MONITORING OF TUNDISH PREHEAT PROCESS FOR THE CONTROL OF HYDROGEN CONTENT IN STEEL

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Abstract

A monitoring system of tundish preheat process has been developed for the control of hydrogen content in molten steel at China Steel (CSC). The hydrogen gas accumulated inside the steel matrix may eventually induce pinholes or hydrogen-induced cracking. And the possibilities of hydrogen pick up during casting could be from the atmosphere, tundish lining, or casting powder. Our study has proved that most of the moisture comes from tundish lining. Therefore, preheated tundish was used to avoid moisture pick-up from lining at CSC. An IR-based temperature sensor has been set up to detect tundish shell temperature in this research. The temperature of tundish shell is recorded during the preheat process. It is been noticed that the temperature profile of the preheated tundish shell has a horizontal zone at 100 ℃. This indicates the moisture of tundish lining is evaporating at that time. When all of the moisture is out of tundish, the temperature of tundish shell will increase with preheating time until casting starts. After compared with the amount of hydrogen pickup in tundish process, the result shows that the hydrogen content in steel will decrease with the highest preheat temperature of tundish shell. When the temperature of tundish shell is higher than 120 ℃, the amount of hydrogen pickup in tundish is less than 1.5 ppm. Accordingly, in this study, we have built up quality indexes for the references of tundish preheat process to reduce the defects of steel product.

Keywords: Tundish, preheat, monitoring, hydrogen pickup

1. INTRODUCTION

With increasing demands on steel quality, reduce and control the amount of dissolved gases in steel become more important. Hydrogen and nitrogen are two of the most important gases which when dissolved in liquid steel affect its properties significantly. It is known the formation of internal cracks during hot rolling as a consequence of dissolved hydrogen within cast steel [1]. More recently, researches indicate that certain amounts of hydrogen in the liquid steel contribute to the formation of pinholes and blowholes during steel solidification, what can lead to serious problems, especially in continuous casting process [2-3]. According to the study [4], some of these problems are embrittlement, delayed fracture, stress corrosion cracking, exfoliation, and environment-assisted cracking. The damage mechanism can be attributed to the solubility behavior of hydrogen in steel, since its solubility in liquid steel is higher than in solid steel. During solidification, the trapped hydrogen can diffuse, increasing the internal pressure within the material. If the hydrogen content is high enough, this pressure can exceed the mechanical strength of the steel and cause cracks to appear. This phenomenon is so-called "hydrogen induced cracking (HIC)". Typical HIC-related internal cracks often found at centerline of plates following hard inclusion [1] are shown in **Figure** 1. Since the formation of defects depends on the hydrogen content, it is directly related to the steel production process and cooling conditions.

Several mechanisms and sources can lead to the increase of hydrogen content during processing of liquid steel [5-7]. Theoretically, hydrogen has some solubility in the slag, but it is only significant if the degassing operation (RH) is not correctly performed. Hydrogen can be originated from refractory in two different ways: from their intrinsic humidity or from organic binders. The possible sources of hydrogen can be summarized in **Table 1** [5]. The main sources of hydrogen pickup were determined to be the tundish lining and shrouding tube. For the tundish lining, a mean increase in hydrogen content of up to 0.8 ppm was found, caused by the moisture of the lining. For the shrouding tube, with an average water content of 3 %, a maximum increase of 0.7 ppm in the measured value was estimated. Therefore, a possible solution to the hydrogen problem is preheating or the use of water-free shrouding tubes and tundish lining.

Figure 2 shows a proof of the hydrogen comes from the moisture of tundish lining at China Steel (CSC). For the 3 heats at RH, the hydrogen contents in steel are lower than 2 ppm. However, the hydrogen content increases at tundish stage, especially in the first heat, and decreases in subsequent heats. It can be concluded that the moisture in tundish decreases with casting time owing to the higher temperature of tundish lining. Even though preheated tundish was used to avoid moisture pick-up from lining at CSC, there is no any index for evaluating the moisutre in tundish lining during tundish preheat process. In this work, a monitoring system of tundish preheat process has been developed for the control of hydrogen content in molten steel at China Steel.

