New mega-sized wet high intensity magnetic separator: a cost-effective solution to reclaim iron ore fines from tailing dams

Novo super separador magnético de alta intensidade: uma solução econômica para recuperação de finos de barragens de minério de ferro

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Resumo

Dez anos de pesquisa e estudos levaram a um importante desenvolvimento no campo da separação magnética de alta intensidade – WHIMS. Com essa tecnologia de ponta, a Gaustec estabeleceu um novo recorde mundial nessa classe de separadores magnéticos, alcançando a capacidade de até 1400 tph de alimentaçao de finos de minério de ferro com o novo GHX-1400.

Embora minas com baixo teor de ferro sejam beneficiadas com essa tecnologia, o foco aqui é centrado na recuperação de barragens de rejeitos de minério de ferro de baixo teor, considerando o seu impacto positivo no meio ambiente e em função de tal tecnologia permitir a sua viabilização comercial.

Com base na nova tecnologia desenvolvida, a construção, na Itaminas Mineração/Brazil, de uma planta de concentração foi iniciada em 2012 para tratar rejeitos com 45% de ferro. Essa planta entrou em operação no corrente ano. Em função dos bons resultados obtidos com essa primeira unidade, foi iniciado o projeto de construção de uma segunda planta do mesmo tipo, com o objetivo de reduzir o rejeito para 18% de ferro, com operação prevista para 2014.

Abstract

Ten years of continuous research and development have led to a major improvement in the field of iron ore **W***et* **H***igh* **I***ntensity* **M***agnetic* **S***eparation - WHIMS. With this cutting-edge technology, Gaustec has established a new world record in this class of Magnetic Separators, by providing a sheer feed rate of up to 1400 tph for iron ore fines.*

Although low-grade iron ore mines will benefit from this new technology, focused on herein is the reclaiming of low-grade iron ore tailing from ponds, having in mind its huge positive environment impact and business opportunity.

Based on this newly developed technology, the construction in Brazil of a Concentration Plant started in 2012 for dressing iron ore tailings at 45% Fe grade, at Itaminas Mine. This plant went into operation this year. Based on the good performance of this first unit, the construction of a second Concentration Plant of the same type, to further reduce to 18% Fe in the tailings, is under way, scheduled to be started-up in 2014.

1. Introduction

This challenging achievement is the result of, on one side, the steady demand for iron ore fines from worldwide markets and, on the other side, the decreasing availability of high-grade iron ore reserves. Nowadays, low-grade iron ore mines and low-grade tailing ponds can no longer be dismissed, since they represent vital ferrous resources for the entire mining industry. And above all, environmental protection involves the rational use of non-renewable natural resources with main focus on maximizing the recovery of rejects that, with help of new technologies, can again be turned into essential raw materials.

The above mentioned facts must be taken into account by the decision makers who develop new business strategies, new plant designers and of course, the equipment manufacturing industries involved in the field of mineral dressing for the present and future generations.

Gaustec's R&D Team, facing this reality designed and achieved an ideal match involving a simple and reliable Concentration Plant flow sheet together with a huge Magnetic Separator. This combination should be able to run several processing stages in a single unit at the highest throughput feed capacity. Additionally, energy savings in the magnetic flux circuit aim to achieve Magnetic Induction levels up to 1.4 Tesla (14000 Gauss); an optimized footprint to reduce investment cost, and, the lowest spray water consumption were also goals to be achieved.

Reportedly, the dressing of low-grade iron ore fines requires several processing stages (Rougher, Cleaner and Scavenger) to achieve a cost efficient mass yield and marketable high-grade pellet feed fines. Before the technical breakthrough disclosed herein, this kind of project would demand a large number of standard magnetic separators, and consequently large and complex buildings dimensioned to accommodate the high feed rate capacity necessary to reach the production break-even point. Projects designed this way would be ill fated and declined.

The first concentration plant specifically designed for tailings recovery was dimensioned for 480 tph of feed, performing three processing stages in a single GHX-1400, (Rougher, Cleaner and Re-Cleaner). Starting from a feed grade of 45% Fe, the quality of the pellet feed fines should reach 65% Fe and the tailings average grade, 35%. The plant yield should be around 30%.

