The 6th International Symposium on East Asian Resources Recycling Technology
October 23 - 25, 2001, Gyeongju (慶州), Korea
ISBN: 89-952527-0-7 93530

Injection of Waste Plastics into the Blast Furnace and Its Effect on Furnace Conditions

Nam-Hwan Heo[1], Chan-Yeong Baek , Chang-Hee Yim
[1]Pohang Iron & Steel Co., Ltd., Korea

Most of the waste plastics are incinerated and landfilled now, leading to much environmental problems. The technology of injection into the blast furnace was developed as a useful recycling method of waste plastics, and applied to the actual operation in several ironmaking companies. We carried out the test operation to inject continuously the two kinds of waste plastics through four tuyeres of the Foundry blast furnace in POSCO by 130 ton of total amount. From this test operation, we analyzed the coke replacement ratio, the permeability, the heat load and other changes of furnace conditions with the injection of waste plastics into the blast furnace. Some trials based upon the theoretical approaches were applied to examine the efficiencies of blast furnace.

Keywords : Waste plastic, replacement ratio, shaft efficiency, blast furnace

Introduction

There are many intensive efforts to develop the recycling technologies of waste plastics in steel works to tackle the saving of resources and the protection of the natural environment. Injection of the waste plastic into blast furnace is one of the most applied technologies. POSCO carried out the semi-consecutive test operation of through one tuyere in 1997[1]. In this study, we modified the injection facilities to operate continuously and tried to analyze the quantitative effects of waste plastic injection into the blast furnace through the test operations. We focused on the replacement ratio, the permeability in the furnace, the heat load in the lower part and the gas utilization and the shaft efficiency change with the injection of waste plastics.

Outlines of the test operation

We chose the four tuyeres among twenty tuyeres of the Foundry blast furnace for the test operations. The test operation was continued for 7 days and the waste PBT (Polybuthylene Terephthalate) and PE(Polyethylene) were used for the injection materials as specified in Table 1.

Table 1. Specifications of plastics for test operation.

Materials	Size	Density	Moisture
PBT, PE	≤ 6mm ϕ	≥ 3.5 g/cm^3	≤ 0.5 %

The injection rate of waste plastics was 6.1~32.8 t-plastic/day (2.5~13.8 kg-plastic/thm). The productivity of blast furnace was 2356~ 2413 thm/day, blast volume, enriched oxygen and blast temperature maintained 1856 Nm^3/min, 2000 Nm^3/hr and 1060℃ respectively during the test operation.

Fig.1. shows the schematic flow of the injection system. This system consists of a silo and three hoppers. The inner volumes of silo, storage hopper, loading hopper and feed hopper are 50, 1.2, 0.9 and 0.9 m^3 respectively. The utility air with 6 kg/cm^2 of pressure was used for the pneumatic conveying and the system controlling.

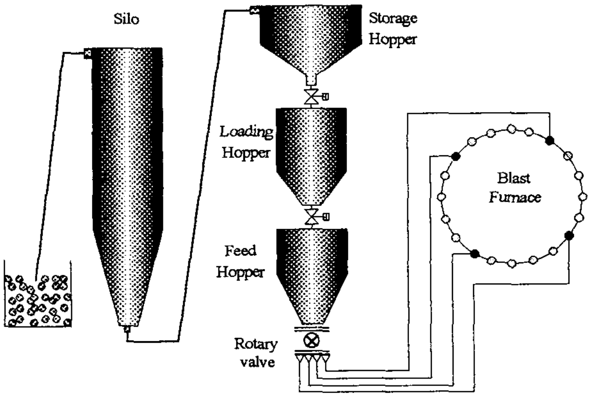


Fig.1. Schematic configuration of test facility.

Results of test operation

The apparent coke rate decreased up to 13.6 kg/thm with the waste plastic injection. We estimated the corrected coke rate taken the several operating indices such as the blast temperature, the silicon content in molten iron, the slag ratio into account. The replacement ratio turned out to be 0.98 kg-coke/kg-plastic with the waste plastic injection up to 13.8 kg/thm of the injection rate as shown in Fig.2. The replacement ratio of this study was low comparing with that of the previous work[1] from one-tuyere test using the waste PE as the injection material. From this result, it could be inferred that the calorific value of PBT, the majority amount of injecting materials in this study, was lower than that of PE. However, there were no significant changes in the replacement ratio when we altered the injecting materials from PBT to PE with the high calorific value under the injection rate of 12.2 and 13.8 kg/thm.

