Crystallization behavior of molten fluxes for high-speed continuous casting of middle-carbon steel

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ABSTRACT

The crystallization behavior of low-viscosity molten fluxes used in high-speed continuous casting of middle-carbon steel has been investigated experimentally on the basis of the continuous cooling transformation curves (CCT curves)[1,2] and the fraction of crystals. The experimental results demonstrate that the degree of crystallization of the melts depends mainly on the MgO content.

INTRODUCTION

During continuous casting of middle-carbon steel, longitudinal surface cracks occur frequently on the solidifying steel shell. Numerous studies have been made to solve the serious problem in the practical operations[3-6]. As a results, it has been known that a high thermal transfer across the thin flux layer is usually associated with a high incidence of longitudinal cracking. From the standpoint of melt's properties, the thermal transfer across the molten flux layer is dependent upon the crystallization behavior of the melt which infiltrates into the space between the mold and the steel shell. Unfortunately, an understanding of the crystallization behavior of low-viscosity molten fluxes for high-speed continuous casting of middle-carbon steel is not entirely satisfactory. In this work, we have examined their crystallization behavior as a function of MgO content at various cooling rates.

EXPERIMENTAL PROCEDURE

The chemical composition and viscosity ranges of the mold fluxes used are given in Table I.

The crystallization temperatures of the molten fluxes were determined using a differential thermal analyzer (DTA). The molten fluxes were cooled from 1300°C to the crystallization temperatures at various cooling rates. Thus, the CCT curves were obtained experimentally.

Table I Composition and viscosity ranges of mold fluxes used in this work.

Chemical composition (mass%)	**MgO**	**0.7～8.0**
	Li_2O	**2.3～5.0**
	F , Na_2O	**～8.0**
	Al_2O_3	**～3.0**
	CaO/SiO_2	**1.26 , 1.45**
Viscosity (Pa•s) at 1300 °C	**0.03～0.08**	

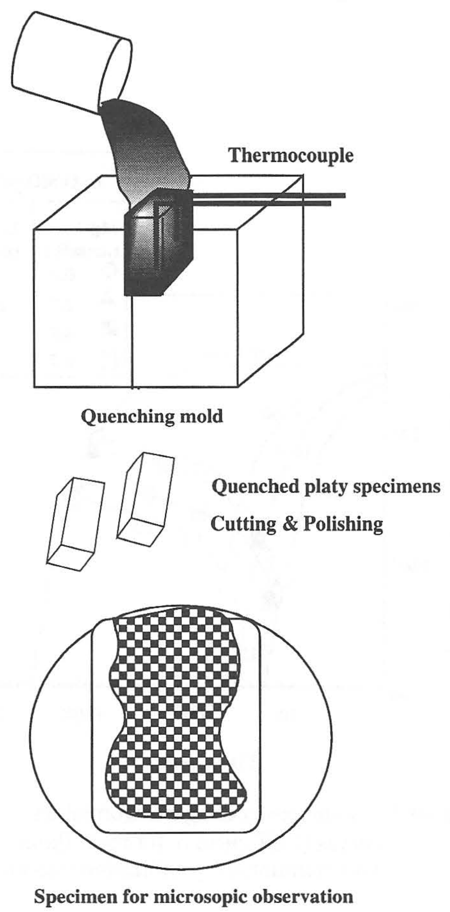

Figure.1 Schematic view of quenching test

The degree of crystallization was determined by observing the quenched mold fluxes, as illustrated in Figure 1. After being melted at 1300 °C in an electric furnace, the molten fluxes were quenched by pouring into the mold of stainless steel (30 × 30 × 5mm), which was held at 300°C. The cooling rate was approximately 2000 °C/min at the center of the fluxes. The fraction of crystals was determined with an image analyzer from the micrographs of the solidified platy fluxes.

RESULTS AND DISCUSSION

CCT curve

Figures 2 and 3, where they differ in the mass ratio of CaO/SiO_2, show the CCT curves obtained at various cooling rates. These figures indicate that all the crystallization temperatures decrease with increasing the cooling rate. Similarly, the curves shift to lower temperatures with increasing the MgO content. As seen, the crystallization temperatures in Figure 3 are slightly lower than those in Figure 2.

