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NEW DEVELOPMENT OF THE *SLON* VERTICAL RING AND PULSATION HGMS SEPARATOR

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Abstract SLON–1000 and SLON 1500 vertical ring and pulsation high–gradient magnetic separators have been developed in recent years. Because of their ability to treat fine weakly magnetic minerals they are being rapidly applied in several mineral processing plants to treat oxidised iron ores. In this paper, their structure, working principles and new applications will be described.

INTRODUCTION

The first SLON–1000 vertical ring and pulsation high–gradient magnetic separator (SLON–1000 VPHGMS) was successfully developed in 1988 at Ganzhou Non–Ferrous Metallurgy Research Institute. It attracted a considerable interest of numerous domestic and foreign specialists owing to its unique design and its excellent mineral beneficiation capability. In recent years an effort was made to scale up the separator to production size. The designers of the separator not only successfully developed the SLON–1500 VPHGMS, improved considerably its design , increased its reliability and benefication efficiency, but also successfully applied the machine on the production or pilot–plant scales at the Gushan Iron Mine of Ma Anshan Iron and Steel Company, Meisha Iron Ore Mine of Shanghai Iron and Steel Company and Gong Changling Mineral Processing Plant of Anshan Iron and Steel Company and promoted the progress of technology at these mines and plants.

DESIGN AND WORKING PRINCIPLES OF THE SLON VPHGMS

The SLON VPHGMS separator utilises the combined force field of magnetic force, pulsating fluid and gravity to beneficiate fine weakly magnetic particles. Its unique feature is the vertically rotating ring whereby the magnetic fraction is flushed in the direction opposite to that of the feed, and the mechanism of slurry pulsation.

When treating fine weakly magnetic minerals, the separator has a higher beneficiation ratio, the matrix cannot be easily blocked and the separator is flexible and adaptable compared to other high–gradient magnetic separators.

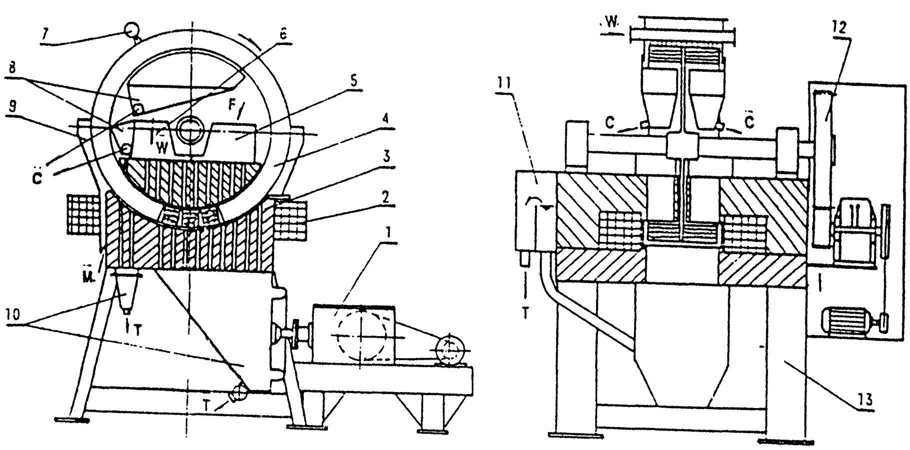


Fig. 1. SLON VPHGMS. 1–pulsating mechanism, 2–energising coil, 3–magnetic yoke, 4–working ring, 5–feeding box, 6–wash water box, 7–concentrate flush, 8–concentrate box, 9–middlings chute, 10–tailings box, 11–slurry level box, 12–ring drive, 13–support frame, F–feed, W–water, C–concentrate, M–middlings, T–tailings

The SLON VPHGMS consists of thirteen main parts, as shown in Fig. 1. The pulsating mechanism, energising coil, magnetic yoke and working ring are the key parts. The frequency of pulsation and the stroke are adjustable. The energising coil is made from hollow copper tube and cooled internally with water. Along the periphery of the ring there is a number of rectangular chambers in which the matrix of the expanded metal sheets made of magnetic stainless steel are placed. When the separator is in operation, the ring rotates clockwise.

The slurry fed from the feed box enters the ring through slots in the upper yoke. The matrix in the working zone is magnetised. The magnetic particles are attracted from the slurry onto the surface of the matrix, then brought to the top of the ring where the magnetic field strength is negligible, and are then flushed out into the concentrate box.

