Magnetic Field Improvement in Electrolytic Cells by Shielding

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Abstract

Magnetohydrodynamics (MHD) plays an important role in the performance of aluminium electrolysis cells. The magnetic field is generated by the electrical current that flows in the reduction cell. The vertical component of magnetic field (Bz) is responsible for MHD instability in the cell. Unlike electricity, magnetic fields lines cannot be blocked or insulated but only deformed or redirected, which makes magnetic shielding a valuable option for reducing the local Bz magnitude, by concentrating the field lines inside the shield material.

A ferromagnetic shielding plate (“Kavach”) was designed using Finite Element modeling, to be employed in Vedanta cells in order to reduce the Bz field located at the cell corners, inside the metal pad. This is the critical location of the vertical magnetic field for this technology. Several trials have been conducted in the live cells using the Kavach shield, where the magnetic field was measured inside the metal by a tri-axial magnetic field probe. These trials included several options of the shielding plate in the cell compared with the no-plate situation.

Long term trials have also been carried out resulting in voltage noise reduction. This shows that the Kavach has played a significant role in reducing the instability of the cells and thereby improving its performance.

Keywords: Magnetic field, Magnetic Kavach, Cell noise, Magnetic field improvement.

1. Introduction

In the aluminium reduction cell, the electrical current is responsible for the electrolytic reduction of alumina to molten aluminium in a molten electrolyte bath. The direct electrical current (DC) that flows in the busbar network, anodes, bath, liquid metal, cathodes and collector bars is responsible for the generation of a very complex and high intensity magnetic field. This magnetic field coupled with the electrical currents in the bath and metal are responsible for the liquid metal movement by electromagnetic (Lorentz) forces. The most important component of the magnetic flux density (interchangeably referred to as “magnetic field” in this work, unless explicitly mentioned otherwise) regarding magnetohydrodynamic (MHD) instability is the vertical one, Bz. Having this component as low as possible is one of the potential strategies to achieve a stable and energy efficient cell.

Around every conductor carrying electrical current, a magnetic field is produced in circular field lines oriented as shown in Figure 1. The magnetic field vector is tangent to the circle and its direction is determined by the right-hand rule.

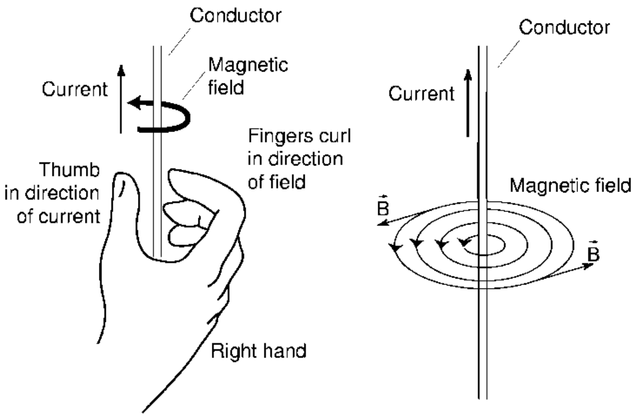

Figure 1. Right hand rule for magnetic field direction around a conductor [1].

Gauss´s Law for magnetic fields states that the total number of magnetic field lines going out of any closed surface is equal to zero, thus the magnetic flux always exists in closed paths [2]. The field lines are continuous and will find a way back to their origin. Therefore, there is no shield or material that will block magnetic fields, the field lines can only be distorted and/or redirected.

The magnetic field lines can be redistributed by concentrating them inside a ferromagnetic material. Reducing the magnetic field in a specific region requires inserting a shield of appropriate material that will change its spatial distribution. The shield causes a change in the behavior of the field, diverting the magnetic lines away from the shielded region. When the shield is inserted, the resulting magnetic field shape is dependent on the shield geometry and the material parameters [3].

The best shape for magnetic shields is thus a closed container surrounding the shielded volume as shown in Figure 2 (left). In a flat shield, as shown in Figure 2 (right), the magnetic field lines which intersect the flat shield will be compressed into the shield, leaving less magnetic field lines on the side behind the shield. However, note that while there is an area near the shield which has lower field intensity, the area near the edge of the shield has higher field. The magnetic fields of large radius are unaffected. The wider the shield, the larger the shielded area, both in width and depth.

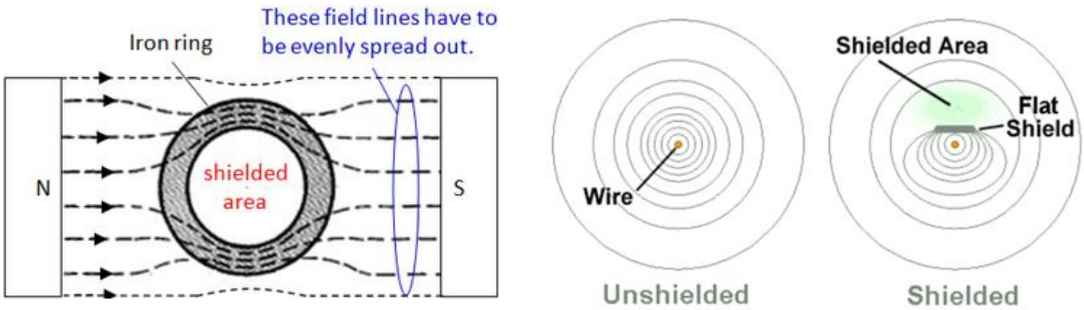

Figure 2. Left: enclosed shielded area [4], Right: opened shielded area [5].

The effectiveness of this type of shielding depends on the material's magnetic permeability. This property describes the ability of a material to be magnetized. If the material used has a greater permeability than the object inside, the magnetic field will tend to flow along this material, instead of inside the object. Permeability is also a measure of a material's ability to concentrate magnetic flux density. The higher it is, the better the shielding device.

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