PHYSICAL PROPERTIES OF MOULD POWDERS FOR SLAB CASTING

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The application of mould powder for certain steel grades is mainly based on experience. In an ECSC-project an inventory was made, addressing the physical properties that are the basis of this experience. It is concluded that for each steel grade common physical properties (e.g. viscosity, melting temperature) can be identified. There is, however, a large variation in the values of physical properties used. It is therefore not possible to find any relationship between slag properties and casting conditions, given the steelgrade to be cast. Wider ranges in physical properties are possible and realistic to enable casting of a steel type at a particular speed.

1. Introduction

In recent years, increases in casting speeds for conventional slab casting and the higher casting speeds employed for thin slab casting, have necessitated a greater understanding of the fundamental physical and chemical properties of mould powders [1,2]. Several authors have reviewed the design of mould powders, resulting in some general rules (viscosity, melting temperature, powder consumption) [3,4,5] and in some trends (slag entrapment, mould heat transfer) [6,7]. However, there are few reported data on mould powder types and their use for various steel grades and casting conditions, particularly for faster casting speeds.

In most cases development and implementation of a mould powder is based on trial and error.

In an effort to obtain more empirical data, an inventory of mould powders in use on European steel plants was commissioned as part of an European Coal and Steel Community project. Analysis of the collected data resulted in discrete knowledge areas based upon the required physical properties of mould powders, relevant to their performance in the continuous casting mould.

2. Inventory

At Corus IJmuiden, a questionnaire on mould powders was developed. After discussion with the project partners, the questionnaire was sent to steel plants throughout Europe and to members of the C3 Committee of the ECSC, with the request to assist by completing the questionnaire. As an example, the situation at Hoogovens BOS No. 2 was sent together with this questionnaire.

The questionnaire consists of four parts:

- Mould Powder Properties
- Casting Conditions
- Production Rules
- Chemical Composition

The first two parts were main items of the questionnaire with the third, production rules, being very subjective. Furthermore, the questionnaire is divided into four steel grades:

- Ultra Low Carbon steel grades ([C]<0.01%)
- Low Carbon steel grades (0.01<[C]<0.07%)
- Peritectics (0.07<[C]<0.14%)
- High Carbon steel grades ([C]>0.140%).

Nineteen replies from slab producers and four replies from thin slab producers were received.

It was expected that collection and evaluation of data from the project questionnaire would result in initial ideas concerning the ranges of relevant physical properties and provide areas of interest regarding plant trials. For comparison purposes, the information was divided into data regarding slab casting and thin slab casting.

The data from the European survey plus results from the evaluation were also used for the development of an expert system on mould powders [8].

3. Results

3.1 Slab Casting

In all cases the data obtained from the questionnaire consisted of the usual or well known properties, i.e. viscosity, melting temperature, basicity (CaO/SiO_2) and free carbon levels (C_{free}). Data regarding the viscosity were mainly based on supplier information and the melting temperatures were obtained by the microscope method [9]. Information on the softening temperature and flow temperature of mould powders was available but gave no additional information. Unfortunately, no information was available regarding melting speed, surface tension, contact angle, heat flux or production rules.
For each steel grade, the data obtained, i.e. the four properties viscosity, melting point, basicity and free carbon can be presented as a function of the casting speed. The data are summarised in Table 1. As an example, data regarding low carbon steel grades and peritectic steel grades are graphically presented in Figs. 1 to 8. In all cases there was a large variation in data points, i.e. the difference between the minimum and maximum values for each set of data points. It was not possible to identify any significant relationship between the casting speed and one of the physical properties so it seems that wider ranges in physical properties of mould powders are possible and realistic to enable casting of a steel type at a particular speed.

Regarding the casting conditions, again only the more conventional properties were given, i.e. slag pool depth, mould level, mould coating, SEN immersion depth, powder consumption, casting speed and oscillation parameters, see Table 2 and Figs. 9 and 10 (slag pool depth, powder consumption). It was not possible to identify any relationship between the mould powder or mould slag properties and the casting conditions; therefore the casting conditions can be considered independent of the steel grades.

