Fundamentals of Mould Powder

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Mould Powders

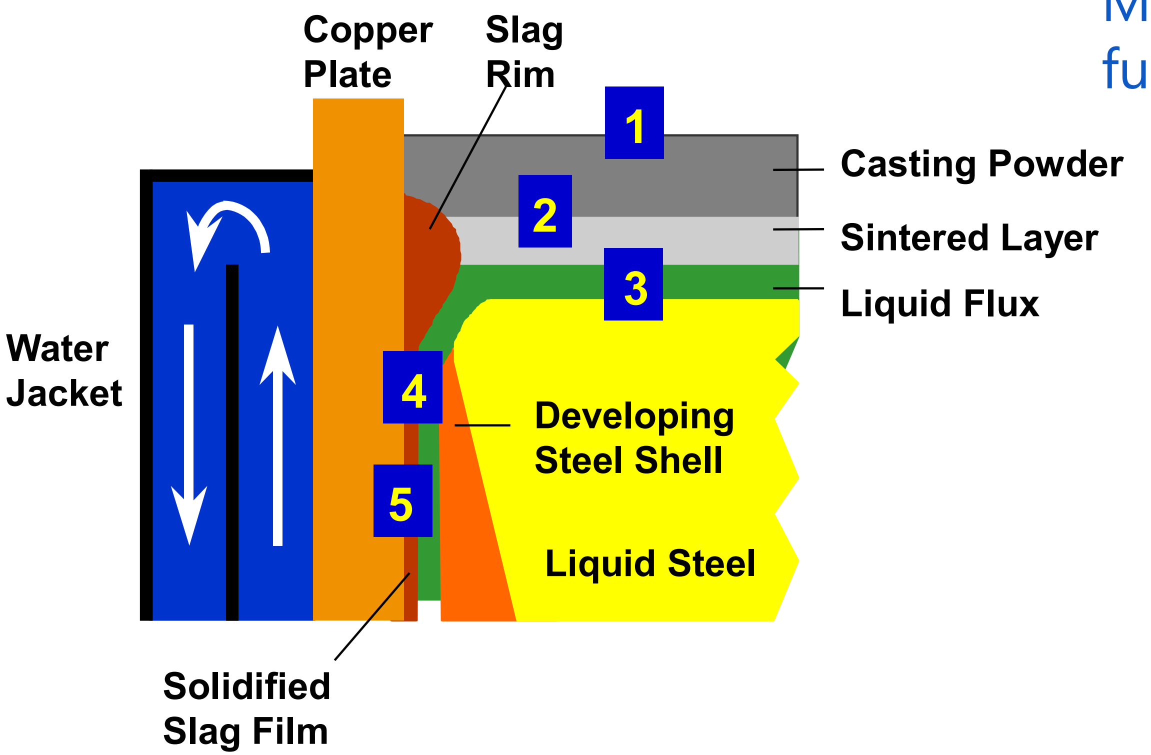
Introduction

Mould powders are a fundamental element of continuous casting and critical in the production of high-quality, defect free, semi finished steel product

In this webinar we will talk about:

- The role mould powders take in casting,
- Some of the sensors developed to measure the condition of Mould Powder
- Numerical modelling of casting powders and slag infiltration
- On going RFCS projects which are looking at new and novel concepts

Function of Mould Powder



Mould powders have 5 main functions

1. Thermal insulation
2. Prevent reoxidation
3. Absorb inclusions
4. Lubrication
5. Uniform heat transfer

Composition of Mould Powders

Standard mould powders are a mixture of glassy components and basic oxides

They have a base composition made up of:

Calcium oxide (CaO) and Silicon dioxide (SiO_2)

Plus other oxides for example:

Magnesium (MgO), Aluminium (Al_2O_3), Sodium (Na_2O), Potassium (K_2O), Titanium (TiO_2), Zirconium (ZrO_2), Boron (B_2O_3), Lithium (Li_20), Manganese (MnO)

To this is added **fluoride** and **carbon**

Fluoride acts as a fluidising agent and to promote crystallisation of cuspidine (3CaO.2SiO2.CaF2)

The degree of crystallinity has a significant effect on the heat transfer properties.

