

WARM UP LUBE SYSTEM (WULS) RELATION BETWEEN A NEW APPROACH TO LUBRICATION DURING START-UP PHASES AND THE THERMAL SHOCK ON THE DIE SURFACE AND SCRAP REDUCTION

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The continuous research for efficiency, associated with higher and higher quality standards in the different industrial production processes, has led, in the last few years, to further and more exhaustive analysis of the various machine cycle phases in the light alloy diecasting sector.

The result of these studies was the development of new interdisciplinary technologies, which have firstly highlighted, and then solved "chronic" inefficiencies during the start-up phases.

Today, the WULS system is able to optimize the Warm Up phase, being based on the die surface temperature value (thanks to the C.T.C. - acquisition module) and retroacting on the lubrication equipment.

In this paper the authors present the WULS technology and highlight the existing relation between the Warm Up phase and the thermal shock generated on the die surface, emphasizing its high level of influence.

It has been well shown by means of several tests in an Italian foundry that WULS technology, together with a specific warm-up phase lubricant, ensure:

- decreasing thermal shock (approx. 66% of reduction in temperature drop)
- reduction of scrap pieces during production starting (approx. - 50%).

KEYWORDS: die-casting cell, die-casting, temperature, die surface, lubrication, release agents, warm-up, temperature control, monitoring.

INTRODUCTION

From some years and in order to operate in a competitive way (high quality of casting and process, low costs) the main actors in the die casting industry (foundries, die-casting machines and lubricants manufacturers, R&D centres) carry out in many countries, also in Italy, a great effort devoted to know in detail all the variables of the

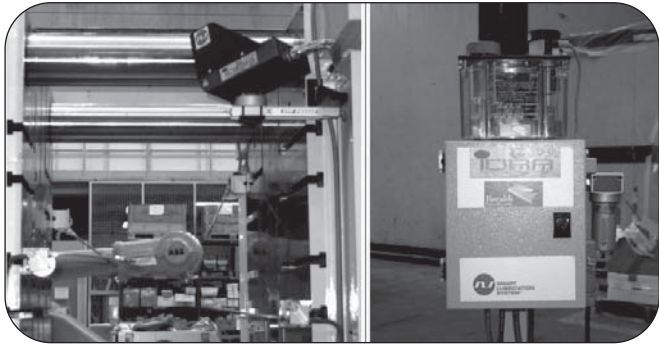
process and their weight, keep them under control and document the fluctuations of those variables.

Arriving to this field from different sectors of interest, and taking profit of the interdisciplinary exchange, the authors of the present work have planned, studied, developed, optimized, applied "in loco" at different foundries in Italy and in foreign countries, and patented devices and technologies that help the foundries in their effort above mentioned (See References 1-5).

From the beginning among all process parameters the main crucial role of the die-surface temperature was underlined [1-5].

Furthermore, the new technologies not only let the operator or producer know in real time – and record – any process variable, particularly the die-surface temperature by means of IR-transducers, but also important feed-back

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Fig. 1

View of the CTC+WULS systems (named "SLSTM" "Smart Lubrication System") installed on board of new die-casting machines produced by Idra.



▲
Fig. 2

Details of the box that assures a long life to the IR transducers used in the C.T.C. module.

actions based on the behavior of those variables were implemented and tested at laboratory scale as well as at true direct industrial scale.

The beneficial was very soon appreciated not only by foundries but also by important customers who became to ask for product (castings) manufactured by using the new monitoring-feed back systems.

Actually these new technologies refers to different goals (they are made up of different modules):

- (I) "C.T.C.": Cycle Temperature Control"
- (II) Decisional system that automatically in the production line accepts or refuses the castings according to given specifications
- (III) "W.U.L.S.": Warm-Up Lube System
- (IV) Modulation of the lubricant-flux according to temperature (work in progress)
- (V) Modulation of the coolant-flux (mass-mould-temperature regulation) (work in progress).

In the present work we explain in detail experimental results achieved with the collaboration of an alpha tester (Nuova Renopress Spa foundry, Bologna, Italy) leading to the definitive demonstration of the beneficial of the CTC and WULS modules. They concern the decreasing of the

thermal shock and the reduction of scrap pieces during production starting.

