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Sideways Tuyere Probe for Measuring Blast Furnace Raceway Zone*

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1 Introduction

Since the existence of the cohesive zone and its role in blast-furnace operation were clarified by a series of investigations into the dissected blast furnace, a number of measuring devices, such as the throat probe and shaft probe, have been adopted as means of controlling the shape of the cohesive zone.[1,2] However, most sensors used to monitor interior conditions in operating blast furnaces measure the lumpy zone. Except for sensors used in the interior of the raceway, no reports have appeared regarding the development of measuring devices for the dripping zone in the lower part of the furnace.[3-5]

In recent low silicon-content operation, it is considered important to control the flows, chemical compositions, and temperature distributions of the gas and molten materials in dripping zone and in the vicinity of raceway, in order to achieve a decrease in the silicon content of the hot metal. A tuyere probe was developed to monitor the raceway zone and the gas composition inside the raceway was measured. The measurement zone of most conventional tuyere probes is limited to the interior of the raceway, and measurement items are limited to the sampling of the gas and dust. Therefore, Kawasaki Steel developed a probe, called the "sideways tuyere probe," capable of measuring the raceway zone, deadman zone, and the zone between two raceways during furnace operation. The features of the sideways tuyere probe are explained in comparison with conventional probes in this report. As examples of measurements using the new probe, the silicon distribution in the hot metal near the blast furnace raceway and the combustion behavior of pulverized coal in the commercial furnace are described.

2 Features of Sideways Tuyere Probe

In conventional practice, a water-cooled probe is inserted into the furnace through the blow pipe and tuyere, which are passages for the hot blast. This method poses a problem, however, as the blast volume and blast temperature are reduced during measurement, disturbing the temperature, gas flow, and reaction in the raceway.

As a feature of the sideways tuyere probe installed at Chiba No. 5 blast furnace, the probe is not passed through the hot blast passage, but rather is directly inserted into the raceway zone. The probe was installed at the No. 25 tuyere of Chiba No. 5 blast furnace, and measured the adjacent No. 24 tuyere raceway. As shown in **Fig. 1**, a blow pipe with a branch pipe is installed in the No. 25 tuyere. The probe is inserted into the furnace through this branch pipe at an oblique angle to the tuyere axis of the No. 25 tuyere. Because of the manner of insertion, the shape of the No. 25 tuyere was also

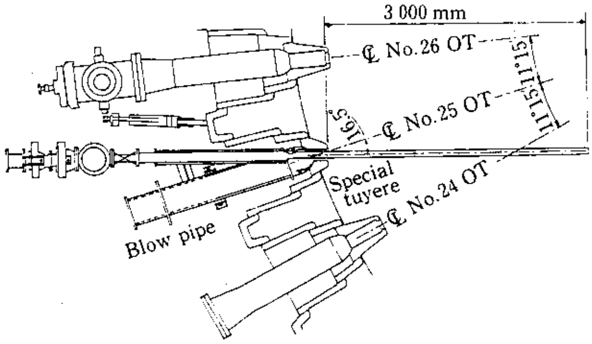

Fig. 1 Location of sideways tuyere probe

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Table 1 Specifications of the probe

Item	Specification
Equipment	
Stroke	3 m from tuyere
Drive system	Chain drive with hydraulic motor
Probe	Water cooled
Measurement	· Sampling of gas, dust and molten materials · Temperature measurement with optical fiber · Observation with image fiber

changed. The unique construction of the sideways tuyere probe offers several advantages: The measuring operation does not disturb the phenomena in the raceway zone, and the zone between the two raceways and that between the raceway and the furnace wall can be measured, operations not possible with conventional probes.

Since measurement must be made under extremely severe conditions in terms of temperature and heat load in and around the raceway, the probe was designed in consideration of following points:

(1) Use of pressurized cooling water for the tuyere was adopted to ensure adequate cooling capacity against high temperature and high heat load.