Carbon is added to control the melting rate.

The amount, particle size and form of carbon added has an influence on the melting rate.

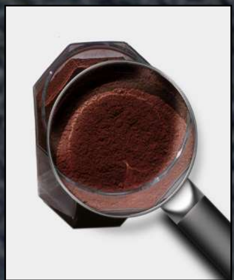
More carbon will reduce the rate, also different types of carbon will react at different rates.

Composition changes

Absorption of Inclusions

Inclusion	Effect	Results
Al2O3 particularly aluminium killed steels containing ~ 1% aluminium	Can increase slag viscosity, basicity and melting temperature. Reducing lubrication	Poor surface quality and sticking in the mould
MnO particularly in high manganese steels with high oxygen contents	Reduces viscosity and solidification temperature	Depressions and cracks in sensitive steel grades

Forms of Mould Powder



- **Pulverised:** Cheaper but produces a lot of dust and is prone to moisture pick-up and segregation during storage.
- **Granulated:** Small pellets of even composition but much more expensive.
- **Prefused:** Gives best performance but more expensive still.
- **Starting:** Powders which melt rapidly to quickly cover the molten steel used at start-up.
- **Exothermic:** Contain compounds that give off heat when they melt to prevent bridging of steel.

Physical Properties

To understand how a mould flux will behave during casting it is important to understand the physico-chemical properties

- Viscosity (η) - A measure of how resistant a liquid is to movement.
- Liquidus Temperature (Tliq) – Temperature at which the flux is completely liquid.
- Solidification Temperature (Tsol) – Temperature at which the flux is fully solid.
- Break Temperature (Tbr) - Temperature at which there is a significant change in the viscosity usually associated with the start of crystallisation.

These properties can be measured in the laboratory using a range of techniques such as heating microscope, rotational viscometry and simultaneous thermal analysis (STA).

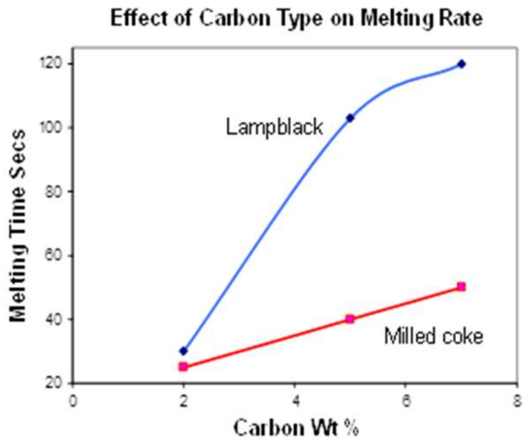
Melting Rate

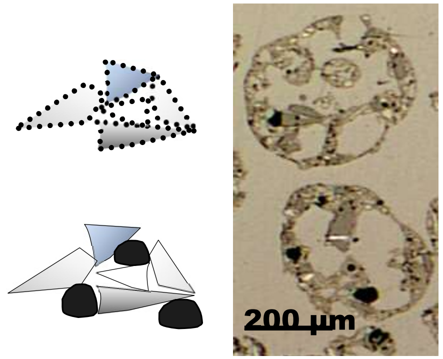
Effect of Carbon

The composition of the powder dictates the melting rate, however Carbon is added to control the rate.

The amount, particle size and form of carbon added has an influence on the melting rate.

More carbon will reduce the rate, also the coarser the carbon element, the slower the reaction.