The non–magnetic particles pass through the matrix and enter the tailings box through slots in the lower yoke under the combined action of the slurry pulsation, gravity and the hydrodynamic drag. The pulsating mechanism drives the rubber diaphragm on the tailings box so that it moves back and forth. As long as the slurry level is adjusted above the fixed level in the slurry level box, kinetic energy due to the pulsation can be effectively transmitted to the working zone.

As the direction of flush of the magnetic fraction is opposite to that of the feed, relative to each matrix pile, coarse particles can be flushed without having to pass through the entire depth of the matrix. The slurry pulsation can keep particles within the matrix in a loose suspended state all the time. It is clear that the reverse flush and the slurry pulsation allow to prevent the matrix clogging while the pulsation improves the quality of the concentrate.

Moreover, these measures not only ensure the effective recovery of weakly magnetic particles as small as 10 μm, but also extend the size range of the feed material up to about 1 mm, thus increasing the upper limit of the particle size to be treated and simplifying a classification operation.

The major parameters of SLON VPHGMS are summarised in Table I while the overall view of the the SLON–1500 separator is shown in Fig. 2. The average magnetic field strength in the working zone is up to 1.0 Tesla which is usually sufficient for most oxidised iron ores.

Table I. Parameters of the SLON–1000 and SLON–1500 VPHGMS

Parameter	SLon-1000	SLon-1500
Ring Diameter (mm)	1000	1500
Background Magnetic Induction (T)	0 to 1.0	0 to 1.0
Energising Power (kW)	25.5	38
Driving Power (kW)	1.1+1.1	3+4
Pulsating Stroke (mm)	0 to 30	0 to 30
Pulsating Frequency (minE-1)	0 to 400	0 to 400
Feed Size (mm)	- 1.0	- 1.0
Throughput (t/h)	4 to 7	20 to 35
Mass of Machine (t)	6	20

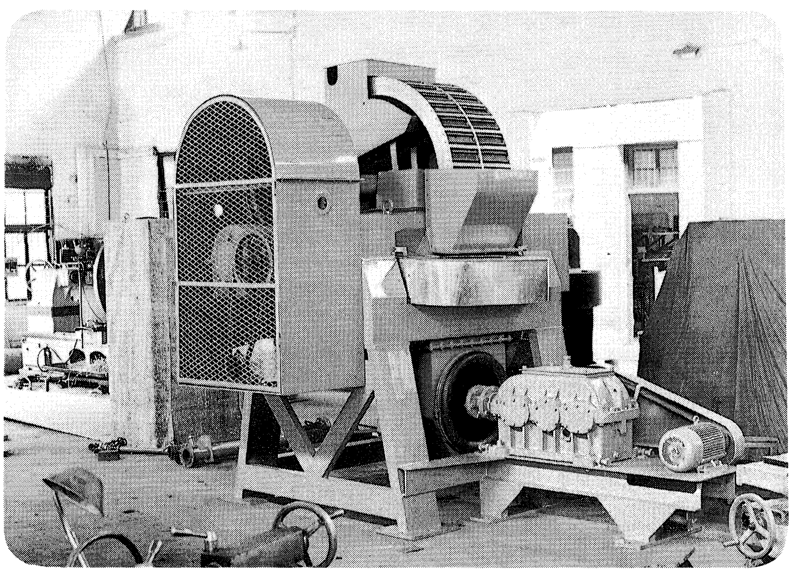


Figure 2. Vertical–ring and pulsation high–gradient magnetic separator SLON–1500

NEW APPLICATIONS OF SLON VPHGMS

Beneficiation of Hematite Ore at Gushan Iron Ore Mine

Gushan Iron Ore Mine is one of the major bases of raw materials of Ma Anshan Iron and Steel Company. The ore is finely disseminated with colloidal hematite and quartzite. The size range of most hematite particles is +5 –30 μm. The ore is difficult to grind and beneficiate. The beneficiation plant was established in 1978; the gravity–based flowsheet used jigs, spirals and centrifugal separators as major beneficiation equipment.

After the ore was crushed down to –12 mm, jigs removed part of coarse iron concentrate and part of coarse tailings. The jig middlings amounting to approximately 50 per cent of the feed ore were ground in a ball mill, classified into two classes and then treated by a spiral concentrator and a centrifugal separator, respectively. The beneficiation results of the milled fraction were quite poor for many years. For instance, the production results of the milled fraction were, in 1988, as follows:

Feed grade:	37.16% Fe
Concentrate grade:	55.22% Fe
Tailings grade:	24.47% Fe
Iron recovery:	61.32%.

