INNOVATIVE TECHNOLOGIES IN MOULD RELEASE AGENTS

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The drive for improved fuel efficiencies in the automobile industry has led to continuing growth in aluminium die casting as manufacturers strive to reduce the weight of automobiles by replacing steel with light metal components. Larger and more complex parts are being cast and this has set new challenges to die casters in their quest for improved quality and productivity. The paper examines the impact of these trends on die lubrication and discusses an innovative lubrication technology that has evolved to satisfy these requirements.

KEYWORDS: : mould release agent, die-casting, high temperature, automotive, die lubricant, solder protection, leidenfrost effect

High Pressure die-casting is a very popular process for making complex mechanical parts out of light metals like aluminium and magnesium alloys. It is capable of rapidly producing parts with high dimensional accuracy. High pressure die-casting grew along with the growth of the automobile industry, where the demands of assembly line manufacture spurred the demand for a quick reliable way to make components. With the growth of JIT manufacturing, the automobile industry still continues to be the dominant user of high-pressure die cast parts. Other end uses for die casting include recreational vehicles, power tools, electrical machinery, electronic components and house-ware. The rapid growth of the world economy has spurred a demand for all of these products and the European die cast industry is gearing up to meet this demand.

The rising cost of fuel and increasingly stringent environment and fuel performance regulations are forcing the auto industry to seek novel ways to achieve these goals. Weight reduction of vehicles is a key step to reducing fuel consumption, so the industry is actively looking at replacing steel components with aluminium and magnesium castings. With constant innovation in aluminium alloys and casting technology, improved strength and other properties are being engineered, that allows bigger and more complex parts to be die cast. Engine blocks, instrument panels and complete door frames are just some of the examples of aluminium components now being produced by die-casting. This has led to a trend towards bigger die-cast machines and larger shot weights.

The complexity of these large parts makes it difficult to design internal cooling to adequately cool all parts of the die uniformly. A natural consequence of this is that die surface temperatures have increased. Previously, the die surface temperatures before spray used to range between 250°C to 350°C. With the large components, the maximum temperature can be as high as 400°C while the cooler portions of the die may be as low as 200°C.

This leads to the development of localized hot spots which, in turn, create solder problems. This places a greater dependence on the die lubricant to provide cooling for the die surface. Yet the higher temperatures encountered before the spray make this difficult to do because of the Leidenfrost effect. This requires greater quantities of die lubricant to be sprayed, which increase cycle times and costs.

The Leidenfrost phenomenon is well known to die casters. When water is sprayed on to a hot surface, which is at a temperature well above the boiling point of water, it is unable to make contact with the metal surface. Instead, the drops of water float on a cushion of water vapor and thus are unable to wet the surface (Fig. 1). Die lubricant active materials are therefore, unable to be laid down on the die surface. The highest temperature at which water, or a water based die lubricant, can contact the metal surface is known as the Leidenfrost temperature.

Our research focused on two separate approaches to develop high performance die lubricants. The first was to try and in-

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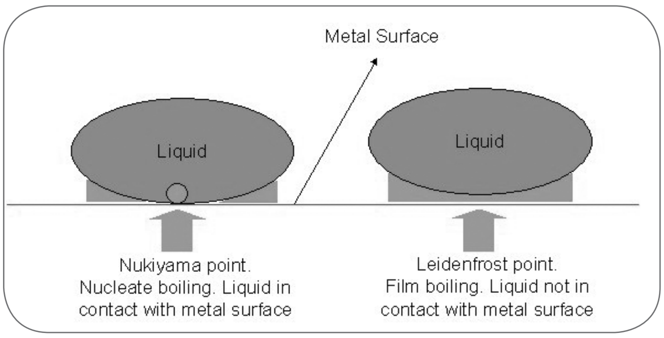

Fig. 1 ***Schematic rendering of the Leidenfrost phenomenon.***
Rappresentazione grafica del fenomeno di Leidenfrost.

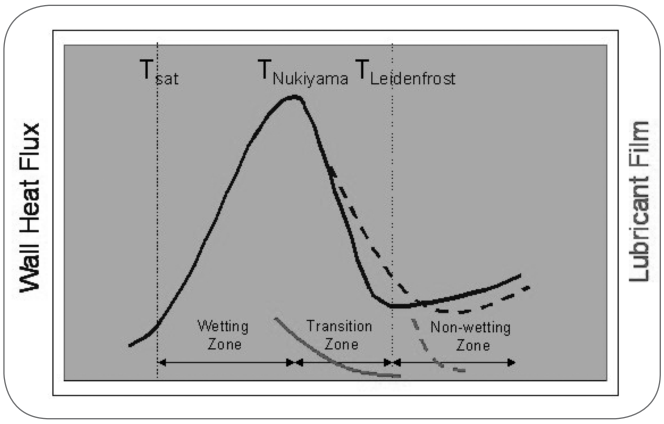

Fig. 2

The cooling curve of water showing maximum rate at the Nukiyama point.

