RESEARCH AND COMMERCIALISATION OF TREATMENT OF FINE ILMENITE WITH SLON MAGNETIC SEPARATORS

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The fine ilmenite material finer than 0.045 mm at the Pang Zhi Hua Ilmenite Processing Plant was discarded for the lack of efficient processing equipment and method. The total recovery of ilmenite in the plant had been only about 17–20%. To increase the ilmenite recovery, numerous laboratory, pilot and commercial tests were conducted in 1995–1996. Finally, a magnetic separation-flotation flowsheet was chosen for the commercial test, in which the fine fraction was fed into 125 mm diameter cyclones for desliming. The underflow of the cyclones was then fed into the magnetic separation-flotation flowsheet. A SLon-1500 vertical ring and pulsating high gradient magnetic separator was applied as a rougher and was followed by flotation as a cleaner. The overall results of the magnetic separation-flotation flowsheet in the commercial test were: feed 11.03% TiO₂, concentrate 47.36% TiO₂, recovery 44.79% TiO₂. The flowsheet of the commercial test has been used as a production process since 1997. The recovery accounted for about 12% TiO₂ of the feed into the ilmenite processing plant.

Keywords: Ilmenite; Magnetic separation; SLon pulsating magnetic separator

1. INTRODUCTION

The Pang Zhi Hua Ilmenite Processing Plant is the biggest producer of ilmenite in China. The deposit consists of vanadium, titanium and iron minerals and other gangues. Magnetite is the major iron mineral and vanadium exists in magnetite. Ilmenite is the major titanium mineral. An iron processing plant recovers magnetite and vanadium before the ilmenite processing plant. The tails of the iron processing plant represent the feed into the ilmenite processing plant.

The previous flowsheet of the ilmenite processing plant was based on classification into +0.1 mm (coarse), 0.1–0.045 mm (middle) and –0.045 mm (fine) fractions. The coarse and the middle particle fractions were treated with spirals and electrical separators. The fine fraction was discarded as the final tails for the lack of efficient beneficiation technology. The overall recovery of ilmenite had been only 17–20% of the feed of the ilmenite processing plant.

The mass of the fine fraction is about 35% and the TiO_2 grade is almost the same as that of the feed to the ilmenite plant. The recovery of ilmenite from the fine particle fraction is thus of great significance for increasing the overall recovery of the ilmenite plant.

2. MINERALOGICAL ANALYSIS

Major minerals and their physical properties in the feed into the ilmenite plant are shown in Table I.

3. THE LABORATORY TESTWORK ON FINE ILMENITE

3.1. Laboratory Tests of Magnetic Separation

Ilmenite is our target mineral to be recovered and the other minerals are considered to be tailings. It can be seen from Table I that magnetic susceptibilities of vanadium–titanium magnetite, ilmenite and pyrite are relatively stronger than the others. But magnetic susceptibility of titaniferous augite is close to that of ilmenite. It is possible to remove plagioclase and part of titaniferous augite by magnetic separation.

The fine particle fraction (–0.045 mm) of the ilmenite plant feed was used as the feed in our laboratory test. SLon-100 cyclic pulsating high gradient magnetic separator (SLon-100) was used as a rougher. In the test, the matrix type, the background magnetic induction, pulsating stroke and pulsating frequency were optimized. Typical results of the magnetic separation test are shown in Table II.

Table II shows that with 4 mm dia. rod matrix in SLon-100 magnetic separation better results can be obtained than with 2 mm dia. rod matrix

TABLE I Minerals and their properties in the feed of the ilmenite plant (%)

<i>Mineral</i>	<i>Molecule</i>	<i>Mass (%)</i>	<i>Grade (TiO₂%)</i>	<i>Specific density</i> (g/cm ³)	<i>Magnetic susceptibility</i> ($\times 10^{-6}$ cm ³ /g)	<i>Specific resistance</i> ($\Omega \cdot \text{cm}$)
Vanadium-titanium magnetite	(V, Ti, Fe) ₃ O ₄	2-5	13.4	4.6-4.8	> 1000	1.38×10^6
Ilmenite	FeTiO ₃	15.3-17.5	51.89	4.6-4.7	240	1.75×10^5
Titaniferous augite	Ca(Mg, Fe, Ti) [(Si, Al) ₂ O ₆]	46-46.5	1.85	3.2-3.3	100	3.13×10^{13}
Pyrite	FeS ₂	2-2.5		4.4-4.9	4100	1.25×10^4
Plagioclase	(100 - n)Na[AlSi ₃ O ₈] · nCa[Al ₂ Si ₂ O ₈]	31-34	0.097	2.7	14	> 10 ¹⁴

