(232) CONTINUOUS CASTING OF LOW-DEOXIDIZED STEELS

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Introduction

Fully killed substitutes for rimming steels have been developed since the introduction of the continuous casting technology. However there remains a need for continuously cast steels with a low deoxidation, for specific applications such as very fine wire drawing, cold heading or welding electrodes; either silicon or alumina are detrimental to the properties of the final product in these cases. The present work was launched in France to study the range of chemical compositions and the continuous casting conditions which would answer that need.

Experimental program

29 experimental heats were prepared in IRSID's Pilot melt shop and teemed on the pilot caster. The range of compositions studied is given in table 1. Typically the steel charge prepared in the 6 t electric furnace was trimmed to a low oxygen level by slag-metal stirring in the induction ladle furnace and allowed to reoxidize during teeming so that it reached the equilibrium with silicon (or silicon and manganese) in the mold of the caster. The section was 120x120 mm. The tundish to mold casting was open. The casting speed was 2.00 m/min. A strong in-mold electromagnetic stirrer (Magnetogyr) capable of producing a steel velocity of 0.80 m/s was used (1).

Modelization of blowhole initiation

A mathematical model was developed in order to sort out the influence of the various gases (O, N, H,) dissolved in the liquid steel during our experiments and to determine the onset of blowhole entrapment in the solid shell. It calculates a total pressure P_t inside the real or virtual blowholes at the solidification front as : $P_t = P_{N_2}+P_{H_2}+P_{CO}$ where P_{N_2} , P_{H_2} and P_{CO} are the partial pressures of N_2, H_2, and CO. The segregation of each element is calculated at a solid fraction of 0,9 using Takahashi's model (2) of the mushy zone in the presence of stirring and assuming that C, H, N and O are distributed according to the equilibrium diagram and Mn and Si according to Gulliver-Scheil's relationship. Deoxidation is allowed for at the solidification front.

Results

Figure 1 gives an example of the products obtained with and without stirring. Figure 2 plots the number of blowholes counted on a transverse cross-section in the first 3 mm below the surface as a function of P_t .

It is clearly concluded that Electromagnetic Stirring (EMS) makes it possible to control bubble entrapment and that the critical pressure P_t for blowhole formation is 1 atm. This both confirms our model and shows that the nucleation oversaturation is negligible in this case.

Figures 3 and 4 show further results calculated from the model as calibrated by our experiments. The range of O, Si, and C (for given H and N contents) where blowhole formation is prevented, is clearly indicated with or without stirring.

Conclusions

Through mathematical modeling and Pilot Plant experiments it has been shown that the continuous casting of low carbon steels with a rather high dissolved oxygen content is indeed possible thanks to the use of in-mold EMS. The silicon level and hence the flow stress of these new grades are both lower than those of the corresponding fully killed grades.

References

1) R. ALBERNY et al.
Steelmaking Proc. 61 (1978) 37-59
2) T. TAKAHASHI et al.
Trans. ISIJ, 16 (1976) 283.

Table 1. Range of chemical composition studied (%).

C	Mn	Si	Al	O	N	H
.028 .130	.120 .900	tr. .290	tr.	.0010 .0510	.0050 .0180	.0004 .0010

Chemical composition(%)

C	Mn	Si	O	N	H
.045	.160	.032	.0150	.0050	.0006

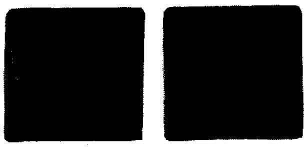

Fig.1. Cross-section of slightly deoxidized low carbon steel billets.

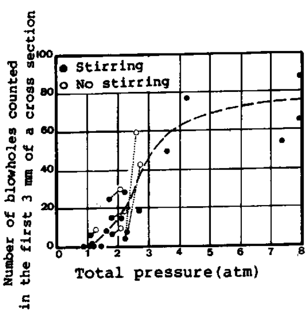

Fig.2.Relationship between number of blowholes and total pressure.

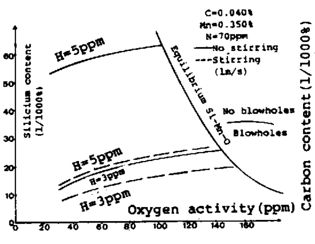

Fig.3.Si and O range where blowhole formation is prevented.

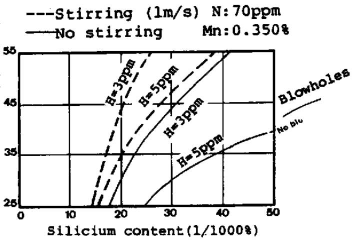

Fig.4.Si and C range where blowhole formation is prevented.