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THE NEW MEDIUM–INTENSITY DRUM–TYPE PERMANENT MAGNETIC SEPARATOR PERMOS® AND ITS PRACTICAL APPLICATIONS FOR THE PROCESSING OF INDUSTRIAL MINERALS AND MARTITIC IRON ORES

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Abstract: KHD Humboldt Wedag AG developed an improved version of a drum–type magnetic separator PERMOS with special magnetic field configuration for the NdFeB permanent magnets which is giving the magnetic field strength of 0.7 Tesla and a wide working range outside the drum. The magnet system within the PERMOS unit is no longer made of relatively large magnet blocks of alternate radial magnetisation; the system is now made up of a multitude of small NdFeB bars with a specially oriented magnetisation. This open–gradient magnetic separator can be used for dry magnetic separations in "top–feed" or "free–fall" feed configuration as well as in the conventional wet "drum–type" feed mode. It allows high throughput rates of up to 40 tonnes of solids per hour per meter of the drum length without any clogging problems in case of higher magnetite content in the feed material. Important design features and the actual machine characteristics of the improved PERMOS units for dry and wet magnetic separation are described and typical examples for their commercial application for industrial minerals and for martitic iron ores are presented.

INTRODUCTION

In the past magnetic separators for the beneficiation of ores and minerals were generally divided into two categories:

–low–intensity magnetic separators for the upgrading of strongly magnetic ores

–high–intensity magnetic separators for the beneficiation of feebly magnetic ores and for the removal of paramagnetic contaminants from industrial minerals.

The low–intensity magnetic separators used in commercial operation are mainly drum–type open–gradient separators (OGMS) in which systems of permanent magnets made of barium ferrites generate magnetic field intensities of less than 0.2 Tesla in the separation zone. These drum–type low–intensity units are used mainly for the upgrading of magnetite iron ores in wet or dry processes and for the recovery of dense media in heavy medium plants.

The high–intensity magnetic separators used on commercial scale are mainly wet–operating matrix–type separators using high intensities (WHIMS) and/or high gradients (HGMS). They provide high throughput rates at magnetic field intensities of up to 1.5 Tesla in the separation zone with electromagnetic coils, and more than 3 Tesla with superconducting coils. Their main field of practical applications is processing of fine–grained, feebly magnetic iron ores, ilmenite ores and beach sands, the removal of iron–bearing contaminants from fine–grained industrial minerals, including improving the brightness of kaolin [1, 2].

Meanwhile, the required medium field strength of up to 1 Tesla can also be made available by using the new permanent high–duty magnetic materials, particularly neodymium–iron–boron (NdFeB) compounds. This material has the remanence of up to 1.2 Tesla, and the coercive force close to 10^6 A/m, with the energy product of up to 300 kJ/m^3. These properties allow relatively high degree of freedom in shaping individual magnet blocks to the desired optimum magnet system.

For efficient performance of drum separators, only forces acting in the radial direction are useful because they attract particles to the surface of the drum. Once being on the surface, the particles must be transported tangentially to the outlet for the magnetic product, by means of friction on the drum surface. Tangentially–acting magnetic forces disturb this more or less smooth movement of the magnetic particles to the outlet. Therefore, it is very important that the magnetic field strength decreases strongly radially (high radial forces), but remains as uniform as possible along the circumference of the drum (low tangential forces) [3].

PERMOS MAGNET SYSTEM FOR MEDIUM–INTENSITY SEPARATION

A completely new magnet configuration has been developed for drum type separators which, compared with conventional systems, require less magnetic material, in spite of a higher effective strength of the magnetic field. Moreover, it generates a very even magnetic field as shown in Fig. 1 [4].