Finally both modules were successfully incorporated to the frame of new die-casting machines presented in a recent exhibition of the sector (see Fig. 1 e 2; Reference 6)

Premises

Different punctual aspects of the complex system die mass/die surface/lubricant agents/water/compressed air/liquid and solid alloys and its thermodynamic behavior have been stressed by previous works [7-12].

During die filling, excess amounts of release agents develop gas causing casting porosity and can cool excessively the die during heating transient increasing the number of scraps.

At production start up, when the die is in Warm-Up phase, the optimum solution is to use release agents with low specific heat and high lubrication capacity and to be able to change the spray time during production in function with die temperature variations when the machine is in full operation.

During production the die temperature should remain constant on all the surface area and at the same cycle time, but in reality it is conditioned to the down times due to various reasons and to variations due to outside factors such as: metal temperature, cooling water temperature and in some cases also environmental conditions.

The use of die thermo regulators has increased but the excess quantity of 250 Kcal to be extracted from the die per Kg of cast alloy is removed by the release agents sprayed on the die surface.

The cooling channels in the die have geometrical restrictions due to the shape of the cavity, presence of ejectors and need of not passing near the cavity surface to avoid premature breaking of the inserts.

To obtain fast production cycles there must be high cooling capacities therefore high fluid flows at low temperature but this can cause breaking due to the temperature gradient.

Hot steels with 5% Cr used for inserts are bad heat conductors therefore the temperature difference between the surface in contact with the cast metal and where the cooling channels slide generates stretching due to thermal expansion.

The most critical phase of the die life is during cooling when the water based release agents atomized on the hot surface of the cavities because of strong stress tractions due to contraction of superficial layers respect to the underlying part which cools much slower for the reduced thermal conductivity.

It is known that the traction breaking load is less compared to the load for other modes of deformation (such as compression mode).

This shows that die pre-heating is important to speed up production but has a limited effect on the surface breaking due to thermal fatigue.

Another important factor is the effect of the die temperature on the casting quality and it is evident how die thermoregulation units are not very efficient because the fluid temperature is adjustable but not the die surface temperature. Thermocouples can be fitted directly into the die but unless they are very close to the surface, causing loss of mechanical resistance, they have a great hysteresis and

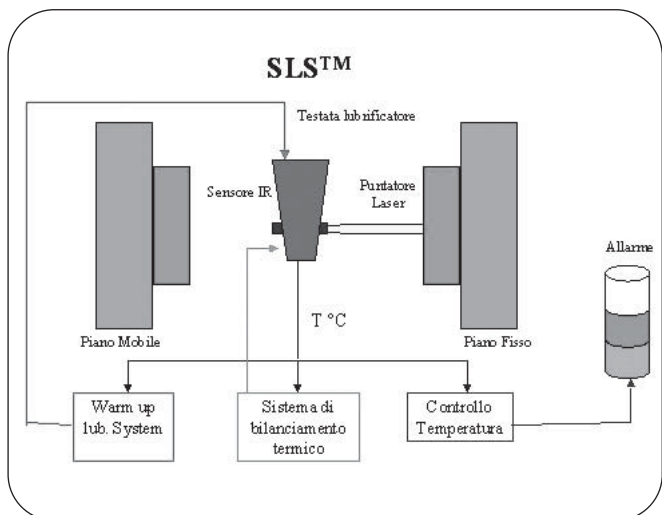


Fig. 3

Scheme of the CTC-WULS modules.