The data from the survey can be considered as operational windows (i.e. minimum and maximum values) for mould powders, based on physical properties and plant conditions.

There are very few global production rules on selecting or using a mould powder. See Table 3.

3.2 Thin Slab Casting

As for slab casting, available information on thin slab casting was also concentrated on common properties. Unfortunately, only limited information was available regarding the free carbon content of the mould powders. The data are summarised in Table 4 and are presented in Figs. 11 to 13 (low carbon steel grades). Evaluation of the data resulted in initial ideas about viscosity, melting point and basicity values. However, it should be noted that the data were based on only four steel plants. From the evaluation it was seen that there was general agreement in the values for the obtained properties. Furthermore, the values for viscosity and melting speed were lower when compared with results of conventional slab casting, which indicated infiltration and lubrication of the mould slag were the primary considerations for thin slab casting mould powders.

4. Discussion

As detailed in section 1, the design of mould powders is reviewed by several authors resulting in some rules and trends. However, the information in literature is based on data from a limited number of steel plants.

The data of the survey concern a number of steel plants in Europe. There is almost no support for the generalised rules and trends, indicating wider ranges in physical properties are possible. Unfortunately, only limited plant operating data were available from the survey. If more detailed plant information were available i.e. the mould heat transfer (horizontal heat flux) and the powder consumption as a function of the casting speed and the mould width, it may be possible to identify more clearly some relationships.

5. Conclusions

1. For each steel grade investigated, properties that are used to describe the mould powder are viscosity, melting point, basicity and free carbon levels. Properties like melting speed, surface tension, contact angle and heat flux are not used to describe mould powders.
2. Based on the data obtained, wider ranges in physical properties of mould powders are possible and realistic.
3. No significant relation was found between the mould powder and the casting conditions.
4. There are very few production rules for selecting a mould powder.
5. Mould powders for thin slab casting are described by the properties viscosity, melting point, basicity and possible the free carbon level. Compared with conventional slab casting, the values for viscosity and melting point are lower. This indicates that infiltration and lubrication of the mould slag are the primary considerations for thin slab casting mould powders.
6. The data obtained can be considered as operational windows (i.e. minimum and maximum values) of physical properties of mould powders and are independent of the casting speed.

