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Gas Tungsten Arc Welding heat transfer simulation

1. The GTAW Heat transfer problem:

The GTA Welding or TIG (Tungsten Inert Gas) process is studied in a simple case involving only the Heat transfer physics. This document describes the coefficients used in the state equation and its boundary conditions in order to understand the gtaw.sif attached to the post (as well as the mesh files…). This is just a preliminary work. I hope to add the Navier-Stokes, the electromagnetism equations in order to take into account the Lorentz force and the free surface deformation on the weld-pool surface. Figure 1, here below, depicts all the phenomena involved in GTA Welding.

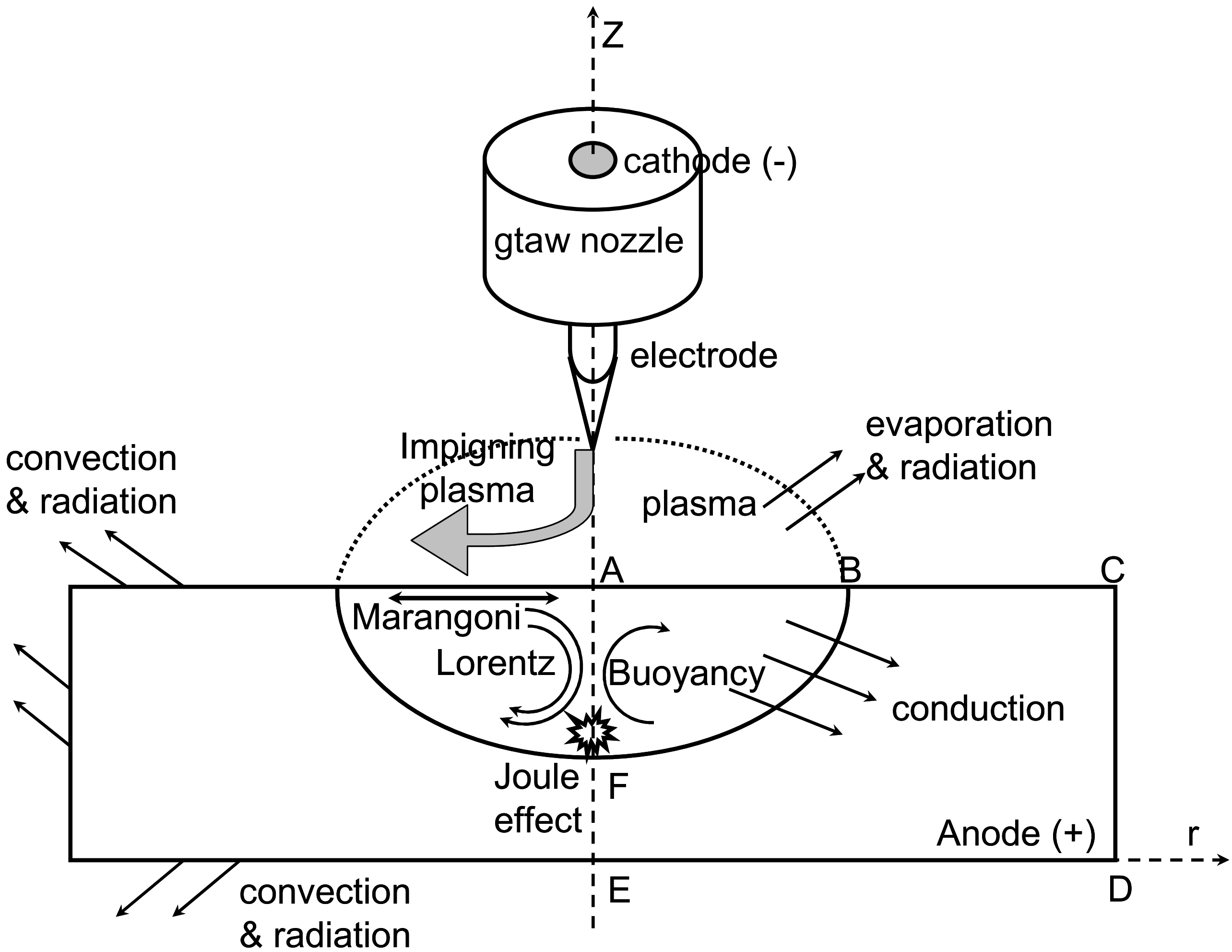

Figure 1: magneto-hydrodynamic problem involved in GTAW.

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In order to simplify the problem, the following assumptions are considered:

- The study is restricted to GTA spot welding, => axis ymmetric coordinate system, figure 2.
- No fluid flow;
- No electromagnetism.

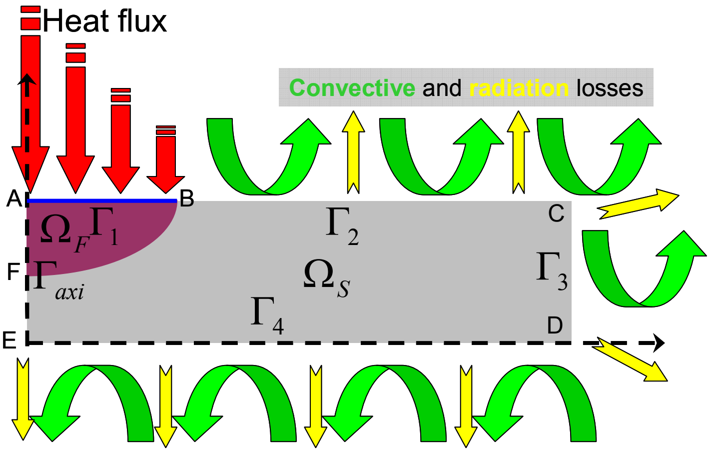

Figure 2 : axisymmetric domain and heat transfer modelling.