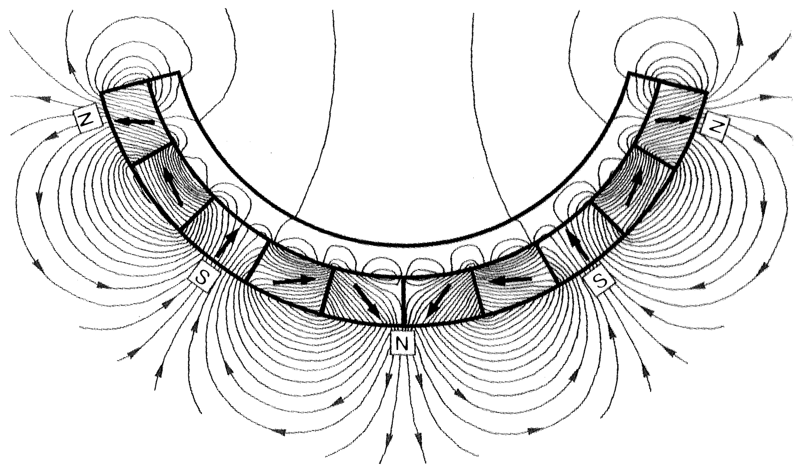

Fig. 1 The magnet structure of the PERMOS separators

It does not comprise any more large blocks of magnets magnetised radially, but contains a plurality of small magnet blocks whose direction of magnetisation changes in small steps. For this system, the number of poles is not the same as the number of magnetic blocks.

An arcuate magnet system with about 50 blocks consisting of small NdFeB elements magnetised in different directions and covering an angle ranging from 90 to 120 degrees of the total circumference was selected for commercial PERMOS separators. Such a design produces the magnetic field intensity of approximately 0.7 Tesla on the drum surface, and more than 0.3 Tesla at the distance of 8 mm from the drum surface, with minimum tangential forces, as is shown in Fig. 2. The PERMOS separator is thus described as the medium–intensity magnetic separator with medium working range.

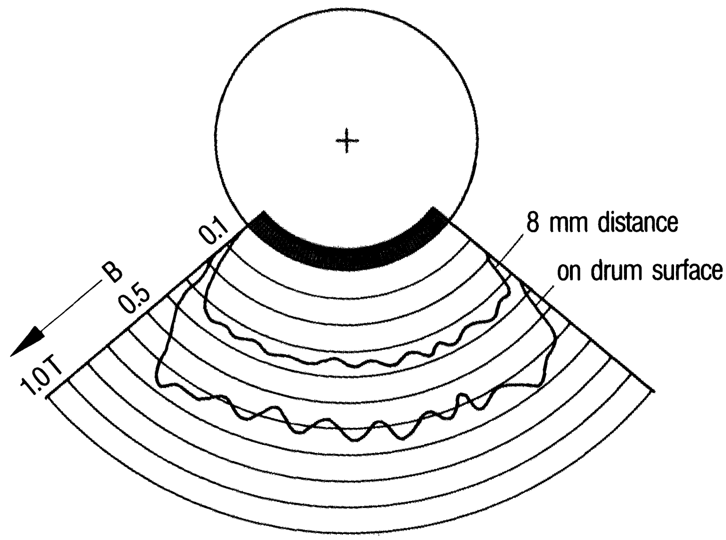

Fig. 2 The measured pattern of the magnetic of the PERMOS separator

The NdFeB magnet system is fixed in a certain position within the revolving stainless steel drum on which separation of strongly and feebly magnetic material from the non–magnetic components takes place. This process is identical to that used in conventional low–intensity drum magnetic separators which are in extensive commercial use for dry as well as for wet separation.

PERMOS DESIGN FOR WET MAGNETIC SEPARATION

The development work for wet medium–intensity separation was performed with an improved version of this PERMOS WET prototype, according to Figs. 3 and 4, with the diameter of the drum of 600 mm and the drum length of 600 mm. The separator had the following features:

–pulp tank made of stainless steel with semi–counter–current flow tank design and adjustable discharge gap at the discharge end of the magnetics, vertical non–magnetic discharge pipe with a valve for flow rate adjustment and lateral pulp overflow lip

–pivoted magnet system made of NdFeB bars giving about 0.7 Tesla on the drum surface, which is positioned more or less horizontally inside the revolving drum made of stainless steel

–two separate drives for the separation drum and the discharge roll with infinitely adjustable geared motors

–special discharge roll equipped with various mild steel elements for facilitating the discharge of the magnetic material from the drum.