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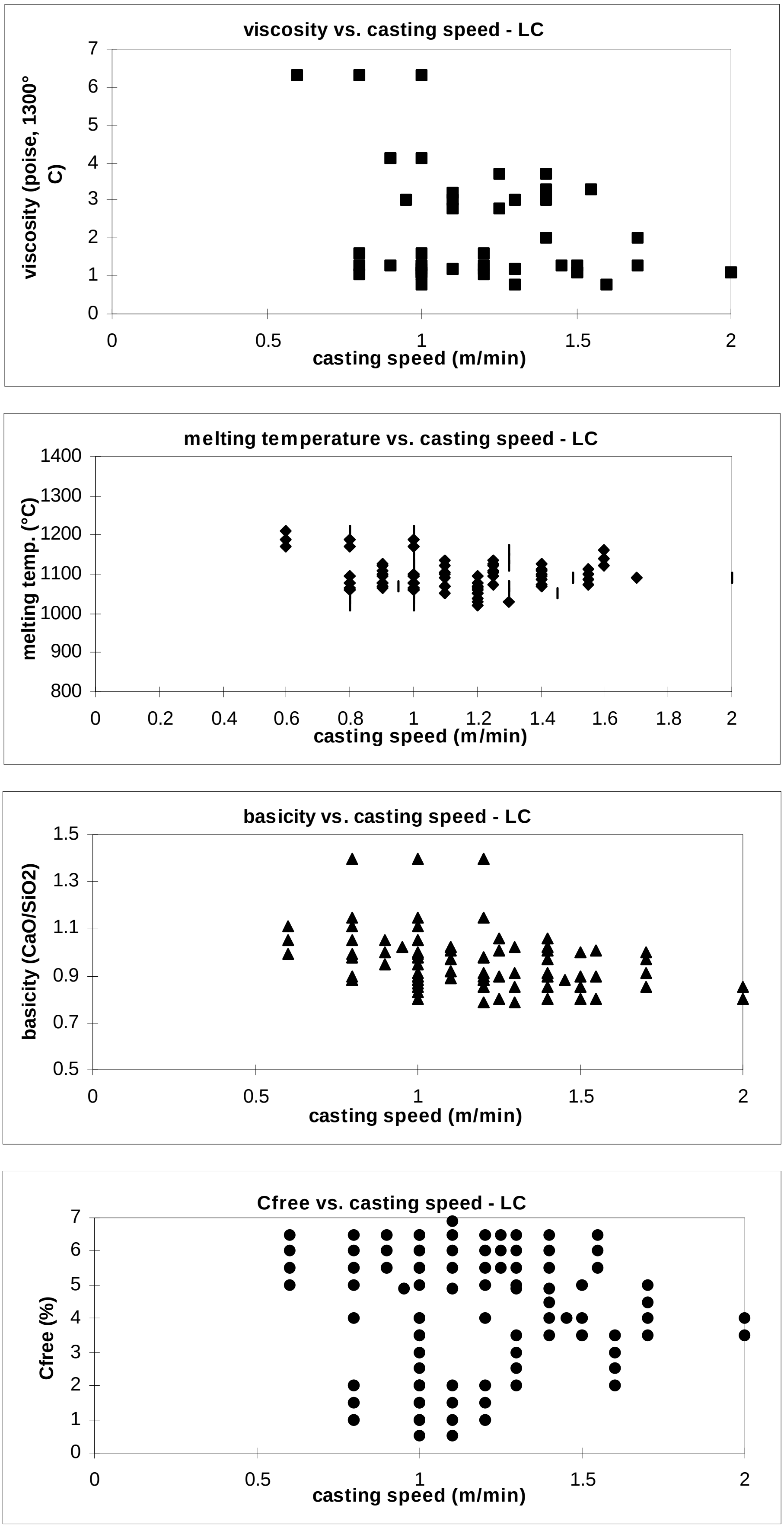
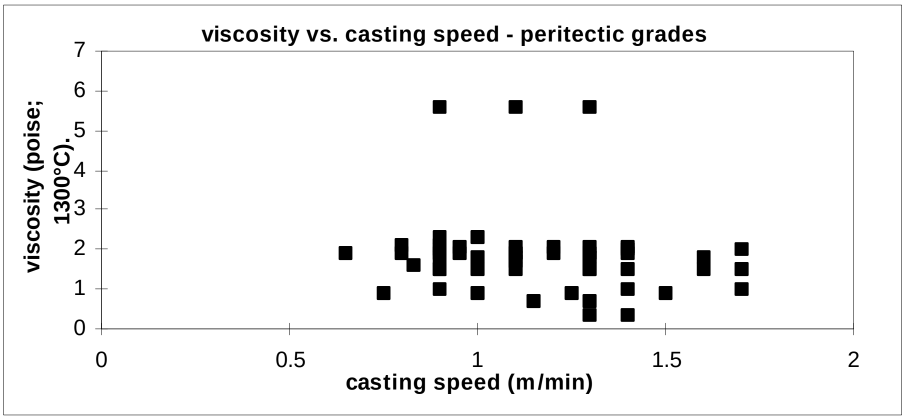
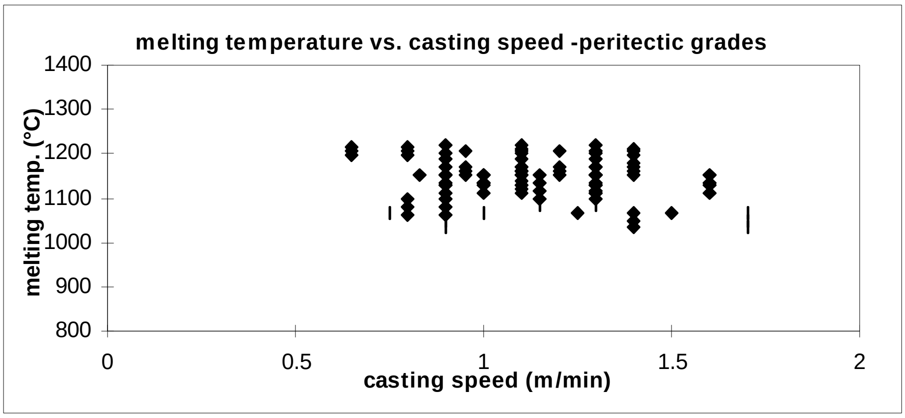
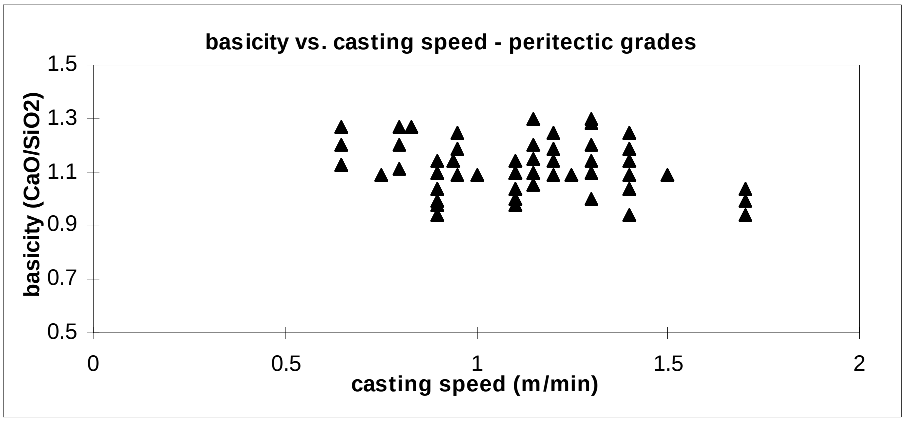


