

The BigFLUX Magnetic Matrix Technology

<http://dx.doi.org/10.1590/0370-44672022750035>

José Pancrácio Ribeiro^{1,4}

<https://orcid.org/0000-0002-6233-1089>

Cláudio Henrique Teixeira Ribeiro^{2,5}

<https://orcid.org/0000-0002-3829-7300>

Eric Guimarães Vieira^{3,6}

<https://orcid.org/0000-0001-5458-3406>

¹Gaustec Magnetismo

Nova Lima - Minas Gerais - Brasil.

²Gaustec USA LLC

Maryland - US.

³Vale S.A., Mina Viga, Operações Paraopeba Sul,
Congonhas - Minas Gerais - Brasil.

E-mails: ⁴pancracio@gaustec.com.br,

⁵claudio@gaustec.com, ⁶eric.vieira@vale.com

Abstract

The Magnetic separation of ultra-fine ore particles has always posed a challenge to the JONES/WHIMS process. Despite many advances in this technology, no effective improvement has been made to its core component: The Magnetic Matrix. The current approach to separate ultra-fine particles teaches that the gap of the matrix and its teeth size must be smaller than usual in order to accommodate the small size of the particles. However, practice proved this approach to be far from ideal. The closing of the gap between grooved plates, whose teeth are smaller, drastically reduces the flow area, reduces the feed capacity, and makes the matrices prone to clogging. In addition, smaller teeth reduce the magnetic field and its gradient, leading to poor results with ultra-fine ore particles. This research proves that bigger teeth are better suited for high intensity magnetic separation of ultra-fines because they avoid matrix clogging thanks to the larger slurry flow area. Additionally, bigger teeth amplify the magnetic field “Bmax” and increases the magnetic gradient “Grad ($\Delta B / \Delta X$)”. The positive results of this new “BigFLUX Matrix” technology, are being displayed in several mining operations worldwide, increasing metallurgical recovery and producing high quality concentrates and low iron content sand from iron ore tailings.

keywords: WHIMS, matrix, field, gradient, BigFLUX, pitch, gap, ultra-fine, magnetic, tailings, slurry.

1. Introduction

Fifty years of the JONES WHIMS magnetic separator prompted huge changes in the mining landscape worldwide. The core element of this equipment and key factor for its operational success is its magnetic matrix – made up of grooved stainless steel plates. This matrix has advantageously replaced the various types of matrices, such as steel balls, steel sponges, expanded plates etc. Among its several advantages, the matrices with grooved plates allow the free flow of the slurry through its chan-

nels without obstacles, and additionally introduce the precise adjustment of the distance between the teeth of the plates, universally called "Gap".

The technical publication (SVOBODA, 2004; JONES, 1967) describes Jones magnetic separators in detail. The JONES/WHIMS have been improved in many ways, but with regards to the grooved plates invented by Prof. Jones, the core matrix component, no significant improvement has been done so far. The purpose of this publica-

tion is to present recent developments in magnetic matrices that led to the use of the new BigFLUX Matrix technology.

The core of this technology relies on the development of new grooved plates with bigger teeth sizes, whose grooves on each side must be offset to accommodate the new teeth dimensions while keeping the stainless-steel plate thickness. This new offset grooved plate is displayed in Figure 1 and can be compared with the common back-to-back teeth plate in Figure 2.

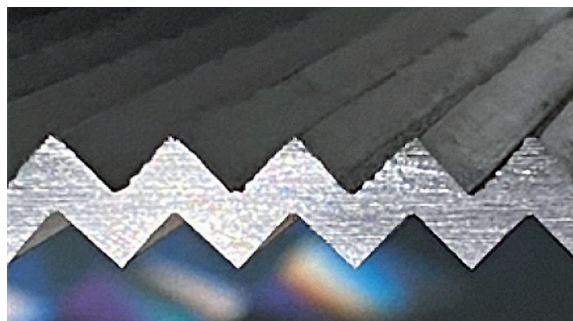


Figure 1 - The new offset grooved plate, model SUPER BigFLUX®.

