Technology

Shaft Preheating System for Blast Furnace

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1. Introduction

The Japanese government has declared its goal of carbon neutrality by 2050, and all industries are required to reduce CO_2 emissions. In the fiscal year 2020, the Japanese steel industry as a whole emitted 130 million tons of CO_2, accounting for 13% of Japan's total CO_2 emissions. In particular, the blast furnace method, which is the mainstay of steel production, accounts for the majority of CO_2 emissions, and thus there is an urgent need to reduce its CO_2 emissions.

In terms of the blast furnace method, the oxygen blast furnace [1)], which is highly efficient and can be operated in various ways regarding raw materials and fuels, has been studied for the purpose of improving productivity and reducing CO_2 emissions. Oxygen blast furnaces are operated by blowing pure oxygen into the tuyeres, and have the advantage of higher combustion efficiency at the tuyeres than conventional blast furnaces in which hot air is blown. This makes it possible to increase the amount of pulverized coal, natural gas, etc. blown in to lower the coke ratio, thereby reducing CO_2 emissions. In addition, by using pure oxygen, the CO_2 concentration in the flue gas is higher than in ordinary blast furnaces because nitrogen is not included in the blowing gas, which facilitates CO_2 separation and recovery.

On the other hand, the amount of gas flowing through the furnace is reduced, resulting in a heat shortage in the blast furnace shaft section. This lack of heat causes the temperature of the raw ore to drop, which delays the reduction process. To compensate for the lack of heat in the shaft section, technology to preheat the blast furnace gas and blow it into the shaft section has been studied both in Japan and abroad, including the ULCOS project [2)] in Europe.

We have developed a high-temperature gas generator that preheats blast furnace gas using the oxygen combustion technology we have cultivated over the years.

2. Overview of shaft preheating system

Figure 1 shows the structure and appearance of the shaft preheating system. This system consists of an oxygen burner and a preheating furnace, and generates high-temperature gas by mixing the high-temperature combustion gas obtained by burning fuel gas (blast furnace gas, coke oven gas, natural gas, etc.) with oxygen by the oxygen burner, with primary diluted blast furnace gas and secondary diluted blast furnace gas in the preheating furnace. Oxygen contained in the high-temperature gas blown into the blast furnace shaft section

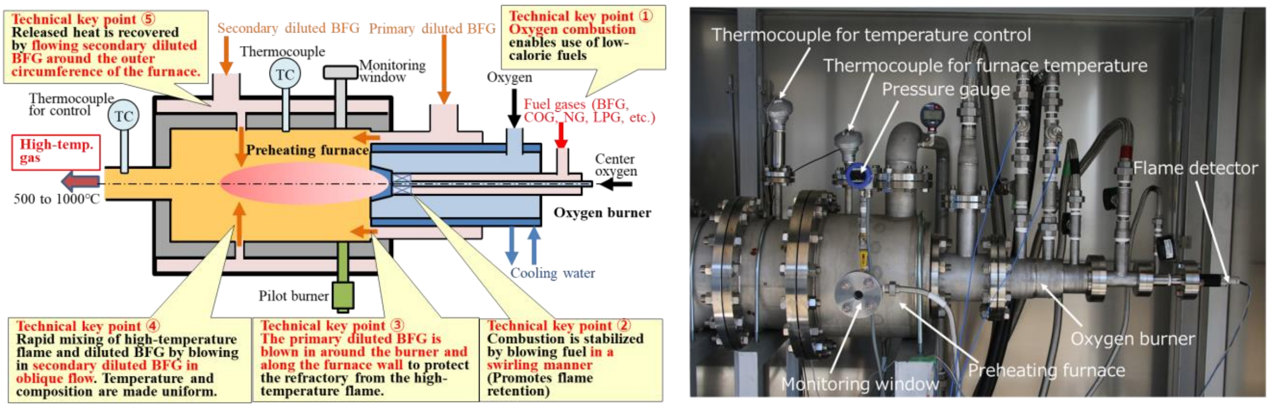

Figure 1　Configuration and appearance of shaft preheating system

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leads to coke depletion, so the high-temperature gas is required to have an extremely low concentration of oxygen. In this system, the oxygen concentration can be kept below 0.1% by rapid combustion using an oxygen burner.

The outer circumference of the preheating furnace is equipped with a heat exchange section to recover heat released from the furnace body, and the secondary diluted blast furnace gas is preheated there and then blown into the preheating furnace. Therefore, the heat loss from the furnace to air is low and high-temperature gas can be generated efficiently. The oxygen burner has high flame retention and can use fuels with low calorific value. In addition, general fuels such as natural gas and LPG can be used, making it possible to accommodate a wide range of fuel types.

This system is equipped with a thermocouple for temperature control at the outlet of the preheating furnace, and the temperature can be automatically adjusted by changing the combustion volume of the oxygen burner.

