Mould Powder Benchmarking for Peritectic Grade of Steel at Tata Steel

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Abstract: The product surface quality of a peritectic slab casting is heavily dependent on the performance of mould powder used for casting. A good mould powder ensures proper lubrication and thermal insulation during continuous casting; therefore the choice of a correct mould powder for the peritectic range is one of the crucial parameters for Peritectic slab casting. At present several plant trials are needed to obtain an understanding on the behaviour of mould powder, however, these plant trials not only incur significant operational costs but also associated with a great risk of caster damages (break out, mould wear and stoppages). Moreover it has been noticed that a chosen mould powder behaves differently even within its known working composition range. Several online and offline plant monitoring were undertaken at various Tata Steel Europe and India plants, and several samples of steel lollypops, raw mould fluxes, slag films and slag rims were collected. Data on casting powder, slag pool depth, oscillation marks and surface quality of different monitored casts have been analysed. Mould powder characterisation techniques such as viscosity measurement, Simultaneous Thermal Analysis, Metallography, chemical analysis have also been used for this benchmarking exercise. A high alumina pickup on the top slag layer along with pick-up and losses of different compounds were observed. Online pickup and loss of compounds such as alumina, calcium oxide, silica, zirconia found to have influenced the mould powder properties.

Key words: mould powder, benchmarking, differential scanning calorimetry, viscosity

1. Introduction

Mould powder is an essential requirement for continuous casting of steel of higher cross sections i.e. slabs, blooms and thin slabs. Mould powder plays many important roles during continuous casting. They can be summerised as:

A) Provides lubrication between the oscillating mould and the solidifying strand, hence helps in reducing the friction
B) As the liquid steel is solidified in the water cooled mould, the mould flux film and the liquid flux between the strand and the mould helps in maintaining the horizontal heat transfer
C) Mould powder is added on the top of the mould, which provides thermal insulation and hence guaranties no meniscus freezing
D) The slag formed on the liquid steel helps in absorbing inclusions from the liquid steel hence helps in improving cleanliness
E) It also helps in protecting the liquid steel to come in contact with atmospheric gases and get oxidized

In Tata Steel, more than 20 percentage of steel slab produced are of peritectic grades. Peritectic grade has lots of issues as this is a very critical grade to cast. Due to peritectic reaction at higher temperatures and change in lattice structure due to this reaction, the shrinkage during solidification is more the double than other grades of steel cast. There are several problems associated in casting these grades at slab caster. The major areas of concern are local thin shell formation, longitudinal cracks and finally the most dangerous break outs. Due to all these hindrances it is difficult to cast peritectic grades at the designed speed. The current average of casting peritectic grades is around 1.15 m/min, whereas the designed speed is 1.5 m/min. There are many factors which affect the casting speed and one of them is behavior of mould powder during casting.

While talking of higher casting speed for peritectic grades of steel, it is important to identify the parameters which will be affected due to higher casting speed. They can be summarized as mentioned below:

- Higher casting speed increases the heat flux density in the mould as fresh liquid steel is put in the mould at a higher rate
- Due to higher csasting speed there will be lower shell thickness at mould exit
- In case of peritectic grades lower shell thickness corresponds to lower shrinkage, thus there is reduced gap between the mould and strand surface
- Lower shell thickness means higher ferrostatic pressure on the shell so there is increased frictional force in the mould
- As more and more metal is cast with time there will be decreased specific mould powder consumption

So to address the above concerns the following experimentations along with plant trials were carried out to identify the range of different mould powder properties best suited for Tata Steel casters.

1) Comparison of chemistry and properties of different mould powders
2) Determining the Range of Important Mould Powder Properties
    a. Viscosity, Break Temperature
    b. Melting Temp. Range, Energy Required for melting
    c. Basicity of slag, Alumina absorption
3) Plant trials results obtained for different powders

2. Experimental

2.1 Sample preparation

As most of the sophisticated equipments use platinum crucibles for carrying out the experiments, material containing carbon cannot be used directly for measurements. As raw mould powders contain carbon which is detrimental to platinum crucibles and also causes a slow melting rate of the powders the mould powders were decarburised at 750°C for about eight hours before any measurements were carried out. The following characterizations were carried out using both the powders.

2.2 Measurements

i) Chemical analysis and other properties of the raw mould powders: Chemical analysis of powder was done to find out if the powder has certain basicity, carbon content and fluorine content. Other properties like bulk density and loss on ignition were also important parameters.

ii) XRD analysis of the mould powders: This analysis was carried out to asses the different phases present in the raw mould powder and the source of raw material used for preparing the mould powders.