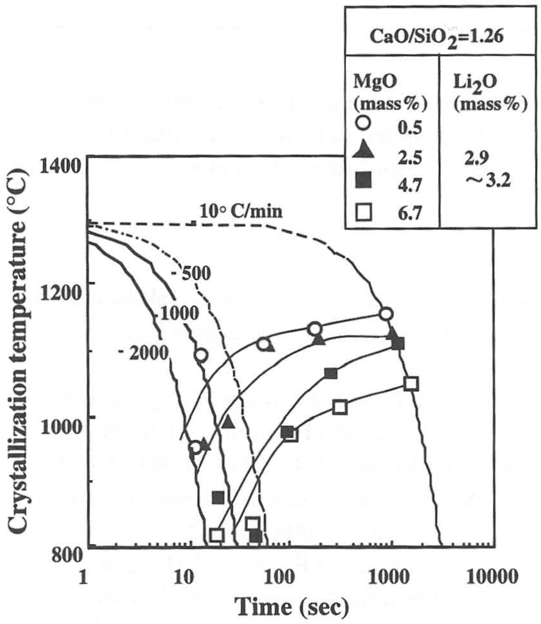

Figure 3. Continuous cooling transformatiom curves (CCT curves) for mold fluxes for determining crystallization temperatures

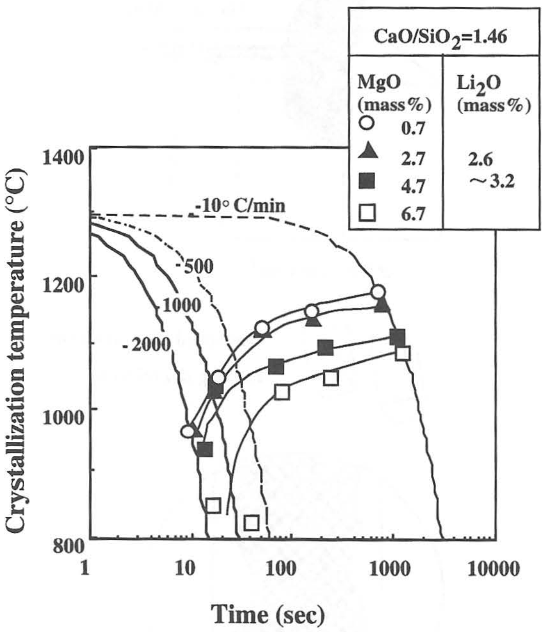

Figure 2. Continuous cooling transformation curves (CCT curves) for mold fluxes for determining crystallization temperatures

Quenching test

Figure 4 shows typical microstructures of the quenched fluxes. As shown in Figure 4, the part of the melt, cooled rapidly, in contact with the cold wall of the mold, solidified as a glassy state, while most of the inner part, cooled slowly, solidified as an equiaxed crystalline state. The results of X-ray scattering experiments revealed that the crystals consist of only cuspidine (i.e. $3CaO2SiO_2CaF_2$)

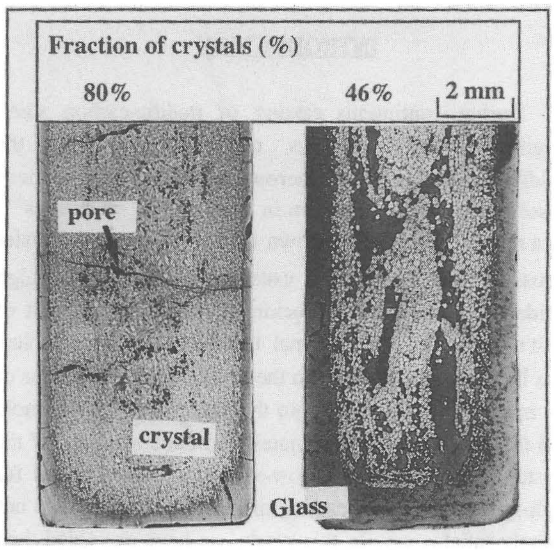

Figure 4. Typical microstructures of longitudinal sections of the quenched fluxes

