Studying Mould Powders for Continuous Casting with the HM 867

Keywords: mould powders, flash heating, crystallization, steel industry, slag

DIL003

ABSTRACT

Heating microscope is essential to fully understand the observed behavior of mould powders, that strongly depends on the heating cycle applied. Heating Microscope HM 867's flash mode enables the user to instantaneously heat/cool a specimen to a pre-set temperature, hence replicating actual process conditions and characterizing mould powders' behavior during continuous casting process. These powders, if tested at too low heating rates, tend to develop crystalline phases that eventually cause changes to their fusibility as well as thermo-physical properties.

The optical method adopted is fundamental to measure dimensional variations that can yield essential explanation of the observed in-mould behavior.

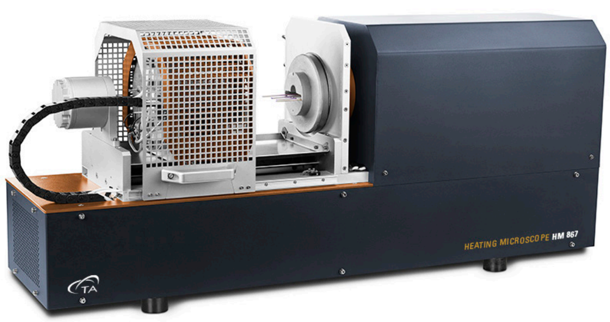

Figure 1. Heating Microscope HM 867

INTRODUCTION

Mould powders are synthetic materials used to cover the liquid steel meniscus during continuous casting of steel.

Continuous casting transforms molten metal into solid on a continuous basis and includes a variety of important commercial processes. These processes are the most efficient way to solidify large volumes of metal into simple shapes for subsequent processing. Most basic metals are mass-produced using a continuous casting process, including over 500 million tons of steel, 20 million tons of aluminum, and 1 million tons of copper, nickel, and other metals in the world each year.

The continuous casting process for steel is shown in Fig.2. Molten steel flows from a ladle, through a tundish into the mould. The liquid steel must be protected from exposure to air: if not, then oxygen will react to form detrimental oxide inclusions in the steel.

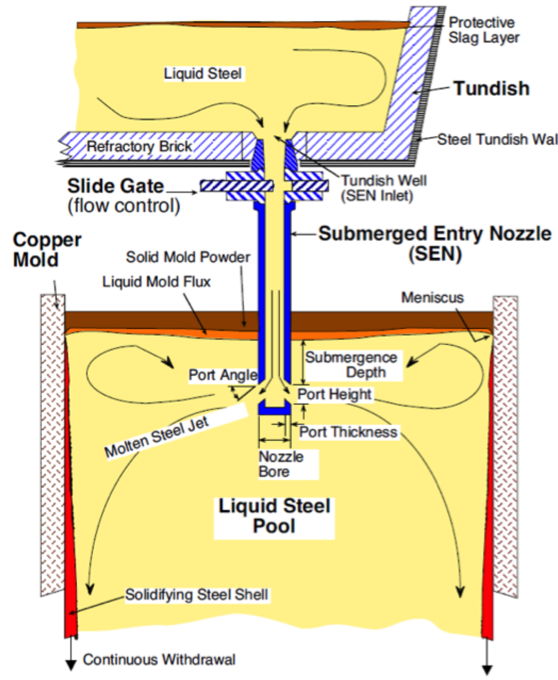

Figure 2. The continuous casting process for steel is shown in this figure. In this process, molten steel flows from a ladle, through a tundish into the mould. The liquid steel must be protected from exposure to air by a slag cover over the liquid. If not, then oxygen in the air will react to form detrimental oxide inclusions in the steel.

