Production of Alloy Cast Iron from Multi–Metallic Magnetite Ore of Nagaland

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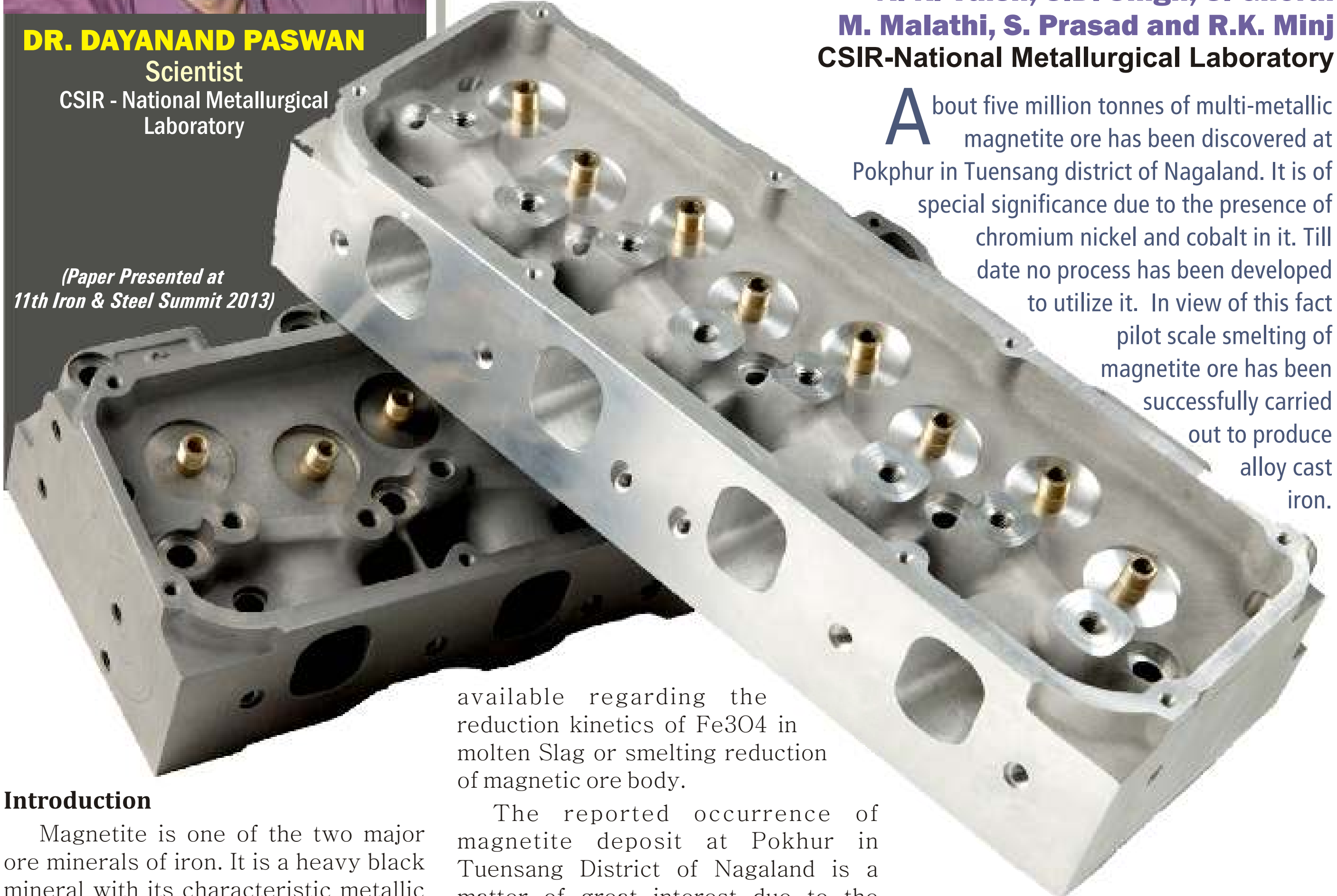

About five million tonnes of multi-metallic magnetite ore has been discovered at Pokphur in Tuensang district of Nagaland. It is of special significance due to the presence of chromium nickel and cobalt in it. Till date no process has been developed to utilize it. In view of this fact pilot scale smelting of magnetite ore has been successfully carried out to produce alloy cast iron.

