Development of Wireless Temperature Monitoring System in Tundish Preheat Process

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A wireless temperature monitoring system for the 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 the tundish lining. Therefore, a preheated tundish was used to avoid moisture pick-up from the lining at CSC. An IR-based temperature sensor has been set up to detect tundish shell temperature for this research. The temperature of the tundish shell was recorded during the preheat process. It had been noticed that the temperature profile of the preheated tundish shell had a horizontal zone of 100℃. This indicated that the moisture in the tundish lining was evaporating at that time. When all of the moisture had evaporated from the tundish, the temperature of the tundish shell increased with preheating time until casting started. The amount of hydrogen pickup in the tundish process was compared, the results showed that the hydrogen content in steel will decrease with the highest preheat temperature of a tundish shell. When the temperature of a tundish shell is higher than 120℃, the amount of hydrogen pickup in a tundish is less than 1.5 ppm. Accordingly, in this study, we have built up a quality index to reference for the tundish preheating process to reduce defects in steel products.

Keywords: Tundish, Preheat, Monitoring, Hydrogen pickup

1. INTRODUCTION

With increasing demands on steel quality, reducing and controlling the amount of dissolved gases in steel becomes 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 that the formation of internal cracks during hot rolling is a consequence of dissolved hydrogen within cast steel(1). More recently, research indicates that certain amounts of hydrogen in the liquid steel contribute to the formation of pinholes and blowholes during steel solidification, which can lead to serious problems, especially in a 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 are often found at the centerline of plates following hard inclusion(1) are as shown in Fig.1. Since the formation of defects depends on the hydrogen content, it is directly related to the steel production process and cooling conditions.

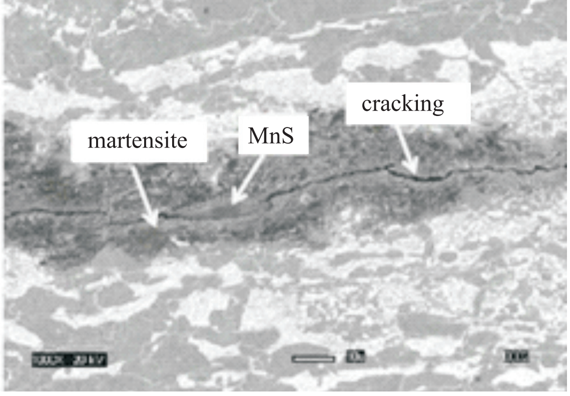

Fig.1. Hydrogen-induced cracking at the centerline of a 20-mm-thickX70 grade linepipe plate. The cracking initiated at the martensite-MnS interface and propagated along the segregated region(1).

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 Ruhrstahl-Heraeus (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 that hydrogen comes from the moisture of tundish linings at China Steel (CSC). For the 3 heats at RH, the hydrogen contents in steel was lower than 2 ppm. However, the hydrogen content increases at the tundish stage, especially in the first heat, and decreases in subsequent heats. It can be concluded that the moisture in the tundish decreases with casting time owing to the higher temperature of the tundish lining. Even though a preheated tundish was used to avoid moisture pick-up from lining at CSC, there is no index for evaluating the moisture in tundish linings during the tundish preheat process. In this work, a wireless monitoring system for the tundish preheat process has been installed at No.1 and No.2 slab caster at CSC.

2. EXPERIMENTAL MEASUREMENT

An IR-based temperature sensor has been set up to detect tundish shell temperature for this research. The temperature of a tundish shell was monitored during the preheat process by an infrared thermometer (CHINO, IR-SAB01N) and its signal was received by a measurement unit (HIOKI, LR-8510). Both of these devices were assemblies on the tundish car and the IR temperature sensor was installed at a distance of 1m from the targeted tundish shell. Figure 3 shows the experimental setup of the monitoring system for tundish shell temperature. Traditionally, the temperature status during a 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,

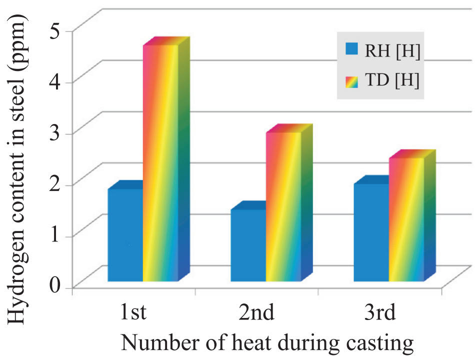

Fig.2. Hydrogen contents in steel in RH and T/D at 3 heats during casting.

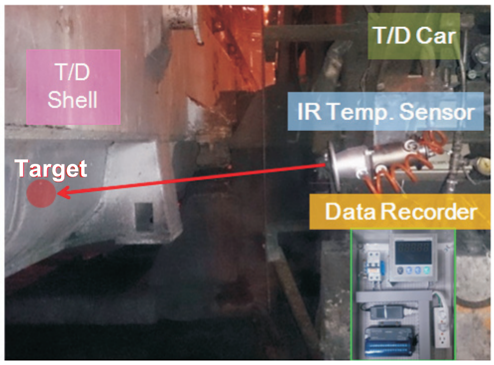

Fig.3. Experiment setup of the monitor system of tundish shell temperature.