Once in the mould, the molten steel freezes against the water-cooled walls of a bottomless copper mould to form a solid shell. The mould is oscillated vertically in order to discourage sticking of the shell to the mould walls. Driving rolls, lower in the machine, continuously withdraw the shell from the mould at a rate or "casting speed" that matches the flow of incoming metal, so the process ideally runs in steady state. The most critical part of the process is the initial solidification at the meniscus, found at the junction where the top of the shell meets the mould, and the liquid surface. This is where the surface of the final product is created, and defects such as surface cracks can form.

Casting powders play an important role in the surface quality of the steel product and in the overall efficiency of the continuous casting process. These powders have a critical influence on the heat transfer from the strand to the mould, the solidification process and the mould lubrication. The powder, which is continuously fed on the surface of liquid pool during casting, melts first and then flows into the gap between mould wall and solidified steel shell. The powder on the meniscus generally consists of four layers (figure 3):

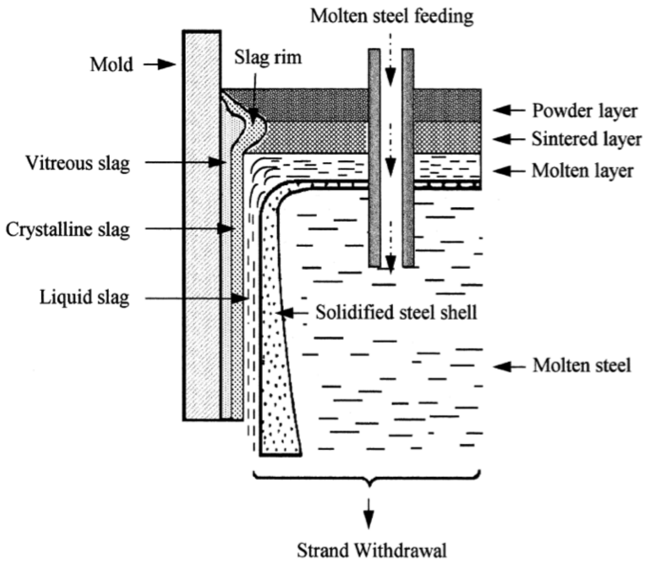

Figure 3: Moving from liquid steel to the external surface of the powders, three different layers can be defined according to their state of aggregation and physical state. Each of them exists for a certain temperature range.The properties of the slag film dictate the main functions of strand lubrication and mould heat transfer. The formation of crystals is favourable for a homogeneous and controlled (horizontal) heat transfer during casting, which is required in order to prevent the formation of surface cracks.

an un-reacted, un-melted, dark powder layer on the top; a sintered, semi-reacted layer; a mushy zone in which the mould powder is melting; and a molten slag layer directly on the molten steel. The lubrication process is almost completely carried out within this last mentioned area and depends on many factors; generally fluxes with lower viscosity and/or melting temperature tend to provide lower friction, better lubrication properties, and thus prevent sticking.

It is clear from Figure 3 that moving from liquid steel to the external surface of the powders, three different layers can be defined according to their state of aggregation and physical state. Each of them exists for a certain temperature range.

On the other side, moving from the molten steel towards the cooled mould, other layers arise, that can be however predicted by the melting curve. The properties of the slag film dictate the main functions of strand lubrication and mould heat transfer. According to the chemical composition and physical properties, two main mechanisms can in turn take place: crystallization and vitrification. The formation of crystals is favourable for a homogeneous and controlled (horizontal) heat transfer during casting, which is required in order to prevent the formation of surface cracks.

But also mould powders that are directly exposed to molten steel will experience a instantaneous heating that is able to provide thermal conditions that are very far from thermodynamics states. Powders usually have a glassy behaviour in this case.

This kind of characterization of mould powders can be extensively carried out with the HM 867. In more detail it is mainly dedicated to get an overview of the melting process: image analysis of the shapes experienced by mould powders is a powerful tool to put a light in a thermal process that is still not considered as a science. In addition, the ideal approach to the problem should be designed to reproduce process conditions, since the melting behavior of ceramic materials, as the ones used, could be strongly dependant on thermal conditions applied.

