Technology

Preheating Technology of Reducing Gases for Blast Furnace Shaft

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1. Background

1.1 CO_2 emissions from domestic steel industry

Japan's carbon dioxide (CO_2) emissions were approximately 1.04 billion tons in FY2022, and the steel industry's CO_2 emissions were approximately 130 million tons, accounting for 12% of the total amount [1]. In particular, the blast furnace steelmaking process produces large amounts of CO_2 emissions, and technologies to reduce these emissions are strongly needed.

1.2 R&D trend

In the domestic steel industry, research and development for reducing CO_2 emissions is ongoing as a national project [2]. In particular, in order to reduce CO_2 emissions from blast furnaces, technological development is underway to reduce iron ore and produce pig iron by supplying reducing gases such as hydrogen gas (H_2) from the shaft of the blast furnace [3]. In the current blast furnace ironmaking process, the maximum amount of pulverized coal that can be supplied is already blown into the blast furnace through the blast furnace tuyere. If additional reducing gas is supplied through the blast furnace tuyere, the temperature distribution near the tuyere will change, making efficient blast furnace operation difficult. Therefore, to supply reducing gas additionally, it is necessary to supply it from the shaft of the blast furnace, where the temperature is generally lower. However, since the reduction of iron ore by H_2 is an endothermic reaction, there is a high possibility that the shaft of the blast furnace will be underheated when H_2 or other reducing gases are supplied through there, so technology to preheat the reducing gas before supplying it is required. This paper explains a technology to preheat the reducing gas (hydrogen-containing gas) to be supplied from the shaft of the blast furnace by utilizing oxygen combustion technology.

2. Explanataion of the Technology

2.1 Overview of reducing gas preheating equipment

Figure 1 shows an overview of the preheating technology for reducing gas using oxygen combustion. This technology consists of a reforming section that reforms coke oven gas (COG) by oxygen combustion to generate reformed gas, and a mixing section that mixes the reformed gas with blast furnace gas (BFG) after CO_2 separation, and is able to obtain high-temperature reducing gas from the outlet of the mixing section. This high-temperature reducing gas is blown into the shaft section of the blast furnace, and the reduction reaction with iron ore proceeds, enabling the reduction of carbon such as coke. We constructed a reforming section with a maximum high-temperature reducing gas flow rate at its outlet of 250 Nm^3/h at our Yamanashi Technology Solution Center as shown in Figure 2, and conducted a demonstration test of this technology.

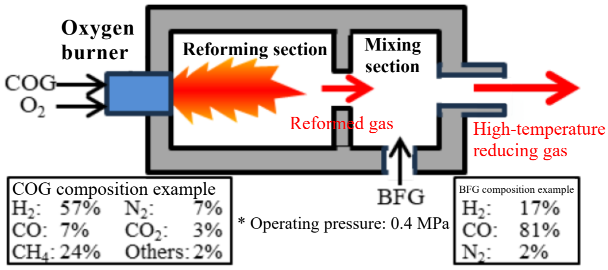

Figure 1　Technological overview

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FIgure 2 Reforming section demonstration furnace

In order for the iron ore reduction reaction to proceed at the shaft of the blast furnace, it is expected that the temperature of the high-temperature reducing gas needs to be 800°C or higher and both the $CO/(CO+CO_2)$ ratio and $H_2/(H_2+H_2O)$ ratio in the high-temperature reducing gas need to be 0.66 or higher [4)], and we set the target values for this technology to those values.

2.2 Demonstration test

Table 1 shows the test conditions. As a substitute for COG, a mixture of natural gas and nitrogen were used. The oxygen ratio was the ratio of the actual oxygen flow rate to the required oxygen flow rate for complete combustion of the fuel, and was set to 0.37-0.51 to partially combust natural gas to generate high-temperature reformed gas.

