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CONSIDERATIONS ON ARC INTERRUPTIONS IN PULSED GMAW

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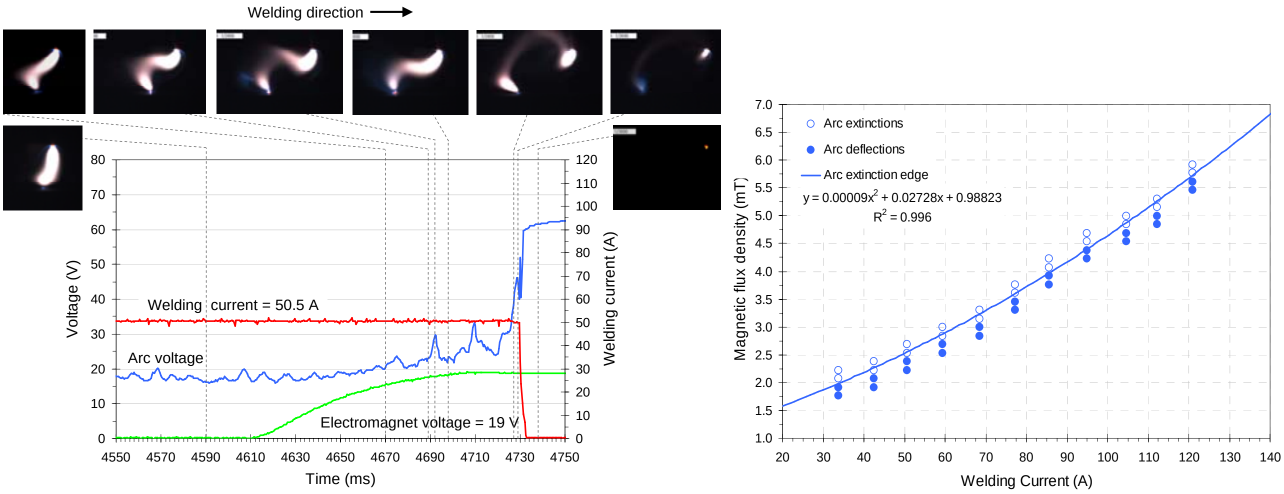
Problems of arc interruption (transitory extinction) and, therefore, oscillation in the amount of energy and molten wire delivered to the plate, have been noticed during pulsed tandem GMAW (UEYAMA et al., 2005). Although it is not so clear, this phenomenon seems to be related to the magnetic field generated by the arcs. In order to clarify this troublesome, this work tries to mimic the situation found in tandem GMAW (magnetic field induced by one arc acting on the other arc). Pulses of external magnetic fields were applied to GTAW arcs in constant current mode to verify their resistance to extinction as a function of the current level. In order to generate the external magnetic fields, an electromagnet was devised and driven by a variable DC power source. High-speed filming was used as an additional tool to understand the extinction mechanism. Figure 1 (a) shows an example of arc extinction. As seen in Figure 1 (b), the higher the electrical current flowing through the arc, the more it resists to extinction. The results found here match the results from Ueyama et al. (2005) for arc interruptions in tandem pulsed GMAW. They showed that the number of interruptions falls as the base current value is raised, which, in turn, express the gain in arc resistance to extinction verified in the present work by raising the welding current.



(a) (b)

Figure 1: (a) Example of arc extinction in GTAW due to pulsed external magnetic field and (b) relationship between welding current and resistance to extinction (arc length = 10 mm; shielding gas = Ar at 14 l/min; torch angle = 90°; electrode: EWTh-2, 2.4 mm, 30° tip)

