STUDIES ON REDUCTION OF ZIARAT LATERITE

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Abstract. Laterite from Ziarat contains the useful constituents iron, alumina and titania. There are various methods which can be used for the separation of these constituents. To explore a possibility low-temperature reduction has been used in the present investigations. Reduction has been carried out from haematite to magnetite or iron and, subsequently, the magnetic material separated by magnetic separation. Concentrations having 59% Fe_2O_3 with 96% recovery of iron and 75% Fe_2O_3 with 76% recovery of iron were achieved in the form of Fe_3O_4 and Fe respectively.

Certain silicate minerals decompose due to weathering into silica and alumina, and the silica is leached out from the residual materials in the geologic time. Aluminium and iron hydroxides remain to form red residues called laterites. Such ores are reported to occur in many districts of Pakistan.[1] The deposits at Ziarat, Quetta Division, essentially contain varying amounts of aluminium, iron and titanium. The reserves have been estimated at about 15 million tons in a quarter of the laterite-bearing area,[1,2] and to be more than 300 million tons according to a recent estimate.[3] The average composition has been reported to be iron 29, alumina 30, titania 5 and silica 9%.[2,4] Phase analysis of the ore has revealed that it contains haematite, kaolinite, diaspore, boehmite and titanium as TiO_2.[5] The X-ray diffractometer analysis of the selected samples by U.S. Geological Survey is in general agreement with this phase analysis.[6]

The laterite ore has been studied as a source of alumina for aluminium industry.[4,7] Besides, it has a higher percentage of recoverable iron as compared to Kalabagh iron ore, which though containing an average of 32% iron includes 8% nonrecoverable type. Moreover, the recovery of alumina and titania is achieved as byproducts. The phase study also suggests that the useful constituents namely iron, alumina and titania do not have complexity which may restrict their separation. The reduction of haematite follows the sequence $Fe_2O_3 \longrightarrow Fe_3O_4 \longrightarrow FeO$ and Fe. When the reduction is carried out to Fe_3O_4 or Fe stage, they could be separated magnetically from the nonmagnetic phase. The reduceability in the unfused stage has been investigated for the concentration and separation of iron from other ingredients.

Experimental

Wood charcoal powder of 100 mesh was intimately mixed with the ore in a 100 ml porcelain availble and placed in a muffle furnace. Magnetic separations of the reduced mass were done by lift method[8] using a Davis magnetic separator (model No. 45V). Sieves conforming to the B.S. Specifications were used for particle-size analysis.

The effect of variation of particle size of the ore, variation of percentage of reductant, variation in time and temperature on the recovery of magnetic concentrate have been studied. The analytical results for the iron contents are given in Tables I–6 (Figs. 1–4).

Results and Discussion

The results (Table 1) indicate that the powders finer than 100 mesh were not magnetically separated because of the interlocking of magnetic and nonmagnetic particles. Although 80% magnetic material could be separated, the magnetic portion and tailings did not show any difference in iron contents. The ore of mesh size—12+80 gave about 80% recovery of iron. Table 2 shows that particle size variation in the range of—12+80 does not show any significant effect on the recovery of magnetic concentrate. Coarser particle size in a particular range such as—12+22 shows highest iron percentage in the magnetic portion without any appreciable change in recovery of iron.

With longer time higher percentage of reductant is needed as compared to reductions at higher temperatures which take shorter time and low percentage of reductant (Fig. 2 a and b, Fig. 3d). With longer reduction time charcoal is probably lost through oxidation which is rapid at high temperatures, the decrease in time results in overall saving of the reductant. At least 5% reductant will be required to achieve reasonable amount of reduction to Fe_3O_4 stage (Fig. 2), and more than 20% to Fe stage. The optimum time at 830°C for recovery of iron in the form of Fe_3O_4 is about 5 min and in the form of Fe is about 10 min (Fig. 2 and 3). With longer times, even with increasing percentage of reductant, the percentage of iron has been dropping under the present conditions of experiments.

As suggested by curves a–d in Fig. 2 the experiments were extended to high temperatures with more than 30% reductant for 30 min in each case (Fig. 1). The curve has two maxima, one at 620°C corresponding to the formation of Fe_3O_4 showing a recovery of 96% iron with 59% Fe_2O_3 contents in the magnetic fraction and another at 810°C corresponding to Fe showing a recovery of 76% iron with 75% Fe_2O_3 contents in the magnetic fraction. The other constituents of

the magnetic concentrate are the impurities which are originally present in the ore, i.e. silica, alumina and titania.

