Three dimensional modelling and measurement of a GTAW electric arc and heat exchanges with a metallic weld plate.

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Objectives

Elaborate a predictive model describing a GTAW plasma arc and its energetic exchanges with a metallic plate.

PhD Background: - material: stainless steel 304L
- method adopted: Experimental tests coupled with CFD calculations

Physical model

Plasma modelling (with Code_Saturne® [1])
- One temperature plasma (LTE)
- Global model containing plasma (argon) and solid electrodes
- Metallic vapor-plasma coupling taken into account
- Researches mainly focus on the energy transferred to the weld plate

3D-model developed

Plasma/work piece interface:
- Heating of the weld plate by thermal conduction
- Heating of the weld plate due to «anodic» sheath
- Cooling of the weld plate by evaporation
- Diffusion of metallic species into the plasma

Electrostatic sheaths:

\[ T_{\text{she, anode}} = \left(\frac{2L}{v} \right) \left( \frac{T_{\text{plate}} - T_{\text{anode}}}{\Delta \Phi_{\text{anode}}} + \frac{T_{\text{plate}} - T_{\text{workpiece}}}{\Delta \Phi_{\text{workpiece}}} + V_{\text{plate}} \right) \]

Electromagnetic forces near the electrode

\[ \Delta \Phi = \Delta \Phi_{\text{anode}} + \Delta \Phi_{\text{workpiece}} \]

Influence of cathodic model parameters on the temperature inside the electrode

Influence of work function (W) and cathodic voltage drop (Δ\Phi) on the electrode temperature

Numerical results

Temperature field in the plasma and electrodes and metallic vapor distribution in the plasma

Velocities are oriented from electrode toward anode (work piece) with a maximum value of 250 m/s, for a 1mm and 200A plasma arc

Time evolution of the workpiece temperature (at 0.4 s and 1.2 s)

Results about the electrode model indicate:
- Major influence of the thermo-electronic model parameters (constant of Richardson-Dushman)
- Huge influence of the work function
- No influence of cathodic voltage drop into the sheath
- No influence of the radiation cooling term

Experimental approach

Plasma diagnostics (atomic emission spectroscopy)

- Advantages: Fast, accurate and non-intrusive

Spectroscopic tests:
- Parallelepipedic specimen (300x30x20 mm)
- 304L Stainless steel

Axial temperature (K) of the plasma. Curve is the simulation, and points are our measures.

OBJECTIVES:
- To obtain plasma temperature and electronic density fields
- To study the effect of different set of welding parameters

Qualitative and quantitative results are encouraging. They must be confirmed under other welding conditions

References