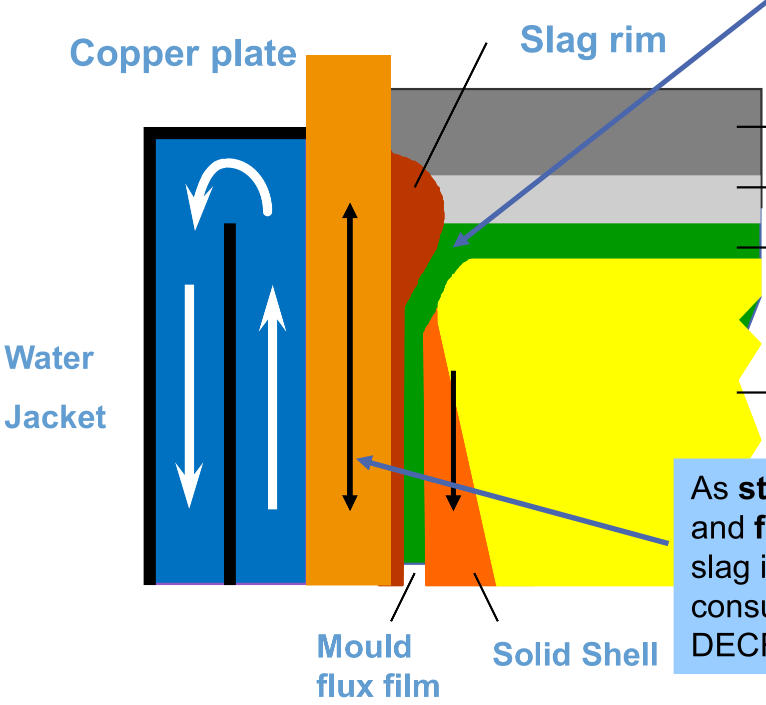
Carbon particle size

Slag infiltration and consumption

Powder is consumed by the flow of liquid flux away from the surface between the strand and the mould by the pumping action of the mould oscillation and by liquid held within the oscillation marks.

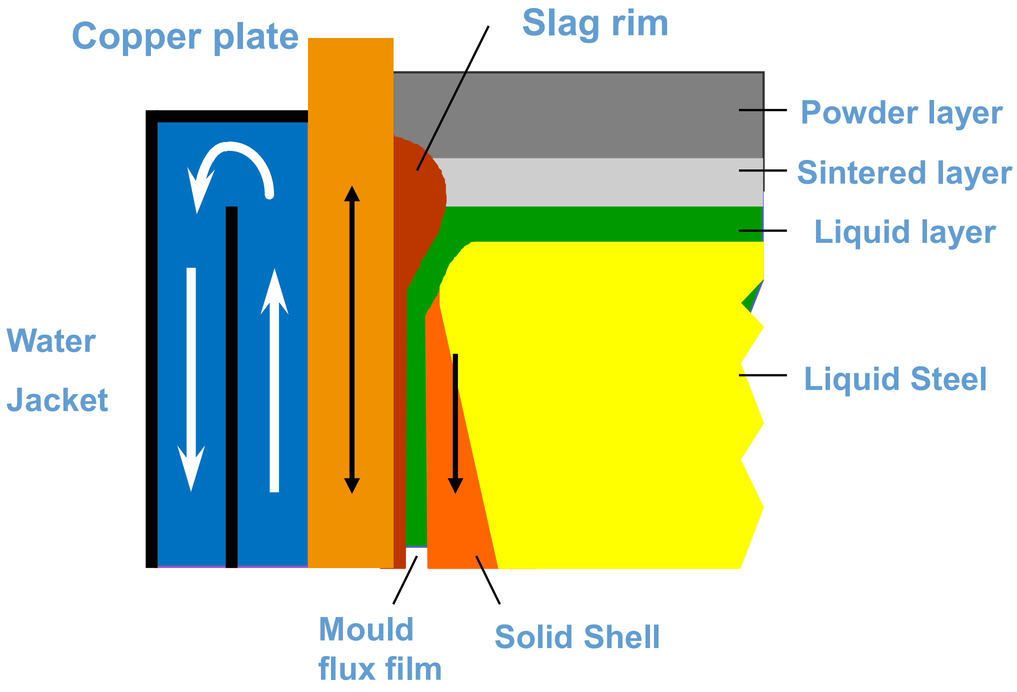
Flux is also consumed by the movement of solid flux down the mould replaced by solidification of new liquid flux at the meniscus. Consumption rate increases as the viscosity and break temperature of the flux decreases.

