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Studies on Aluminothermic Reduction of Manganese ore for Ferro–Manganese Making

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ABSTRACT

It is well known that lowering the carbon content of ferro–alloy increases the value of the metal. This grade of ferro–alloy results in lowering the cost of production in steel melting stage. Aluminothermic process produces carbon free ferro–alloys. In this paper, details of investigations on ferro-manganese making are given. Influence of pre-reduction of manganese ore to Mn_2O_3 and Mn_3O_4 stage, excess aluminium over stoichiometric requirement, addition of fluxes etc., on metal yield is discussed. Metal yield of 58–64% on 10 kg scale with alloy composition of Mn–83%, Fe–13%, Si–1.4 to 2%, Al–0.008% and P–0.16% has been successfully achieved at the Laboratory.

Keywords : Manganese ore, Aluminothermic reduction, Ferro-manganese.

INTRODUCTION

India's manganese ore reserves, total recoverable has been estimated at 176.5 million tonnes, out of which only 16.2% is in proved category. Karnataka is having the highest share of 36% followed by Orissa and Goa. Manganese is very important element in steel as it improves the strength, toughness, hardness and workability. Manganese ore also acts as deoxidizer and helps in getting ingots free from blow holes.

There are eleven major ferro–alloy industries in the country. Their production is only about 52% of the rated capacity. The total consumption of manganese ore in ferro–alloy industries is around 6,00,000 tonnes/annum. The carbon content in this ferro–alloy is around 6%. Medium carbon ferro–alloy is made by silico–thermic process and low carbon ferro–manganese is made by aluminothermic method. Low carbon ferro–manganese finds application in alloy and special steel making where carbon content in steel is very low. Steel with 1% carbon 11–13% Mn shows very

high abrasion resistance.

The technology of aluminothermic process is available with the private sector and it is very difficult to get details about the process. At Regional Research Laboratory, Bhubaneswar a successful effort has been made to develop a process for producing ferro-manganese by aluminothermic method upto 10 kg ore scale. Some salient datas are given in this paper.

For production of ferro-manganese by aluminothermic method, the ore should have more than 46% Mn. The Mn/Fe ratio desired is 9. However, 6 and above is acceptable. Sulphur and phosphorus are deleterious impurities in the ore. Phosphorus is more dangerous as almost all passes into the alloy. The average acceptable ore composition is as follows:

Mn	Fe	SiO_2	Al_2O_3	P
48%	6–7% (max.)	6% (max.)	4% (max.)	0.12% (max.)

ALUMINOTHERMIC REDUCTION

Table 1 gives the heat balance for aluminothermic reduction for manganese oxides. It may be observed that when the ore is used as its is, i.e., MnO_2, the reaction is violent because the heat available is much more than the heat required. Also if the ore is reduced to MnO stage the material become more inert. Therefore, it is essential that the ore is reduced to Mn_3O_4 or Mn_2O_3 stage before it is used for alumnothermic reduction.

Table 1 : Heat balance of aluminothermic reduction of manganese oxides

Oxides	Heat required (kCal)	Heat available per mole of Al_2O_3 (kCal)
MnO	157	124
Mn_3O_4	139	152
Mn_2O_3	133	171
MnO_2	121	214

On heating above 530°C, MnO_2 transforms into Mn_2O_3 and above 940°C into Mn_3O_4. Keeping this in view, experiments have been planned to heat the ore to 650°C for 3 hours and 950°C for 3 hours in an electrically heated muffle furnace.

Lime is added to decrease the formation of aluminates as this results in loss of metal oxide. The addition of fluorspar (CaF_2) helps in lowering the viscosity. Higher temperatures results in higher yield, but more silicon in the alloy. Low temperature results in formation of $MnO.SiO_2$ and $2MnO.SiO_2$ which will go with the slag and therefore, less silicon in the alloy. Basicity of 1.2 (CaO/SiO_2) is desirable for formation of $CaO.SiO_2$ and $(2CaO).SiO_2$ and therefore, results in less silicon in the alloy.

EXPERIMENTAL

Table 2 gives the chemical analysis of the ore used for carrying out the experiments. The ore particles were more than 80% –4 mm size which was crushed and ground to –0.25 mm. The particle size of lime and fluorspar were also maintained at the same level. The particle size of aluminium used was –0.852 + 1.68 mm.

Table 2 : Chemical of manganese ore and size of the raw materials

Mn	Fe	SiO_2	Al_2O_3	P
47.10	4.50	6.13	1.20	0.09

Size of the raw materials		
Crushed and Ground ore	:	–0.250 + 0.075 mm
Particle size of Al	:	–0.850 + 1.680 mm
Particle size of Lime	:	–0.250 mm
Particle size of fluorspar	:	–0.250 mm

The experiments have been carried out on 3—10 kg ore scale using refractory lined reactors of various sizes closed from bottom. The L/D of reactor was approximately 3:1. Tables 3 and 4 give the details of process parameters, with yield and chemical analysis of the alloy produced.

Experiments No. 1 to 3 give the influence of excess aluminium over stoichiometry for the material roasted at 650°C for 3 hours, experiments 4,5 and 6 give the results for material roasted at 650°C and 950°C. As the objective of the work was to get higher yield, the number of parameters varied were more than one at a time. Influence of fluxes and scale up factor have been simultaneously studied. All experiments were carried out taking 20% of the material in the reactor and triggering the reaction with BaO_2 and aluminium powder mixture. Rest of the material was charged slowly by top charging method. The alloy was allowed to cool in the reactor before discharging. Roasting at higher temperature results in lower consumption of aluminium with almost the same recovery.

Table 3 : Process parameters

Expt. No.	Ore (kg)	Aluminium		Lime (%)	Fluorspar (%)	Yield (%)
		% Ore basis	% Excess over stoich			
	Influence of Aluminium on yield : Roasting at 650°C for 3 hours.					
1	3.0	27.0	10	7.5	20	55
2.	9.5	28.5	15	7.5	4.2	55
3.	11.2	30.0	20	7.5	4.2	65
	Influence of roasting temperature : Roasting at 650°C for 3 hours.					
4	3.0	28.5	15	13.5	4.0	60
5	10.0	28.5	15	13.5	8.5	58
	Roasting at 950°C for 3 hours.					
6	3.0	26.0	15	13.5	4.0	64.7

Table 4 : Chemical analysis of alloy products

Expt. No.	Mn (%)	Fe (%)	Si (%)	Al (%)	P (%)
1	74.16	16.27	6.43	0.032	0.24
2	74.57	15.75	8.85	0.013	0.22
3	70.30	12.30	9.50	0.004	0.17
4.	79.30	13.70	4.97	–	–
5.	76.08	13.80	5.12	–	–
6.	83.80	13.32	1.37	0.008	0.16

CONCLUSIONS

Every kilogram of aluminium saved per tonne of alloy is very important for the economy of the process. On the basis of this study, the following optimised process parameters are suggested.

1. The ore should be pre-roasted at 950°C for 3 to 4 hours to bring MnO_2 to Mn_3O_4 stage.
2. The aluminium requirement is 15% over stoichiometric which may be around 10% when the experiments are carried out at higher scale for production of alloys.

3. Lime 13 to 13.5% of ore and fluorspar 4% of ore may be used for proper slag metal separation.
4. The metal yield of 60—64% has been achieved.
5. The alloy produced is having very low content of aluminium and phosphorus.

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