Technical Note

Beneficiation studies on ilmenite rocks of Bhandar mines

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ABSTRACT

Various mineralogical occurrences of titanium With special reference to rock deposits have been briefly reviewed. Method of beneficiation followed for the Bhandar ilmenite rock and the analytical procedure for the concentrate obtained thereof are briefly outlined. Effect of process variables such as particle size of the ore and water flow rate on the beneficiation by tabling has been studied and the results hate been codified in the form of a correlation. Experimental findings have been critically interpreted.

INTRODUCTION

Chief mineralogical occurrences of titanium are in the form of oxides, titanates and silicotitanates. Some of the common titanium minerals are rutile (TiO_2), ilmenite ($FeTiO_3$), arizonite ($Fe_2Ti_3O_9$) ,PerovsKite ($CaTiO_3$) and sphene ($CaTiSiO_5$) .However, rutile and ilmenite are the two titanium minerals which are of commercial importance. Rutile analyses more than 95%. TiO_2 with small amounts of iron, vanadium and other impurities and is comparatively less abundant in nature. Theoretically, ilmenite is ferrous titanate($FeO.TiO_2$) containing 52.6% TiO_2 and 36.8% iron. Although lunar ilmenite is almost pure $FeTiO_3$[1] , the terrestial ilmenites have wide variations in composition because of partial replacement of the ferrous iron by Mn, Mg and ferric iron during the process of alteration of natural ilmenite[2]. Ilmenite has been mined both from rocks and beach sand deposits. Ilmenite occurs as accessory minerals in igneous and metamorphic rocks which upon weathering, transportation and concentration by wave action yield the placer deposits[3]. These are the secondary deposits of ilmenites.

The rock deposits are the primary deposits of ilmenites. Nearly all the known commercially important rock deposits of titanium minerals are found in anorthositic or gabbroic rocks. These deposits may be broadly classified as (i) ilmenite-magnetite, (ii) ilmenite-hematite and(iii) ilmenite-rutile types[2].

The titaniferrous (ilmenite-magnetite) deposits usually contain ilmenite and magnetite as granular intergrowths which can be readily separated to yield ilmenite and magnetite concentrate. Ilmenite-hematite deposits usually contain these minerals as intimate intergrowths with hematite in the form of lense-shaped masses and are found in anorthosite and nelsomite dikes. Ilmenite rutile deposits, associated with anorthosite may contain ilmenite and rutile separately of together.

The rock deposits of ilmenites found in Bhandar Mines, Sambalpur (Orissa) belong to the second category of deposit, viz., ilmenite-hematite type. The type of mineralogical constituents present in the ore has been predicted from a ternary phase diagram of $FeO\text{-}Fe_2O_3\text{-}TiO_2$[4,5] (Fig. 1.) and it is found to be composed Of pseudobrookite and rhombohedral phases. The Chemical Composition of this ore is given in Table I.

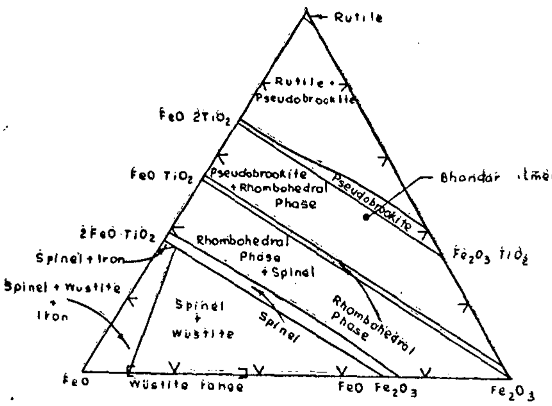

Fig. 1 Phass diagram for the system $FeO\text{-}Fe_2O_3\text{-}TiO_2$.

TABLE I – Average analysis of ilmenites.