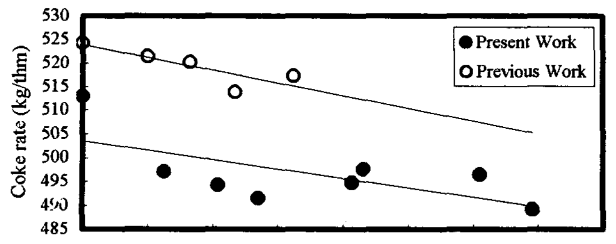


Fig.2. Relationship between the plastic injection rate and the corrected coke rate.

From the definition of the gas permeability index in the blast furnace (K-value), the K-value was increased with increasing the pressure differences between the tuyere and the furnace-top.

$$K = \frac{(PB + 1033)^2 - (PT + 1033)^2}{VBG^{1.7}}$$

where, PB, PT and VBG represent the blast pressure (g/cm^2), the furnace-top pressure (g/cm^2) and the bosh gas volume (Nm^3/min) respectively.

The injection of the waste plastics through tuyeres led to change the characteristics of combustion zone and finally the K-value. The coke properties, one of the prevailing factors affecting the K-value, had been changed during the test operation. The changes of permeability indices with the plastic injection rate can be shown in Fig.3, divided into two periods according to the properties of charging coke.

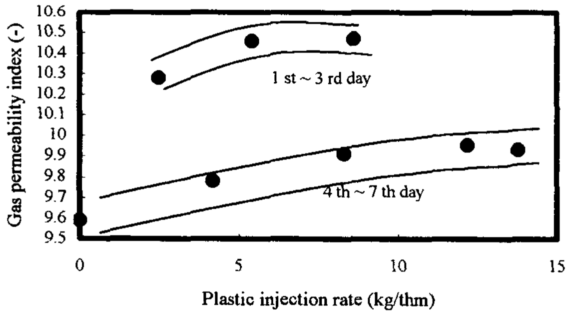


Fig.3. Changes of gas permeability indices with plastic injection rate.

The gas permeability indices increased remarkably in the first three days of the test operation because the properties of charged coke were very poor at that time. For example, the CSR(coke strength after reaction) of charged coke was 54~55% whereas 60~67% in the last four days. However, the permeability index increased with increasing the injection rate of waste plastic in case that the properties of charged coke had similar level. Because the furnace-top pressure was held 1.28 kg/cm^2 through test periods, it could be inferred that the changes of the blast pressure was the main factor of the gas permeability as shown in Fig.4.

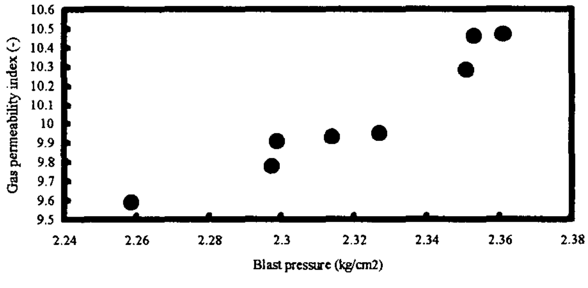


Fig.4. Effect of blast pressure on gas permeability.

Similar phenomena appeared in the pulverized coal injection (PCI) operation. Under the PCI operation into the blast furnace, it could be explained that the blast pressure increased with increasing the pulverized coal injection rate because that shortened the depth of raceway and brought about the resistance to gas permeability through this region. Moreover, the particle size of waste plastics was about 100 times larger than that of pulverized coal, so the combustibility of waste plastic was inferior to the pulverized coal[2,3]. Therefore the retention time of plastic granules was prolonged, then the porosity was reduced in the raceway. The gas volumes in the blow-pipe and raceway increased with the combustion of plastics, and then the pressure of blast also increased. These were the main reasons to increase the gas permeability.

Fig.5 shows the changes of belly brick temperatures in circumferential directions before, in and after the test operation. From this result, we could see the brick temperatures of 45° , 135° , 225° and 315° were higher than those in other directions, these directions were nearby the tuyeres injecting the waste plastic.