Curva del raffreddamento dell'acqua con picco al punto Nukiyama.

crease the Leidenfrost temperature. By allowing the die lubricant to wet the surface at a higher temperature, film formation begins earlier, allowing shorter spray durations. The second approach was to develop materials that would form a film rapidly on the die surface at elevated temperatures. The cooling curve of water shows the rate of cooling approaches a maximum at a temperature known as the Nukiyama point. (Fig. 2) [1]. By increasing the Leidenfrost temperature, we are able to increase the operating window to form a film. However, if the film formation was slow at the higher temperatures, any advantage gained by raising the Leidenfrost temperature would be lost. Many different factors affect the Leidenfrost temperature. Mechanical factors like the distance and angle of sprays, the size of the droplet and impact pressure all affect the wetting temperature. Last, but not the least, constituents in the spray can affect Leidenfrost temperature. [2]

Studies with water showed that the presence of dissolved salts caused an increase in Leidenfrost point. Fig. 3 shows cooling profiles with different fluid compositions. We see that DM water had a wetting temperature of about 315°C under experimental conditions. Soft water wets at about 320°C while hard water has a Leidenfrost point of about 340°C. Conventional die lubricants made with soft water show similar results. Note that these temperatures are higher than what is seen in the field due to differing operating conditions.

We decided to screen a variety of inorganic and organic compounds and our efforts were able to develop materials that produced significant increases in the Leidenfrost point. The comparable values under the same conditions were in excess of 370°C.

The benefit to a die caster is clearly seen. If a die is initially at a high temperature and needs to be cooled to about 250°C to get complete solidification, using these new materials could reduce the spray time by 20% to 30%. This directly translates into an increase in productivity, compared to conventional lubricants.

Cooling is only one of the functions of the die lube. The primary function is release, and this can only take place if an adequate amount of the lubricant film is formed over the die surface. Lubricant components do not always adhere to very hot surfaces. Materials were screened for high temperature film formation by weighing the amount of film formed by spraying a dilute spray containing a fixed quantity of actives onto a pre-weighed stainless steel plate maintained at specific temperatures. Stainless steel was used as experiments showed that H13 tool steel became oxidized and created a large source of error in the observations. The use of stainless steel minimized this error.

In an actual die, there is wide variation in the temperature of the die surface. When die lube is sprayed on the surface, film can be formed rapidly at the cooler parts of the die, but may not form very well at the hotter regions. Our initial tests tried to maintain a single plate with a standard temperature gradient similar to what may be encountered on a die. We were unable to get repeatable temperature gradients so we decide to measure the die adhesion at specific temperatures. We then compared the performance of different materials at the range of temperatures commonly encountered on the die.

Fig. 4 shows the Hot Die Adhesion Index, which is ratio of the weight of film formed at 350°C and 250°C. This index is a measure of the uniformity of the film formed on a tool operating at different temperatures. A value of 100% means exactly the same amount of film is formed at all temperatures. In actual practice this is very difficult to achieve. The results show that the new materials were at least 2 to 3 times more efficient than conventional die lubricants. These results were validated, by carrying out field trials on full-sized machines at customer sites. Field performance corresponded well with our experimental results.

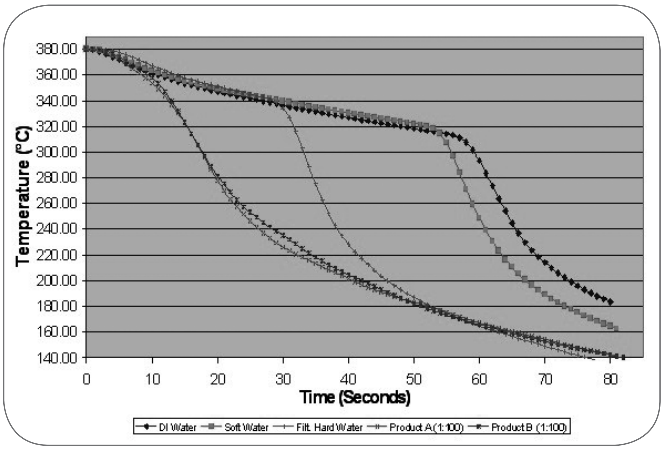

Fig. 3

Die cooling curve.