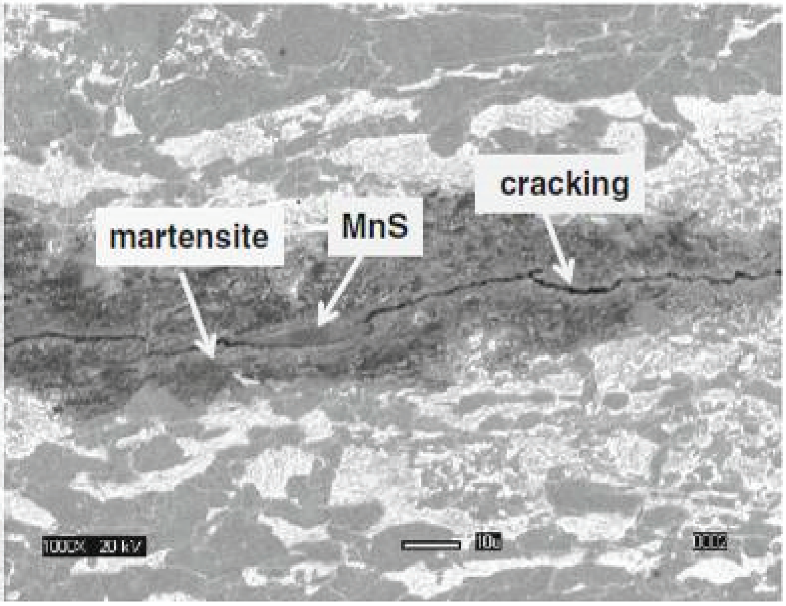

Figure 1 Hydrogen-induced cracking at centerline of a 20-mm-thickX70 grade linepipe plate. The cracking initiated at the martensite-MnS interface and propagated along the segregated region [1].

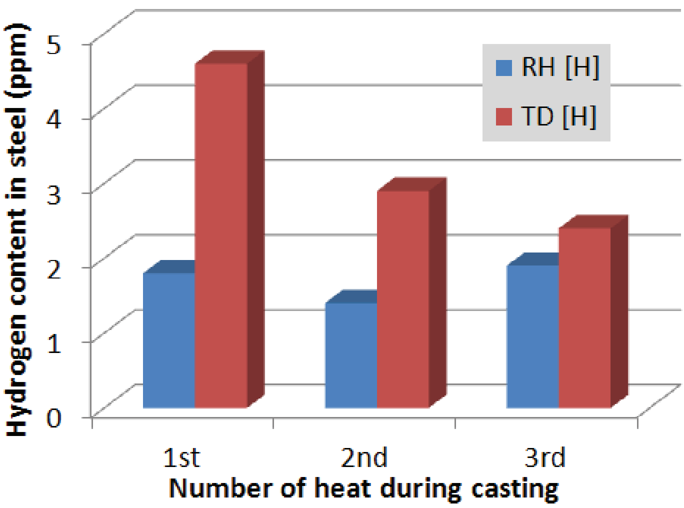

Figure 2 Hydrogen contents in steel in RH and T/D at 3 heats during casting

Table 1 Possible hydrogen source during continuous casting of steel.[5]

	Amount used, kg	H_2O content, %	Equivalent H_2 input in 185t of steel, ppm	Measured H_2 increase, ppm
Packing sand for sliding gate	20	1.0	0.1	<0.1
Shrouding tube	30	3.0	0.5	0.4-0.7
Tundish lining	1800	0.5	5.4	<0.8
Tundish slag	70	1.1	0.5	<0.1
Casting powder	180	0.8	0.8	0.2-0.3