As **viscosity increases**, slag infiltration, powder consumption, lubrication and heat transfer tend to DECREASE



As **stroke length decreases** and **frequency increases**, slag infiltration, powder consumption and lubrication DECREASE

Slag infiltration and consumption



The depth of the flux pool increases with the casting speed and melting rate. The flux pool depth is dependent on the balance between the consumption rate and melting rate.

If the melting rate is too high, it is impossible to maintain a stable layer of loose powder

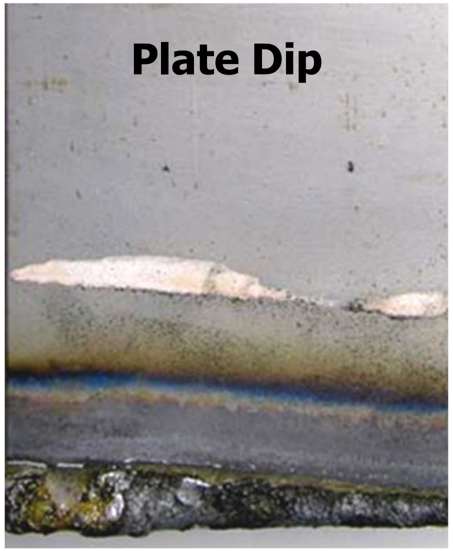
If it is too low there will be insufficient liquid flux to lubricate the mould. The melting rate of a powder must be sufficient to maintain a liquid slag depth of greater than the oscillation stroke length.

Monitoring Powder Melting on Plant

Dip Tests

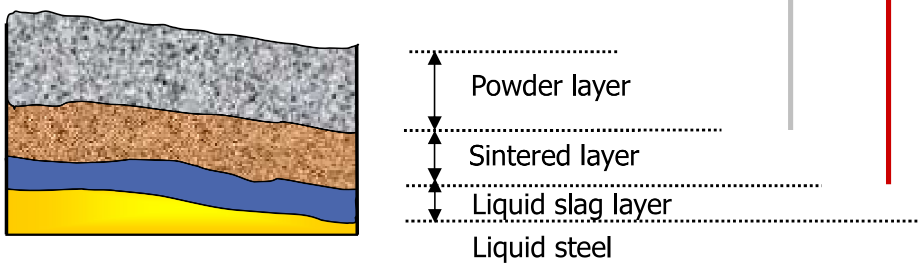
Many trials have been carried out to study the melting rate and relative layer thicknesses in the mould using physical dip techniques. both with different wires and plates.

Plate Dip

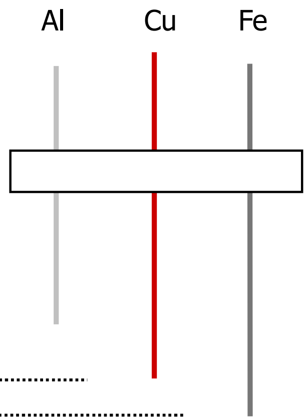


Physical sticking
Temper effects

Layers in mould



Three-wire method



Temperatures
(Melting)

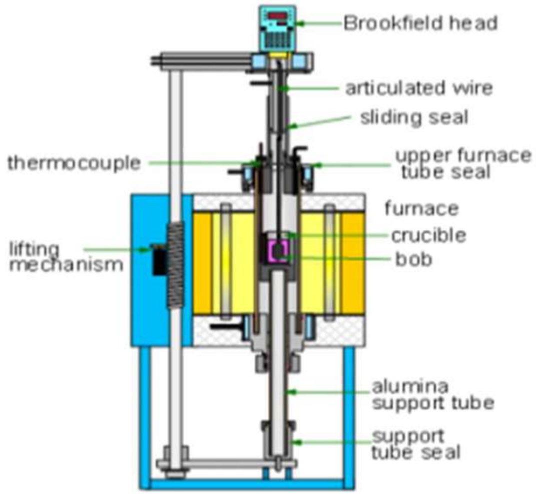
Viscosity

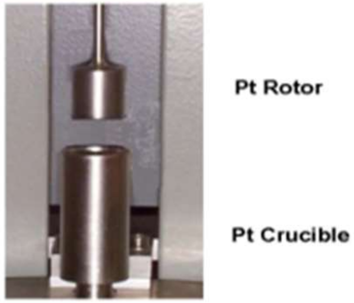
Measurement

Viscosity is a key property of the powder. It can be measured in the laboratory using techniques such as high temperature rotary viscometry.