In order to improve the production results, the flowsheet of the milled fraction was modified in, 1989–1992, into a stage grinding–high–intensity and high–gradient magnetic separation. Two SLON–1500 VPHGMS separators are being used as scavengers and the SQC high–intensity magnetic separators are installed as roughers or cleaners. The flowsheet of the plant is shown in Fig.3.

The overall results of this flowsheet are as follows:

Feed grade:	32.48% Fe
Concentrate grade:	58.19% Fe
Tailings grade:	13.76% Fe
Iron recovery:	75.49% Fe.

Compared with the previous gravity flowsheet, the grade of the iron concentrate is 2.87% higher and the recovery is 14.17% higher. The increase in the recovery is mainly due to the SLON–1500 VPHGMS separators which recover part of the iron from the tailings of the SQC cleaner, which otherwise would be difficult to recover.

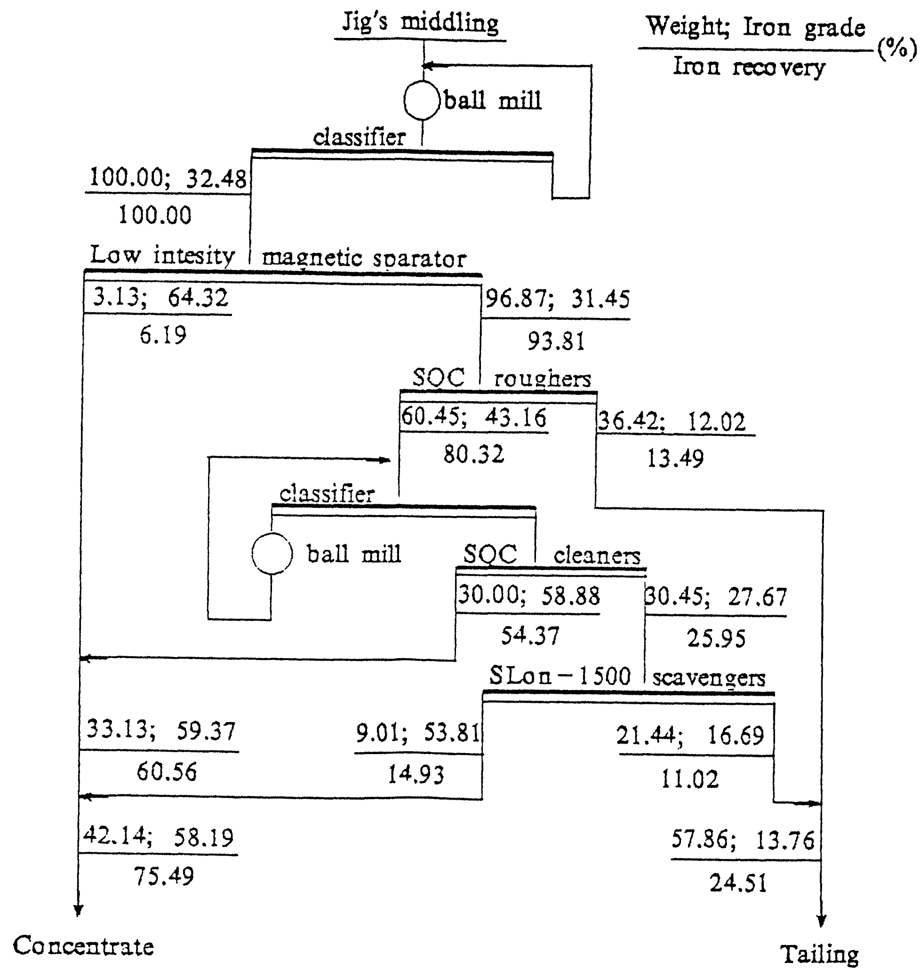


Fig.3. The application of the SLON–1500 VPHGMS separator in the magnetic separation flowsheet of the Gushan Iron Ore Mine.

The Application in Desulphurisation and Dephosphorisation

There is a large iron ore deposit at Meishan Iron Ore Mine. The ore contains a mixture of magnetite, siderite, hematite and pyrite. The iron concentrate is supplied mainly to the Shanghai Metallurgical Company as a ball raw material. However, because of a high content of sulphur and phosphorus, the iron concentrate alone cannot be used as a ball raw material but rather as an auxiliary material. Production of the iron concentrate is thus limited.

In order to reduce the concentration of sulphur and phosphorus, the Meishan Iron Ore Mine cooperated with several research institutes and performed site trials in 1990 with a magnetic separation flowsheet for desulphurisation and dephosporisation of the iron concentrate. Principal flowsheet is shown in Fig. 4. The SLON–1000 VPHGMS was applied as scavenger which effectively controlled the grade of the tailings and made important contribution to guarantee the total recovery of iron.