Table 1 Test conditions

Natural gas flow rate	[Nm^3/h]	16.4-36.3
Oxygen ratio	[-]	0.37-0.51
Fuel preheat temperature	[°C]	430
Oxygen preheat temperature	[°C]	500
Operating pressure	[MPa]	0.4

Figure 3 shows the relationship of H_2 and CO concentrations in the reformed gas with respect to the oxygen ratio, and Figure 4 shows the relationship of the reformed gas temperature with respect to the oxygen ratio. Under natural gas flow rates of 16.4 to 36.3 Nm^3/h, the H_2 and CO concentrations and the temperature of the reformed gas showed the same trend with respect to the oxygen ratio. It was found in this reforming furnace that the amount of reformed gas generation can be controlled by controlling the flow rates of fuel and oxygen.

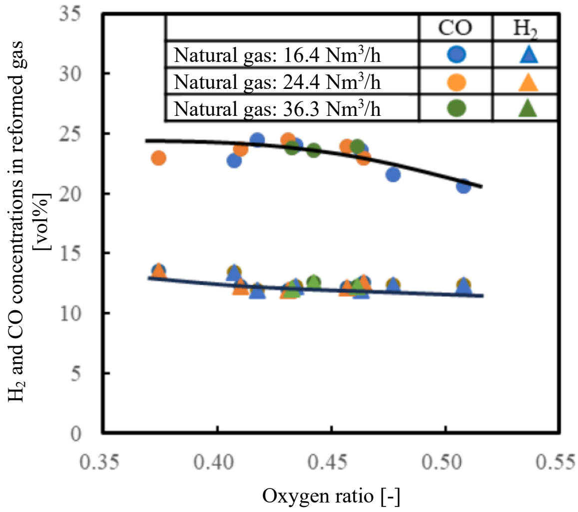

Figure 3 Relationship of H_2 and CO concentrations in reformed gas with respect to oxygen ratio

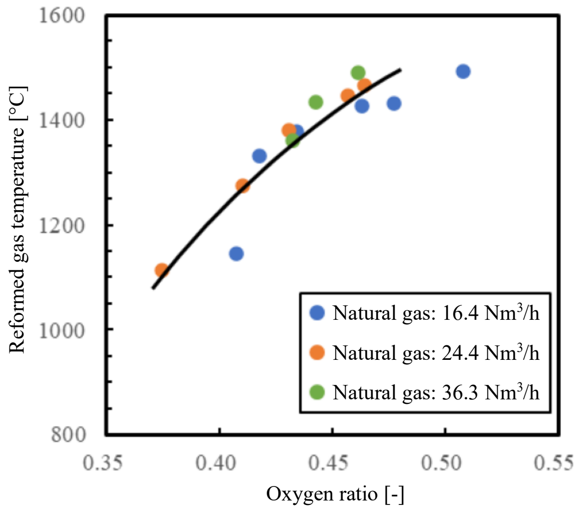

Figure 4 Relationship of reformed gas temperature with respect to oxygen ratio

Based on the data of the reformed gas generated under the test conditions of 16.4 Nm^3/h natural gas flow rate and 0.46 oxygen ratio, the $CO/(CO+CO_2)$ ratio and $H_2/(H_2+H_2O)$ ratio were calculated for the case where the reformed gas was diluted by blast furnace gas BFG in the mixing section to produce high temperature reducing gas at 800°C. The resulted ratios were 0.97 and 0.88, respectively, which are higher than the target value of this technology (0.66). These results indicate that iron ore can be reduced by the reformed gas produced in this reforming section demonstration furnace and verify the feasibility of the reducing gas preheating technology using oxygen combustion.

3. Conclusion

This paper presented a reducing gas preheating technology using oxygen combustion technology for heat compensation of the shaft of a blast furnace. Compared to electric heating, which is one of the competing technologies, the reducing gas preheating technology using oxygen combustion technology has advantages in that the system can be compact and fuel can be used as the heating source.

In the future, the demonstration of the entire system, including the mixing section, is planned. We will continue developing technologies using oxygen combustion technology for the steel industry and to contribute to the reduction of CO_2 emissions from the steel industry.

Reference

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