(2) A duplex seal was provided to ensure safety against accidents such as leakage of furnace gas in the event of probe burn out.

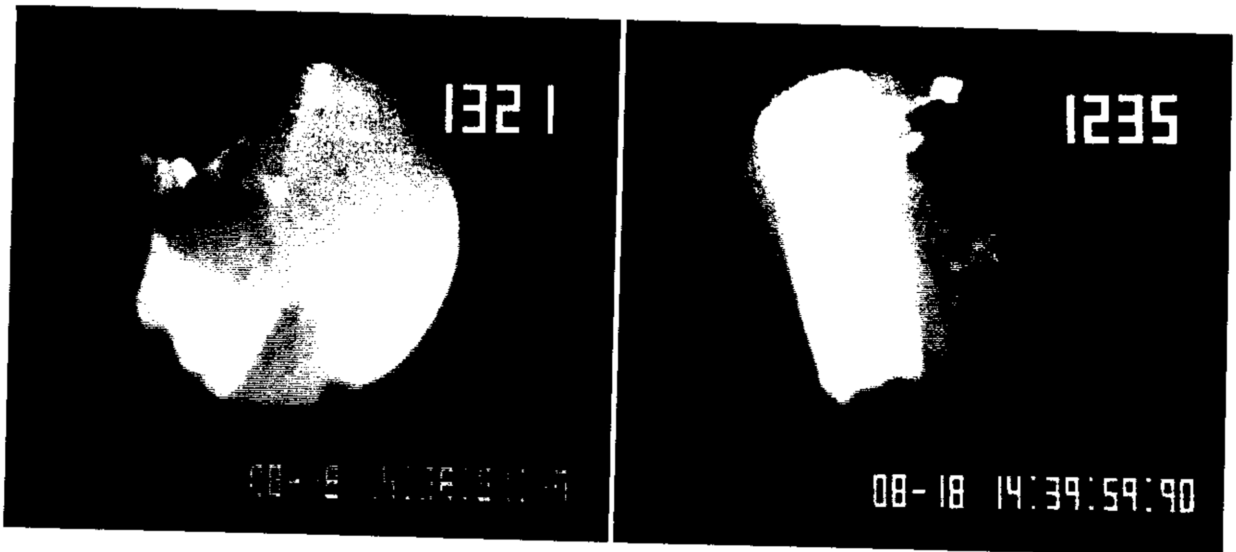
Major specifications of the sideways tuyere probe are shown in **Table 1**. The drive system is of a hydraulic-motor-and-chain type and permits stepless speed control. The measurement range is 3.0 m from the tip of the No. 25 tuyere into the furnace, making possible measurement from beyond the raceway zone up to the deadman zone.

In addition to the normal measurement items, which include the sampling of furnace gas and dust, several other functions are provided, such as the sampling of molten materials, and measurement of the temperature and observation of the interior of the furnace. Use of a two-color optical fiber pyrometer avoids the effect of in-furnace burden emissivity changes on temperature measurement. The quartz-based image fiber (30 000 pixels) also makes it possible to record, observe, and analyze the behavior of coke and molten materials in the furnace by use of a TV camera.

3 Measurement Results

3.1 Results of Inside-Furnace Observation by an Image Fiber

Direct observation of the interior of an operating blast furnace gives indispensable information for interpreting numerical data such as gas and hot metal compositions and generally for better understanding the phenomena inside the furnace. The results of the in-furnace observation by an image fiber were recorded by video recorder, and typical examples, as shown in **Photo 1**, were photographed. Photo 1 (a) shows the results of in-furnace observation at the position where the circulation of coke around the raceway has stopped. Several coke particles were observed within the total angle of view of 35°. Coke particles in front of the probe are cooled by the purge gas and become black, while coke in the interior is very hot and glowing white. Photo 1 (b) shows the results of observation at a position where molten materials are flowing. The molten materials flow



(a) Coke particles around the raceway (b) Flow of molten materials

Photo 1 Observation of coke particles and molten materials in the furnace by use of an image fiber

