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

The Optimal Composition of Cold Bonded Pellet for Recycling EAF Dust Directly to the Furnace

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Abstract

The degree of iron recovery from dust agglomerates was investigated experimentally to determine the optimum mixing ratio of coke in cold bonded pellet(CBP) which is fed into electric arc furnace(EAF) in the minimill plant. From the XRD analysis for EAF dust, magnetite(Fe_3O_4) and franklinite($ZnFe_2O_4$) was identified as major components. Maximum iron recovery was obtained for the solid carbon content of approximately 18 weight percent. From plant trials of CBP composed of this optimal mixing condition , it was observed that electric power consumption and sulfur content increased with increasing the quantity of CBP.

Keywords: Recycling, EAF dust, coke

Introduction

Kwangyang Works has been put into operation of the direct current electric arc furnace of 130 ton since August 1996. It has produced mainly the hot rolled coil using hot metal and scrap returned from the integrated works. Since then, considerable effort has been paid to develop processing technologies for cost saving and production improvement as well as to recycle EAF dust directly to the furnace. EAF dust is approximately generated 20kg per ton of steel. Accordingly, the quantity of dust will be increased with increasing the production of crude steel. However, EAF dust is currently classified hazardous waste because of the leachy of its toxic constituents such as lead, cadmium and hexa-valent chromium. It will become increasingly difficult to dispose of EAF dust locally by landfill owing to the diminishment of disposal area. It is foreseen that the available period of close-type disposal area in POSCO will have been finished in 2003. It is necessary to take a proper measures such as chemical fixation[1], on-site recycling[2], and processes to recover the valuable metal.[3~6] The major shortcomings of the various processes suggested for recovering the valuable metal have been the high capital cost of the equipment and the need for large quantities of dust for the processes to be economical. Furthermore, it is known that the processes require dust with zinc and lead contents greater than 20 percent. By the way, it remains in a dilemma for the treatment of EAF dust in environmental and recycling aspects because the summation of zinc and lead contents in EAF dust of our company is about 10 percent. Therefore, we have chosen the method recycling EAF dust directly to the arc furnace. It is known that this method has the advantages of the low cost, relative insensitivity to EAF dust composition, and applicability to mini-mill process.

The study described here consisted of a series of laboratory and plant trials. Firstly, the reduction of EAF dust with coke has been examined. Secondly, the degree of iron recovery with coke mixing ratio was investigated experimentally to determine the specification of cold bonded pellet (hereinafter CBP). Thirdly, the effect of CBP on the EAF operation and the sulfur pick-up in melt has been investigated.

Experimental Method and Plant Trials

Materials

The chemical composition of EAF dust is given Table 1. Its main components were Fe_2O_3, ZnO and CaO. The mean particle size of EAF dust is 1.3Πm. EAF dust consisted of magnetite and franklinite, etc. The coke dust generated in the equipment of coke dry quenching (hereinafter coke) was used as the reducing agent of EAF dust.

Table 1 Chemical composition of EAF dust used in the experiments (wt%)

T.Fe	FeO	Fe_2O_3	CaO	ZnO
49.4	4.5	65	6.1	11

Method

Reduction of EAF dust with coke was experimented at the temperature range of 1100~1300℃ in air atmosphere. The briquetted EAF dust with coke mixing ratio was heated in muffle furnace for a given time, quenched in liquidized nitrogen.

The degree of iron recovery in EAF dust was investigated using a vertical tube furnace. CBP containing EAF dust and coke were prepared on a rotating disk with 10 percent cement as the binder. CBP was spherical in shape, with diameter 10 to 20mm. The experimental procedure for the evaluation of iron recovery in CBP is as follows. The electrolytic iron was melted under Ar atmosphere, and then CBP was added into the melt. After a given time was elapsed, the crucible was removed out of the furnace and then was immediately quenched in liquidized nitrogen. The reduced iron is weighted, and the components of metal and slag was analyzed.

In addition, the reaction phenomenon between EAF slag and CBP was observed by X-ray fluoroscopic furnace. To investigate the behaviors of sulfur in steel with the addition of CBP, experiments using 25kg inductive furnace were carried out.

Based on these experimental results, CBP with an optimum composition was prepared for plant trials

Plant trials

CBP was put into the arc furnace in the initial of 1st and 2nd melting stage from hopper. The total quantity of CBP is 2000~2500 kg. The electric power consumption of EAF was investigated to evaluate indirectly the extent of heat loss. The samples of steel were taken at ladle furnace after the tapping of EAF to evaluate the extent of sulfur pick-up.