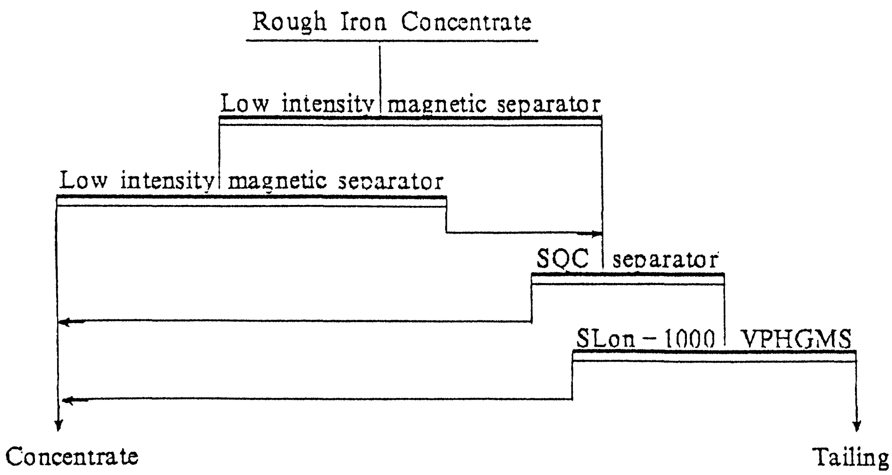


Fig. 4. The application of SLON–1000 to desulphurisation and dephosporisation of the Meishan iron concentrate.

The test results summarised in Table II. show that 49.99% of sulphur and 45.55% of phosphorus reported into the tailings, the loss of iron being 4.37% only. The grade of the iron concentrate was increased from 53.69% to 57.50%

Fe while the concentrations of S and P were greatly reduced. The quality of the iron concentrate was thus considerably improved. Presently, this flowsheet is being implemented in the second extension stage.

Table II. The test results of desulphurisation and dephospohorisation of the Meishan iron concentrate.

Product	Mass (%)	Grade (%)			Recovery (%)		
		TFe	S	P	TFe	S	P
Concentrate	89.3	57.5	0.14	0.23	95.6	50.0	54.5
Tailing	10.7	21.9	1.20	1.62	4.4	50.0	45.5
Rougher Concentrate	100.0	53.7	0.26	0.38	100.0	100.0	100.0

Processing of the Gong Changling low–grade hematite ore.

Gong Changling Mineral Processing Plant is one of the major raw material bases of Anshan Iron and Steel company. Its hematite–processing plant treats 2.8 million tonnes of ore annually, with stage grinding and benefication flowsheet. The fine fraction (80% – 200 mesh) representing approximately 50% of the feed ore is treated by Φ 1600×900 centrifugal separators with one roughing stage to eliminate the tailings, and with two cleaning stages to produce the iron concentrate.

The main problem in the production is that the concentration of iron in the tailings is too high which seriously affects the recovery of iron into the concentrate. In September 1989 the Ganzhou Non–Ferrous Metallurgy Research Institute initiated a joint project with the Anshan Mine Company and its Gong Changling Mineral Processing Plant. Pilot–plant tests using SLON–1000 magnetic separators were carried out, continuously treating, for a period of one month, the fine fraction of the ore. The SLON–1000 VPHGMS was installed at the position of the roughing centrifugal separator and treated the same feed. During the trials the separator worked for 713 hours and its availability was as high as 99%. Comparison of the metallurgical results achieved using the SLON separator and the centrifugal separator are shown in Table III.

Table III. Results of SLON–1000 and of the centrifugal separator (%Fe)

Separator	Grade (%)			Mass of Conc. (%)	Recovery of Conc. (%)
	Feed	Conc.	Tails		
SLon-1000	31.7	50.8	9.1	54.3	86.9
Centrifuger	31.8	46.7	19.2	45.9	67.3

Compared to the centrifugal separator, the grade of the concentrate produced by the SLON separator was 4.12% higher, the grade of the tailings 10.16% lower and the recovery of iron 19.65% higher. It can thus be seen that the results obtained using the SLON separator were considerably better. The pilot–scale tests laid firm foundations for the production–scale application of the SLON VGHGMS in the plant.