Designed for making use of another single GHX-1400, the second concentration plant under construction is scheduled to start-up in 2014.The main task will be to further downgrade the tailings to 18% Fe. Rated at 320tph of feed using magnetic matrix gaps of 2.5 mm, the planned pellet feed quality would be 60% Fe, and the mass yield 40%. The material output at the grade of 18% would then be destined for the tailings pond and considered as final tailings for this mining operation.

2. The GHX-1400 - Early Development Stages and the Technical Features

The new GHX-1400 Magnetic Separator was not done from scratch. It is the result of continuous developments which started-up in the year 2004 with the well-known Bipolar WHIMS G-3200.

In this new design, several previously unfaced issues had to be overcome and the starting point was the concept of a magnetic circuit, powerful enough to provide the Magnetic Induction Intensity "B" of up to 1.4 Tesla (14000 Gauss).

The evolution of the Hex-Polar magnetic circuit can be better understood by comparing the magnetic circuit path of the new GHX-1400 with the Magnetic Circuit path of the two preceding models, each one with its own characteristics, developed respectively in the year 2004 (The Bi-Polar Model –Type G) and in 2008 (The Tetra-Polar Model –Type GX).

The first one, is the well-known two pole Magnetic Separator, or Bi-Polar type, depicted in the Figure 1.

In this type of magnetic separator, the magnetic field lines flow from North to South through the rotor diameter, and provide magnetic induction "B" by crossing the magnetic matrix boxes. This basic physics effect permits separation of the magnetic from the non-magnetic contents present in the ore.

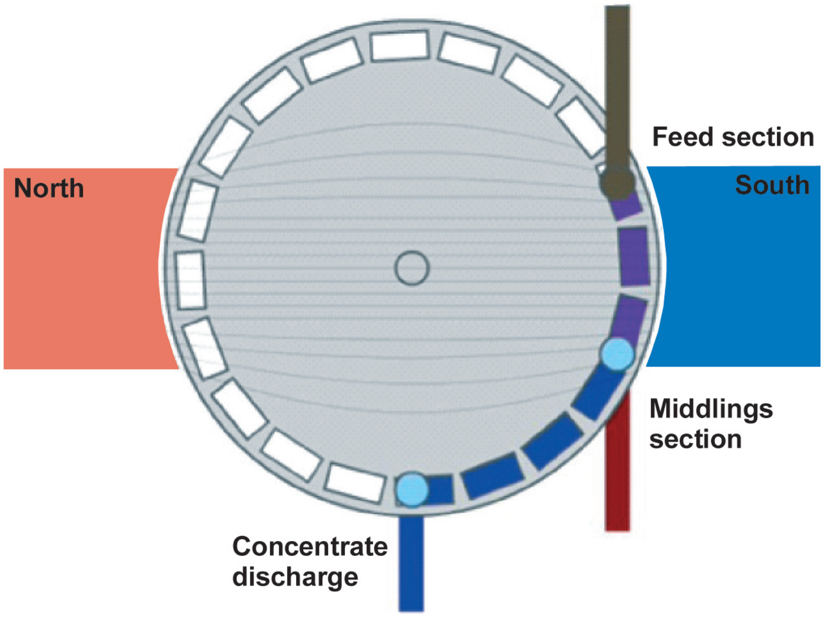

Figure 1
The Bi-Polar Model – Type G.

3. Working Principle of the WHIMS Bi-Polar Separator

Turning clockwise, the rotor carrying several magnetic matrix boxes, introduces an empty and clean matrix box at the tip of the magnetic South Pole, starting Feed Section at this point. The empty matrix is immediately magnetized and receives the flow of the slurry transporting the ore to be separated. From the effect of the gravity force, the non-magnetic material present in the feed flows unnoticed through the magnetized vertical matrix grooves and discharges into the tailings collector. This is the first stage of the magnetic separation process.

The magnetic material, on the other hand, gets caught by the magnetic forces inside the matrix and is transported by magnetic gradients towards the tips of the matrix grooves. As the rotor is continuously turning around, this matrix already filled up with magnetic material is displaced to the next step of the magnetic separation, the Middling's Section.