Results and discussion

Reduction behaviors of EAF dust

Fig.1 shows the effect of coke mixing ratio on the metallization degree of the reduced EAF dust treated in muffle furnace.

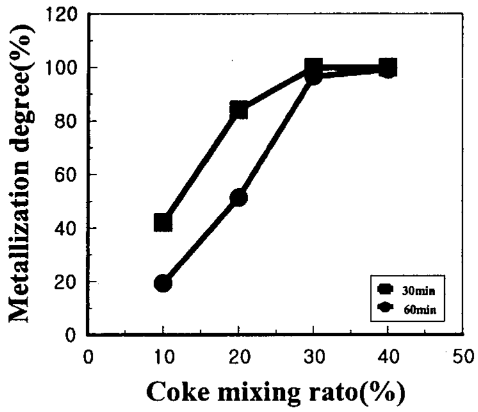

Fig.1 Effect of the coke mixing ratio on the metallization degree of the reduced dust

The metallization degree is defined as;

$$Metallization\ \deg ree\ \ \frac{\%Metallic\ Fe}{\%Total\ Fe}\upsilon 100$$

The metallization degree of the reduced EAF dust increases with increasing the coke ratio, it reached a maximum at the 30% of the coke ratio. At a given coke ratio below 30%, it decreases with the reduction time. It is clear that the metallization degree has a close relationship with the coke ratio and the reduction time. It is thought that the iron produced from the reduction of EAF dust is changed into FeO and Fe_2O_3 due to air atmosphere, as it turns out, the metallization degree is inversely proportional to the reduction.

It is reported that kinetics of reduction of EAF dust is determined by the burnt-down rate of carbon within coke(the rate of carbon gasfication[7,8]). The fraction of carbon reacted at any time is derived as follows;

$$f\ \ (\frac{3\ \ 4\Delta}{5.46})(1\ \ \exp(\ kt))\ \ \frac{\ni W_V}{1.6W^*}$$

f = the reacted fraction

α = the fraction of carbon used in the reduction of EAF dust

k = the coefficient of the burnt-down rate

Δ Wv = Weight loss of carbon disused in the reduction of EAF dust

W* = initial carbon weight

Fig.2 shows the plot of the coefficient of the burnt-down rate vs. temperature. The activation energy is determined by this Arrhenius-type expression for the reaction. From the slope of the straight line in Fig.2, the activation energy of EAF dust reduced with 30% coke is determined to be about 13.5kcal/mole at the temperature range of 1100℃ to 1300℃ under air atmosphere.

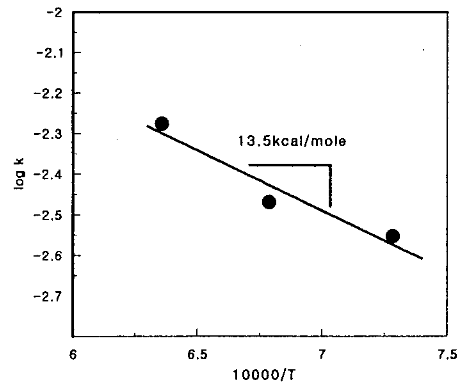

Fig.2 Arrhenius-type plot for the determination of activation energy

Degree of iron recovery

The degree of iron recovery is defined as dividing the quantity of iron recovered into melt by the quantity of total iron within CBP.

$$Degree\ of\ iron\ re\operatorname{cov} ery(\%)$$

$$\frac{\text{the quantity of iron recovered into melt}}{\text{the quantity of total iron within CBP}}\upsilon 100$$

Fig.3 shows the effect of coke ratio on the degree of iron recovery for the elapsed time of 15min. As the coke ratio is increased up to 18%, the degree of iron recovery is increased as can be expected.