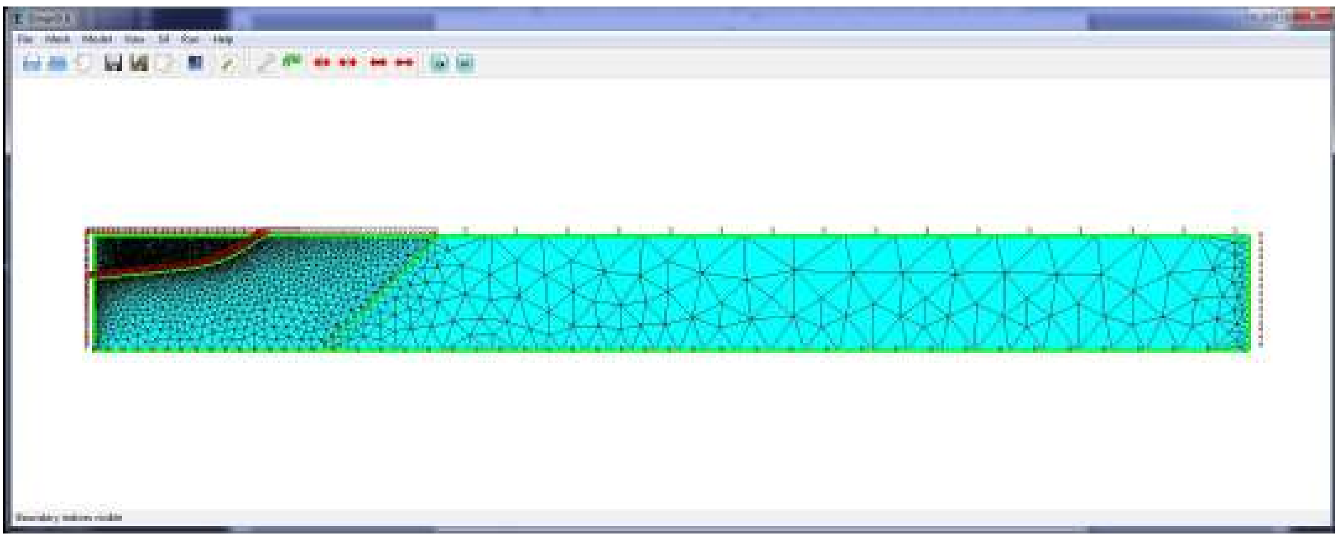

Figure 3: mesh used (radius = 20mm and thickness = 4 mm). On the top, the boundary numbers are 1, 2 and 3; the right vertical is 4, the bottom ones are 5 and 6. The left vertical (symmetry axis) are 7 and 8. the inner ones are (from center to outward) 10 and 9.

THE HEAT TRANSFER & FLUID FLOW MODELLING:

- **Energy conservation (for the computation of the temperature T):**

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$$\rho C_p^{eq}\frac{\partial T}{\partial t}-\frac{1}{r}\frac{\partial}{\partial r}\left(r\lambda\frac{\partial T}{\partial r}\right)-\frac{\partial}{\partial z}\left(\lambda\frac{\partial T}{\partial z}\right)=0$$

With T is the temperature field. ρ, C_P and λ are respectively the mass density, specific heat and thermal conductivity of the Stainless Steel Metal.

The heat transfer boundary conditions are (it refers to figure 2):

- → On the top surface $\Gamma_1 \cup \Gamma_2$: $-\lambda\dfrac{\partial T}{\partial z}=-\Phi(r,t)+h(T-T_0)+\varepsilon\sigma\left(T^4-T_0^4\right)$
- → On the lateral side Γ_3: $-\lambda\dfrac{\partial T}{\partial r}=h(T-T_0)+\varepsilon\sigma\left(T^4-T_0^4\right)$
- → On the bottom surface Γ_4: $\lambda\dfrac{\partial T}{\partial z}=h(T-T_0)+\varepsilon\sigma\left(T^4-T_0^4\right)$
- → On the symmetry axis : $-\lambda\dfrac{\partial T}{\partial r}=0$
- → The initial condition is: $T(r,t=0)=T_0$

$\Phi(r)$ is a surface heat flux exchanged between the plasma arc and the work-piece. We will assume that this heat flux distribution obey to a Gaussian distribution. So it can be written as follows: $\Phi(r,t)=\eta\dfrac{1}{2}\dfrac{Us.Is}{\pi r_b^2}e^{-\frac{1}{2}\left(\frac{r}{r_b}\right)^2}$ where Us is the welding tension, Is is the welding intensity, η is the GTAW efficiency and r_b is called the Gaussian radius.