Experiments conducted with increasing time periods although, clearly reveal the different stages of reactions (Fig. 4) i.e.
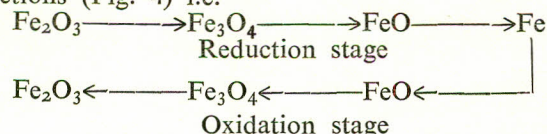
$$Fe_2O_3 \longrightarrow Fe_3O_4 \longrightarrow FeO \longrightarrow Fe$$
Reduction stage

$$Fe_2O_3 \longleftarrow Fe_3O_4 \longleftarrow FeO \longleftarrow $$
Oxidation stage

TABLE 1. EFFECT OF PARTICLE SIZE ON MAGNETIC SEPARATION. Temperature of reduction 760–790°C.

Particle size of the ore (B.S.I. mesh No.)	Char- coal (wt %)	Time of reduc- tion (min)	Recovery of mag- netic con- centrate (wt%)	Iron % Magnetic concen- trate	Iron % Tail- ings
—200	7	25	80	24.38	24.78
—100	25	60	54	25.20	23.80
—100	25	60	—	19.60	19.60

*This expression wherever used in this paper means percentage recovery of magnetic concentrate based on the weight of the reduced mass.

TABLE 2. EFFECT OF PARTICLE SIZE ON RECOVERY OF IRON IN THE MAGNETIC CONCENTRATE. Charcoal (weight %), 33; temperature of reduction, 780–800°C. Iron percentage in sample No. 1, 29.12; sample No. 2, 33.71.

Sample No.	Time of reduction (min)	Particle size of the ore (B.S.I. mesh No.)	Magnetic concentrate Re- covery (wt %)	Magnetic concentrate Iron contents (Fe%)	Magnetic concentrate Re- covery of iron (%)
1.	45	—12+80	61.08	40.04	80.46
		—12+52	62.87	40.32	78.45
		—12+22	57.77	43.68	76.08
		—12+22	62.4	49.8	77.32
		—22+44	62.3	47.6	76.33
2.	30	—44+60	61.7	49.6	78.74
		—60+85	62.9	45.4	78.81

—12+80 indicates the particle size passing through mesh No. 12 and retained on mesh No. 80.

but it has not been possible to calculate the equilibrium constants for reactions taking place during reduction process and study of exact equilibrium conditions because of the finely disseminated nature of the ore

TABLE 3. EFFECT OF TEMPERATURE OF REDUCTION. Charcoal (wt%) 33; Time of reduction, 30 min; Iron percentage in; sample No. 3, 33.28; sample No. 4, 30.93.

Sample No.	Particle size of the ore (B.S.I. mesh No.)	Temperature of reduction (°C)	Magnetic concentrate Re- covery (wt%)	Magnetic concentrate Iron con- tents (Fe%)	Tailings Re- covery of iron (%)	Tailings Iron con- tents (Fe%)
		620	82·83	45·4	93·54	18·5
		640	82·19	43·7	93·13	18·2
		560	79·59	45·4	91·81	17·4
		680	71·90	44·2	86·72	17·4
		700	68·90	45·9	84·03	19·0
		720	60·09	47·6	76·65	21·8
3	—12+22	740	57·88	48·2	74·22	23·0
		760	57·98	45·9	73·16	23·2
		780	59·29	45·9	71·68	19·04
		800	56·52	46·20	75·88	19·04
		820	56·59	52·08	75·68	21·84
		840	56·66	47·0	73·81	21·8
		860	56·19	45·4	73·72	24·1
		880	54·01	46·2	70·79	22·4
		550	86·5	39·20	91·09	24·64
		580	87·5	39·76	93·26	20·16
4	—22+85	600	86·4	38·64	92·80	19·04
		620	88·5	40·88	95·79	15·68
		640	86·8	40·88	93·56	18·48

TABLE 4. EFFECT OF TIME ON REDUCTION AT 620°C. Particle size of the ore (B.S.I. mesh No.)= —20+85; Charcoal (wt%), 33; Iron percentage in the original sample, 30.93.