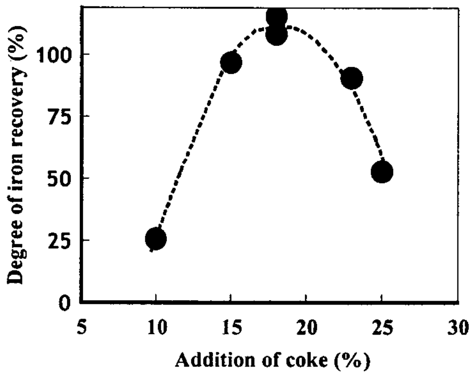

Fig.3 Relationship between the addition of coke and the degree of iron recovery

However, above this coke ratio, the iron recovery decreased with increasing the addition of coke by contraries. To study the reason why the iron recovery is low more than 18% coke ratio, the carbon and total Fe contents in slag after experiment were analyzed for the sample of 10%and 25% coke ratio which showed similar iron recovery with each other. The content of carbon and total Fe were 0.08% and 42% at 10% coke ratio, were 19% and 27% at 25% coke ratio. That is to say, it means that the needful carbon to reduce the iron oxide within CBP is insufficient for 10% coke ratio, but is excessive for 25% coke ratio. To disclose the cause given above, The crystal structure of the residual slag after experiment is analyzed by X-ray diffraction method. Metallic iron, iron oxide, carbon and dicalcium silicate($2CaOSiO_2$) in slag is identified. The above result may be caused by the fact the slag viscosity is increased due to the precipitation of undissolved dicalcium silicate and carbon, and then the resistance against transferring of the reduced iron into melt is increased. Therefore, it is thought that the iron recovery of 18% coke ratio is high, in comparison with 25% coke ratio.

Reaction phenomena between EAF slag and CBP

The reaction phenomena between EAF slag and CBP is shown in Photo.1.

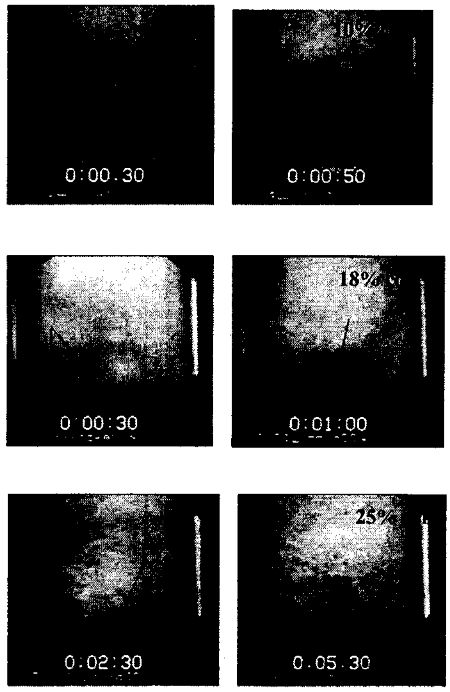

Photo.1 X-ray fluoroscopic image of EAF slag/CBP reaction

The figure in the photograph denotes the elapsed time after the addition of CBP. The photographs show that the slag foaming occurs because of CO and CO_2 gas generated by the reduction of EAF dust. The higher coke ratio in CBP becomes, the longer the slag foaming exist. The slag foaming time for CBP containing the coke ratio of 10%, 20% and 30% is about 1min, 2min and 5min, respectively. In the case of the coke ratio of 20% and 30%, the slag foaming height cannot be observed in the photograph because the foam layer goes up to the upper limit of the screen.

The behaviors of sulfur content with coke ratio in melt are shown in Fig.4. It is reported, as the sulfide capacity of EAF slag is very low, the final content of sulfur in melt increases in the case of the addition of raw material containing the sulfur[9]. The sulfur content EAF dust and coke is about 0.3% and 0.5%, respectively. To its expectation, the sulfur content in melt increased with increasing the treatment time and coke mixing ratio.

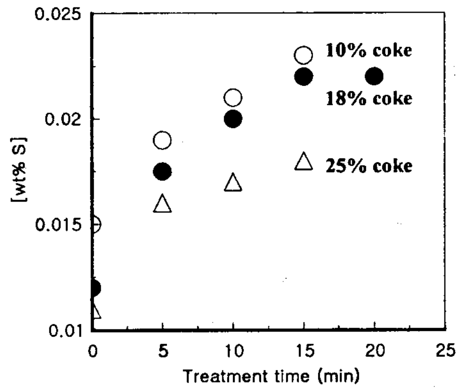

Fig.4 Behaviors of sulfur content in melt with coke mixing ratio

Result of plant trials

The electric power consumption of EAF and the sulfur content in steel at LF position for the conventional and CBP-added EAF operation is increased from 0.136 to 0.142 kwh/℃/ton-s., from 218 to 280ppm, respectively.

Conclusions

The activation energy of EAF dust is about 13.5kcal/mole at the temperature range of 1100℃ to 1300℃ under air atmosphere. Maximum iron recovery was obtained at the solid carbon content of approximately 18 percent. From plant trials, electric power consumption and sulfur content increased with increasing the quantity of CBP.

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