iii) Simultaneous Thermal Analysis (STA): (combining Thermo-gravimetry - TG and Differential Scanning Calorimetry - DSC). For the mould powder analysis, this equipment is normally used to predict the melting temperature, melting range of the powder, energy required for melting the powders and recrystallisation temperature of the slag. During the simultaneous thermal analysis test, a sample of approximately 30-40mg was heated at a set rate (10°C/min) to approximately 1400°C, held at this temperature for thirty minutes to allow it to approach thermal equilibrium and then cooled to the ambient temperature. The powders were tested in the decarburised state. It was because appreciable amount of MnO in the mould powders with the carbonaceous surrounding leads to the foaming of the liquid flux. This may cause an overflow of the material and possibly damage the sample holder.

iv) High Temperature Viscometery (HTV): This equipment measures the viscosity of the mould powders at high (operating) temperatures, variation of viscosity with change in temperature and evaluation of break temperature (glassy to crystalline transformation) of slag. For the high temperature viscometry, 40 – 50gm decarburised powder sample was melted in a platinum crucible in a muffle furnace. Another standardized platinum crucible used to measure viscosity, was then filled (up to the required height) with the molten flux outside the furnace. This crucible with the solidified flux is placed in the viscometer furnace to remelt the flux at 1350^{o}C and the viscosity of the melt was measured dynamically using a platinum bob rotated at 300 revolutions per minute inside the melt while the melt cool down at 10°C/min.

Two selected mould powders were characterized in the lab and subsequent plant trial were carried out to verify the lab experimental results with the plant trial results.

3. Results

Chemical Analysis:

Chemical analysis of both the powders to detect different oxides has been carried out, and the results are reported in Table 1.

Table 1: Chemical composition of raw mould powder

Mould Powder	Fe_2O_3	CaO	SiO_2	MgO	Al_2O_3	MnO	K_2O	Na_2O	C	F
Powder 1	1.5	36.5	30.4	0.1	5	4.5	1	5.5	5.5	6
Powder 2	1.1	38.5	31.5		5.9	4.3	0.5	3.4	5.3	7.4

Bothe powders are of almost similar composition except in powder 1 the percentage of alkali (Na_2O+K_2O) is higher than powder 2. From **Table 2** it can be seen that powder 1 has more bulk density than powder 2. This is because powder 1 is a pulverized powder whereas powder 2 is spherical granules.

Table 2: Other properties of mould powder

Properties	Powder 1	Powder 2
BASICITY (CaO/SiO_2)	1.2	1.22
Loss of Ignition (LOI)	11.45	8.85
Bulk Density (gm/cc)	1.05	0.6
Melting Point (^{0}C)	1160	1170

XRD Analysis:

XRD analysis of raw powders suggests the phases present in the raw material and hence the source used for preparation of the powder is defined. The XRD analysis of both the powders is shown in **Figure 1**. From this we can see that powder 1 contains more SiO2 which is a network former so helps in increasing the viscosity of powder during melting. In case of powder 2, it contains more flurite which helps in reducing the viscosity of slag during melting.

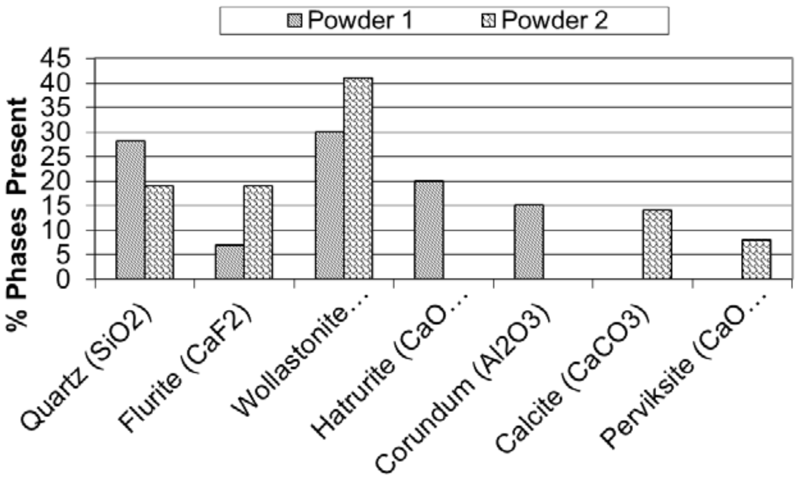

Figure 1: XRD results comparison for both the powders

Simultaneous Thermal Analysis (STA):

Simultaneous thermal analysis has been carried out by using about 30-40 mg of decarburised mould powders. The differential scanning calorimetry (DSC) heating profile curves of powder 1 and powder 2 are shown in **Figure 2**. Powder 1 shows the DSC curve passes through a minimum, melting point at about 1160°C whereas powder 2 shows a melting temperature of 1170°C. It can also be seen from **Figure 2** that powder 2 requires less energy for melting than powder 1, as the area under the melting curve is less. This helps in better powder melting and infiltration in the mould strand gap. Hence helps in casting at higher speed.

