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Effect of electromagnetic stirring in mold on the macroscopic quality of high carbon steel billet

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An industrial plant trial for optimizing the process parameters in a round billet continuous casting mold with electromagnetic stirring (M-EMS) was performed, in which the influences of stirring parameters with M-EMS on the solidification macrostructure of high carbon steel were investigated. The results show that the billet quality is not well controlled under the condition of working current and frequency with EMS, in which the subsurface crack of grade 1.0–2.0 ups to 38.09%, the central pipe of grade 1.0–1.5 reaches to 14.28%, and the central porosity of grade 1.5 is 14.29%. The parameters of current 260 A and frequency 8 Hz as the final optimum scheme has a remarkable effect for improving the macroscopic quality of billet, in which the subsurface crack, central pipe and skin blowhole are all disappeared, and the central porosity and carbon segregation are also well improved.
KEY WORDS Round billet continuous casting; Electromagnetic stirring in mold; Macroscopic quality; High carbon steel

1 Introduction

Electromagnetic fields have become one of the most promising methods for controlling fluid flows and particle movements in many engineering application and production, which is being widely used in industry. Electromagnetic stirring, as a well established high efficiency technique, is possible to achieve effective and reliable stirring of the molten steel in the continuous casting process, which can meet the metallurgical objective of improving the quality and productivity of cast products. It has been widely accepted in the conventional practice to use the electromagnetic stirring in mold (M-EMS) in order to control the initial solidification so as to reduce various defects and increase the equiaxed grain zone in the continuous casting of high carbon steel billets and slabs[1−10].

Since the benefits of EMS are now widely recognized by industry, so how to reasonably control the solidification structure of casting steel with EMS is important because the solidification structure would directly influence the mechanical properties of final products. In order to predict the optimum conditions and obtain a desired solidification structure,

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it is important to clarify the effects of stirring process parameters with M-EMS on the solidification structure and quality of casting billet. Although there is a great deal of theoretical work[11−17] to reveal the stirring characteristic of EMS, it can not practically reflect the stirring effects of the industrial EMS. Moreover, it is almost impossible to predict the surface and internal defects of casting billet with M-EMS by mathematical models. Therefore, many inspection works of the billet quality would be required in order to understand the macroscopic quality of billet and get an optimal stirring condition of M-EMS.

An industrial plant trial was performed to clarify the effect of M-EMS on the macroscopic quality of high carbon steel billet in this study, in which the effects of different schemes of stirring parameters were taken into account. The macroscopic qualities of steel billets were investigated by the methods of hot acid etching tests in order to explore the quality defects of billets with different stirring parameters of M-EMS. Finally, an optimum scheme of stirring parameters would be proposed to apply to the practical casting production.

2 Plant Trials

2.1 Trial conditions

To assess the effects of M-EMS on the macroscopic quality of round billet more accurately, an industrial plant trial was carried out on a six strands square/round billet caster at the same time with a casting speed of 3.0 m/min and superheat value of 15–20 °C. The M-EMS is externally mounted, namely, installations where the stirrer is mounted outside the mold housing, and the detailed system structure and installation position of M-EMS are expressed in literature [17]. A high carbon steel grade of 82B has been used to assess the effects of M-EMS. Typical chemical composition (wt pct) of 82B is C 0.799, Mn 0.793, P 0.012, S 0.008, Si 0.249, Cu 0.014, Ni 0.006, Cr 0.231, Mo 0.010 and Fe bal.

2.2 Trial schemes and methods

The hot acid etching tests of steel samples for different stirring parameters were conducted in order to understand the influence of M-EMS on the macrostructure of 82B steel and verify the accuracy of optimal parameters of EMS. The detailed stirring parameter schemes of M-EMS for plant trial are shown in Table 1. 300 A and 4 Hz of scheme 1 is the practical working current and frequency of EMS in production plant. The plant trial process includes the sampling of 82B steel, the treating and etching of samples, and the quality examination of samples. The sampling numbers for each group stirring parameters of EMS were 21 samples, in which the sampling process was completed in three continuous casting furnaces and 7 samples were taken from each continuous casting furnace. Second, the surface roughness for all steel samples was processed to be 1.6 μm. Then, the samples were etched in the industrial hydrochloric acid and continuous being heated 45 min, the concentration of acid is 30% and its temperature is 65–80 °C. Finally, quality examination

Table 1 Stirring parameter schemes for plant trial

Scheme	1	2	3	4	5	6	7	8	9
Current, I/A/Frequency, f/Hz	300/4	300/6	300/7	300/8	280/6	280/7	280/8	260/7	260/8