In Figure 5, the fraction of crystals is plotted against a tentative parameter, i.e. $CaO+CaF_2-MgO$ (mole%). According to Figure 5, the fraction of crystals for the fluxes containing 2.5-3.2 mass% Li_2O increases gradually up to about 40 mole% ($CaO+CaF_2-MgO$), above which it increases abruptly. By contrast, in the case of fluxes containing 4.0-5.0 mass% Li_2O, the fraction of crystals is below 20%. Figure 6 shows the results of electron probe X-ray microanalysis (EPMA) for the quenched specimens. The EPMA micrographs indicate that calcium and fluorine, which are the consitituents of cuspidine, are concentrated in the interior of grains; magnesium, aluminum and sodium segregate to grain boundary regions; silicon is randomly distributed. The polarizing microscopic observations revealed that the grain boundary regions are in a non-crystalline state. A conclusion to be drawn from these observations is that the decrease in the fraction of crystals may be caused by the segregation of magnesium, i.e. MgO, at grain boundaries.

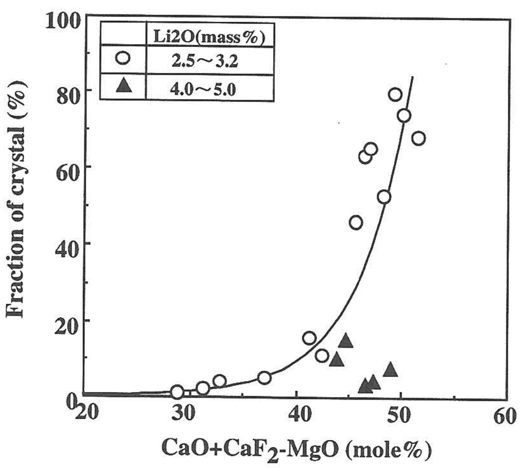

Figure.5 Relationship between fraction of crystal and parameter of ($CaO+CaF_2-MgO$)

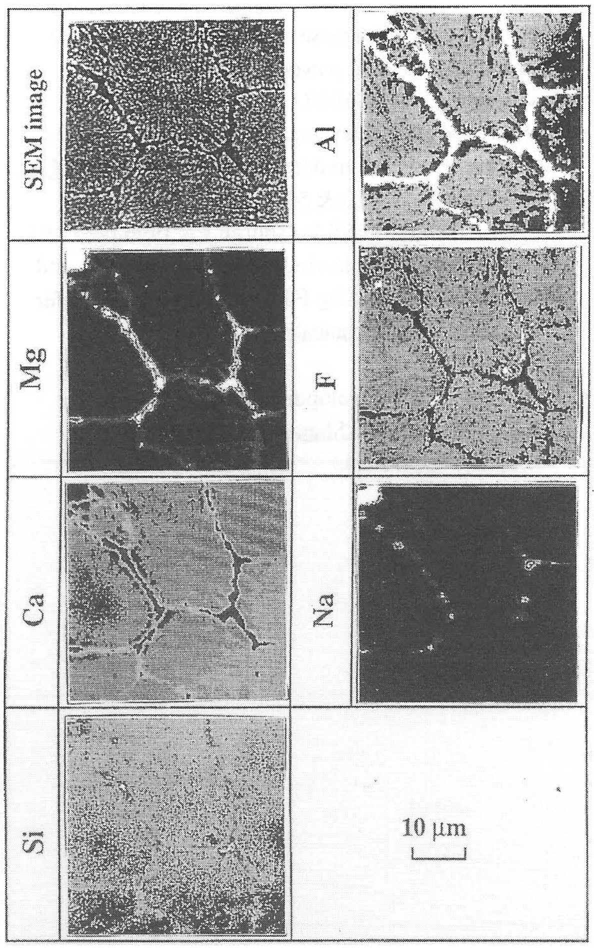

Figure 6 EPMA micrographs of the quenched specimens (Fraction of crystal = 70 %, CaO/SiO_2=1.46, MgO 1.5, Al_2O_3 2.9, F 8.9, Na_2O 8.5, Li_2O 3.0 mass%)

CONCLUSIONS

The crystallization behavior of low-viscosity molten fluxes for high-speed continuous casting of middle-carbon steel has been determined at various cooling rates.

(1) The crystallization temperatures decrease with increasing cooling rate.
(2) The CCT curves shift to lower temperatures with increasing the MgO content.
(3) The fraction of crystals increases with increasing the parameter ($CaO+CaF_2-MgO$), in the case of 2.5-3.2 mass% Li_2O content.

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