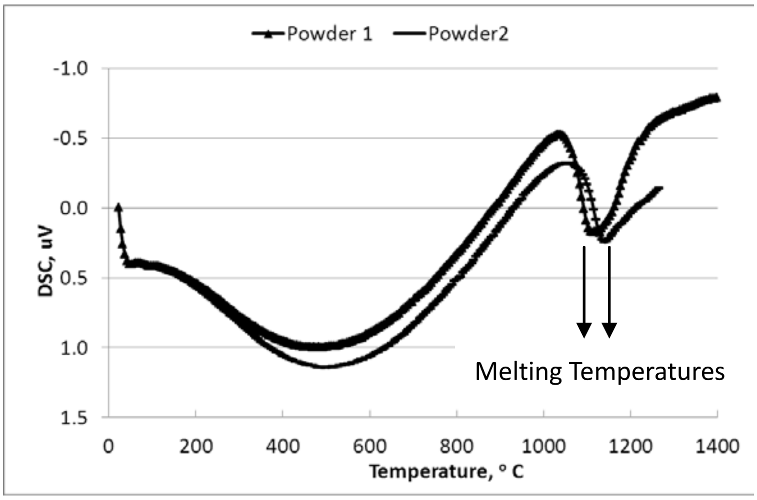

Figure 2: DSC curve of heating cycle for both the peritectic powders

High Temperature Viscometry (HTV):

The viscosity vs. temperature plots for both the mould powders are shown in **Figure 3**. Viscosities (at 1300°C) show that powder 1 and powder 2 has very similar viscosity. So it suggests that slag infiltration is almost similar in both the powders. It can also be seen that the break temperatures of both the powders are almost same at 1140^{o}C. This suggests that both the powders have similar crystallization tendency. Higher break temperature and crystals formation at higher temperature hinders heat transfer from the strand to mould, which is a requirement for peritectic mould powders.

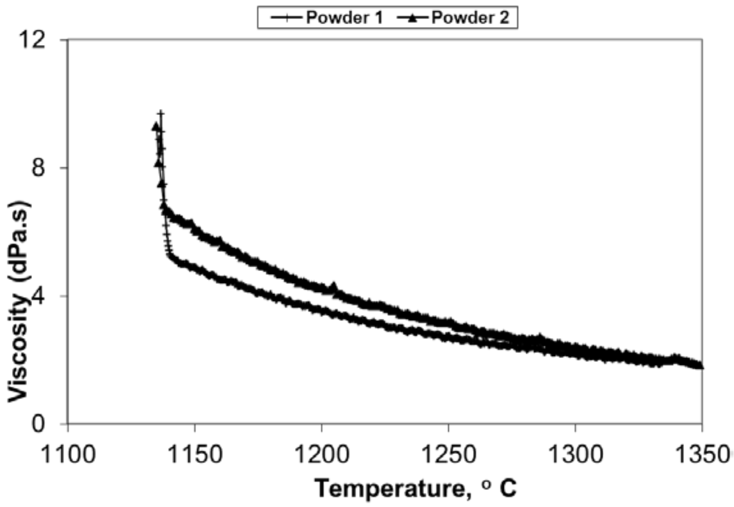

Figure 3: Change in viscosity with temperature for both the peritectic powders

Plant Trial:

Similar number of heats were cast using both the powders and molten slag pool depth was measures during casting. Further alumina pick up by the slag was measured by chemical analysis of the mould slag. No of local thin shell alarms were also monitored from the mould thermal monitoring (MTM) system. Finaly the slab surface was inpsected for any defects due to sticker and crack formation. The following things were reported in Table 3.

Table 3: Analysis of plant trial results

Parameters	Powder 1	Powder 2	Remark
No of Heats observed	57	63	
Sticker, per heat (%)	14.03	6.3	Powder 2 better
% Slabs with sticker	8.7	6.52	Powder 2 better
LTS Alarms/ heats (%)	73	65	Powder 2 better
% Al2O3 Increase in Slag	9.14	7.94	Powder 2 better

4. Discussion:

Both powders show similar composition, viscosity and break temperature. But in case of powder 2 from DSC curve it is clear that it requires less energy for melting than powder 1. Also as powder 2 is granular so spreadability of the powder in the mould was better. This suggests that mould powder can be used for high speed casting than powder 1. During plant trial it was observed that rim formation was not a problem for both powders. Slag pool depth was also similar in both the powders.

5. Conclusions:

Various characterisations were carried out on both the mould powders. The following conclusions can be drawn from the above study.

a) Powder 1 was a pulverised powder whereas powder 2 was spherical granule, suggesting powder 1 has higher bulk density
b) STA analysis showed that powder 1 requires more energy for melting, so powder melting is better in case of powder 2
c) Viscosity measurement showed both the powders have similar viscosity at 1300^oC and also have similar break temperature, so slag infiltration as well as crystallinity will be similar for both cases
d) During plant trial powder 2 behaved better than powder 1, as there were less percentage of defect due to sticker, less number of thin shell formation and better alumina absorption

Hence it can be concluded that powder 2 behavior is better than powder 1. Also a powder with similar break temperature as powder 1 and 2with little lesser viscosity can be designed for higher casting speed of peritectic grades of steel for the particular caster.

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