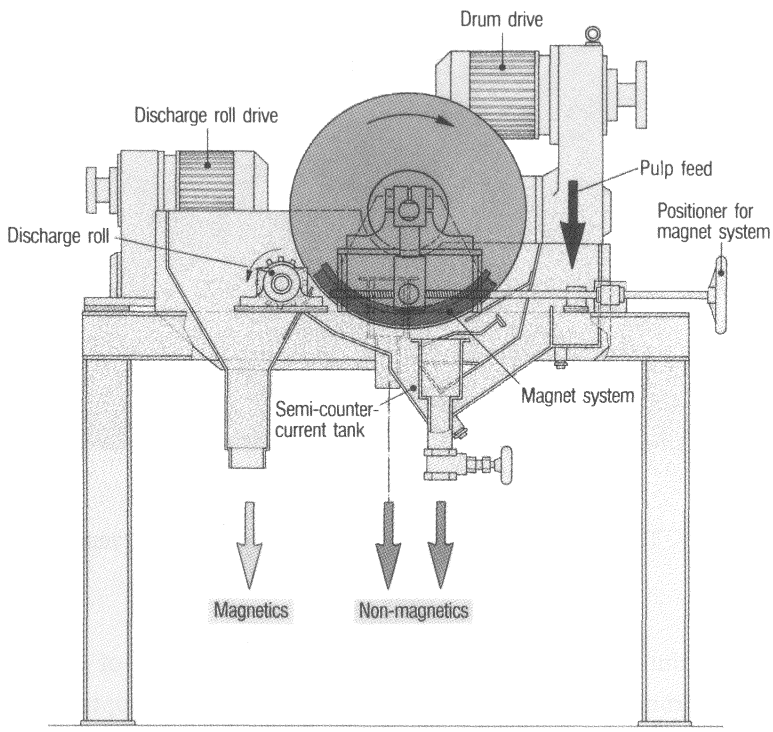

Fig. 3 Cross section of the PERMOS 606 WET separator

PERMOS APPLICATION FOR WET MAGNETIC SEPARATION

The PERMOS WET separator has been tested, so far successfully, for the removal of pyrrhotite from intermediate flotation products, for the cleaning of industrial minerals and/or abrasives, and for the treatment of martitic iron ores.

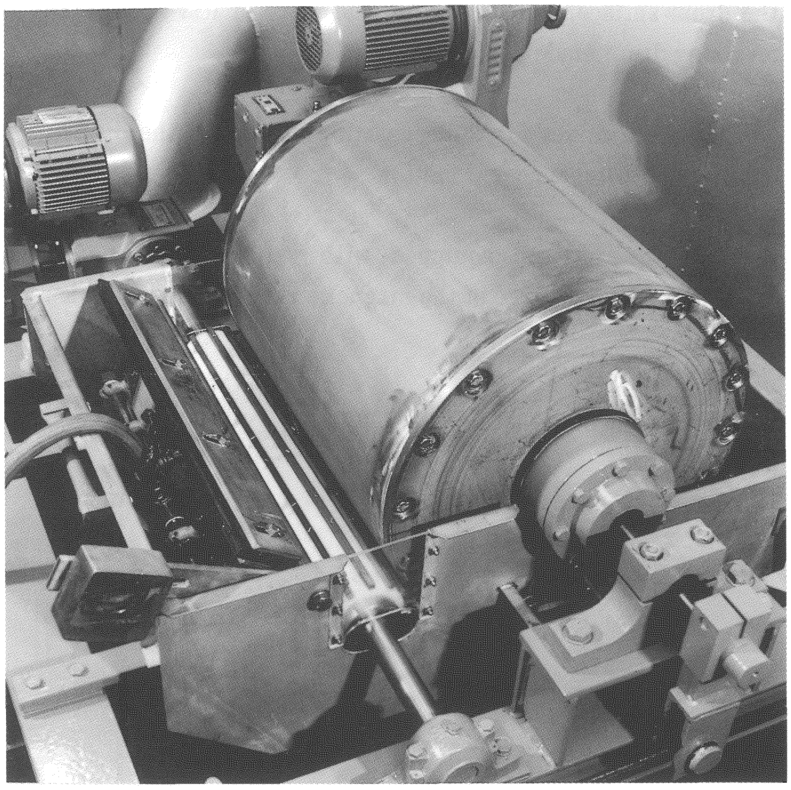

Fig. 4 Top view of the PERMOS permanent magnet separator

Further successful testwork was carried out with the removal of the iron–bearing contaminants from slimes originating from the polishing of optical glasses. The results are summarised in Table I. It should be noted that presently the total amount of this feed material must be deposited as the critical waste in special waste deposits. Since the two–stage magnetic separation using PERMOS reduces the concentration of Fe_2O_3 to less than 0.6 %, it will be most probably possible to recycle more than 90% by mass of the polishing waste back into the feed blend for the glass melting charge, and send only about 10% by mass to the special waste deposit.

