Ongoing Development of Aluminium Welding in Strong Magnetic Fields

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Abstract

The development of higher amperage aluminium electrolysis potlines has resulted in industrial environments with significantly stronger magnetic fields. These stronger magnetic fields present operational challenges and they also directly impede the arc welding of aluminium components. Indeed, the electric arc of the welder can be deflected and destabilized, and the molten aluminium pool can be displaced during the welding process. In weak to medium magnetic fields these phenomena can be mitigated by experienced welders and the use of simple general magnetic shields. For the more intense magnetic fields encountered in high amperage electrolysis potlines, specific magnetic attenuation equipment is required, in addition to a specialized understanding of magnetic fields and welding physics. Rio Tinto Aluminium developed the required knowledge and experience at the AP5X experimental cells in LRF (Laboratoire de Recherche des Fabrications) in France and at the Arvida - AP60 Technology Center in Saguenay, Canada. Welding activities are required in the electrolysis potlines for equipment maintenance, cell replacement and conductor modification projects. These led to the development of methods and technologies to control the magnetic field intensity at the welding position. The use of these technologies has already saved several hours of potline shutdown to perform welding work. The technology is also being further developed for welding on energized busbars. This next generation of the technology represents a large potential to further reduce the number of potline shutdowns even more and contributes to the overall productivity goals.

Keywords: Aluminium reduction technology, Aluminium welding, Magnetic fields, Magnetic fields control, Welding in magnetic fields.

1. Introduction

Arc welding in aluminium smelter potlines has always been a very challenging activity. The high magnetic fields generated by the high DC currents destabilize the electric welding arc and often make the welding process impracticable. These constraints have become greater as the electrical current applied in modern cell technologies has increased.

The startup of the Arvida - AP60 Technology Center [1] posed new magnetic challenges and indeed required an extensive magnetic field study program to validate the behavior of numerous parts and practices before startup. This demonstration plant has always provided a supportive environment for further testing and development, particularly with respect to magnetic fields. A great deal of knowledge and expertise was hence developed and is in the process of being applied to all the Rio Tinto plants.

To compensate or attenuate the effect of the magnetic fields on the arc welding process, several solutions have been presented in the past and are detailed in their respective patents. The most common solutions induce electrical currents in the welded part to attenuate the magnetic fields at the weld location [2, 3]. However, these solutions do not work on parts that are not ferromagnetic, such as aluminium conductors. In aluminium smelters, magnetic field control has been developed using electrically induced counter magnetic fields with some success [4]. However, simpler non-powered solutions are required to overcome this difficulty in a wide range of situations in the potlines.

This paper aims to present the work carried out at Rio Tinto in recent years to achieve better welding results in potlines with increasing magnetic fields.

2. Arc Welding and Magnetic Field Interactions

The arc welding process involves creating an electric arc between the welding tip and the welded part. This arc is in fact an electrical conductor. In the presence of magnetic field, a conductor carrying an electric current will be subject to an electromagnetic force, given in Equation (6). The force is perpendicular to the electric current and to the magnetic field. The orientation of the force is illustrated in Figure 1.

$$\mathbf{F} = \mathbf{J} \times \mathbf{B} \qquad (1)$$

where:

F	Force on the conductor (N/m^3)
J	Current density in the conductor (A/m^2)
B	Magnetic field (T)
x	Vector cross product

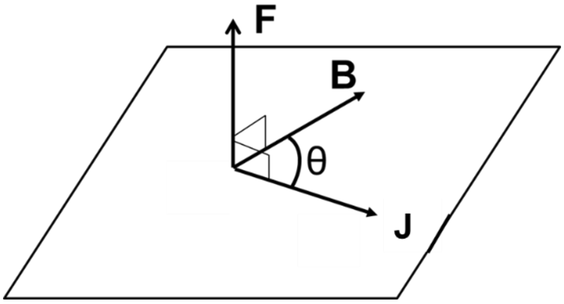

Figure 1. Vector product of current density and magnetic field gives a force perpendicular to the current density and the magnetic field.

Equation (1) can be simplified in scalar form for a given straight conductor to Equation (2):

$$F = I \times L \times B \sin\theta \qquad (2)$$

where:

F	Force acting on the conductor (N)
I	Current in the conductor (A)
L	Length of the conductor in magnetic field (m)
θ	Angle between the current and the magnetic field direction.

The conductor subjected to this force will be displaced if not restrained. For this reason, the busbar supports must be designed to prevent their displacement due to this electromagnetic force. An electric arc of the welding torch which carries current cannot be restrained and will move in the direction of the force. Since the arc if flexible it continuously changes the direction in a dynamic way, making it extremely unstable. Stronger magnetic fields and increased welding currents amplify this detrimental behavior.

For typical welding currents, a magnetic field of 5 mT (50 Gauss) will begin to destabilize the electric arc, reducing weld quality, because the arc is blown away and does not stay attached long

6. References

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