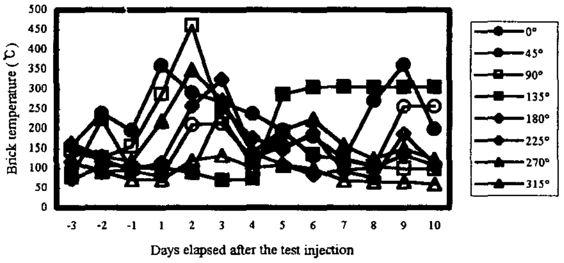


Fig.5. Variation of belly brick temperatures during test injection of plastics.

Fig.6 shows the variations of pressures in the bosh(SP1) and belly(SP2) parts. From this figure, the pressures differences in the belly region increased when the waste plastic was injected. However, there were no significant changes in pressure difference in bosh region. From these results, the gas flowed non-uniformly in the lower part of blast furnace with the plastic injection.

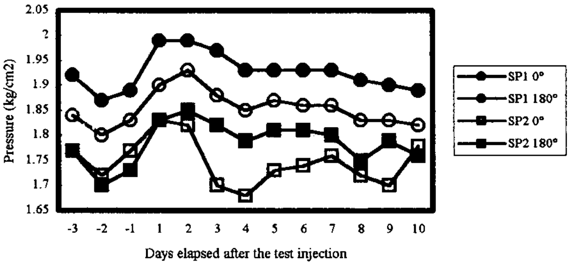


Fig.6. Changes of bosh and belly pressures during test injection of plastics.

The heat content ratio is defined as follows.

$$HCR = \frac{0.31CR + 0.22OR}{(C_{p,H2}H_2 + C_{p,CO}CO + C_{p,CO2},CO_2 + C_{p,N2}N_2)Vtop}$$

where, HCR, CR and OR represent the heat content ratio(-), coke rate (kg/thm) and ore rate (kg/thm) respectively, Cp means the heat content of each gas denoted in subscripts. H_2, CO, CO_2 and N_2 are the volumetric contents of gases in the top-gas(%).

The heat content ratio of burden materials to the ascending gas in furnace-top might be changed when the waste plastic injected.

As shown in Fig.7, the heat content ratio decreased with the plastic injection rate increased. The gas temperature of furnace-top decreased owing to the decrease of the heat content ratio as shown in this figure.

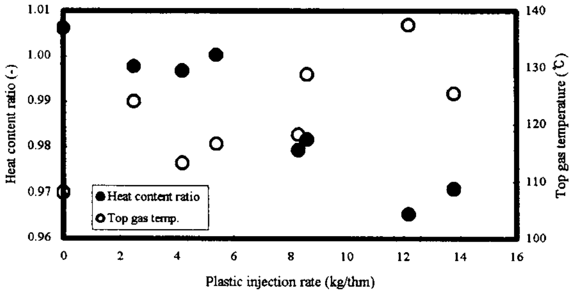


Fig.7. Changes of the heat content ratio and the gas temperature of furnace-top with the plastic injection rate.

The input hydrogen from steam and plastics through tuyeres might generate H_2 gas in the combustion zone. The ascending H_2 gas leaves the furnace-top after taking part in the reduction processes in the furnace. Stoichiometrically, 39.3 kg of PBT or 28 kg of PE contains 1 kg-mole of hydrogen. Therefore the more the amount of hydrogen input from the waste plastics, the more the hydrogen content in the top-gas as shown in Fig.8. In this figure, the previous results of one-tuyere test[1] are also shown. Besides the coke saving, we could get the high calorific top-gas when the waste plastic was injected in the blast furnace, from these results.