Introduction

Magnetite is one of the two major ore minerals of iron. It is a heavy black mineral with its characteristic metallic lusture and contains about 72.4% iron in pure form. It has very little porosity and high density with a specific gravity of 5.1 and hardness of 5.5 to 6.5 on Mho's scale. Smelting of magnetite is difficult due to its low porosity and therefore only 5-6% of world's total iron production comes from magnetite source. Magnetite deposits are common in Sweden parts of United States and Russia. In India, the total reserve of iron ore is reported to be around 25 billion tonnes. Out of which around 10 billion tonnes is magnetite. Although a large number of studies(1-5) have been carried out on the reduction kinetics of iron oxide in molten slag, as such no literature is available regarding the reduction kinetics of Fe_3O_4 in molten Slag or smelting reduction of magnetic ore body.

The reported occurrence of magnetite deposit at Pokhur in Tuensang District of Nagaland is a matter of great interest due to the presence of Ni, Cr and Co. The discovery of nickel - chromium-cobalt bearing magnetite in the Tuensang district of Nagaland assumes particular significance since India is totally dependent on imports with reference to strategic metals like nickel and cobalt. The magnetite ore deposit at Pokphur is shown in Figure 1 and the collection of sized magnetite ore in Figure 2.

Figure 1: Magnetite Ore Deposit at Pokphur

Figure 2: Collection of Sized Magnetite Ore

The smelting route was selected for the recovery of all the metallic values in alloy cast iron from the multi – metallic magnetite ore without going in for the fine grinding. The main objective of this investigation is to selectively reduce all the nickel, chromium, cobalt and iron oxide present in the ore into their metallic form while leaving the other oxides viz titania, silica, magnesia, alumina etc. The petroleum coke was used as reductant and limestone as flux. The recoveries of nickel, chromium and cobalt were found to be 96.5%, 94.5% and 92.5% respectively at optimum smelting temperature.

Experimental

Raw Materials

The charge mix used comprised of lumps of multi–metallic magnetite ore, petroleum coke as reductant and limestone as flux. The chemical analysis of multi–metallic magnetite ore, petroleum coke and limestone are given below in Tables 1, 2 and 3.

TABLE 1 : CHEMICAL ANALYSIS OF MULTI-METALLIC MAGNETITE ORE

Radicals	Range (%)	Radicals	Range (%)
Fe(T)	46.28 – 53.07	P	0.038 – 0.047
FeO	14.527 – 17.921	CaO	1.04 – 1.52
Fe2O3	48.012 – 59.41	SiO2	9.58 – 10.67
Cr	2.40 – 3.21	Al2O3	7.18 – 10.35
Ni	0.38 – 0.81	MgO	1.67 – 2.22
Co	0.036 – 0.062	TiO2	0.07 – 0.28
S	0.012 – 0.020	LOI	3.86 – 7.30

TABLE 2 : CHEMICAL ANALYSIS OF PETROLEUM COKE AS REDUCTANT

Reductant	Moisture (%)	Ash (%)	Volatile Matter (%)	Fixed Carbon	S (%)	Calorific Value (K.Cal/Kg)
Petroleum Coke	0.50	0.30	9.20	90.00	1.68	8360

TABLE 3 : CHEMICAL ANALYSIS OF LIMESTONE AS FLUX

Radicals	Percentage
CaO	52.35
SiO2	1.80
FeO	0.007
Al2O3	0.28
MgO	1.92
Loss of ignition (LOI)	40.95

Smelting Operation at Pilot Scale

The long smelting campaign of magnetite ore was carried out at two smelting temperatures in 500 kVA pilot scale Submerged Arc Furnace (SAF) on continuous basis adopting different combinations of charge mix (Table 4) in order to optimize the required percentage of reductant and flux materials. The metal composition varied with respect to temperature, percentage reductant and percentage flux in the charge mix.