Time of reduction (min)	Magnetic concentrate Re- covery (wt%)	Magnetic concentrate Iron contents (Fe%)	Magnetic concentrate Re- covery of iron (%)	Tailings Iron con- tents (Fe%)
15	88.64	36.96	93.9	19.04
30	88.50	40.88	95.8	15.68
45	85.10	37.52	92.8	16.80
60	70.77	40.32	80.7	23.52
75	63.29	40.88	74.4	24.64

TABLE 5. EFFECT OF PARTICLE SIZE AND TIME OF REDUCTION AT 820°C. Charcoal (wt %), 33; Iron percentage in the sample, 33.28

Time of reduction (min)	Iron % in magnetic concentrate Mesh size —12+22	—22+44	—44+60	—60+85	Iron % recovered in magnetic concentrate Mesh size —12+22	—22+44	—44+60	—60+85
10	48.7	49.3	46.48	45.4	—	71.86	70.74	72.54
20	46.5	46.5	48.2	47.6	74.52	71.97	77.93	82.02
30	49.8	43.1	49.6	45.4	77.32	76.33	78.74	78.74
40	49.02	51.0	50.70	—	63.14	62.12	64.73	—

TABLE 6. EFFECT OF CURRENT SUPPLIED TO THE MAGNETIC SEPARATOR ON PERCENTAGE IRON RECOVERED. Charcoal (wt%), 33; temperature of reduction, 760–790°C.

Particle size of the ore (B.S.I. Mesh No.)	Time of reduction (min)	Percentage recovery of the magnetic concentrate (wt%)				Percentage iron recovered in the magnetic concentrate			
		Amperage supplied				Amperage supplied			
		0.15	0.25	0.5	0.8	0.15	0.25	0.5	0.8
22	60	48.6	54.2	63.9	—	69.3	75.9	84.6	—
22	60	43.4	56.5	72.4	—	59.6	73.2	85.9	—
—22	90	5.0	—	50.0	75.0	6.48	—	52.1	77.4
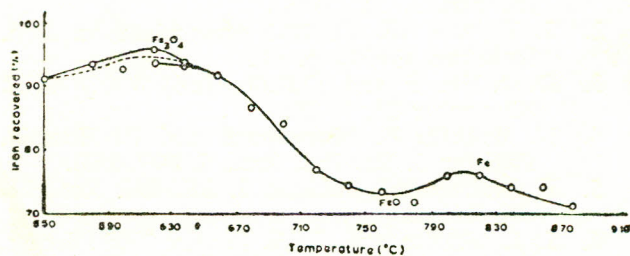
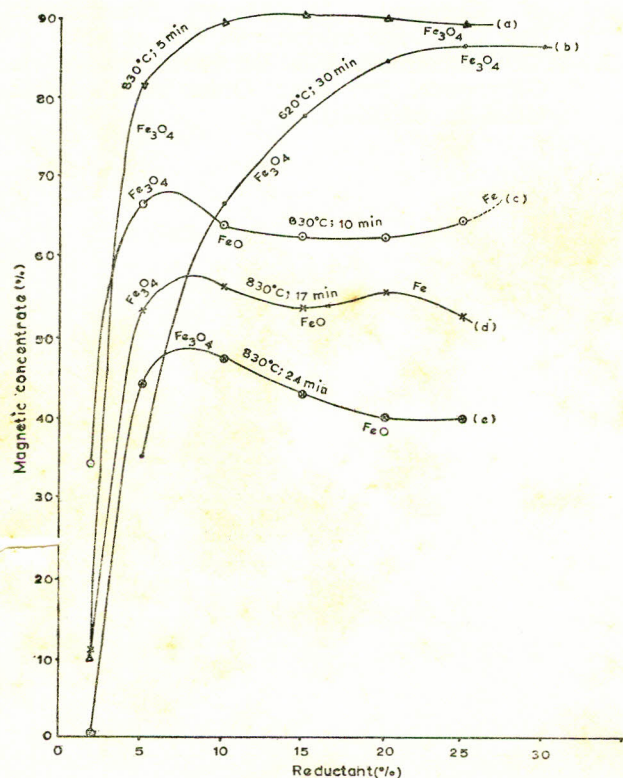Fig. 1. Recovery of iron in the magnetic concentrate by reduction with 33% charcoal for 30 minutes.