2. EXPERIMENTAL MEASUREMENT

An IR-based temperature sensor has been set up to detect tundish shell temperature in this research. The temperature of tundish shell is monitored during the preheat process by an infrared thermometer (CHINO, IR-SAB01N) and its signal is recorded by a datalog (HIOKI, LR-8341-20). Both of these equipments are built-up at the tundish car and the IR temperature sensor is at a distance of 1 m from the target of tundish shell. **Figure 3** shows the experimental setup of the monitor system of tundish shell temperature. Traditionally, the temperature status during tundish preheating process has been measured by inserting a thermocouple in the tundish lining. This study has replaced these troublesome thermocouples with non-contact and low-maintenance infrared thermometers. The infrared thermometer, providing a direct measurement of refractory temperature, allows for the surface temperature measurement in hard-to-reach places and in dangerous areas such as casting stand. In addition, the elimination of problematic thermocouple maintenance is also a significant advantage of the infrared thermometer. By this arrangement, the temperature of tundish shell could be monitored both in preheating and casting process without interruption. Meanwhile, in order to check the representative of the measured spot of tundish shell, a thermal image analysis is applied before temperature measurement (**Figure 4**). From the result, there are different temperature zones on the tundish shell. As a result of weak thermal convection, the corner zone is found at low temperature range. And it's better to avoid the water-stain zone, which has different surface emissivity, to reduce temperature disturbance. Hence, the most suitable target zone locates at the area higher than drain holes on the tundish surface.

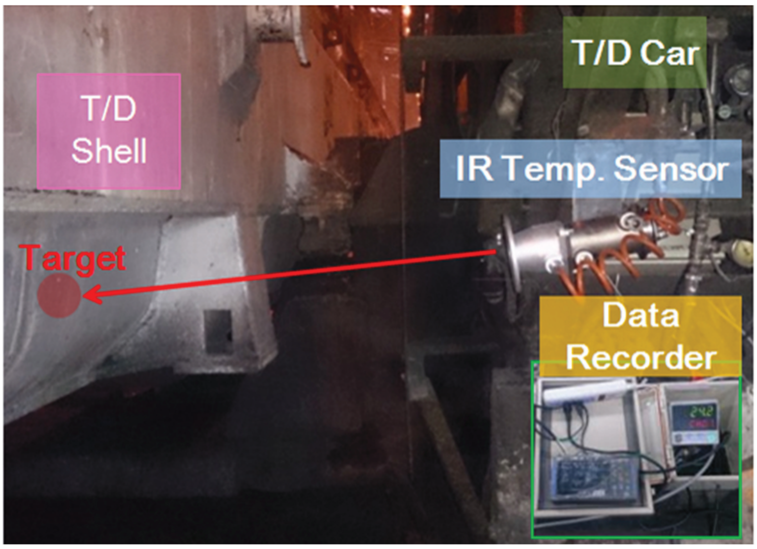

Figure 3 Experiment setup of the monitor system of tundish shell temperature

Figure 4 Thermal image analysis of tundish shell (right) compares with optical photo (left)

3. RESULT AND DISCUSSION

After built up the temperature monitor system, the tundish shell temperature is recorded during preheating and casting process. **Figure 5** shows an example of the temperature profile of tundish shell. From the beginning of tundish preheat process for about 2 hours, it is been noticed that the temperature profile has a horizontal zone at 100 ℃. This indicates the moisture of tundish lining is evaporating at that time. In addition, the sustained period of time of the horizontal zone at 100 ℃ means the total moisture of tundish lining, that would be an index for understanding the maintenance quality of tundish refractory. When all of the moisture is out of tundish, the temperature of tundish shell will increase with preheating time until casting starts. After compared with the amount of hydrogen pickup in tundish process, the result shows that the hydrogen content in steel will decrease with the highest preheat temperature of tundish shell (**Figure 6**). That is, the higher preheat temperature of tundish, the less moisture (hydrogen) diffuse into molten steel. From this research, when the temperature of tundish shell is higher than 120 ℃, the amount of hydrogen pickup in tundish is less than 1.5 ppm. Hence, the highest preheat temperature of tundish shell will be an important index for the control of hydrogen content in steel in tundish process.

