



Exergy recovery from steelmaking off-gas by latent heat storage for methanol production

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Abstract

This paper proposes a new thermal energy recovery process of hot gas exhausted from the steelmaking converter by utilizing not only latent heat but also endothermic heat of reaction. The intermittently emitted LD gas was first transferred into continuous, constant-temperature heat source in the form of latent heat in the Phase Change Material (PCM) of copper. Then, the stored heat was supplied to Coke Oven Gas (COG) to induce endothermic reaction of steam reforming of methane. Methanol was finally produced from the obtained gas in the proposed system. A heat and material balance model predicted all operating data of the system and then exergy analysis based on the predicted data was conducted to validate the system theoretically. The results showed that the proposed system has a possibility to produce a large amount of methanol corresponding to 20% of total demand in Japan, with only 28% of exergy consumption in the conventional method.

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1. Introduction

The Japanese steelmaking industry consumes as much as 11% of total primary energy, and then releases 5% in the form of waste heat. Although many equipments for energy saving have been introduced after two oil crises, the waste of high temperature such as blast furnace (BF) slag and LD converter slag still remains unused. Thus, authors have reported several papers [1–9] to save energy and to decrease carbon dioxide emissions. In the steelmaking process the converter has also released high temperature waste gas (LDG) over 1873 K (1600 °C), as a result of oxygen blowing into the converter.

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Nomenclature

$C_{\text{COG,IN}}$	composition of COG at inlet [-]
$C_{\text{COG,OUT}}$	composition of COG at outlet [-]
C_{LDG}	composition of LDG [-]
$C_{\text{P,AV}}$	average specific heat [$\text{JK}^{-1}\text{mol}^{-1}$]
f_{CH_4}	content of CH_4 [$\text{CH}_4\text{-mol/mol}$]
ΔH	latent heat ($i=1$ per unit mol [kJ/mol], $i=2$ per unit kg [kJ/kg], $i=3$ per unit volume [kJ/m^3], $i=4$ per unit yen [kJ/yen])
k	thermal conductivity [W/m K]
M	molecular weight [g/mol]
Q_{g}	sensible heat of COG from $T_{\text{COG,IN}}$ to T_{mp} [kJ/mol]
Q_{IN}	inflowing sensible heat of LDG [kJ/thm]
Q_{L}	latent heat of PCM [kJ/kg]
Q_{OUT}	outflowing sensible heat of LDG [kJ/thm]
Q_{R}	heat of reaction [$\text{kJ/CH}_4\text{-mol}$]
ΔQ	recovered LDG sensible heat [kJ/thm]
$T_{\text{LDG,IN}}$	temperature of inflowing LDG to the recovering process [K]
t_{B}	blowing time [s]
t_{NB}	non-blowing time [s]
$T_{\text{COG,IN}}$	temperature of inflowing COG [K]
$T_{\text{COG,OUT}}$	temperature of out flowing COG [K]
T_{MP}	melting point of PCM [K]
$T_{\text{LDG,IN}}$	temperature of inflowing LDG to the recovering process [K]
$T_{\text{LDG,OUT}}$	temperature of out flowing LDG to the recovering process [K]
ΔT	temperature drop [K]
ΔT_{MAX}	maximum of temperature drop [K]
$V_{\text{COG,IN}}$	flow rate of COG at inlet [mol/s]
$V_{\text{COG,OUT}}$	flow rate of reformed COG at outlet [mol/s]
V_{LDG}	flow rate of LDG [Nm^3/thm]
V_{H_2}	hydrogen generated [$\text{Nm}^3/\text{charge}$]
W_{PCM}	weight of PCM [ton]
α	increment of flow rate [-]

Most of its sensible heat becomes waste in spite of its large potential [6]. This is mainly because the temperature of LDG is too high to recover it efficiently by conventional technologies and the emission is intermittent, not constant, due to unsteady operation: that is, charging of hot iron, oxygen blowing for de-carbonization and discharging of steel. In addition, the incomplete sealing system of the converter by skirts makes direct heat recovery of LDG more difficult. The existing Off-Gas (OG) boiler may be effective for recovering the lower temperature part of LDG, however, it does not recover the higher one elementally [6]. Therefore, a new technology is needed to utilize LDG heat over 1273 K (1000 °C) in temperature.

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