Figure 1 to 4: Mould powder properties vs. casting speed - slab casting (low carbon steel grades)







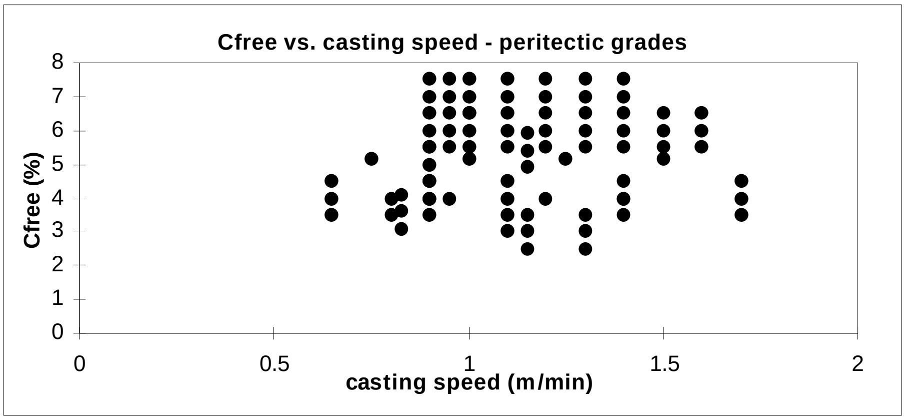
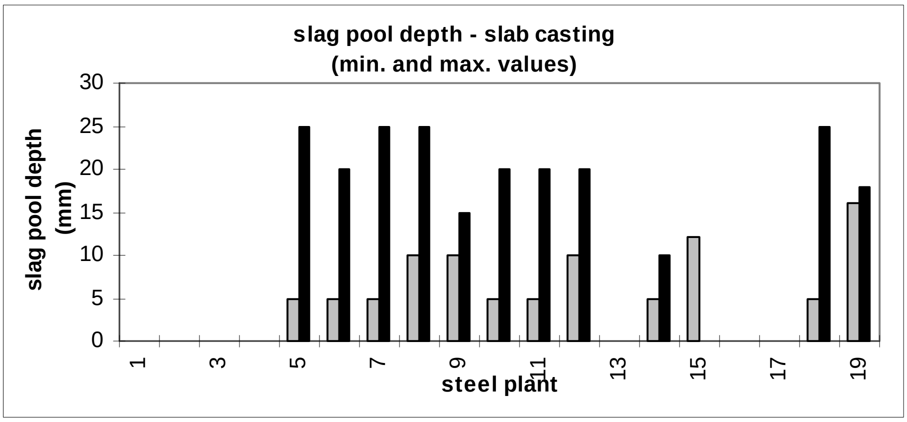