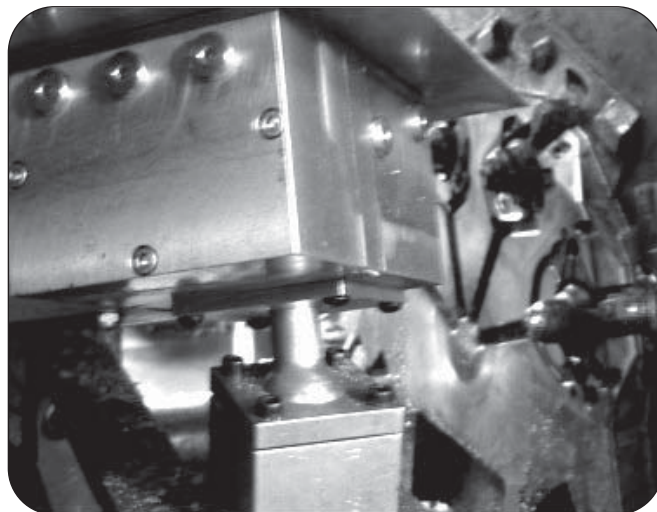


Fig. 4

Prototype used during test at the Alpha-Tester.

the correction effect given by the fluid temperature variation is restrained and with a very high time variable. Using water limits the fluid temperature to 120°C (pressurized circuits) whereas thermal fluids that can reach a temperature of 350°C have a specific heat which is half the value of water therefore are not suitable to remove great heat quantities in short periods.

The simulation models used, allow to make precise simulations of the die thermal dynamics with different geometries of the cooling channels, therefore we can say:

- Constant die temperature is necessary for product quality and for die life
- The cavity surface temperature is the most important because it is subject to important thermal cycles
- The most important factor for removing heat from the die is to spray release agents and to keep a thermal balance.

In fact, the release agent carried in water and sprayed on the die at each cycle substantially performs two functions:

1. to form a lubricating-releasing film
2. to contribute to the thermal balance of the die.

Before the above mentioned works [1-5], this second function has never been continuously and deeply monitored or managed, leaving the process engineer the task to optimise production cycles (always shorter) and the relevant adjustments of peripheral devices (lubricators, robots, etc.).

EXPERIMENTAL

The SLS™ “Smart Lubrication System” Technology To allow die casters to deal with the above topics and provide an efficient device that can be used in difficult foundry environments, Idra, Baraldi and Venezia Tecnologie have developed a system that monitors the die surface temperature with infrared rays and necessary protection to allow the use near the die, the acquisition system and software for processing data and its use on the lubrication cycle. It is named SLS™ “Smart Lubrication System” and it takes profit of the two modules, CTC and WULS, simultaneously.

The monitored temperature is used to control the lubrication circuit that atomizes oil at low temperature during production start-up and after cycle stops that exceed a

certain period time, as well as to modify lubrication time during production when die temperature variations occur that exceed the set tolerances.

In traditional running, oil spraying at start up and injections with low speed and low pressure are manually carried out by the operator. The number of castings for warm-up and above all the ones after cycle interruptions, represent a significant percentage of the total machine scrap when producing difficult castings. To be able to manage the transition phases generates important economical advantages.

Here below is a comparison between traditional warm-up values and the ones using the SLS™ system, carried out in an important Italian foundry that has a well structured operational situation with processes and training given to operators.

Testing protocols have been determined which foresee the transition surface temperature from low speed/pressure to 290-300°C, production of 5 castings with simulated stop and die cooling using the lubricator and re-start cycle.

In Protocol 1 (Fig. 5), operations are according to the traditional method, therefore after 5-6 castings the passage to the production conditions is manual.