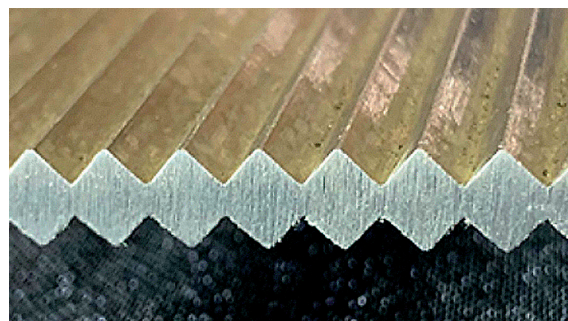


Figure 2 - The Old 8R common grooved plate with back-to-back teeth.

2. Previous Works on Grooved Plates to Improve the JONES WHIMS

As mentioned, many years had passed without advances in the WHIMS magnetic separator matrices. This was changed in 1991, with the publication of the article "Recent Developments in the Separation of Feebly Magnetic Materials" (Wasmuth & Unkelbach, 1991).

This article proposed a direct relationship between the particle size and the teeth size of the grooved plate, concluding that: *Ultra-fine Particles should be processed with Smaller Teeth* on the matrices.

The outcome of this approach,

wherever it was tried, was clogging and lowering production capacity of the magnetic separator due to the smaller area (reduced by smaller teeth), and also had poor concentration performance due to the lower magnetic field and gradient.

3. Larger Teeth as a Key Factor in Increasing Magnetic Attraction Forces and Improving Ultra-fine Particle Separation

For the separation of ultra-fine particles, the magnetic field must be increased, and this is usually done by reducing the gap of the matrices. Reducing the gap without impairing the slurry flow can be achieved by increasing the teeth size, which also has the positive effect of increasing the magnetic field and its gradient. This amplification effect can be understood with the help of Figures 3(a, b, c).

Figure 3(a) shows a magnetic circuit with two flat-faced steel plates that are separated by an air space called gap. As can be seen, field lines pass through this gap, forming uniform and homogeneous field lines (resulting in no magnetic gradient). In order to amplify the magnetic field of such a magnetic circuit, the flat-faced plates can be replaced by plates with triangular grooves as shown in Figures 3(b) and 3(c). The high magnetic permeability of

the steel triangles (teeth) concentrates and makes the magnetic field stronger at the triangle tips, facing each other, forming a bridge of field lines. However, the degree of the amplification depends on the triangle (teeth) size : the smaller ones (Figure 3(b)) create more bridges for the field lines to cross than bigger ones (Figure 3(c)), leading to a smaller magnetic field and smaller gradient on the circuit of Figure 3(b) than the one in Figure 3(c).

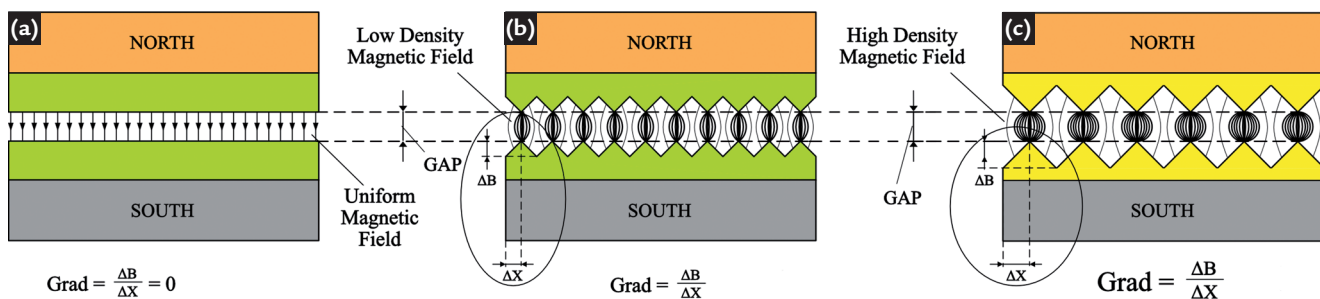


Figure 3 - Bigger teeth increasing field and magnetic gradient.