3. Performance evaluation of shaft preheating system

We evaluated the stable combustion range of the developed shaft preheating system (with a high-temperature gas generation rate of 250 Nm^3/h and high-temperature gas temperature of 800°C) by changing the heating value and hydrogen concentration of the fuel gas. For this evaluation, stable combustion was defined as no temperature fluctuation and a residual oxygen concentration of 0.1% or less in the gas at the outlet of the preheating furnace.

Figure 2 and Figure 3 show the evaluation results for pressures of 0.15 MPa and 0.30 MPa, respectively. As a result, this system provided stable combustion up to a calorific value of 3.8 MJ/Nm3 at a pressure of 0.15 MPa in the absence of hydrogen in the fuel. As the concentration of hydrogen, which burns at a high rate, was increased, stable combustion was observed even with fuels of lower calorific value. When the pressure was increased to 0.30 MPa, the stable combustion range was extended to the lower heating value side.

It was confirmed from the results of this evaluation test that stable combustion occurred under the blast furnace gas conditions of the oxygen blast furnace and the normal blast furnace shown in the figures.

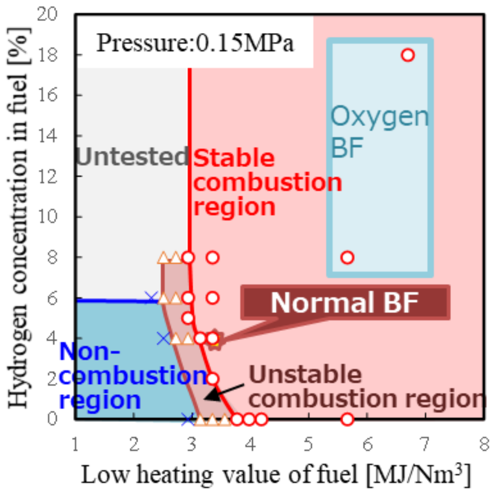


Figure 2 Stable combustion region at pressure 0.15 MPa

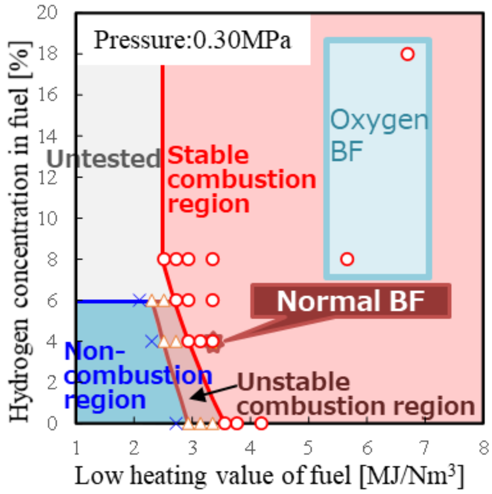
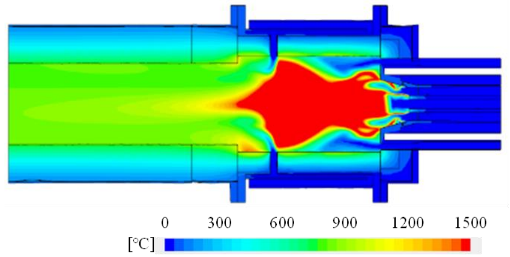


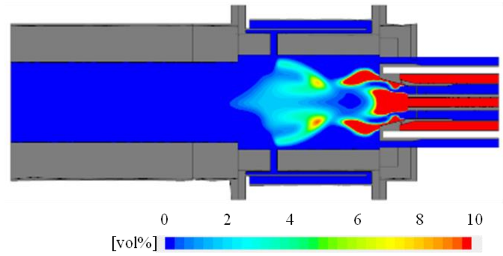
Figure 3 Stable combustion region at pressure 0.30 MPa

4. Design by CFD analysis

We built CFD analysis models based on the data obtained from the test equipment and developed design techniques for shaft preheating system of various scales.Figure 4 shows the result of a CFD analysis with a rate of 12500 Nm^3/h. It can be observed from this result that the residual oxygen is low at the outlet of the system at a uniform temperature, indicating that the structure of the burner and preheating furnace has been optimized.



(a)Temperature distribution



(b)Oxygen concentration distribution

Figure 4 CFD analysis results
(high-temperature gas 12500 Nm^3/h)

5. Conclusion

The developed shaft preheating system can use fuels with a wide range of heating values and hydrogen concentrations, and the temperature and flow rate of the high-temperature gas can be adjusted as desired. By using this system, it is possible to adjust the shaft temperature according to the operating conditions of the blast furnace. In the future, we will contribute to the reduction of CO_2 emissions by applying this system to innovative blast furnaces such as oxygen blast furnaces, which require shaft preheating.

References

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2) Jun Zhao, Haibin Zuo, et al. Review of green and low-carbon ironmaking technology. Ironmaking & Steelmaking, 2020, 47, p296-306