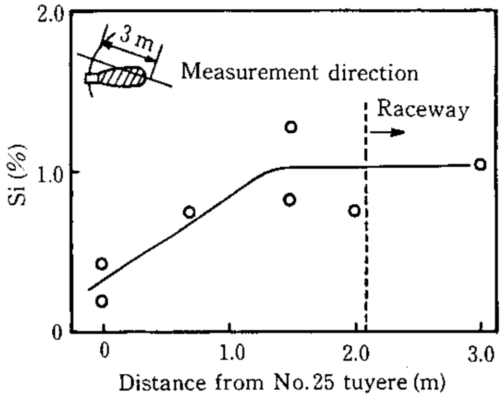


Fig. 2 Silicon content distribution around the raceway

in large quantity locally at the outside of the coke circulation zone. The figure on the right above of the photo indicates the temperature in the furnace as measured by the two-color optical fiber pyrometer.

3.2 Hot Metal Compositions near the Raceway Zone

Figure 2 shows the distribution of silicon content in the measurement direction and the raceway zone, calculated on the basis of gas composition at the time of measurement. Silicon content near the furnace wall at a distance from the raceway shows a value nearly equal to the tapped value, but silicon content near the raceway shows a value of 1 to 2%, which is very much greater than the tapped silicon value of 0.35%. These hot metal composition distributions are indispensable data for clarifying the silicon transfer mechanism in the furnace and for establishing low-silicon-content operation techniques.

4 Examination of Combustibility of Pulverized Coal by Sideways Tuyere Probe

Because the pulverized coal has low combustibility compared with the oil used in oil injection, it is important to clarify the combustion characteristics of pulverized coal in the raceway region of the blast furnace. The combustion conditions of pulverized coal were examined by use of the sideways tuyere probe. The formation of unburned pulverized coal will be discussed in relation to the injection rate, specification of coal, and blast temperature with conclusions based on the chemicial composition of the dust samples obtained in and around raceway.

Figure 3 shows changes in carbon content in dust with the injection rate. Carbon content increases at a pulverized coal injection rate of 60 kg/t or above, indicating a marked presence of unburned products.

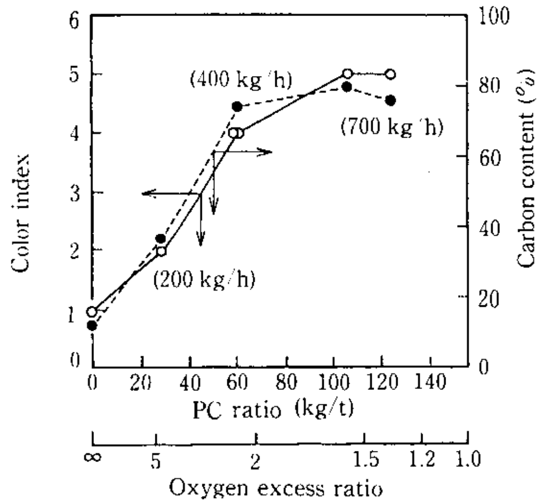


Fig. 3 Effect of oxygen excess ratio on combustion condition of pulverized coal in the raceway

5 Concluding Remarks

The authors developed a sideways tuyere probe effective in clarifying in-furnace conditions by the sampling of gas, dust, hot metal, and slag and by in-furnace observation in the vicinity of the raceway and the deadman zone of an operating commercial blast furnace.

From the results of measurement by this sideways tuyere probe, it is clear that the probe can contribute to the development of furnace operation in the following ways:

(1) The clarification of phenomena in the raceway zone and dead zone, such as the chemical composition of hot metal, slag, gas, and dust in the furnace, and the establishment of deadman zone activation techniques and low silicon-content techniques based on the above-mentioned knowledge.

(2) The examination of the combustibility of pulverized coal under commercial furnace conditions and the establishment of economical pulverized coal injection conditions.

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