Constituents	Ore	Concentrate
TiO_2	32.32	41.20
FeO	7.83	10.26
Fe_2O_3	38.66	33.85
SiO_2	7.38	1.52
Al_2O_3	8.04	6.60
MnO_2	0.85	0.98
MgO	0.54	0.89
CaO	3.13	3.88
Loss in ignition	1.21	0.80
Total Fe	33.15	31.68

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In view of the low TiO_2 content of the ore, it is essential that proper beneficiation techniques be employed with a view to enriching the ore, so that commercial exploitation becomes feasible. The enriched ilmenite can be used for the production of low carbon ferrotitanium by the aluminothermic process. With this end in view, beneficiation studies have been conducted on Bhandar ilmenite rock and the effect of different process variables on enrichment has been investigated. An empirical correlation has also been suggested which relates enrichment with various system parameters.

EXPERIMENTAL

Table II lists the specific gravities of possible constituents present in the ore[6]. Keeping in view the differences in specific gravities of some of the impurities and the versatility of the process, gravity separation by tabling was adopted in the present study.

The set-up consists of a constant level tank, rotameter, feed mixer, Wilfley table and collecting troughs (Fig. 2). The table had a capacity of 10 kg of concentrate per hour and was set at an inclination of 5°.

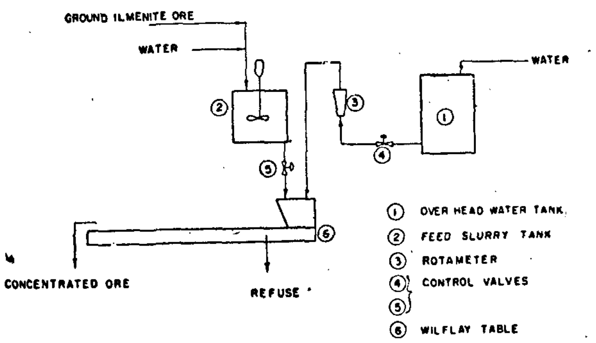

Fig. 2 Schematic diagram of the experimental setup (1) Over head water tank, (2) Feed slurry tank, (3) Rotameter, (4) and (5) Control valves, (6) Wilfley Table.

The ilmenite rock was crushed in a jaw crusher and ball milled. Four different sizes, viz., 36/60, 60/85, 85/100 and 100/150 B.S.S. were then prepared by sieving. For each batch a 1 kg feed was taken in the feed mixer and a uniform pulp of 15 pct slurry was prepared. A steady flow of pulp at the rate of 30 kg per hour was maintained on the table through the feed box. The flow rate of water was adjusted with the help of rotameter included in the circuit. The concentrate obtained from the table was dried, weighed and analysed for different constituents. Four different flow rates were tried with each feed sample and the procedure was repeated for all the four feed sizes.

TABLE II—Specific gravities of relevant constituents of ore.

Constituents	Specific Gravity
Rutile	4.2—4.6
Ilmenite	4.5—5.0
Hematite	5.2—5.3
Silica	2.6—2.68
Alumina	3.6—4.0

Amounts of titanium dioxide and total iron in the concentrates were determined by Jone's Reductor Method. Detailed analysis with respect to FeO, Fe_2O_s and SiO_2 was done for the feed and the concentrate.

RESULTS AND DISCUSSION

Amounts of TiO_2 and total iron in the concentrates obtained at different flow rates and from different feed sizes are given in Table III and presented in Figs. 3 and 4. Table III also indicates the yields of concentrates expressed in percentage with respect to the original feed sample.