Running HM with different heating rates can reasonably provide information about the state the different layers will be at. As mentioned before, the HM can be in fact equipped with a special system able to provide instantaneous heating conditions to the sample. This particular version of HM has been designed to reproduce some heavy industrial conditions requiring fast heating treatments. The working principle is based on a self movable furnace, that is heated in a stand-by position in between the optics and the sample.

Then, once reached the test temperature, a motorized stage brings the furnace in a few seconds over the sample, that is at room temperature.

EXPERIMENTAL

The graph of Figure 4 shows that, when a low heating rate (30 °C/min) is applied on these mold powders for continuous casting, a horizontal plateau is observed between 1000 and 1100 °C. During this interval, the specimen dimensions remain constant as the temperature varies. This indicates that a crystallization process is occurring inside the material. The melting temperature of this specimen was identified as 1150 °C. The test performed with flash mode, on the contrary, doesn't show any crystallizations and, surprisingly, melting occurs about 100 °C before the in the previous case.

The general trend suggests the presence of crystals growth with different kinetics and subsequent differences in melting behaviour. The higher is the heating rate applied, the earlier powders melt because of lack in time for crystal growth.

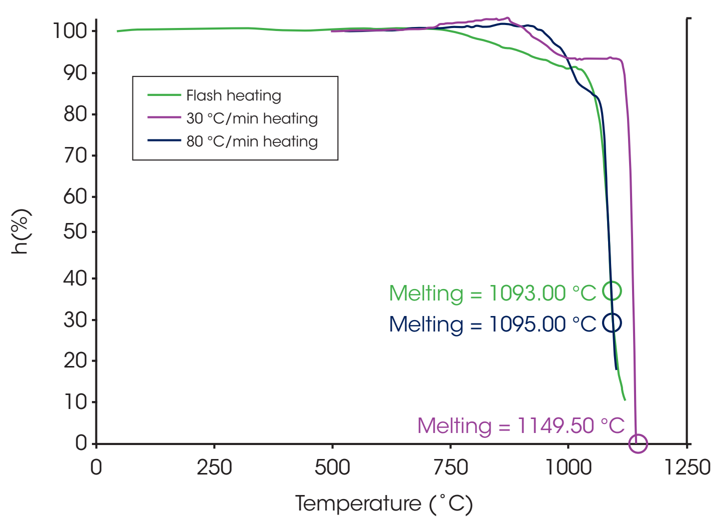

Figure 4: Effects of the heating rate on the melting behaviour of a mould powder sample.

CONCLUSIONS

- Mould powders can have many components or a complex composition: the reason for such a composition is not always clear or is even absent. Within the operational windows of the casting process, a simplification of the chemical composition and raw material choice is desired.
- The casting process itself is complex and depends on a multitude of variables: processes in the mould are not fully understood and essential material properties of the solidifying steel are mostly unknown. It is difficult and sometimes nearly impossible to measure the process conditions in the mould and to characterise the various material properties at casting temperatures. As a consequence, essential data on the casting process and the material properties, especially at high temperatures, are needed to evaluate the process and to develop more reliable models.
- Experimental work is crucial for a further understanding of powders and process: successful casting is a consequence of the choice of optimum casting conditions and mould powder properties. For all these reasons, fundamental research on mould powders and the casting process is essential in order to increase knowledge, to improve the casting process and to be able to cast novel steel grades.
- Heating microscopy proved to be essential, in addition to conventional characterization methods, for better explanation of the observed in-mould behavior.
- Step forward: the flash system to reproduce industrial conditions.

This work emphasises the need for powders characterization: the thermal behaviour of the materials tested strongly depends on the heating cycle applied. The instantaneous heating is the analysis mode enabling to better reproduce the thermal stresses that actually occur into a mould. When low heating rates are adopted, crystallizations are enhanced inside the material.

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