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

allows for the surface temperature measurement in hard-to- reach places and in dangerous areas such as the 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 the tundish shell could be monitored both in preheating and during the casting process without interruption.

In addition, the temperature data of a tundish shell transmits from tundish car to control room using Bluetooth technology. The main advantage of the wireless data transmission over that of a cable one is that the tundish car can move around from the standby zone to casting stand without any limitations. Then, a wireless logging station (HIOKI, LR-8410) could continuously receive the temperature data of a tundish shell in the control room. An industrial computer was used to collect the temperature data and also display realtime information of the tundish preheat for the operators reference. Finally, an analog output module (ADAM) converts the digital signal to analog (4~20mA) for the application of Distributed Control System (DCS). As a result, the system could provide a well of understanding in the relationship between casting process data and the quality of steel product. The schematic of the wireless temperature data transfer system from tundish car to control room is as shown in Fig.4.

Meanwhile, in order to check a representative of a measured spot of a tundish shell, a thermal image analysis was applied before temperature measurement (Fig.5). From the result, there are different temperature zones on the tundish shell. Owing to weak thermal convection, the corner zone was found to be in a low temperature range. And it was better to avoid the water-stain zone, which has different surface emissivity, to reduce temperature disturbance. Hence, the most suitable target zone was located in the area higher than the drain holes on the tundish surface.

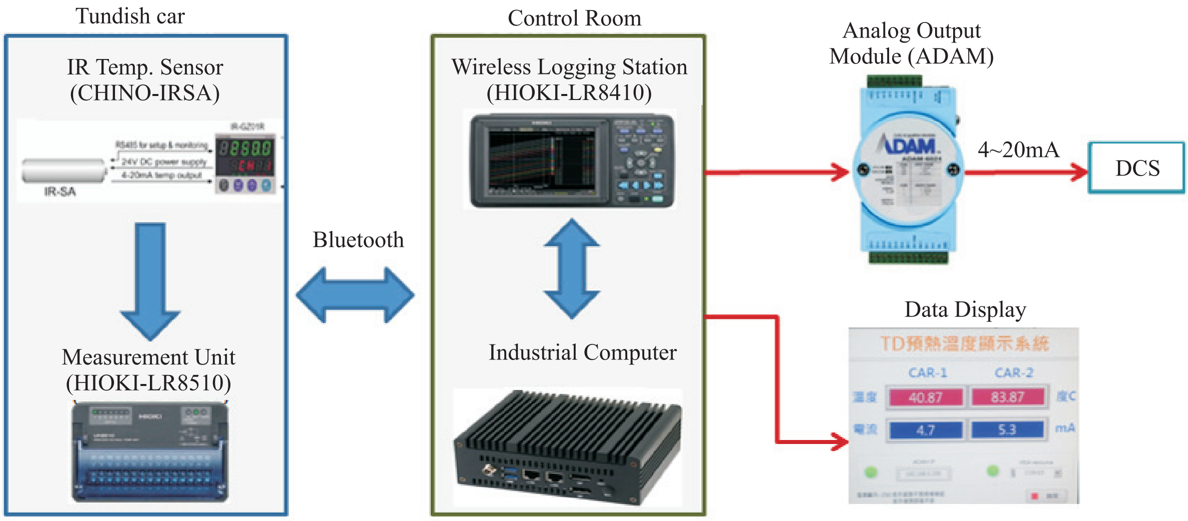

Fig.4. Schematic of wireless temperature data transfer system from tundish car to control room.

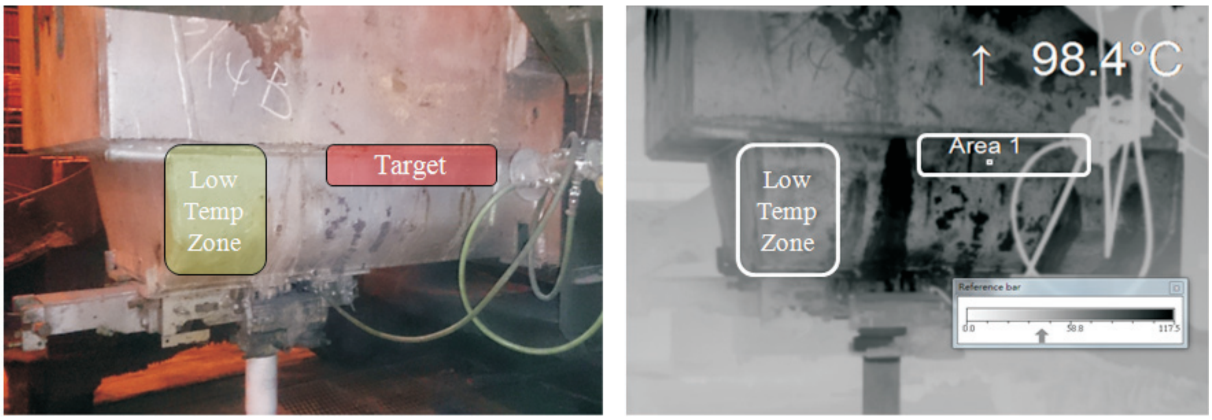

Fig.5. Thermal image analysis of tundish shell (right) compares with optical photo (left).