4. Bigger Teeth with Smaller Gaps: A New Concept for Separate Ultra-fine Particles

The concepts disclosed so far are outlined in Figure 4(a,b), in which the old rule for separating ultra-fine particles is compared with this new approach. In

Figure 4(a), the teeth are smaller, the intensity of the magnetic field and the magnetic gradient are lower, and the slurry flow area is smaller; meanwhile

in Figure 4(b), the teeth are large, the magnetic field and magnetic gradient are higher and the slurry flow area is also significantly larger.

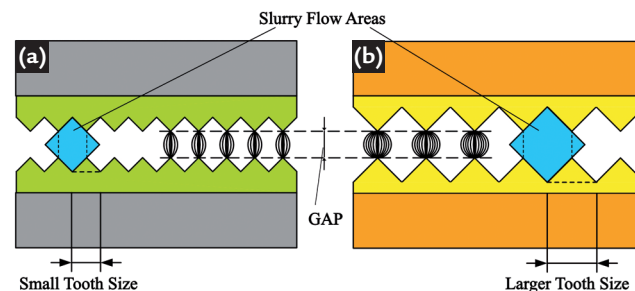


Figure - 4 (a, b): Previous concept (a) and proposed concept (b) to separate ultra-fine particles.

This new technology has the following advantages:

1. There is a stronger magnetic attraction force to overcome the hydrodynamic drag which is the main competing force for ultra-fine particles around 50 microns according to Stokes (Svoboda, 2004).
2. Reduction in the probability of clogging;
3. Greater efficiency of the washing sprays, improving quality;
4. Easier cleaning of the matrix in case of eventual clogging;
5. Higher volumetric feeding capacity allowing greater production;
6. Possibility to feed slurries with low solids content and improve selectivity.

5. Comparison of BigFLUX Matrix Types with the Old 8R Common Model

The BigFLUX Matrix family (Figure 5) is composed of several types, each type with a corresponding multiplying factor for the available slurry

flow area, taking the old 8R common matrix flow area as reference. Four types of BigFLUX matrices are presently available: Standard BigFLUX (area twice

as large), Super BigFLUX (Area three times larger), Mega BigFLUX (Area five times larger) and Giga BigFLUX (Area seven times larger).

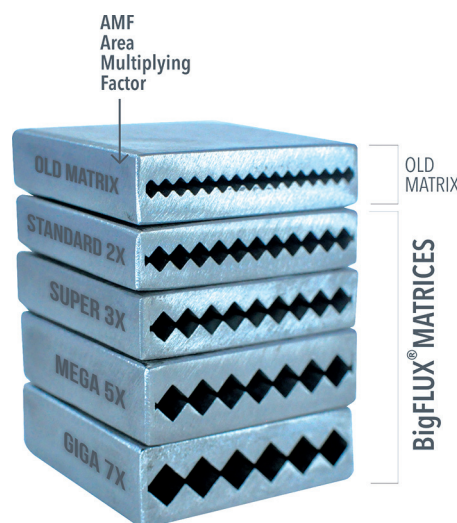


Figure 5 - The Old Common Matrix compared to four BigFLUX types.

6. Modeling Grooved Plates with the EMS Software

The greater magnetic efficiency of the Offset grooved plate in comparison to the back-to-back teeth plate was demonstrated using the ElectroMagneticWorks (EMS) software, as shown in

Figure 6(a) and Figure 6(b). Each matrix model was simulated with the 4.5 mm teeth in the grooved plates, both at 1.1 mm gap and magnetized at the same 9,000 Ampere x Turns. The magnetic

efficiency (coil energy converted to magnetic field induction) at the matrix tips, making use of the offset design, increased by 15.2 % compared to the back-to-back old plate model.