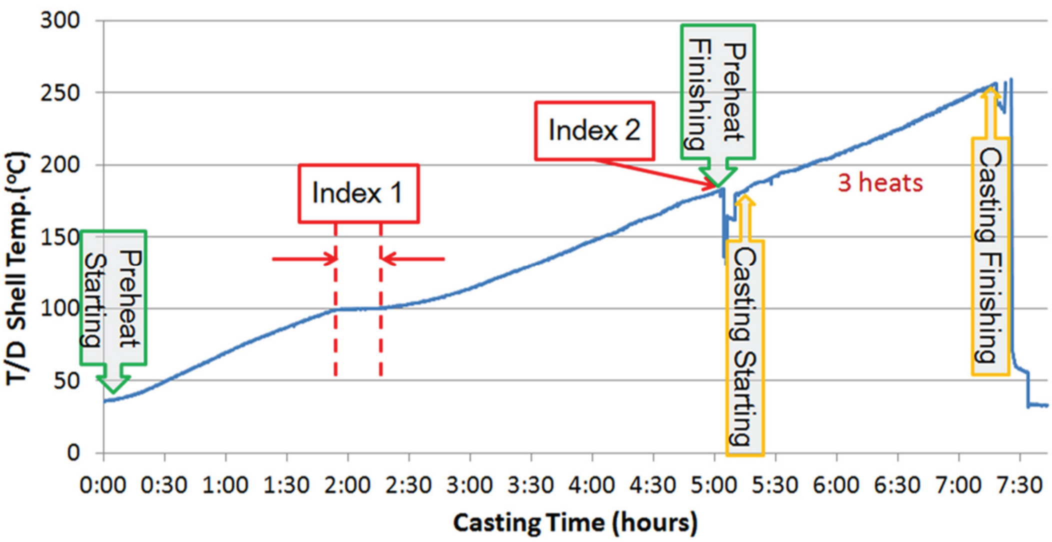

Figure 5 Temperature profile of tundish shell during preheating and casting process

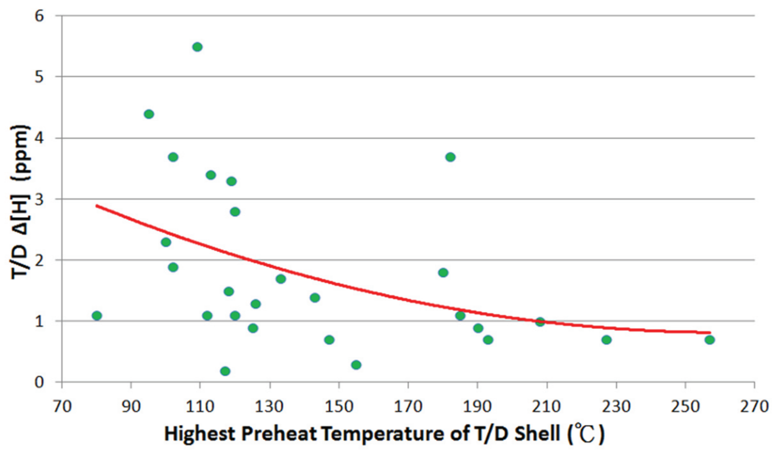

Figure 6 The relationship between highest preheat temperature of tundish shell and the hydrogen pickup in tundish process

4. CONCLUSION

It is well known that the presence of dissolved hydrogen in cast steel can cause defects that appear in steel products and also contributes to the formation of internal cracks and blowholes during the solidification of the liquid steel. These problems are especially important in the continuous casting process. So, hydrogen levels must be kept at a minimum in this process.

A monitoring system of tundish preheat process has been developed for the control of hydrogen content in molten steel at China Steel (CSC). Our study has already proved that most of the moisture comes from tundish lining. Therefore, preheated tundish was used to avoid moisture pick-up from lining at CSC.

An infrared thermometer, with the advantages of non-contact and low-maintenance, has been setup to detect tundish shell temperature in this research. The temperature of tundish shell is recorded during the preheat process. It is been noticed that the temperature profile of the preheated tundish shell has a horizontal zone at 100 ℃. This indicates the moisture of tundish lining is evaporating at that time. After compared with the amount of hydrogen pickup in tundish process, the result shows that the hydrogen content in steel will decrease with the highest preheat temperature of tundish shell. When the temperature of tundish shell is higher than 120 ℃, the amount of hydrogen pickup in tundish is less than 1.5 ppm. In brief, we have built up quality indexes in this study for the references of tundish preheat process to reduce the defects of steel product.

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