3. RESULT AND DISCUSSION

After the temperature monitor system installation at No.1 and No.2 slab caster, the tundish shell temperature was recorded during the preheating and casting process. Figure 6 shows an example of the temperature profile of the tundish shell. From the beginning of the tundish preheat process and continuing for about 2 hours, it was noticed that the temperature profile had a horizontal zone of 100℃. This indicated that the moisture of the tundish lining was evaporating at that time. In addition, the sustained period of time of the horizontal zone at 100℃ equates to the total moisture of the tundish lining, which is an index for understanding the maintenance quality of the tundish refractory. When all of the moisture had evaporated from the tundish, the temperature of the tundish shell increased with preheating time until casting started. When compared with the amount of hydrogen pickup in the tundish process, the result showed that the hydrogen content in steel decreased with the highest preheat temperature of the tundish shell (Fig.7). That is, the higher the preheat temperature of the tundish, the less moisture (hydrogen) diffuses into the molten steel. From this research, when the temperature of the tundish shell is higher than 120℃, the amount of hydrogen pickup from the tundish is less than 1.5 ppm. Hence, the highest preheat temperature of the tundish shell will be an important index for the control of hydrogen content in steel in the tundish process.

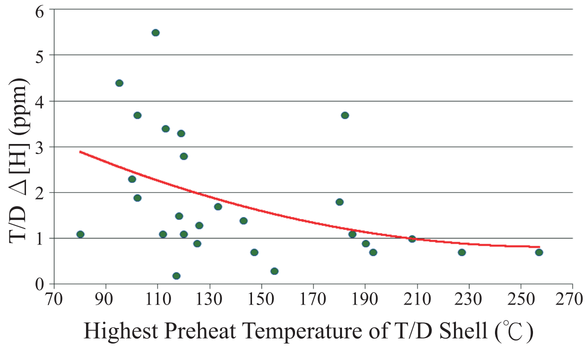

Fig.7. The relationship between highest preheat temperature of tundish shell and the hydrogen pickup in tundish process.

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 wireless temperature monitoring system for the tundish preheat process has been developed for the control of hydrogen content in molten steel in No.1 and No.2 slab caster CSC. Our study has already proved that most of the moisture comes from the tundish lining.

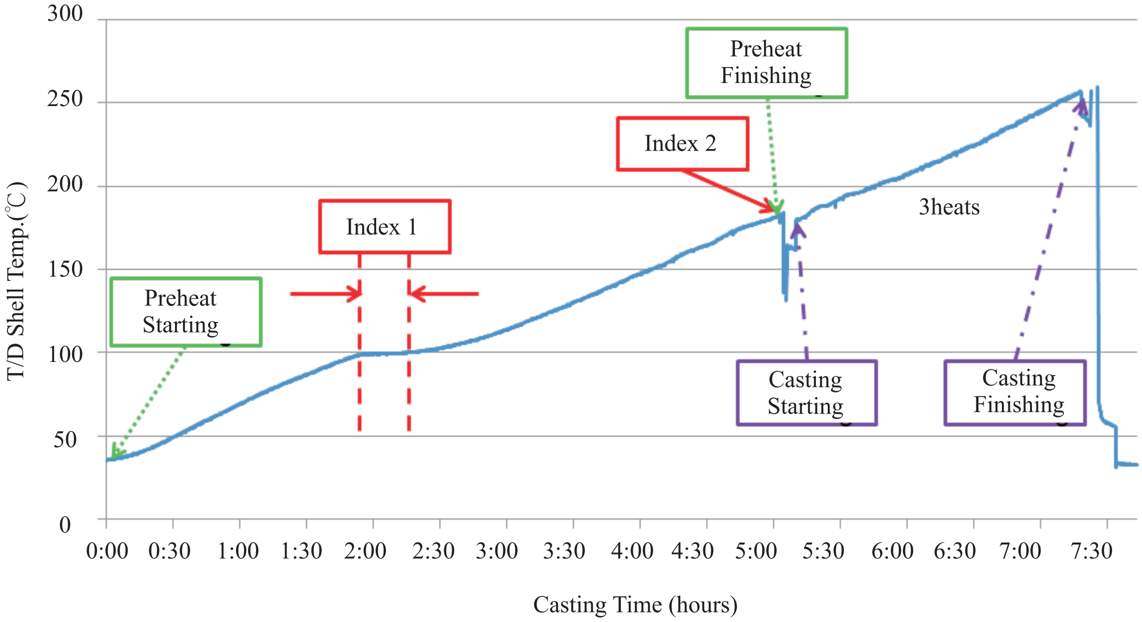

Fig.6. Temperature profile of tundish shell during preheating and casting process.

Therefore, a preheated tundish was used to avoid moisture pick-up from the lining at CSC.

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

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