TABLE II Test results of SLon-100 magnetic separation of fine ilmenite

<i>Product</i>	<i>Mass (%)</i>	<i>Grade (TiO₂%)</i>	<i>Recovery (TiO₂%)</i>	<i>Separating conditions</i>		
				<i>Matrix type</i>	<i>Background induction (T)</i>	<i>Pulsating stroke (mm)</i> <i>Pulsating frequency (min⁻¹)</i>
Concentrate	27.71	21.77	65.22	2 mm dia. rod	0.46	12 200
Tails	72.29	4.45	34.78			
Feed	100.00	9.25	100.00			
Concentrate	26.95	22.29	64.93	4 mm dia. rod	0.58	12 225
Tails	73.05	4.44	35.07			
Feed	100.00	9.25	100.00			
Concentrate	28.21	20.55	62.67	Expanded mesh	0.46	12 225
Tails	71.79	4.81	37.33			
Feed	100.00	9.25	100.00			

or expanded mesh. When the feed is 9.25% TiO_2 and with 4 mm dia. rod matrix, the concentrate grade is 22.29% TiO_2 , the tails grade is 4.44% TiO_2 , recovery in the concentrate is 64.93% TiO_2 , the mass of the concentrate is only 26.95% and the mass of the tails is 73.05%. The importance of magnetic separation is that it can discard about 73% by mass of the low-grade tails and only about 27% by mass of the concentrate enters into next cleaning stage. For example, if flotation is used for the cleaning, a lot of flotation reagents can be saved.

3.2. Laboratory Tests with Flotation as a Cleaning Stage

In the laboratory flotation tests, several reagents as collectors were tested and the flowsheet was optimized. Typical results are shown in Table III.

The Table shows that the grade of the ilmenite concentrate can be upgraded to about 47% TiO_2 by flotation. Recovery of TiO_2 in the flotation stage can reach about 60% in the open circuit or about 85% in the closed circuit.

3.3. Summary of the Laboratory Tests

Table IV shows the overall results of magnetic and flotation separation in laboratory tests. With SLon-100 magnetic separation as a rougher and flotation as a cleaner, we can get the final concentrate with 47.10% TiO_2 grade and 55.47% recovery in the closed flotation circuit or 46.87% TiO_2 grade and 39.12% recovery in the open flotation circuit.

TABLE III Results of the laboratory test of flotation in the cleaning stage

<i>Product</i>	<i>Mass (%)</i>	<i>Grade ($\text{TiO}_2\%$)</i>	<i>Recovery ($\text{TiO}_2\%$)</i>	<i>Flotation flowsheet</i>
Concentrate	40.43	47.10	85.44	One roughing, one cleaning, one scavenging (closed circuit)
Tails	59.57	5.45	14.56	
Feed	100.00	22.29	100.00	
Concentrate	28.65	46.87	60.24	One roughing, one cleaning, one scavenging (open circuit)
Tails	71.35	12.42	39.76	
Feed	100.00	22.29	100.00	
Concentrate	27.21	47.54	58.04	One roughing, one cleaning, one scavenging (open circuit)
Tails	72.79	12.85	41.96	
Feed	100.00	22.29	100.00	

TABLE IV Summary of the results of the laboratory tests of magnetic and flotation separation

<i>Product</i>	<i>Mass (%)</i>	<i>Grade (TiO₂%)</i>	<i>Recovery (TiO₂%)</i>	<i>Flotation flowsheet</i>
Final concentrate	10.90	47.10	55.47	SLon-100 roughing, flotation cleaning (closed circuit)
Total tails	89.10	4.62	44.52	
SLon-100 feed	100.00	9.25	100.00	
Final concentrate	7.22	46.87	39.12	SLon-100 roughing, flotation cleaning (open circuit)
Total tails	92.28	6.10	60.88	
SLon-100 feed	100.00	9.25	100.00	

The laboratory tests-scale showed the direction for subsequent pilot and commercial tests.

3.4. Pilot-Plant Tests on Fine Ilmenite

In 1995, SLon-1000 vertical ring and pulsating high gradient magnetic separator [1] was moved to Pang Zhi Hua Ilmenite Processing Plant for pilot-plant tests to recover ilmenite from the discarded -0.045 mm ilmenite slime. SLon-1000 was installed in the production flowsheet and a slurry stream of -0.045 mm ilmenite slime was used as its feed. The magnetic product (the rougher concentrate) was used as the flotation feed in the cleaning stage. The flowsheet of the pilot test is shown in Fig. 1.

In the pilot-plant tests technical parameters were first optimized. Then SLon-1000 ran continuously for 72 h to get more reliable results. As is shown in Fig. 1, SLon-1000 removes about 75% by mass of the low-grade tails, and most of the slimes ($-10\ \mu\text{m}$ fraction) which are harmful to the flotation reaction, reported into the tails. Only about 25% of the mass enters the flotation cleaning stage.