At the Middling's Section, a further separation of the non-magnetic material, which is normally imprisoned within the magnetic material, takes place. This entrapping effect can be better understood by considering that when the magnetic force pulls the magnetic particles to make them move in the direction of higher magnetic gradients, some of the non-magnetic particles crossing their way are surrounded and mechanically arrested. This imprisoning, in most cases, can jeopardize the quality of the magnetic material, the concentrated product.

To remove the imprisoned particles, water sprays are positioned inside the magnetic pole in such a way that the middling's washing takes place in the matrix while it is still under the effect of the magnetic forces. This procedure provides the struggle of the magnetic force against the hydraulic drag inside the matrix. The water pressure tries to remove the non-mags and the magnetic force tries to hold the mags. Setting the pressure of the water sprays determines the amount of non-mags to be removed so that the target quality can be achieved. The achievement of the quality at the middling's section is its main objective even if some magnetic material will be removed together with the contaminant. The material flowing out from this washing process can be returned in closed loop to the feeding point avoiding losing valuable material. The rotor movement towards the Concentrate Discharge Section, transports the magnetic product concentrate kept inside the matrix after the middling's washing.

At the Concentrate Discharge Section, the magnetic field vector will cross a point of zero magnetic intensity, whose position is at the crossover of the magnetic lines going from the North Pole to the South Pole.

Water sprays located at this point of Zero magnetic field intensity forces the discharge of the concentrate to the collecting launder and at the same time, washes the matrix completely for it to be fed again in the next magnetic pole. The same processing cycle described above repeats again in the same sequence. Working independently from each other, both cycles repeat indefinitely as long as the rotor is turning around.

The Tetra-Polar GX-800 and the Hex-Polar GHX-1400

The Tetra-Polar GX-800 (Figure 2), developed in 2008, a new concept in magnetic separation gave birth to the GX-3600. Rated for 800 tph, this model established at that time a new production level never achieved before and set new design parameters described in REM: v.63, n. 4, pages 691-694. The Magnetic concepts developed for the GX Model, set the principles for future designs. Several units of this equipment are in use in Brazil and abroad providing successful performance. The working principle of the GX Type is the same as described for the Bi-Polar Model, with each magnetic pole displaying a Feed Section, a Middling's Section and a Concentrate Section.

The Hex-Polar GHX-1400 (Figure 3) displays the main concept behind the high feed capacity achieved: An annular rotor with surrounding length long enough to accommodate six magnetic poles. Each pole corresponds to a process-

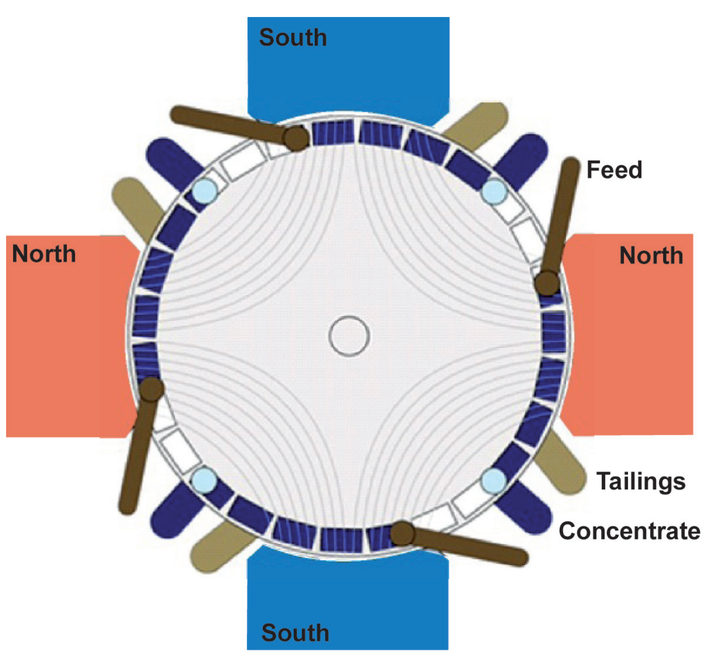

Figure 2
The Tetra-Polar Model – Type GX .

ing cycle stage, already described. This gives the GHX-1400 an equivalent feed capacity of three single Bi-Polar machines.