Viscosity is measured over a temperature range during cooling.

The break temperature can be also be identified. This is the point at which there is a sudden increase in viscosity due to solid particles precipitating in the melt. The break temperature is important as it determines the thickness of the solid and liquid flux layers in the mould-strand gap, relating to heat flux and lubrication.





Viscosity

Calculation

Measurement techniques are expensive and time consuming. A number of models have been developed to use composition data to calculate the viscosity. A commonly used example is the IRSID model.

Viscosity (IRSID formula):	temperature	viscosity
	1300 °C	1.3 dPa·s

Riboud model (IRSID)

Based on chemical composition.

Simple and applicable to a wide range of slags.

The model divides the slag constituents into five different categories.

The five values obtained are used to calculate A_W and B_W.

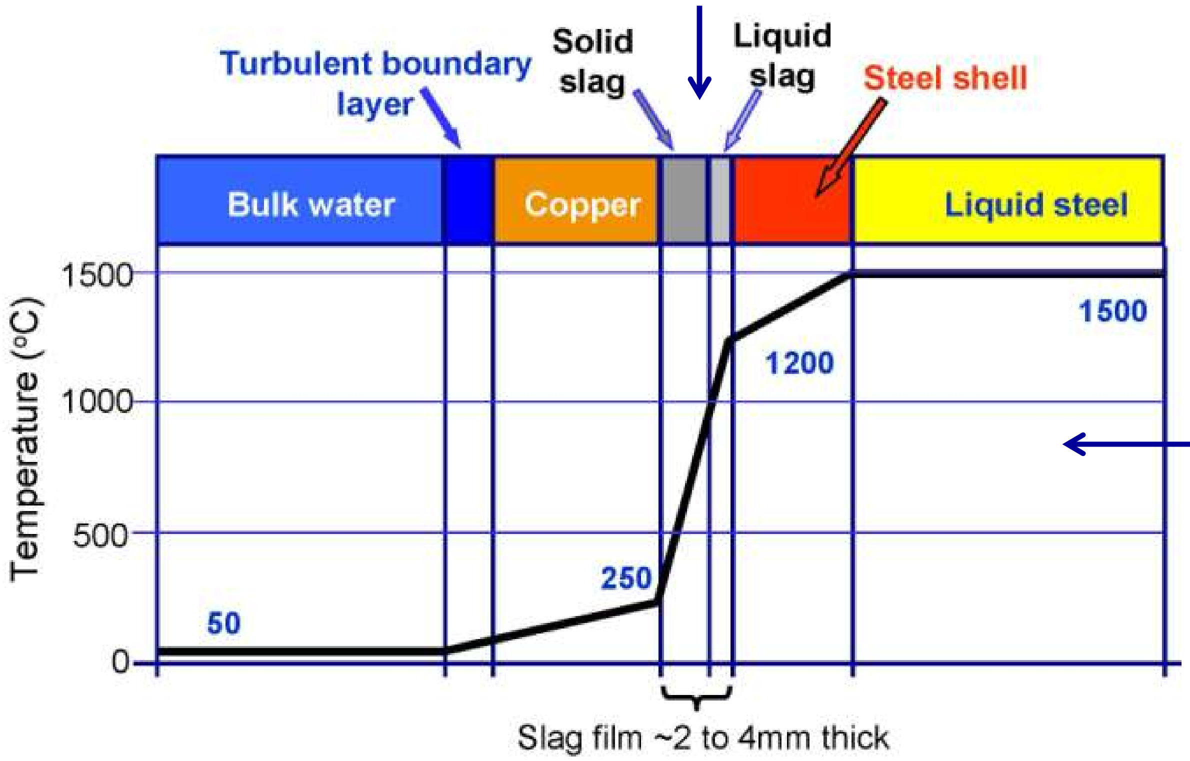
The temperature dependence is expressed via the Weymann equation

$$\{\eta(dPas) = A_W\, T \exp(B_W/T)\}$$

It is very hard to calculate the break Temperature. This must be measured.

