floor beneath the sleeve, where they can become a fire hazard. More importantly, this a waste of material that has been paid for by hard earned profits.

Basic chemistry tells us that, in general, gases burn more completely than liquids, which in turn, burn more completely than solids. Water-based materials generally produce the least smoke compared to oil based lubricants, which in turn produce less smoke and flame than wax based pellets.. This has to be balanced against the fact that water based lubricants have a lower lubricating effect and so may need a higher dosage to get the same lubrication results. Typically graphite-containing lubricants produce more smoke than graphite-free materials as the graphite usually does not burn under the conditions encountered.

One common practice at many die casting plants is to over-feed the plunger lubricant. Poor lubrication of the sleeve can result in a poor shot or even cause the piston to stick in the sleeve, which leads to a machine shutdown and troublesome clean-up. Rather than risk this eventuality, most operators tend to increase the quantity of plunger lubricant. This is sometimes also done to overcome poor die lubrication practices and prevent sticking in the gate area. A natural consequence of this is increased smoke and flame at the pour hole as all the excess material serves as a fuel. This can also result in erratic shot profiles, air entrapment and porosity. Using a dosing pump for liquids and ensuring the correct amount of lubricant is added can go a long way in minimizing these problems.

NEW DEVELOPMENTS

There have also been recent developments in technology that have contributed to reducing the environmental impact of plunger lubricants while enhancing performance. Graphite containing plunger lubricants are often used for large and difficult to control applications. One drawback of such products is the tendency of graphite to separate from the suspension. This often results in a thick sludge in the bottom of the container which is difficult to remove and contributes to waste. More importantly, this results in varying levels of graphite actually being applied into the sleeve. Many manufacturers compensate for this loss of graphite by increasing the amount of graphite in the product, which in turns aggravates the problem.

Fig 5: Filled product stability

Today, newer and more stable formulations are available that do not settle out even after standing for long periods of time. Figure 5 shows samples of conventional and improved plunger oils containing graphite. The sample on the left shows clear separation while the one the right is completely homogeneous even after 6 weeks. Even in cases when a sharp break between oil and graphite is not seen, the level of graphite changes between the top and bottom of the container and this can occur within 24 hrs.

Another recent development involves improving the combustion characteristics of the lubricant to reduce its flammability and consequently reduce combustion by-products. The flame propagation test (ASTM D-5306) covers the determination of the linear flame propagation rates of lubricating oils by applying the test material into a ceramic fiber media and then introducing a flame at one end. The ceramic fiber media is 15.2 cm long and the test measures the time it takes the flame to propagate from one end of the media to the other. Figure 6 shows the relative performance of conventional and improved products. Products A & B are unfilled products, while C & D both contain graphite. The longer times show the improved combustion resistance of the newer technology.

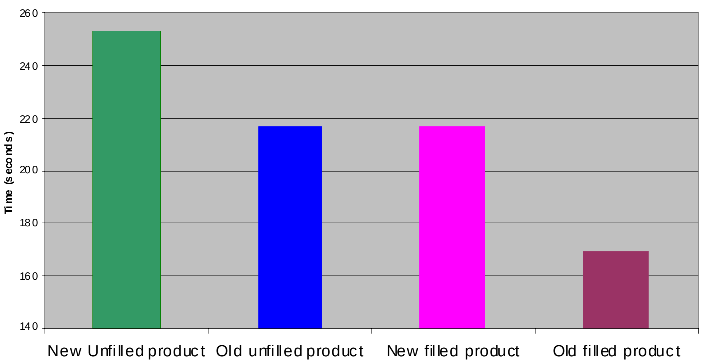

Fig: 6 Flame Propagation Test Results

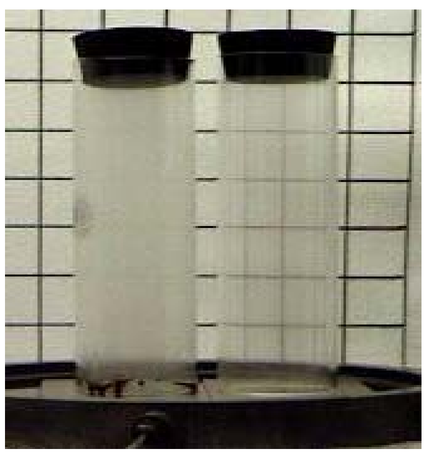

Fig 7: Smoke comparison

Further research by Chem-Trend has led to the development of products that produce significantly lower smoke on combustion as compared to conventional technology. Figure 7 shows the smoke generated from equal quantities of a conventional and a new plunger lubricant placed on a hot surface maintained at typical sleeve temperatures. The new product is on the right. As is obvious from the picture, the newer product achieves significantly less smoke. The lubrication performance of this material was then tested in the field against a pellet product.