This configuration with alternated polarities creates an inversion region between the poles where the magnetic field starts from a maximum value in front of a pole, say North, the vector field, orthogonal to the surface of the magnetic matrix, and decreases until zero. After reaching the zero value, the vector magnetic field inverts and increases again toward the maximum value, achieved when reaching the next pole of reverse polarity, say South. The region in the neighborhood of zero magnetic fields, called Neutral Line, allows the discharge of the magnetic product as already described.

The magnetic field lines have a behavior similar to that of the Tetra-Polar model, i.e, the flow is tangential, that is, the lines of force circulate in the periphery of the rotor, rather than transversal. This tangential behavior of line flow allows for the construction of the rotor in a ring shape instead of the usual and heavy massive rotor.

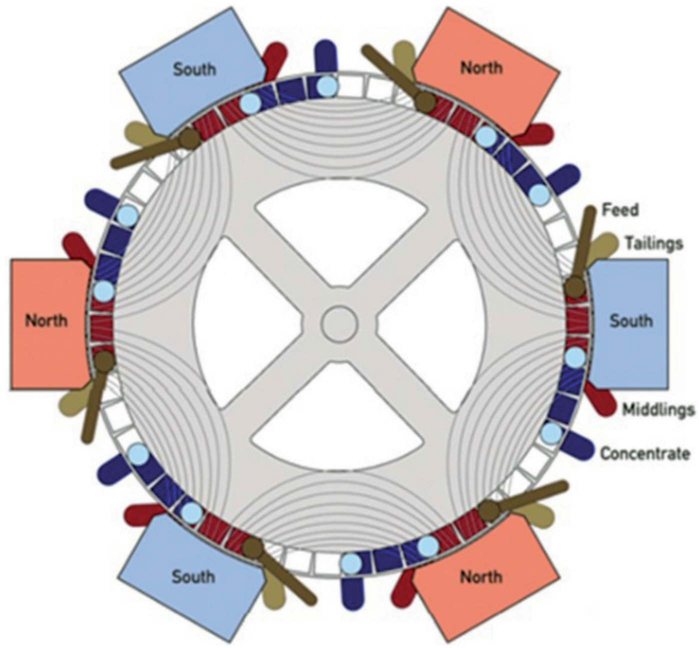

Figure 3
The Hex-Polar Model – Type GHX.

4. GHX-1400 Finite Element Modeling (FEM) of the Magnetic Circuit

The Method of Finite Elements FEM modeled the design of the Hex-Polar magnetic Separator. The modeling targeted, primarily, to achieve maximum generation of the magnetic field with a minimum consumption of electric energy. Figure 4 displays the levels of magnetic saturation for three widths of the ring section. The results indicated 6.25% magnetic induction increase in the Hex-Polar model in relation to the Bi-Polar one for the same electric power consumed.

The second target of the modeling was to define the ideal width of the ring, in the ring shaped rotor, to optimize the weight of the equipment without harming the first objective. The results indicated that the rotor reaches the best relationship Weight versus Magnetic Saturation, for the size of the Rotor ring Width calculated according to the following equation:

$$\frac{W}{D} = -0.0336D^2 + 0,2518D - 0,1942 \quad (1)$$

Where: W = Rotor Ring Width and D=Rotor Diameter .