In order to demonstrate that the SLON VPHGMS can fully replace the roughing centrifugal separators on the production scale, the Anshan Mine Company and Gong Changling Mineral Processing plant, in cooperation with the Ganzhou Non–Ferrous Metallurgy Research Institute and Ganzhou Non–Ferrous Metallurgical Machinery Plant installed, in the period from March 1991 to July 1992, five SLON–1500 VPHGMS separators in the 7–8 lines of the hematite processing plant. These separators replaced 24 units of the Φ1600×900 mm roughing separators and the production–scale tests were carried out for 16 months. Results of the total test flowsheet, for the last three months (from May to July 1992) and of the original flowsheet (lines 5–6) are shown in Table IV.

It can be seen that after the installation of the SLON–1500 VPHGMS in lines 7–8 the grade of the tailings drop sharply, the recovery of iron increased by

15.99% and the grade of the concentrate increased by 1.53% Fe. These results established an efficient way of increasing the recovery of the Anshan–type hematite ore. Presently, five SLON–1500 VGHGMS separators are in operation and they are shown in Figure 5.

Table IV. The overall results as obtained using either the original flowsheet or the modified circuit which employed the SLON–1500 VPHGMS.

System	Grade of feed ore	Concentrate (% Fe)			Grade of tails
		Grade	Mass	Recovery	
7-8 (test)	28.5	64.3	31.8	71.9	11.7
5-6 (unmodified)	28.5	62.8	25.4	55.9	16.8
Difference	0	+1.5	+6.4	+16.0	-5.1

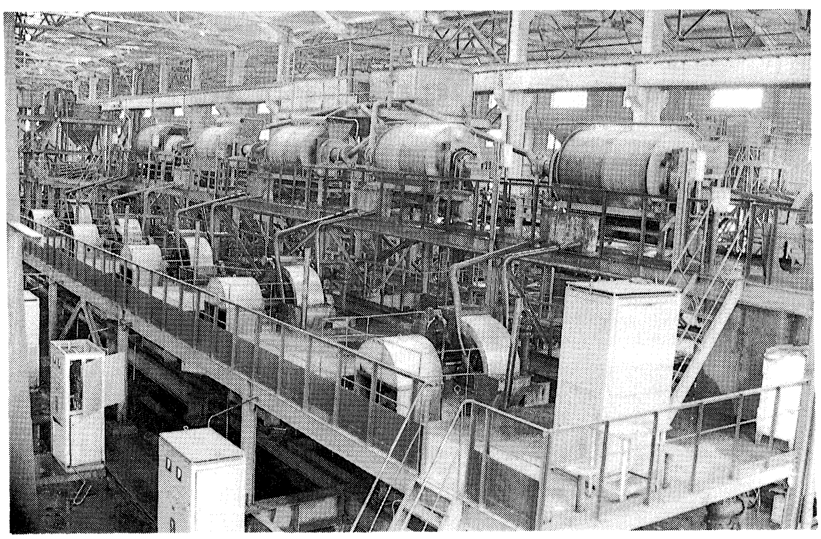


Fig. 5. SLON–1500 magnetic separators at the Gong Changling Mineral Processing Plant of the Anshan Iron and Steel Company.

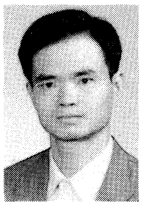
CONCLUSIONS

The application of the SLON vertical ring and pulsation high–gradient magnetic separators at the Gushan Iron Ore Mine, Meishan Iron Ore Mine and Gong Changling Mineral Processing plant demonstrated that the separator can efficiently beneficiate fine weakly magnetic minerals.

The SLON–1500 VPHGMS was applied at the Gushan Iron Ore Mine and Gong Changling Mineral Processing plant to treat fine hematite ore and considerable increase in the recovery of iron was achieved. SLON–1000 VPHGMS, as applied to desulphurisation and dephospohorisation of the rough iron concentrate at the Meishan Iron Ore Mine substantially reduced the concentration of sulphur and phosphorus in the iron concentrate. Successful application of magnetic separation technology at these plants and mines promoted advances of their technology and production.

In general, SLON VPHGMS separator which combines theories of gravity concentration and of magnetic separation became the first industrial continuous mineral processing separator which utilises the combined force of a pulsating fluid, gravity and high–gradient magnetic force. It not only possesses advantages of conventional HGMS separators in recovering fine weakly magnetic minerals, but it also considerably increases the grade of the magnetic concentrate, eliminates the matrix clogging, extends the range of particle sizes of the feed material and improves mechanical stability.

It represent a new type of an efficient magnetic separator for fine particle treatment and may contribute to a technological reform of old plants and to a construction of new mines. It is expected that the separator will be further developed and applied in a near future.



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Keywords: high–gradient magnetic separation, slurry pulsation, combined force field, hematite beneficiation, desulphurisation