TABLE 4 : SMELTING OF MAGNETITE ORE IN 500 KVA – SAF IN DIFFERENT TAPPINGS WITH DIFFERENT CHARGE COMPOSITIONS

Tappings Numbers	Charge Composition Number	Charge Mix Composition (Kg.)		
		Magnetite Ore	Limestone	Petroleum Coke
6 to 10 26 to 41 49 to 60	1st	50	12.5	10
11 to 16	2nd	50	15	10
17 to 25	3rd	50	10	10
42 to 48	4th	50	12.5	12.5
61 to 62	5th	50	11	10
63 to 79	6th	50	12.5	11

The live operation of 500 kVA Submerged Arc Furnace is shown in Figures 3, 4, 5 and 6 exhibiting the charging, metal tapping, metal casting and alloy cast iron.

Discussion of Results

The smelting reduction process comprises of iron oxide reduction at high temperature using carbonaceous material petroleum coke as reductant. It involves both reduction and melting accompanied by chemical reactions. In the case of smelting reduction the electricity is the source of heat and petroleum coke acts as reductant cum fuel. The most important reaction common in all the smelting reduction processes except Corex, is the reduction of iron oxide in the liquid phase by solid carbon particles and gaseous CO from the reductant.

It was observed that the specific power consumption is dependent on the stability of the furnace also. In the beginning of the smelting campaign, the average specific power consumption was much higher than the theoretically calculated value. With the progress of smelting campaign, the furnace got gradually stabilized and the specific power consumption got reduced significantly from 3883 kWh/tonne to 3326 kWh/tonne. It got further reduced from 3326 kWh/tonne to 3187 kWh/tonne as the furnace operation was well stabilized. Finally the specific power consumption got reduced to its minimum value of 2760 kWh /tonne with minimum loss of energy for tappings 63 – 79 in very well stabilized smelting operation.

The process parameters for the pilot scale smelting of magnetite ore were suitably optimized for the maximum recovery of chromium, nickel and cobalt in the hot metal. It can be observed from Table 4 that 20% petroleum coke as reductant and 25% limestone as a flux is most appropriate in the charge mix for the optimum recovery of the chromium, nickel and cobalt in the product. The typical composition of the alloy cast iron produced comprises of Fe: 88.50 90.0%, Cr: 4.0–5.5%, Ni: 0.7–1.2%, Co: 0.06–0.09%, C: 3.5–5.0%, P: 0.03–0.10% and S: 0.10–0.50%.

The furnace stability has great impact on the recoveries of the Ni, Cr, Co and Si. Poor recoveries of Ni, Cr, Co and Si were observed in the initial

FIGURE 3 : A VIEW OF SMELTING OPERATION OF MAGNETITE ORE

FIGURE 4 : A VIEW OF HOT METAL TAPPING

FIGURE 5 : A VIEW OF METAL CASTING

FIGURE 6 : ALLOY CAST IRON (Ni-Cr- Co ALLOY)

tappings as furnace was not stabilized. As the furnace got fully stabilized the recoveries of Ni, Cr, Co and Si reached to their maximum values in the tappings. It was possible to recover maximum 96.90% Ni, 94.5% Cr, 92.50% Co and 28% Si under very well stabilized furnace operation with smelting temperature > 16500C.

Application of alloy cast iron

The Rockwell hardness of the product ranged from 572 to 600 BHN. The alloy cast iron was used for making grinding media balls for cement and mineral beneficiation industries. This grinding media has been successfully tested in cement plants. The alloy cast iron can be further utilized for making a wide range value added products with chromium and nickel.

Conclusions

- The optimum requirement of reductant in the charge mix was found to be 20-22% of the weight of magnetite ore and that of limestone about 25% of the weight of magnetite ore in the charge mix
- The requirement of flux is more due to substantial amount of alumina and silica present in the multi – metallic magnetite ore
- The smelting studies at pilot scale were carried out in lower temperature range (1600 to 16500C) and higher temperature range (> 16500C)
- Higher smelting temperature range (> 16500C) is favorable for the maximum recovery of chromium, silicon and manganese whereas, nickel content in the product is not at all dependent on the smelting temperature.
- The percentage sulphur and phosphorus in the product gets reduced at higher slag basicity
- It was possible to extract about 97 – 98% iron, 91 – 93% chromium, 95 – 96% nickel, 89 – 91% cobalt, 2.0 – 22% silicon and 7.0 – 34% manganese present in the ore.
- The alloy iron obtained is suitable for the manufacture of special cast iron like Ni-hard iron and abrasive resistant cast iron alloys
- The most optimum specific power consumption was found to be about 2760 kWh per tonne of product.

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