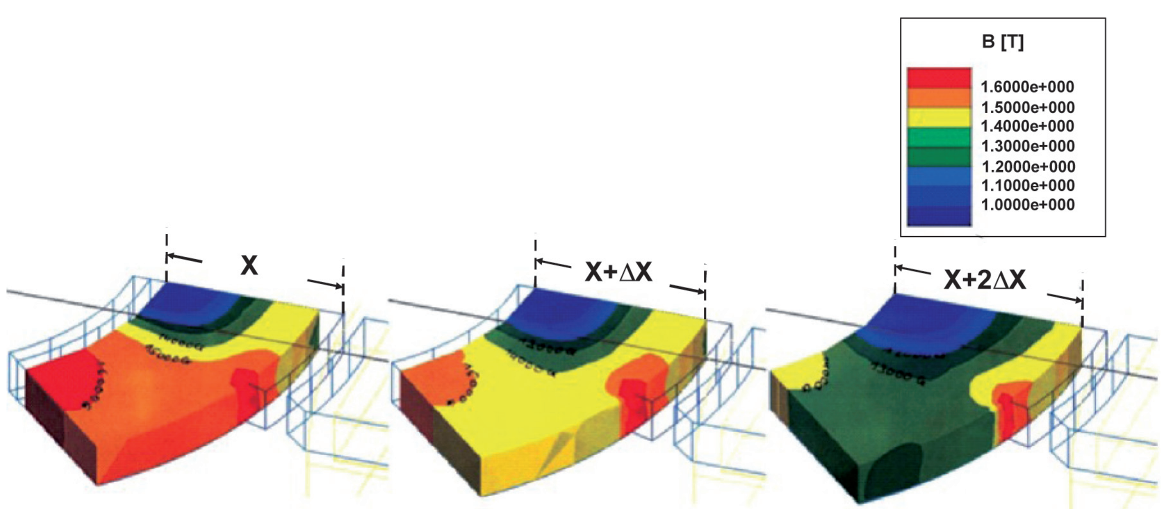

Figure 4
Levels of magnetic saturation for three widths of the ring shaped rotor (FEM).

5. PLOT of Magnetic Induction (Gauss) versus Power (kW)

The GHX-1400 has proved its energy efficiency to provide the Magnetic Induction of up to 1.4 Tesla (14000 Gauss) according to the plot displayed below in the Figure 5. The data shown in the figure are the magnetic inductions measured for each Gap size, and the corresponding to the total power consumed by the 12 coils installed in the magnetic separator.

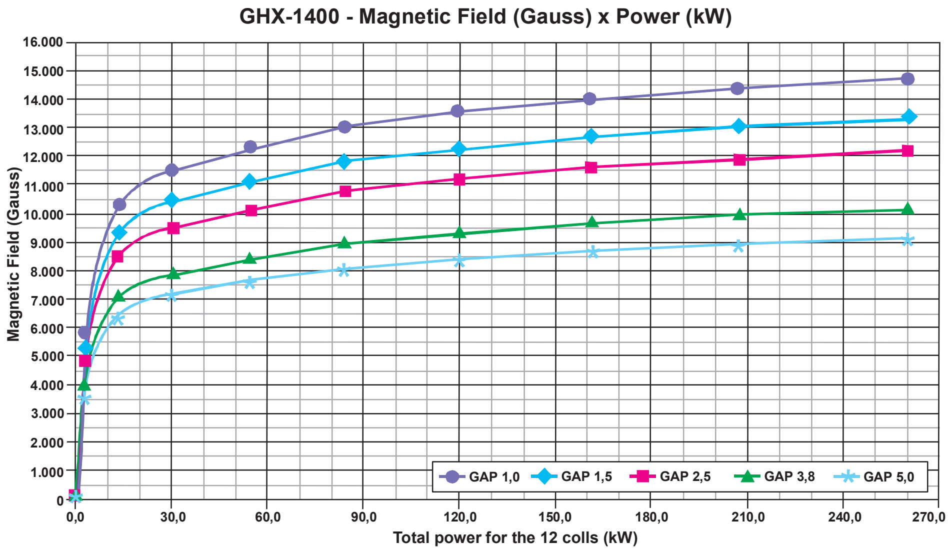

Figure 5
Magnetic induction (Gauss) in function of the GAP size (mm) and the power (kW).

6. GHX-1400 Feed Capacity in function of the Matrix Gap

The Feed Capacity in function of the GAP of the grooved plates in tph:

- Gap 5.0 mm / 1400 tph
- Gap 3.8 mm / 1230 tph
- Gap 2.5 mm / 880 tph
- Gap 1.5 mm / 630 tph
- Gap 1.0 mm / 450 tph.

These data are based on iron ore fines, Specific Gravity 4.0 t/m^3; 50% mass of solids and 5.0 Rotors RPM.

7. Conclusion

The GHX-1400 has proved its capacity to achieve the goals established to turn viable the recovery of low-grade iron ore fines from tailing dams. After four months of operation, the performance data displayed by the first unit proved satisfactory results for guiding the decision makers to invest in the installation of a second similar unit to further reduce the Fe in the tailings. Reportedly, the worldwide need for real solutions that can improve the iron ore processing technology, the GHX-1400 has accomplished its task.

The reader can find further technical information regarding the GHX-1400 Technology, such as training movies and concentration plant in operation, at www.gaustec.com.br