From high-speed filming, it was verified that all arc extinctions occurred at the middle of the plasma column. Taking this fact into consideration, a model is proposed to explain the phenomenon. Let us start from Figure 2. The plasma column (arc) exists if the total heat generated in and entering into the plasma column matches the heat leaving this arc region. The loss of heat at the plasma column takes place by advection, diffusion and radiation. However, it is common to find references to convection, conduction and radiation, which would be, to some extent, incorrect, since convection usually stands for advection and diffusion (conduction). The advection term accounts for the heat loss due to the shielding gas flow (there is a difference of velocity between the gas flow and the plasma jet) and for the heat loss due to the movement of matter inside the arc (caused by the plasma jet). Eventually, a fraction of the heat lost by convection (advection and diffusion) reaches the plate. For Richardson (1989) and Allum (1983), the heat loss by convection is the most significant. However, there are controversies, and Tanaka and Lowke (2007), for instance, mention radiation as the predominant heat loss mechanism in the plasma column.

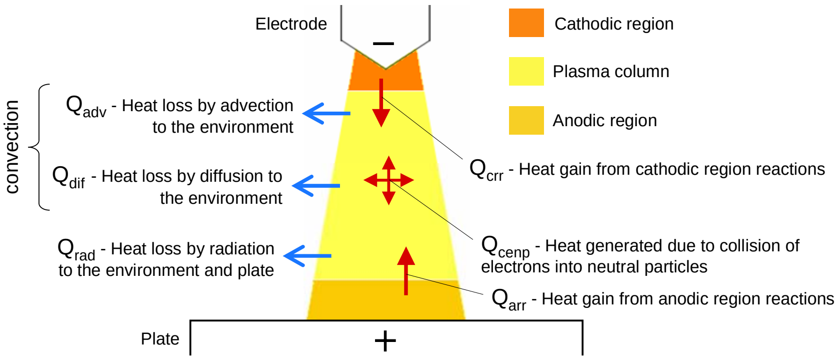


Figure 2: Schematic heat balance at the plasma column of a GTAW arc

According to the proposed model, the arc resistance to extinction is controlled by deionisation and re-ionisation processes, which occur simultaneously and constantly during arc welding. Plasma column deionisation is due to energy lowering of atoms as a consequence of heat losses. Re-ionisation is as a result of inelastic shocks between travelling electrons and non-ionized particles (including the deionised ones). The more energy demanded by the atom to become ionised, the higher the difference of potential (DoP), popularly called by voltage, required. In addition, the smaller the number of electrons travelling (lower current), the higher the DoP required (not only as a consequence of a smaller number of shocks, but also because a reduction in the input heat from the anodic and cathodic areas, which turns lesser for lower currents).

When the arc is lengthened, such as in magnetic deflection, its superficial area enlarges and, consequently, the heat loss increases. Thus, the rise of voltage (DoP) as the arc is deflected is due to the need of increasing its re-ionisation level to compensate for an increasing deionisation process.

In conclusion, a likely explanation for the arc extinctions is based on:

- During the elongation of the arc, its superficial area increases proportionally and more voltage (DoP) is demanded;
- If the power source is set at constant voltage (CV), the welding current takes values progressively lower (less shocks of electrons). As the power source cannot provided higher voltage, the arc is not able to be sustained by the low number of low potential inelastic shocks (low current and low voltage);
- If the power is set at constant current (CC), the welding current is kept at the same value (same likelihood of collisions), regardless of the voltage demanded by the arc. As the power source has a limit to provide voltage (open-circuit value), at a certain length the arc is not able to be sustained by the potential energy of the inelastic shocks anymore;
- One way or another, when the arc is lengthen beyond the steady state conditions, its radius becomes shorter (narrower arc). This is a natural geometric rearrangement of the arc looking for less energy to be sustained (the narrower the conducting column, the lesser the needs of DoP, since the arc superficial area, and the deionisation process, decreases);
- When this narrowing reaches its critical size, the arc is extinguished, usually before reaching null current (CV power source) or the open-circuit voltage (CC power source);
- The arc extinction happens at the middle of the arc column in where the heat availability is the lowest, in contrast to the electrode and plate vicinities.

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