Curva di raffreddamento dello stampo.

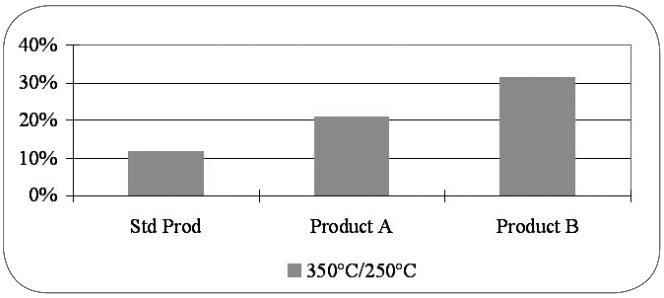

Fig. 4

Hot Die Adhesion Index.

Indice di adesione a caldo dello stampo.

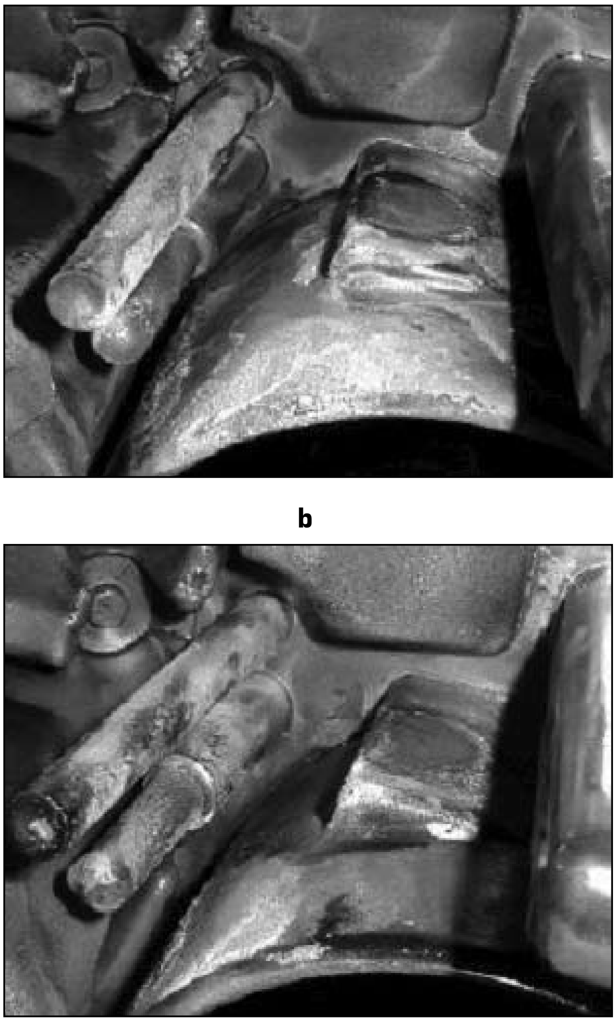

Fig. 5
a) Old product (after 8 hours); b) New Product (after 8 hours).
a) Vecchia tecnologia (dopo 8 ore); b) Nuova tecnologia (dopo 8 ore).

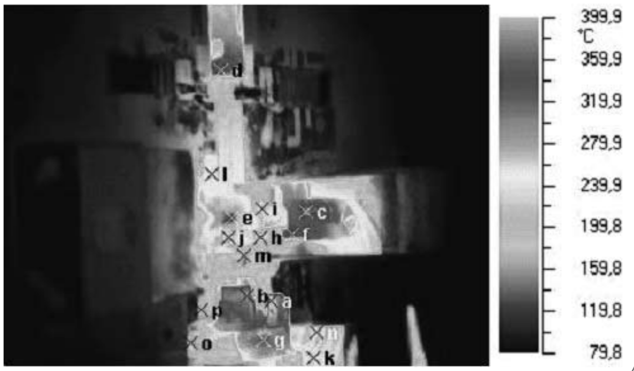

Fig. 6
Thermal image of die before spray.
Immagine termica dello stampo prima della spruzzatura.

