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Original Article

Influence of the chemical composition on steel casting performance

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ABSTRACT

Improving the quality of steel and the steelmaking process has been a matter of routine for metallurgical engineers and steelmaking companies in a demanding market for quality products at highly competitive price. The chemical and temperature adjustment are made during the secondary refining process, as well as the inclusion modification required to product quality, and also the demand for castability accuracy. Continuous casting process is the most used solidification casting process, in which the flow of pouring liquid metal through the submerged entry nozzle is assured by the correct temperature and the formation of liquid inclusion in the casting temperature. Thermocalc and CEQCSI were the software used in this work to assess the effect of carbon, silicon and sulphur in the castability window of the aluminium vs calcium phase diagrams. They have proved to be highly suitable and effective and the results showed that the chemical elements used directly affected the position of the castability window of carbon steel. An analysis of a 0.2%C billet sample using Scanning Electron Microscopy showed that there is a great heterogeneity of inclusions in aluminium-killed and calcium-treated steel.

1. Introduction

The accurate treatment of steel in ladle for the proper control of deoxidation and inclusions in the products is essential to produce billets from the continuous casting process [1,2]. The formation of liquid inclusion after the secondary refining is considered a precondition for the steady flow of liquid metal through the small diameter nozzles of the continuous caster. The steel castability is mainly influenced by the formation of solid micro-inclusions into liquid metal, and the inclusion deposition rating in the nozzle is due to the steel cleanliness [3]. The chemical adjustment in the ladle furnace can be very accurate, as well as the desulphurization and calcium-treatment. The addition of the calcium cored wire is able to change the physical characteristics of the inclusions during the deoxidation process. Clearly, the solid–liquid transformation is a function of the *liquidus* temperature of these

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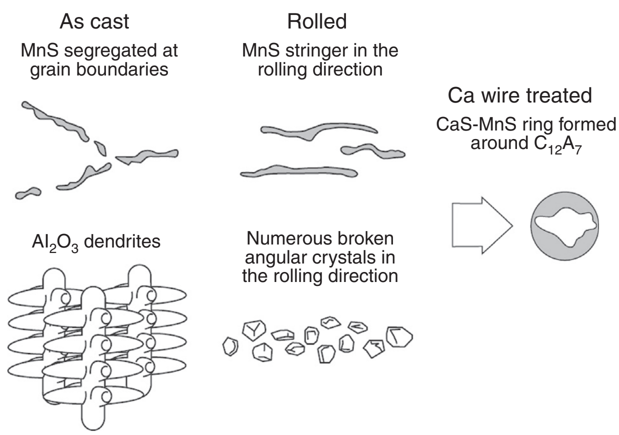

Fig. 1 – Schematic illustration of the modification in the morphology of the inclusion after calcium treatment [8].

inclusions. Inclusion phases at a work temperature can be predicted by calcium vs aluminium phase diagrams, in which the liquid phase defines the area of the diagram called "castability window" [4–6].

The modification of the morphology of the inclusions in steel by calcium treatment not only allows the continuous liquid steel stream during the continuous casting process but also provides an important enhancement of the quality of high-strength alloy steel. For instance, the properties of fatigue strength required in some applications depends directly on the inclusion chemical composition, shape, and distribution of their sizes. Angular, long and hard inclusions must be avoided as they cannot be deformed along with the steel matrix along the hot rolling process, which can result in stress concentration into the interface steel/inclusion [7]. Fig. 1 shows, schematically, how the morphology of the inclusions can be changed by calcium treatment [8]. In this outline, the inclusions in aluminium killed and calcium treated steel are spherical with a low-melting-point calcium aluminate core, covered by calcium and manganese sulphides. The inclusions at relatively-low melting point, smaller in size and spherical are recommended to improve the fatigue strength and toughness properties and also prevent or decrease the hydrogen embrittlement [1,3,7,9,10].

The aim of this study is to assess the influence of the sulphur content and the deoxidant elements, silicon and carbon, in the steel castability window produced by the ladle furnace → continuous caster process.

2. Experimental procedure

Fifty-four steel chemical compositions with different content of carbon (0.2, 0.4 and 0.6%), silicon (0.02 and 0.20%) and sulphur (0.005, 0.010 and 0.015%) were selected corresponding to the industrially produced alloys (e.g. SAE 1020, SAE 1040 and SAE 1060). The *liquidus* temperatures were calculated by using Thermocalc, a thermodynamic computer software, since it can calculate accurately the *liquidus* temperature to a wide range of the chemical composition [11].

Calcium vs. aluminium phase diagrams were calculated for the fifty four alloys by the software Thermocalc using SLAG2 database. The diagrams were calculated in function of aluminium and calcium content at 50 °C above the *liquidus* temperature of the steel. Although they may affect the "castability window", the total oxygen content and pressure used in the trials were continual at 20 ppm and in 1 atm respectively, and the other chemical elements present in steel were also assumed constant. The effects of these influences will be assessed in future studies.

The minimum and maximum calcium content required to achieve liquid inclusion in function of the aluminium content were identified in these aluminium versus calcium diagrams, and the aimed value was taken as the average between the minimum and maximum values. By using the aimed calcium content from the calculations and the chemical composition of the alloys, a multiple regression was carried out by using the software Minitab.

The casted samples of industrially-produced billets through continuous casting were assessed. The inclusions were analysed by the Scanning Electron Microscopy (SEM), in which the types of oxides present were identified in semi-quantitative analysis. The *liquidus* temperature and phase fraction of the inclusions were calculated on the basis of chemical composition by the thermodynamic software CEQCSI (Crystal module).

Fig. 2 shows the main screen of the thermodynamic software used in this work.

3. Results and discussion

The aluminium–calcium phase diagrams at 50 °C above the *liquidus* temperature of the alloys were calculated for all the proposed chemical compositions, keeping the other elements constant, as described above. As known, carbon content

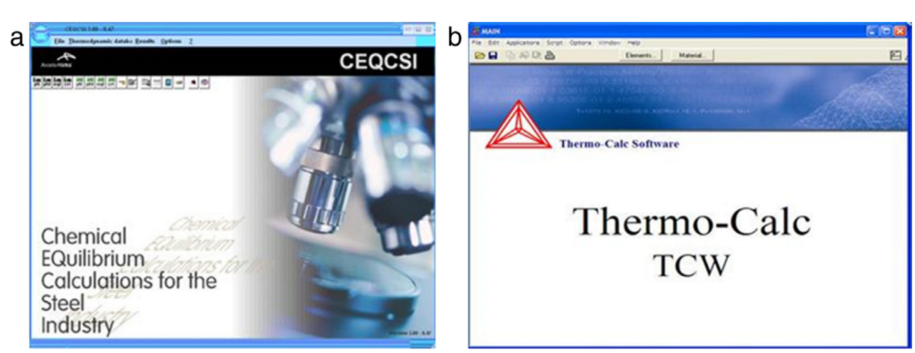

Fig. 2 – Screen of the thermodynamic software (a) CEQCSI (b) Thermocalc.