Figure 5 to 8: Mould powder properties vs. casting speed - slab casting (peritectic steel grades)



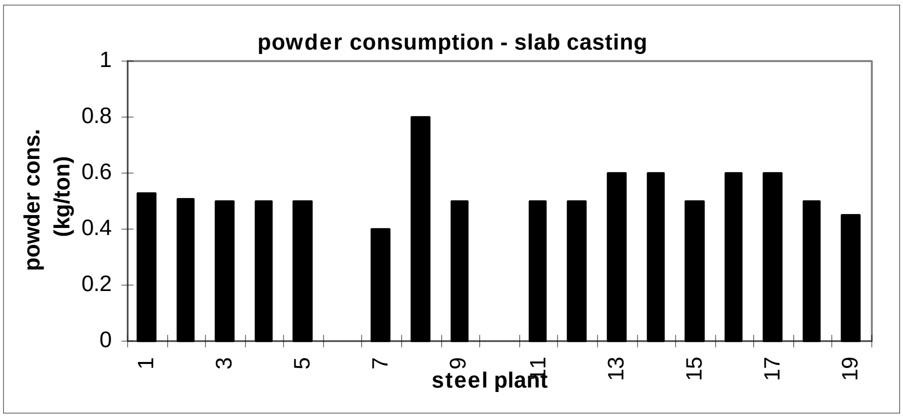
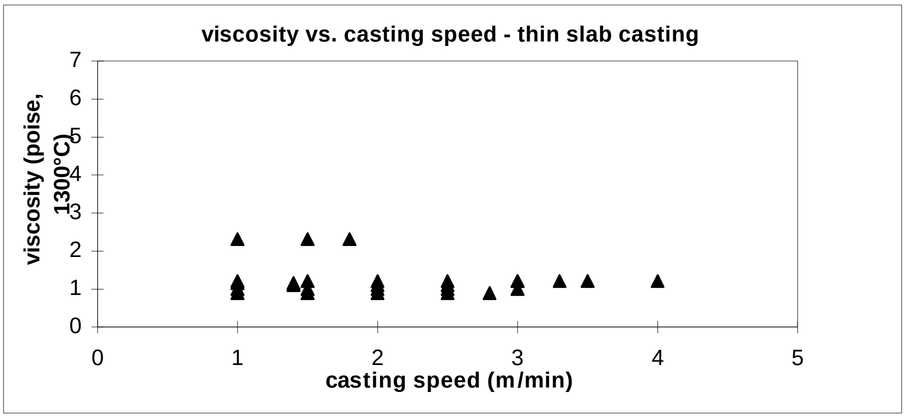
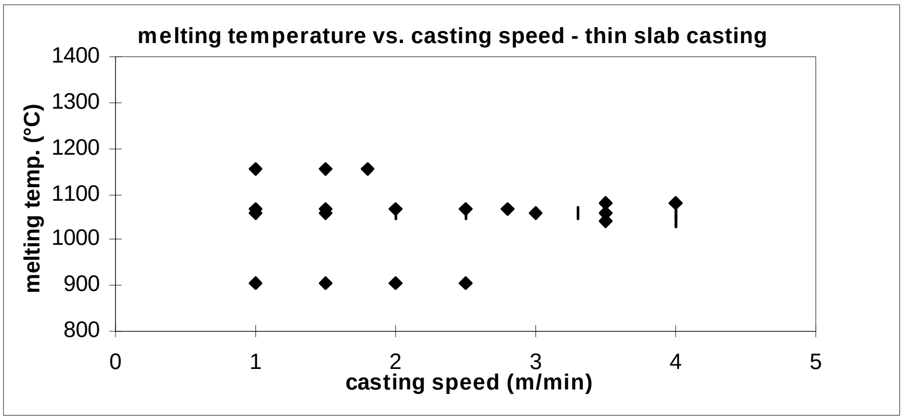