Table I Magnetic separation of the polishing waste, using PERMOS WET magnetic separator

Stage	Product	Mass-%	Fe_2O_3-Gr.(%)	Fe_2O_3-Rec.(%)	SiO_2-Gr.(%)	Al_2O_3-Gr.(%)
ROUGHER	Magnetics I	3.58	97.91	81.60	10.29	8.43
	Non-Mags I	96.42	0.82	18.40	37.21	36.22
	Orig. Feed	100.00	4.29	100.00	36.25	35.22
CLEANER	Magnetics II	8.18	4.19	8.35	35.80	34.71
	Non-Mags II	88.24	0.49	10.05	36.54	35.33
	Non-Mags I	96.42	0.82	18.40	37.21	36.22

Complex martitic iron ores are characterised by a wide range of magnetic susceptibilities and for their magnetic separation the magnetic field strength and configuration of the separators must be adapted according to the concentration of martite.

Table II Magnetic separation of the martitic iron ore using the PERMOS separator followed by JONES WHIMS

Unit	Product	Mass-%	Fe-Gr(%)	FeRec	P-Gr.(%)	SiO_2-Gr.	MagEqui
PERMOS	Mags I	35.0	68.75	41.5	0.039	1.00	0.33
	N-Mags I	65.0	52.26	58.5	0.045	23.40	0.23
JONES	Mags II	44.0	65.24	49.5	0.045	5.27	0.27
WHIMS	Mids	4.3	25.32	1.8	0.045	60.66	0.12
	N-Mags II	16.7	25.00	7.2	0.045	61.57	0.13
PERMOS	Tot Conc.	79.0	66.80	91.0	0.042	3.38	0.30
plus	Fin. Tails	21.0	25.07	9.0	0.045	61.38	0.13
JONES	Feed	100.0	58.02	100.0	0.043	15.56	0.27

The PERMOS WET drum separator was tested with various iron ores, for instance for the production of superconcentrate pellet feed from the Venezuelan martitic iron ore containing only 0.27 of the magnetite equivalent. As can be seen in Table II, this ore with 58% Fe feed grade could have been upgraded to the pellet feed 0f 66.8% Fe and less than 3.5% SiO_2 by a simple wet separation using PERMOS followed by the JONES WHIMS. In spite of very low magnetite equivalent, the PERMOS separator itself produced already 35% by mass of the concentrate with excellent grade of 68.75% Fe, and only 1.0% SiO_2.

In the capacity test series performed so far for wet magnetic separation of martitic iron ores from Brazil, Venezuela, Iran and others, the solids throughput rates of up to 40 t/h per meter length of the drum, and the pulp throughput rates up to 160 m^3/h were obtained without apparent changes in the metallurgical results.

PERMOS DESIGN FOR DRY MAGNETIC SEPARATION

The essential parts of the standard PERMOS unit for dry separation ,with 600 mm diameter are illustrated in Fig.5.

–pivoted magnet system made of NdFeB bars, giving approximately 0.7 Tesla on the drum surface. The magnet system is positioned approximately vertically inside the revolving drum made of stainless steel

–the drum drive with continuously adjustable geared motor, not shown in Fig.5

–continuously adjustable vibration feeder feeding directly horizontally onto the drum

–complete bipartite dust sealed housing with a relatively large volume in the separation zone, made of ordinary steel sheets

–adjustable inclined splitter made from stainless steel, for effective separation into magnetics, middlings and non–magnetic products.

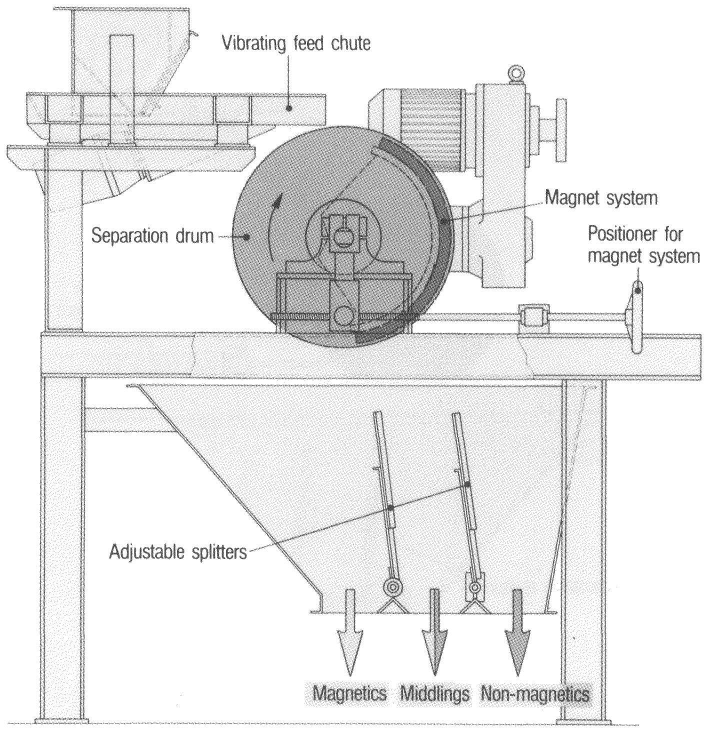

Fig. 5 Cross–section of the PERMOS DRY separator with horizontal feeding onto the drum