CASE HISTORY

A North American die caster was concerned about the wastage and performance issues with their current pellet plunger lubricant. They have a number of machines ranging in size from 150 T to 900 T, with water cooled Copper-Beryllium tips ranging from 2.5" to 4" (60 mm to 100 mm). The plant was experiencing:

- build-up and wear on their tips
- plugging in the vacuum system leading to porosity on critical parts
- significant downtime each shift for housekeeping on the machine

A trial was started with the new low smoke oil-based plunger lubricant, on a 350 T machine with a 3.5" (~90 mm) tip and a 28" (~711 mm) sleeve. 1.5 ml of lubricant was applied per shot. The plant noticed an immediate improvement in cleanliness around the shot end of the machine. After three weeks, there was no build-up in the vacuum system, machine or the tip. The casting quality also increased, leading to a sharp drop in the rejection rate. Tip life was improved and the number of shots per tip increased by 200%. Figure 8 shows the appearance of tips after 2500 shots each. The improved productivity and savings in tip and sleeve life was estimated at over $15,000 per year. The customer was very pleased with the trial and converted all their machines to the new lubricant and improved profitability.

Fig 8: Comparison of Chem-Trend plunger lube tip (left) and the competitive product tip (right).

Another technology advance is the development of new chemistries that greatly reduce the amount of lubricant required to get good performance. New high efficiency oil based plunger lubricants are typically dosed at between one half to one third the dosages of conventional oils. This greatly reduces the amount of lube that can get burnt, while at the same time produces excellent tip life. Figure 9 shows the typical dosage on a 75mm (~3") tip. The practical effects of this technology have been validated by field trials.

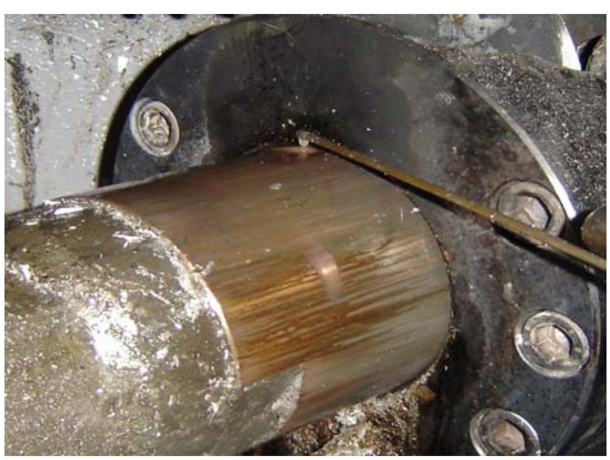

Fig 9: High efficiency lubricant

CASE HISTORY

A European die caster was using a conventional oil based plunger lubricant on a 750T Italpresse machine running with a 100 mm (~ 4 ") copper-beryllium tip. The sleeve was thermally regulated to a typical temperature of 140C (~285 F). The plunger lubricant was applied on the tip at about 2.5 gm per shot and even this gave rise to a lot of flame and smoke. In addition, the area beneath the sleeve was very dirty with oil and metal fines. Typical tip life was around 2000 shots.

The high efficiency Chem-Trend plunger lubricant was initially applied at a dosage rate of 1.6 gm per shot but this was rapidly reduced to about 1.2 gm per shot. Despite this low dosage, we were able to run continuously for over 10000 shots, at the end of which the plunger tip was still functional. When they switched back to the older product the plunger seized after an additional 1000 shots.

Fig 10: Conventional product. Note pool of oil below piston

Fig 11: High efficiency lube. No spillage below piston

Figure 10 shows the excess lubricant on the floor below the sleeve, while the new high efficiency product (figure 11) had no spillage at all, resulting in more savings and a cleaner and safer work environment.

CONCLUSION

In today's challenging business climate, the primary focus of all die casters is to increase profitability and productivity without sacrificing quality. Environmental issues usually have a lower priority. However, as can be seen from the above examples, this does not have to be a zero-sum game. It is possible to significantly improve the casting environment without adversely affecting casting quality or productivity. The continued efforts of die lubricant suppliers and die casters can help achieve significant improvements in the workplace and indeed, the global environment.

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