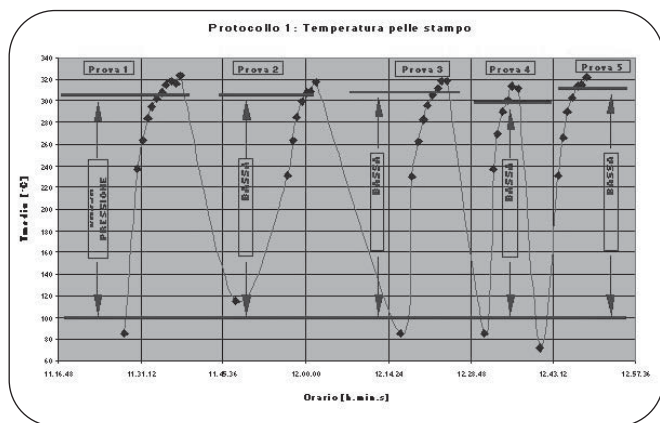
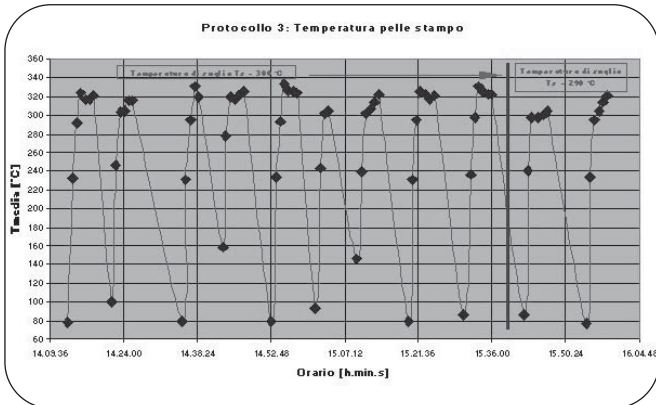


Fig. 5



▲
Fig. 6

It was experimented that the transition temperature evidenced is at limit between good castings and scrap castings. The average number of parts scrapped at every re-start is 4,6.

Protocol 3 (Fig. 6) shows the temperature monitored to pass automatically from the anhydrous lubricant (Warm Up Lube 04™ was used in this work) to the standard water base type. Considering the same transition temperature of 290-300°C. 3 reduced cycle were averaged to reach the working conditions.

The transition is automatically managed and not conditioned to interpretations or errors that can be made by the operator.

Management of restart is very delicate and involves qua-

lity staff. The risks are: lack of selecting scrap castings or on the other hand scrapping an excessive number of parts.

In both cases with repercussion on the total cost of the lot. The average number of castings produced in "reduced" conditions was 3 with a reduction of 35% in comparison to the conditions without anhydrous lubricant and automatic management of Protocol 1.

Graphs in Protocol 1 and 3 above show the temperature trend for each cycle of the 2 tests. It clearly indicates how the number of cycles under the transition temperature in Protocol 3 are less and how the die surface temperature increased more rapidly.

The anhydrous lubricant (Warm Up Lube 04™) in effect reduces notably the capacity of extracting heat from the die during the warm-up phase. The low thermal capacity (less than half in comparison to the water type - Tab.1) reduces drastically the cooling property. The result is also sustained by the low thermal conductivity.

Moreover the Warm Up Lube 04™ boiling temperature is higher than 300°C, so decomposition starts before reaching the boiling temperature. Therefore the product is not capable of removing a significant amount of heat with the evaporation mechanism as occurs with the traditional release agent.

The main components of the Warm Up Lube 04™, have been selected and carefully examined in laboratory tests and specific tests conducted directly on field for different types of castings.

The product creates a film on the die surface that has a very high lubricating capacity and guarantees smooth sliding of the moving parts for dies with movements and

PHYSICAL PROPERTIES	Thermal Capacity at 20°C 10 ⁶ J/m ³ K	Thermal conductivity at 20°C W/m K	Density at 20°C Kg/m ³
TRADITIONAL AGENT RELEASE	4180	0.6	1000
ANHYDROUS LUBRICANT (WARM UP LUBE 04™)	ca. 1600	ca. 0.20	930

▲
Tab. 1

T (Sample temperature) [°C]	W (Residual weight) [% by weight]
200	> 99
250	85
300	74
350	59
400	45

▲
Tab. 2

ejectors, avoiding cracking and braking during the delicate production start up phase. Furthermore the Warm Up Lube 04™ has an excellent separating power and doesn't deposit oily residuals on castings, therefore reducing pollution in remelting baths.

The Tab.2 was determined by thermo gravimetric analysis on a sample of 5.0 mg of Warm Up Lube 04™: The product is heated very slowly by means of an automatic cycle (2 °C/min) and the weight variation (loss) is registered.

As noted in the table, there is no change in the product up to 200°C whereas up to 300°C 74% of the initial weight remains stable. A temperature of 300°C is reached in an average to large die only at the end of the warm-up cycle, when the system passes automatically to the traditional release agent. Whereas at the beginning of the warm-up cycle it is normally much lower with values varying from <100°C to max 180°C.