The overall results showed that a good ilmenite concentrate containing 47.60% TiO_2 with the total recovery of 44.20% TiO_2 can be obtained.

4. THE COMMERCIAL TESTS

Based on the results of the pilot test a commercial test was carried out in 1996. SLon-1500 vertical ring and pulsating high gradient magnetic

FIGURE 1 The flowsheet of the pilot-plant test of magnetic separation and flotation of the -0.045 mm ilmenite slime.

separator was installed in the production flowsheet as shown in Fig. 2. In order to increase the throughput of SLong-1500, 125 mm diameter cyclones were used to dewater and deslime the -0.01 mm slime fraction. The operational results of the cyclones, of SLong-1500 and of flotation are shown in Tables V–VII respectively.

Table V shows that the cyclone operation is important because the solids concentration in the feed is only 5.42%. The solids concentration of the cyclone underflow is 28.32%. Most water and -0.01 mm slimes report into the cyclone overflow. This creates a much better condition for the SLong-1500 operation. As shown in Table VI, the capacity of SLong-1500 reaches 25.25 t/h with 76.24% TiO_2 operational recovery. Figure 2 shows that the combined TiO_2 recovery of the cyclone and SLong-1500 is 50.51%, almost the same compared with the pilot test shown in Fig. 1.

FIGURE 2 The flowsheet of the commercial test of magnetic separation and flotation of the -0.045 mm ilmenite fraction.

TABLE V The operational results of 125 mm diameter cyclones (%)

Feed			Under flow product			Overflow product		
Solid density	TiO ₂	TiO ₂ distribution	Solid density	TiO ₂	TiO ₂ distribution	Solid density	TiO ₂	TiO ₂ distribution
5.42	10.12	100.00	28.32	11.03	66.24	2.94	8.71	33.76

The operation of the cyclone and SLon-1500 created very good conditions for the flotation stage. The first two operations discarded 75.91% of mass and most of the -0.01 mm slimes into the tails. Only 24.09% of mass of the magnetic concentrate enters into the flotation cleaning stage. As shown in Table VII, the flotation results are very

TABLE VI The average operational results of SLon-1500 (%)

t/h	<i>Feed</i>		<i>Concentrate</i>			<i>Tails</i>		
	−0.045 mm	<i>TiO₂</i> <i>grade</i>	<i>Mass</i>	<i>TiO₂</i> <i>grade</i>	<i>TiO₂</i> <i>recovery</i>	<i>Mass</i>	<i>TiO₂</i> <i>grade</i>	<i>TiO₂</i> <i>distribution</i>
25.25	75	11.03	39.63	21.22	76.24	60.37	4.34	23.76

TABLE VII The average operational results of flotation (%)

<i>Product</i>	<i>Mass</i>	<i>TiO₂</i> <i>grade</i>	<i>TiO₂</i> <i>distribution</i>
Pyrite	2.70	12.57	1.60
Ilmenite concentrate	39.73	47.36	88.68
Tails	57.57	3.59	9.72
Feed (SLon-1500 Mags)	100.00	21.22	100.00

good. The final grade of ilmenite concentrate reaches 47.36% TiO_2 and the flotation recovery is 88.68% TiO_2 . The overall ilmenite recovery of the full flowsheet is 44.79% TiO_2 .

5. THE PRODUCTION-SCALE APPLICATION

The commercial test shown in Fig. 2 was completed at the end of 1997, and the flowsheet was implemented on production scale. In 1998, about 10 000 t of > 47% TiO_2 ilmenite concentrate was recovered from the −0.045 mm fine fraction. After more than a one year-long production practice, it was demonstrated that the SLon-1500 VPHGMS magnetic separator works very reliably. In 1999, the production scale of the −0.045 mm fine fraction is expected to reach 15 000–20 000 t of the ilmenite concentrate as the flowsheet becomes more optimized.

6. CONCLUSIONS

A magnetic separation-flotation flowsheet is applied to the recovery of the −0.045 mm fine ilmenite minerals from the previous tails in the Pang Zhi Hua Ilmenite Processing Plant. SLon-1500 vertical ring and pulsating high gradient magnetic separator is used in the roughing stage. It is a key equipment for the flotation cleaning stage. The overall flowsheet is relatively simple and reliable. It has been put into production

by the end of 1997. The overall results of the flowsheet are as follows: feed grade 11% TiO_2 , ilmenite concentrate grade $\geq 47\%$ TiO_2 and TiO_2 recovery 44%. Approximately 10 000–20 000 t of such ilmenite concentrate can be recovered from the previously abandoned tails. It is a significant technological innovation in the history of the Pang Zhi Hua Ilmenite Processing Plant.

Reference

- [1] Xiong, Da-He. New development of the SLon vertical ring pulsation HGMS separator. *Magn. Electr. Sep.* **5** (1994), 211.