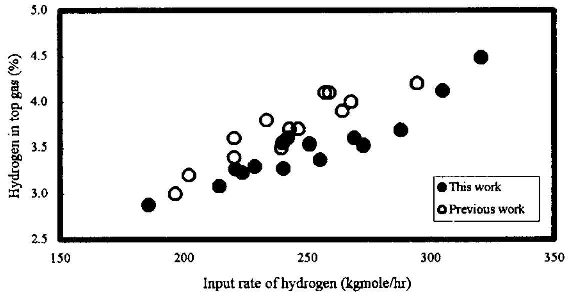
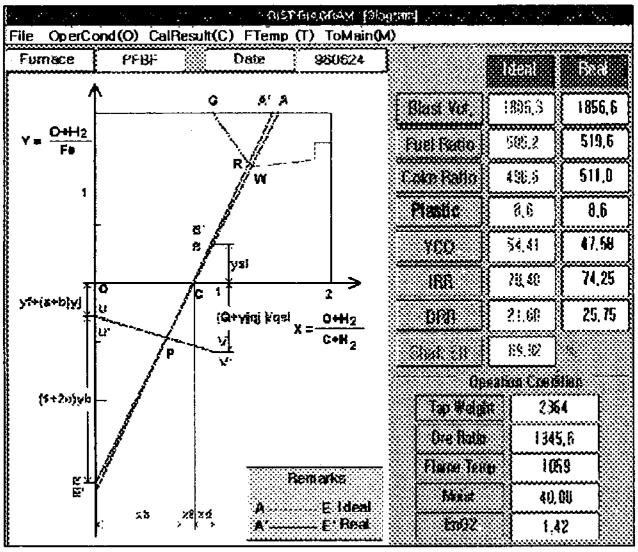


Fig.8. Relationship between H_2 input and H_2 in top gas.

Analysis of test operations by RIST diagram

The RIST diagram consisting of the mass and heat balances is a useful tool to analyze the furnace operation under the steady state[4]. The two-dimensional diagram driven from the mass and heat balances of the blast furnace, we can evaluate the furnace efficiencies as shown in Fig.9.



	Ideal	Real
Blast Vol.	1806.3	1856.6
Fuel Ratio	505.2	519.6
Coke Ratio	496.5	511.0
Plastic	8.6	8.6
YCO	54.41	47.58
IRR	78.40	74.25
DRR	21.60	25.75
Shaft Eff.	89.92	

Operation Condition

Top Height	2364
Ore Ratio	1345.6
Flame Temp	1059
Moist	40.00
EnO2	1.42

Fig.9. RIST diagram displayed for the Foundry blast furnace of the 2nd day during the test operation.

From Fig.9, the results of actual operation were departed from the ideal ones by 50 Nm^3/min of blast volume and 13.4 kg/thm of coke rate. The gas utilization, direct and indirect reduction ratio and shaft efficiency had some differences from the ideal ones due to these results.

We defined the shaft efficiency as the difference ratio of the ideal operation to the real operational result from the RIST diagram, namely the ratio of line GR/GW in Fig.9. Fig.10. shows the variations of the shaft efficiencies with the plastic injection rate. The shaft efficiencies decreased with the increase the plastic injection rate. These results meant the furnace operations were deviated from the ideal one with the plastic injection operation. As the shaft efficiencies decreased with the increase of the plastic injection rate, the gas utilizations also increased as shown in this figure.

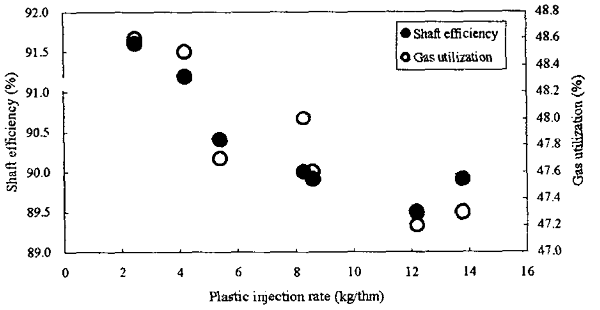


Fig.10. Changes of shaft efficiency and gas utilization with plastic injection rate.

Conclusion

The continuous test operations of waste plastic of PBT and PE were carried out through the four tuyeres of the blast furnace. The coke replacement ratio turned out to be 0.98 with the waste plastic injection up to 13.8 kg/thm of injection rate. The permeability in the furnace became worse and the thermal load in the lower part of blast furnace increased with increasing the injection rate of waste plastics. As the rate of plastic injection increased, the top gas utilization and shaft efficiency also decreased from the RIST diagram analysis.

References

[1] Heo, N.H. and Yim, C.H. 1998. *J. of Korean Inst. of Resources Recycling* 7 : 16-22.

[2] Heo, N.H. Baek, C.Y and Yim, C.H. 2000. *ibid.,* 9 : 15-22

[3] Asanuma, M *et al.* 1996. *CAMP-ISIJ*(Japanese) 9 : 754.

[4] RIST, A. and Meysson, N., 1967, *J. of Metals*, 50-59.