We have highlighted and verified that the special characteristics of the Warm Up Lube 04™ allow to pass from low to high injection speeds without defects due to die lubrication, from the first casting produced in standard conditions with high injection speed. The automatic application is very rapid and eliminates manual brush lubrication, which is a normal foundry procedure.

The Warm Up Lube 04™ has also many advantages on environment and health conditions of the working area. The product is 100 % synthetic and 90% biodegradable with no harmful or irritating effects. By replacing during warm up the use of lubrication pastes or greases or anti-sticking products eliminates the dangerous steams which the operator is exposed to.

Economical evaluation

Considering an average size machine producing castings with a technical cadence of 65 parts/hour, excluding efficiency, with 10 stops in the range of 24 hours (approx. 1 stop every 1 1/2 hours), which represent an average value for completely automatic diecasting cells producing critical castings, but without considering particularly delicate dies for which you can easily consider also twice the number of stops, you have a time saving of 15' per day, representing 1% of the available time.

Hard to evaluate but real is the decrease of "outside" scraps not intercepted by "Quality Control" but found after mechanical machining with relative costs.

The SLS™ is a simple and manageable system to measure the die surface temperature without complicated solutions which make die change difficult. Foundry activities are already difficult therefore solutions need to be simple and robust. The proposal to use sensors in the die, like other devices, has been eliminated and put on foundry shelves.

With the feedback module, the monitored temperature is also used to control "Idra" lubricators to change spraying time and keep constant surface temperature during the process, but this will be the next topic in discussion.

DISCUSSION AND CONCLUSIONS

CTC offers to the operator and/or the plant engineer, for

the first time, the possibility to see and follow (and record) "on line" all the phenomenon that is to say to know and recognize the signature of all the variables related directly or indirectly with the key parameter (the die surface temperature) versus time and/or cycles or castings. And the powerful of the signature was found by the authors but already by operators in different foundries very strong in comparison with the traditional approach based on single numeric values running in a table on a display

A further advantage of the diffuse application of the CTC module is the improvement of knowledge about skin temperature of die (its true or relative value and most important its evolution) and its relationship with other environmental conditions.

CTC is a useful instrument or medium to improve the diffusion of the culture of the quality and a tool very useful in order to achieve the best conditions in HTDC development and improvement.

WULS leads to a reduction in the cycle time during the warm-up phase and to a strong fall-off in the lubrication time. But especially the scrap reduction (with an identify target of at least - 50%).

Further important advantages coming from WULS are the improvement in the working place safety and healthiness and the lower environmental impact due to the replacement of greasy products with Warm Up Lube 04™ a completely synthetic, biodegradable compound.

The reduction in mould thermal stress is very hard to quantify with direct measurements because it depends also on many different variables, it will be the subject of further survey.

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ABSTRACT

**WARM UP LUBE SYSTEM (WULS)
RELAZIONE TRA UN NUOVO APPROCCIO
ALLA LUBRIFICAZIONE DURANTE
LE RIPARTENZE E LO SHOCK TERMICO
SULLA SUPERFICIE STAMPO**

Parole chiave: lubrificazione, tecnologie, pressocolata

La continua ricerca di efficienza, unitamente a standard di qualità sempre più elevati, nei diversi processi della produzione industriale ha stimolato negli ultimi anni ulteriori approfondi-

menti delle differenti fasi del ciclo macchina nella pressocolata delle leghe leggere.

Da questi studi sono emerse nuove tecnologie interdisciplinari che hanno dapprima evidenziato, e poi risolto, inefficienze "croniche" durante le ripartenze.

WULS è oggi un sistema in grado di ottimizzare la fase di Warm Up basandosi sul valore di temperatura superficiale dello stampo e retroagendo sull'impianto di lubrificazione.

In questo lavoro gli autori presentano la tecnologia WULS ed evidenziano la relazione esistente tra la fase di Warm Up e lo shock termico generato sulla superficie degli stampi, sottolineandone l'alto livello di influenza.