Mould Flux Heat Transfer

The viscosity and solidification characteristics of the mould powder slag (glassy or crystalline) have a great influence on heat transfer



Differing steel grades require different heat transfer rates for optimum surface quality and security against breakouts

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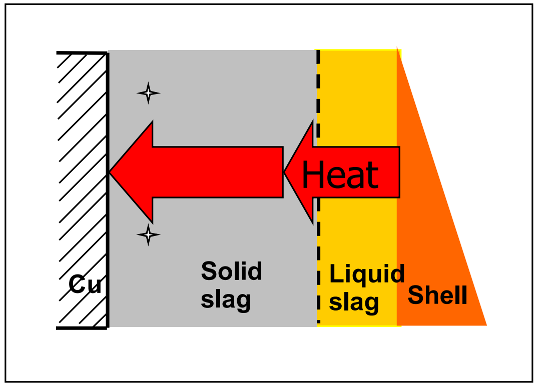
Heat Transfer

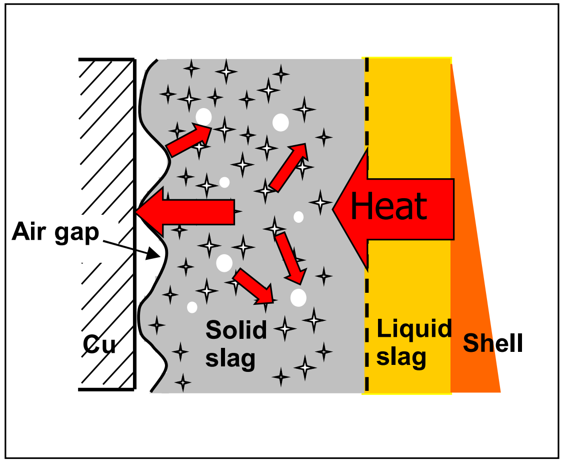
Prediction of mould powder crystallinity

Heat transfer through the flux is controlled by thickness of the layers and the amount of crystalline slag. Heat transfer is reduced by the scattering effect of the crystal boundaries.

The crystallisation rate has been shown to impact on film thickness which in turn regulates the heat flux .

The proportion of the crystalline phase cuspidine is promoted by the fluorine content and as the liquid slag cools, crystallisation begins at the break temperature.





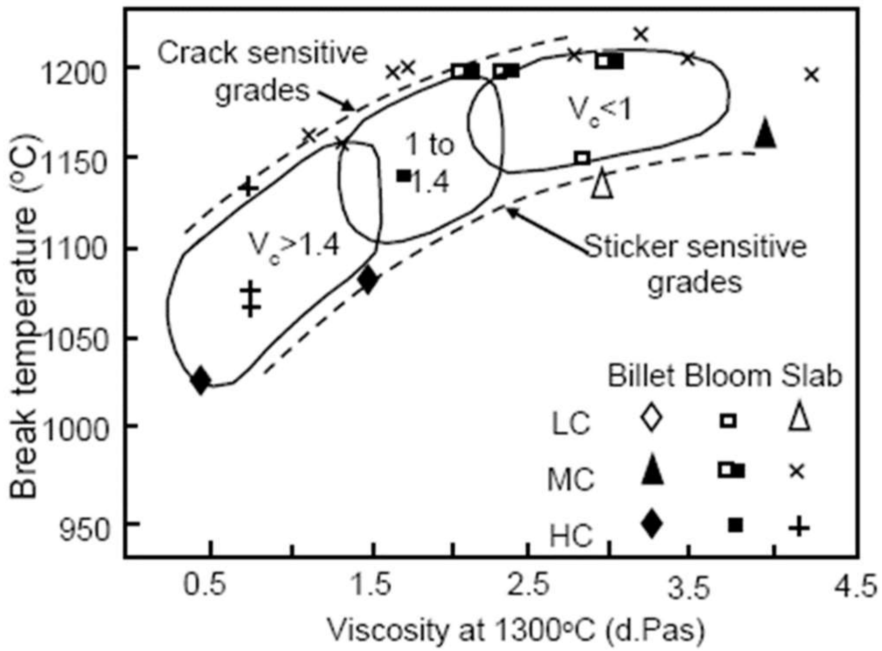
Many regard basicity (Lime/Silica Ratio) as a measure of the potential degree of crystallinity in the flux layer. When specifying a powder, the basicity can be used as an indication of the likely thermal resistance in practice.