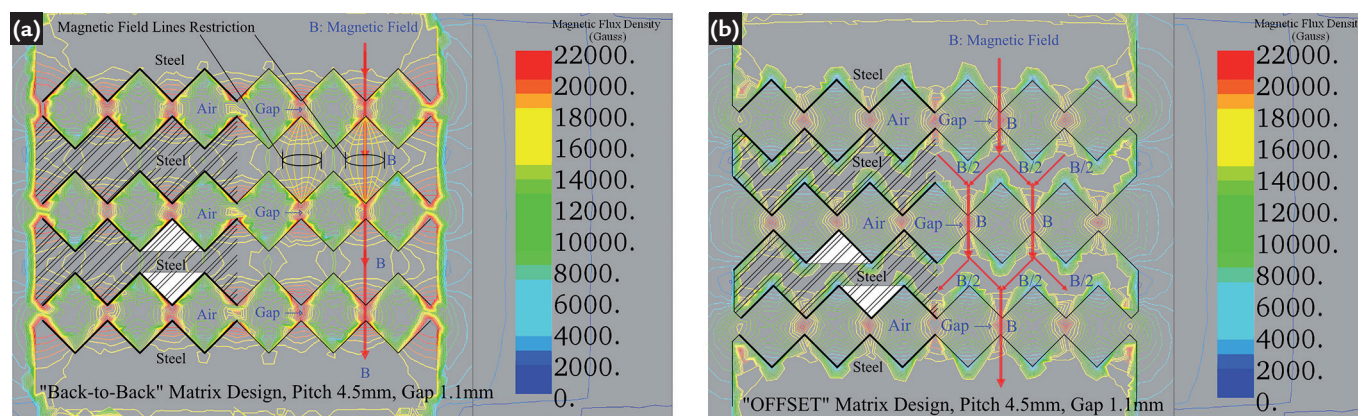


Figure - 6: (a) Grooved plate with back-to-back teeth, (b) Offset grooved plate opposite teeth.

7. Conclusion

The new BigFLUX matrices, with the offset magnetic plates, make it possible to use small gaps (industrial applications already in place using gaps as small as 0.5 mm, (half mm) thanks to their wider flow areas. These technical advances in High Intensity Magnetic Separation are already successfully applied in several mines and have opened a new field of research to raise the efficiency of concentration plants to a higher level.

The need to reduce the volume of tailings as much as possible, eventually turning them into marketable products like the Iron Sand, led to the research of new solutions capable of meeting these goals. And finally, a new concept is established: ultrafine particles must be separated with smaller gaps and larger teeth grooved plates, making use of the new offset magnetic matrix design. The performance of the JONES WHIMS equipped with these

BigFLUX matrices has been increased to higher levels never reached before. So, it is highly recommended that any prior test work of the JONES making use of the old common matrices 8R to compare performance with competing equipment should be repeated, making use of the new BigFLUX matrices. This procedure will benefit Process Engineers with the advances described here and avoid erroneous decisions.

Acknowledgments

The authors would like to thank VALE SA / Viga Mine for providing valuable support to enable all the research that gave rise to this important publication. VALE provided samples of the ores, chemical and physical laboratory analysis, qualified personnel and all

the necessary resources, so that these research work could be carried out. Also, our thanks to ITAMINAS Mineração/Sarzedo MG, which for more than a decade has supported and applied in his operations the innovative technologies developed by the authors for high

intensity magnetic separation. To Dr. Jan Svoboda for the kindness to provide theoretical and valuable comments on these matters. To Dr. Herbert Papacek, our lifelong friend, for his constant international support and insights toward these recent technical developments.

References

- JONES, G. H. *Magnetic separator with washing scouring means*. Assignee: Quebec Smelting and Refining Ltd. US3326374A. Deposit: 23 Jul. 1963. Grant: 20 June 1967.
- RIBEIRO, J. P.; RIBEIRO, C. H. T. New mega-sized wet high intensity magnetic separator: a cost-effective solution to reclaim iron ore fines from tailing dams. *REM: Revista Escola de Minas, Ouro Preto*, v. 66, n. 4, p. 529-533, Dec. 2013.
- SVOBODA, J. *Magnetic techniques for the treatment of materials*. Dordrecht: Kluwer Academic Publishers, 2004. 642 p. ISBN 978-1-4020-2038-4.
- WASMUTH, H. D.; UNKELBACH, K. H. Recent developments in magnetic separation of feebly magnetic minerals. *Minerals Engineering*, v. 4, n. 7-11, p. 825-837, 1991.

Received: 19 June 2021 – Re-submitted: 23 February 2022 - Accepted: 04 June 2022.