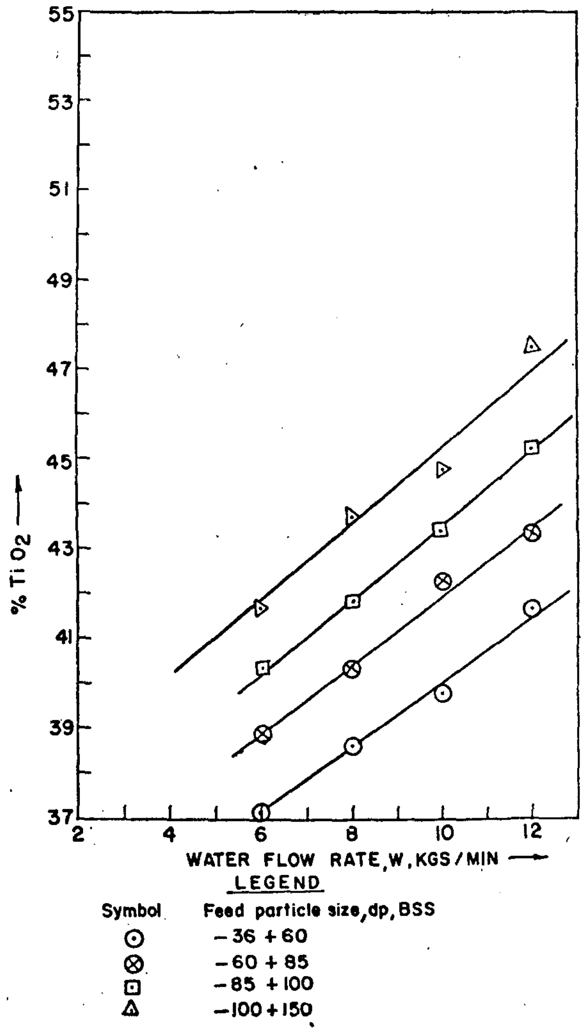

Fig. 3 Variation of % TiO_2 in concentrate with water flow rate.

TABLE III—Variation of % of TiO_2 and % of total iron with water flow rates and feed particle size.

Batch Size : 1 Kg of ground ore as 15% slurry

Sl. No.	Feed Particle Size BSS	Water flow rate Kg/min.	Yield of concentrate %	% Total Iron	Enrichment as % TiO_2		% deviation of calculated values from the experimental values.
					From Expt.	From Corelation	
	−36+60	Untreated fraction	—	33.18	31.74	—	—
		6	96.3	35.82	37.15	37.20	+0.14
1	(0.337 mm).	8	95.0	34.81	38.57	38.80	+0.60
		10	91.8	33.72	39.80	40.40	+1.51
		12	92.0	33.05	41.70	42.00	+0.72
		Untreated fraction	—	32.37	32.28	—	—
		6	94.7	35.08	38.86	39.35	+1.26
2	−60+85	8	92.4	34.21	40.40	40.95	+1.36
		10	91.5	33.62	42.32	42.55	+0.55
	(0.215 mm)	12	85.2	32.16	43.35	44.15	+1.85
		Untreated fraction	—	33.06	31.96	—	—
	−85+100	6	93.7	33.42	40.35	40.20	−0.37
3		8	93.2	32.16	41.83	41.80	−0.07
	(0.165 mm)	10	90.1	31.36	43.42	43.40	−0.05
		12	83.6	30.28	45.29	45.00	−0.64
		Untreated fraction	—	33.52	31.13	—	—
	−100+150	6	89.5	31.51	41.66	40.85	−1.94
		8	82.1	30.26	43.69	42.45	−2.84
	(0.128 mm).	10	75.6	28.90	44.80	44.05	−1.68
		12	75.1	27.88	47.50	45.65	−3.90

It is evident from the above table and figures that enrichment (with respect to TiO_2) varies directly with the flow rate of water and inversely with the feed size. The relationship with flow rate was found to be linear. Water flow rate beyond 12 kg/minute was not employed as it resulted in rapid carry over of the materials without bringing about effective separation. A correlation of the following form has been suggested for the prediction of enrichment of a particular feed sample at a definite flow rate of water.

$$E = 0.8\,W + 38.5\,(0.60)^{d_p}$$

Where, E = Enrichment expressed as percentage of TiO_2 in the concentrate.

W = Water flow rate kg/min.

d_p = Average particle size, mm.