However, the ***LUBRIMOULD*** project suggested that the depolymerisation index (NBO/T) is a better parameter for evaluation of the thermal properties. The index NBO/T is a calculated parameter based on the chemical composition of the casting powder.

Prediction of Mould Powder Properties

To aid in the selection of powders a lot of effort has been put into predicting the performance by modelling and empirically using past performance.

One example is the use of a Viscosity verses Break temperature plot which represents lubrication vs heat flux. This can be used to help avoid the most likely defects.



Links between powder and cracking

A number of types of cracking have been linked with mould powder

Crack Type	Susceptible grades	Best Powder Practice
Longitudinal cracking	Medium-Carbon Peritectics	High thermal resistance, thick crystalline slag layer
Longitudinal corner cracking	Medium-Carbon Peritectics	High thermal resistance, thick crystalline slag layer
Sticker Breakouts	High Carbon	Low viscosity glassy slag
Oscillation Marks	In general	Thicker crystalline slag will help but oscillation practice is much more critical
Transverse and Corner Cracking	Peritectic, Micro-alloyed, Low-Carbon	High thermal resistance, thick crystalline slag layer
Star Cracking	Peritectics	High thermal resistance, thick crystalline slag layer

Special Mould Powders - Low F/LowC

Research into novel powders to overcome specific issues has increased with a significant effort going into carbon and fluorine-free powders.

When casting low or ultra-low carbon steel grades pickup of carbon from the mould powder can be a problem which can lead to surface defect issues. Low carbon mould powders help to prevent this, but without enough carbon in the mould powder, the melting rate becomes too high and can cause slag rim issues.

The use of fluorides in mould powders to control crystallinity has significant negative aspects:

- Fluorides react with cooling water to form hydrogen fluoride which is a potential health and safety issues for operators.
- By-products such as hydrofluoric acid lead to issues with corrosion in the casting machine.

There are ongoing projects looking at the selection of suitable low fluorine or fluorine-free powders. The main thrust is the replacement of the fluorine bearing components with an alternative such as Na_2O or B_2O_3. In trials these have been shown to perform in a similar manner to conventional powders for specific steel grades.

There is an associated benefit that erosion of refractory at the slag layer seemed to be less than with conventional powders.

Powder feeding

As well as the composition and form of Mould powder. The way it is applied is also important to performance of mould powders in terms of consistency and repeatability of the casting process.

The feeding process must try and maintain an even cover with sufficient un used powder to ensure that the liquid flux is maintained and that the surface is fully covered.

Powder feed can be performed manually by and operator or by using semi automatic or fully automatic control system.

Manual powder feed performed by operators is the most basic method. This results in a batch feed process with poor consistency. The ideal for consistent and reliable feed is closed loop control. A number of systems are available with techniques including radiological, optical or laser-based powder thickness measurement to control feed rate.

Summary

- Mould powders are essential to crack free casting and there has been a number of projects dedicated in whole or part to the study of mould powder behaviour.
- The majority of cracking is initiated in the mould during initial solidification. The performance of mould powders has a significant effect on initial solidification.
- The composition of a mould powder can alter during casting particularly the alumina content as alumina inclusions are absorbed by the liquid flux changing the flux properties.
- Selecting a mould powder is a complex issue. New and more powerful tools for powder selection have been developed in RFCS projects to help with the selection process.
- Best practice for powder feed is consistency of application either by applying the powder 'little and often' or using automated continuous feed.

Thank you for your attention.

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