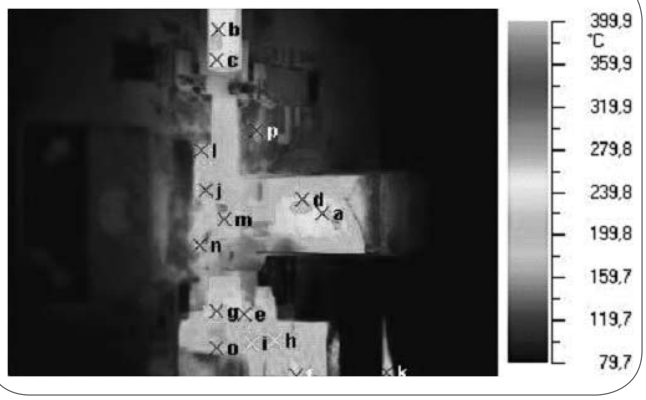

Fig. 7
Thermal image of die after spray (old product).
Immagine termica dello stampo dopo la spruzzatura (vecchia tecnologia).

The first case is from a North American die caster making engine blocks with steel cylinder inserts on a 3500 T Ube® machine with a total cycle time of less than 120 seconds. They were getting good solder protection, with low overspray and in-cavity buildup with a conventional die lubricant. When they started casting a new engine design, they noticed solder formation near the water jacket area on the part. This required them to do die polishing for about 30 minutes once every 8 hours. Running at richer concentrations did not help, giving buildup that also needed to be polished. Increasing the spray duration also had a major impact on productivity.
We took thermal images of the die before and after spray to monitor temperature profiles and spray distribution. The temperature ranged from 450°F to 750°F (232°C to 399°C) before spray on the ejector die. We also observed that the previous product was not covering the problem area adequately particularly at the high temperature zones. The new Safety-Lube® product could wet the hot surface earlier providing better coverage and could rapidly form an adequate lubricating film at the high temperatures seen on the die. Fig. 5 shows the dramatic reduction in solder. The improved performance from the Safety-Lube® product eliminated the need to polish every shift and reduced the cleaning time by 50%.
The second example is from a European die caster making automotive components, who were extremely concerned about the long cycle times needed to make a particular casting. They also had problems with porosity, soldering and in-cavity build-up which led to poor yields and productivity. Investigation of the problem revealed a clear pattern. Fig. 6 shows that the die temperatures before spray ranged from 417°C to 230°C across the face of the die.
The incumbent product was unable to form adequate protective film against solder, therefore a long spray time was needed. However, this caused some areas of the die to be cooled excessively, leading to in-cavity build and porosity. Reducing the spray time gave solder, and in both cases downtime was needed to do die polishing. As can be seen in Fig. 7, the typical die temperatures after spray with the conventional product ranged from 250°C to 160°C.
From this analysis, it was clear that we needed to form good

Fig. 8

Thermal image of die after spray (new product).

Immagine termica dello stampo dopo la spruzzatura (nuova tecnologia).

solder protection at the high temperature areas quickly, so that excessive cooling of the die did not take place. A trial was run with the new high temperature product. Based on the product capabilities we reduced the spray time by 27%. The images in Fig. 8 show the die temperatures after spray ranged from 300°C to 215°C. Most importantly, no soldering or build-up was seen, reducing the downtime for die maintenance from 3 hrs per day to 1 hour every 2 days. Because of the shorter cycle time, the daily yield was also increased by 15%.

These products have now been launched commercially and acceptance of this technology has been outstanding. We have a range of products designed for a wide range of castings. By carrying out a comprehensive survey of the system and customer-specific issues, we are able to ensure that the most suitable products can be recommended.

The die casting industry is rapidly changing to meet the new demands of their customers, New alloys are being developed to meet the ever- increasing demands of a high strength to weight ratio. We continue to develop new technology so we can maintain our leading position as partners to the die cast industry,

REFERENCES

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ABSTRACT

TECNOLOGIE INNOVATIVE RELATIVE A AGENTI DI DISTACCO DALLO STAMPO

Parole chiave: metalli leggeri, pressocolata, lubrificazione

La spinta verso il miglioramento dell'efficienza energetica nel settore automobilistico ha portato alla continua crescita dell'impiego della pressofusione dell' alluminio, in quanto i produttori si sforzano di ridurre il peso delle autovetture sostituendo parti in acciaio con componenti in metallo leggero. Con questo processo vengono prodotte parti sempre più grandi e più complesse e ciò ha posto nuove sfide per gli specialisti di pressocolata nella loro ricerca di migliorare qualità e produttività. Il presente studio esamina l'impatto di queste richieste sulla lubrificazione degli stampi e presenta una tecnologia di lubrificazione innovativa che è stata messa a punto per soddisfare nuovi requisiti.