Enrichment for all the sixteen cases (experimental) has been calculated by the above equation and compared with the actual values obtained from investigations in Table III. The percentage deviations lie within −3.90 to +1.85. The mean and standard deviations are 1.26% and 1.58% respectively. The ranges of applicability of the above correlation are

$$W = 6.0 - 12.0 \text{ kg/min.}$$

$$\text{and } d_p = 0.128 - 0.337 \text{ mm.}$$

The total iron in the concentrates shows decreasing trend for the finer size whereas it has a tendency to increase in the coarser fractions when the flow rate is gradually increased. Moreover a comparison of the composition of the average feed with that of the average concentrate reveals a decrease in ferric iron and an

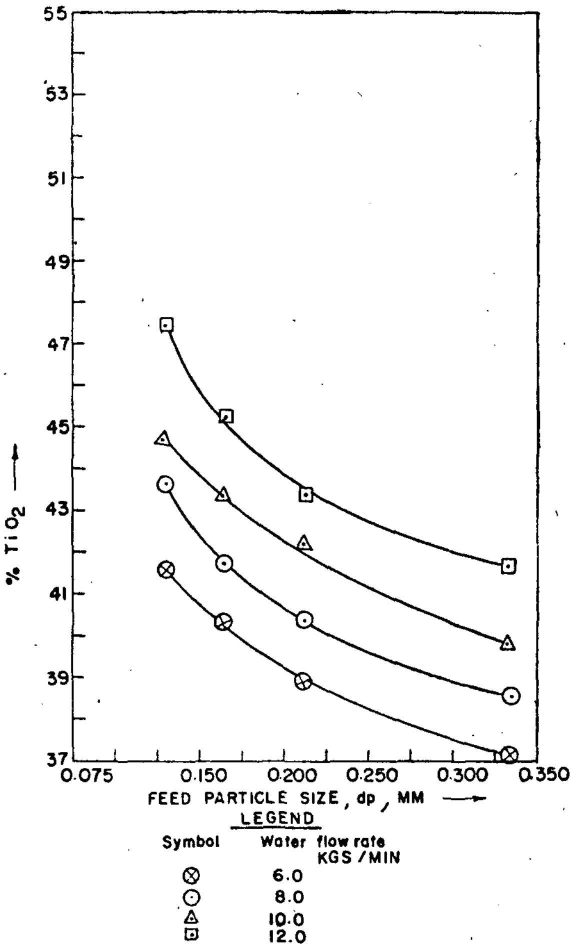

Fig. 4 Variation of % TiO_2 in concentrate with feed particle size.

increase of ferrous iron content. The ferrous iron is generally present in combined form with TiO_2 as ilmenite and an enrichment of TiO_2 by the process of beneficiation will naturally enhance its percentage. On the other hand, ferric iron which is one of the major constituents of the ilmenite-hematite type ore is present in the rock as part of the structure both as a result of solid solubility of Fe_2O_3 in ilmenite and because of the process of alteration of natural ilmenite. The ferric iron formed from altered ilmenite is likely to be present along the grain boundaries which are left free by the process of crushing and grinding and are separated easily by the conventional methods of beneficiation like tabling. Though hematite (ferric iron) has higher specific gravity, it has higher grindability and, hence, in the process of crushing and grinding, becomes very fine. These fines get washed away easily during beneficiation by tabling. However, the ferric iron present in solid solution remains intact and is unaffected by such beneficiation processes. Thus, the total iron gets reduced in the finer size ranges and increases in the case of coarser ones where proper breaking of the grain boundaries does not occur. Also, for the whole range of operation it is the ferric iron that gets reduced.

Thus, it is seen that the process of beneficiation as adopted in the present study can be effectively employed for the rock deposits of ilmenite-hematite type as a primary step of enrichment of the ore.

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REFERENCES

1. A. A. Leuinson and S. Ross Taylor, "Moon Rocks and Minerals", Pergamon Press, (1971), 65.
2 H N. Sinha, "Proceedings, International Symposium on Fifty Years of Metallurgy" (1973), 97.
3. Jesse. A. Miller, "Titanium-A Materials Survey", Bureau of Mines, Information Circular. (1957), 7791.
4. R. W; Taylor. The American Mineralogist, 49 (1964), 1016.
5. J. B. Macchesney and A. Muan, Ibid, 44 (1959), 926.
6 E S.Dana and W. E. Ford,"A Text Book of Mineralogy", 4th Edition, (1958).