This unit can also be used as the so–called "free–fall" magnetic separator, if the vibrating feed chute is positioned in the opposite direction, as shown in Fig. 6. In this case the revolving drum will be fed by the vertical free fall of the material directly in a small horizontal distance from the drum shell. The vertical fall of the non–magnetic feed material is thus not hindered and only the magnetically susceptible components of the feed are attracted onto the drum, or their trajectories are at least directed towards the revolving drum, so that they can be separated from the non–magnetics by the splitters.

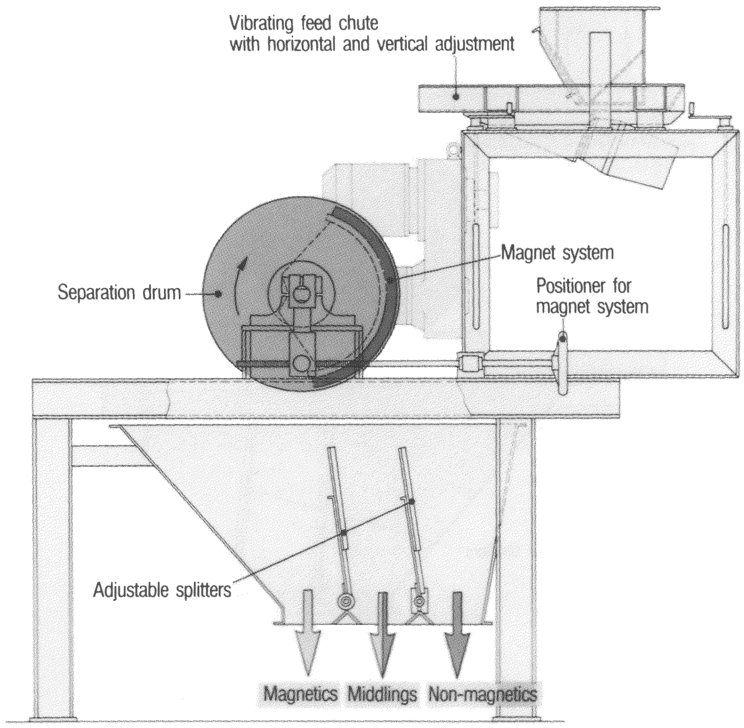

Fig. 6 Cross–section of the PERMOS DRY separator with the vertical "free fall" feeding

THE PERMOS APPLICATION FOR DRY MAGNETIC SEPARATION

The main application for the PERMOS DRY separators is the removal of iron–bearing impurities from abrasives and other primary industrial minerals as well as dry preconcentration of martitic and hematite iron ores in those cases where no water or not enough water for wet processing is available. The results of a typical possible application are shown in Table III, for the final cleaning stage by magnetic separation after preconcentration by the DESCOS superconducting magnetic separator and by subsequent scrubbing. Feebly magnetic gangue mineral serpentinite is more or less completely removed over the entire size range fraction, producing a concentrate with the silica content of less than 0.5%, to obtain a very high–grade and high–quality sinter magnesia in a rotary kiln plant in Turkey.

Table III The removal of the serpentinite gangue from the preconcentrated crude magnesite, 8.0 to 1.0 mm particle size, by magnetic separation, by PERMOS DRY separator in the free fall feed mode.

Product	Mass-%	SiO_2-Gr.(%)	SiO_2Rec.	Fe_2O_3-Gr.	Fe_2O_3-Rec.
Magnetics	11.72	12.92	4.28	2.24	87.55
Nonm.Conc.	88.28	0.32	15.72	0.05	12.46
Feed	100.00	1.80	00.00	0.33	100.00

In the capacity test series performed so far for dry magnetic separation, the feed rates of up to 50 t/h per meter of the drum length were obtained, with different feed materials without apparent change in the metallurgical separation results., for the direct horizontal feeding onto the drum, as well as for the free fall feed mode. At higher throughput rates, a reduction on the selectivity of separation with the increasing feed rates was observed.

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