Figure 9 and 10: Slag pool depth and mould powder consumption - slab casting





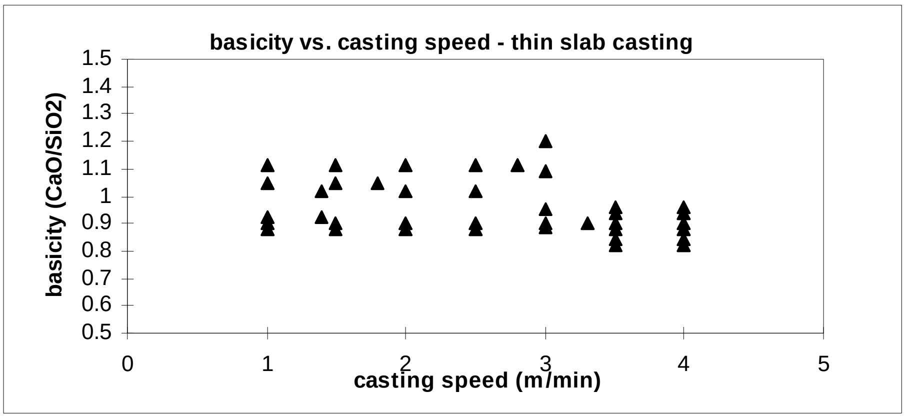


Figure 11 to 13: Mould powder properties vs. casting speed - thin slab casting (low carbon steel grades)

Table 1: *Summary of mould powder data - slab casting*

STEEL GRADE	CASTING SPEED (M/MIN)	PROPERTY	MINIMUM	MAXIMUM
IF	0.6-2.0	viscosity (poise, 1300° C)	1.1	6.9
(C<0.01%)		melting point (°C)	1020	1300
		basicity (CaO/SiO_2)	0.8	1.06
		C_{free} (%)	0.4	2
LC	0.6-2.0	viscosity (poise, 1300° C)	0.8	6.3
(0.01<C<0.07%)		melting point (°C)	1020	1210
		basicity (CaO/SiO_2)	0.8	1.4
		C_{free} (%)	0.5	6.5
Peritectics	0.65-1.7	viscosity (poise, 1300° C)	0.34	5.6
(0.07<C<0.14%)		melting point (°C)	1035	1220
		basicity (CaO/SiO_2)	0.94	1.28
		C_{free} (%)	2.5	7.5
HC	0.5-1.7	viscosity (poise, 1300° C)	0.34	7
(C>0.14%)		melting point (°C)	1030	1220
		basicity (CaO/SiO_2)	0.79	1.28
		C_{free} (%)	2.5	11.5

Table 2: *Summary of plant data - slab casting*

PROPERTY	MINIMUM	MAXIMUM
slag pool depth (mm)	**5**-16	10-**25**
mould level	always used: about 11 NKK, 5 Co 60, 1 NKK+VUHZ, 1 floating device	
mould coating type	Ni coating at 13 steelplants (total of 19 plants)	
SEN immersion depth (mm)	**70**-180	140-**210**
powder consumption (kg/ton)	0.4	0.8
casting speed (m/min)	see table 1	
oscillation: • frequency (min-1) • amplitude (mm)	 $66V_c$ or 70 3	 $120V_c$ or 150 5

Table 3: *Production rules*

viscosity	<4 poise (slab casting), < 2 poise (thin slab casting)
basicity	1.2 (peritectics)
C_{free}	<2% (ULC); 4-5% other steel grades
use black powder practice	

Table 4: *Summary of mould powder data - thin slab casting*

STEEL GRADE	CASTING SPEED (M/MIN)	PROPERTY	MINIMUM	MAXIMUM
LC + HC	1.0-4.0	viscosity (poise, 1300° C)	0.9	1.2 (2.3)
		melting point (°C)	905	1155
		crystallisation point (°C)	965	1100
		basicity (CaO/SiO_2)	0.82	1.11
Peritectics	1.0-4.0	viscosity (poise, 1300° C)	1.15	1.3 (2.43)
		melting point (°C)	1130	1185
		basicity (CaO/SiO_2)	1.04	1.22