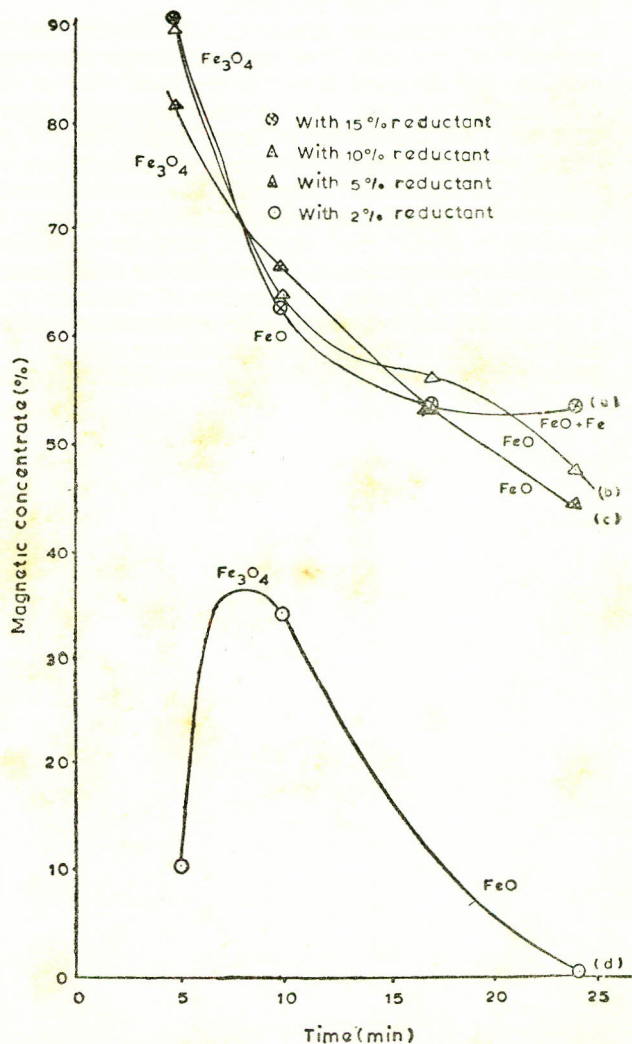Fig. 2. Recovery of magnetic concentrate by reduction at 830°C and 620°C.

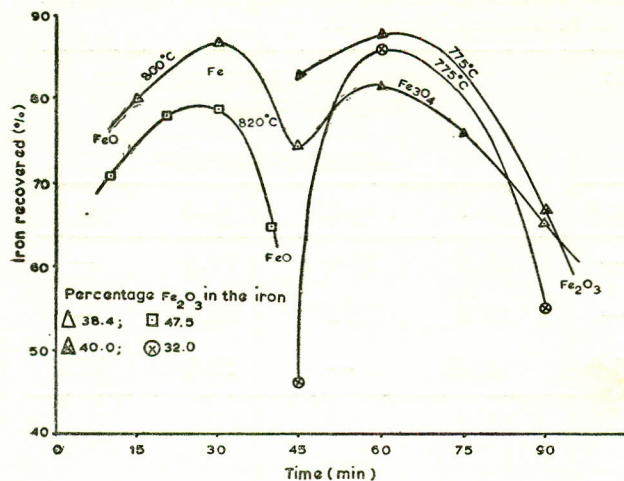Fig. 3. Recovery of magnetic concentrate by reduction at 830°C with varying amounts of charcoal.

Fig. 4.   Effect of time on reduction with 33% charcoal.

which hindered the magnetic separation of magnetized portions from the unreduced ore and FeO (wustite), one of the reduction products.

The concentrations achieved with respect to the recovery of iron and iron contents in the recovered portion may be good from the point of view of the concentrate to be used as iron ore.   Separation aimed at nearly 100% recovery of iron in the form of Fe could be more useful, because the product can be directly fed to the steel furnace.   It is hoped that with improved magnetic separation technique it may be possible to avoid interlocking of particles to achieve required concentration of Fe suitable for steel furnace or alternatively higher temperature of reduction with slag forming ingredients must be employed to convert all the iron in the ore to iron globules or sinter.   The latter process will add to the fuel cost for heating the

burden to higher temperatures than that used in present investigations.   This type of process can be more economical if recovery of alumina is also made possible from the nonmagnetic portion (slag) in a single step sintering or roasting procedure.[9]

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