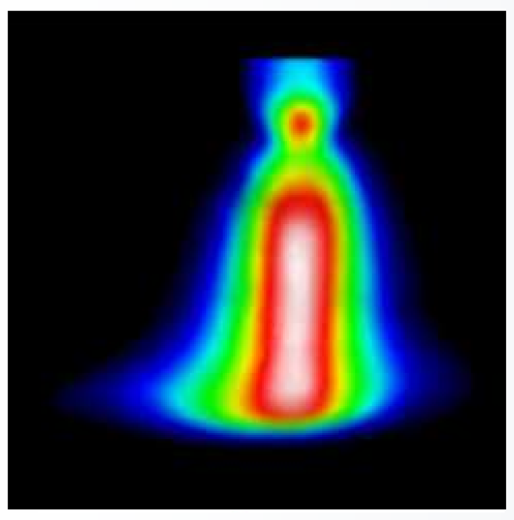


# Three dimensional modelling and measurement of a GTAW electric arc and heat exchanges with a metallic weld plate.

D. Borel[*,1,3], J-M Carpreau[1,4], C. Delalondre[2], B. G. Chéron[3], P. Boubert[3]

1 EDF R&D department MRI, 6 quai Watier 78400 Chatou, France

2 EDF R&D department MFEE, 6 quai Watier 78400 Chatou, France

3 CORIA, UMR 6614, Site Universitaire du Madrillet, 76801 Saint Etienne du Rouvray, France

4 LaMSID UMR EDF-CNRS-CEA 2832

*damien.borel@coria.fr

## 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

**3D-model developed**

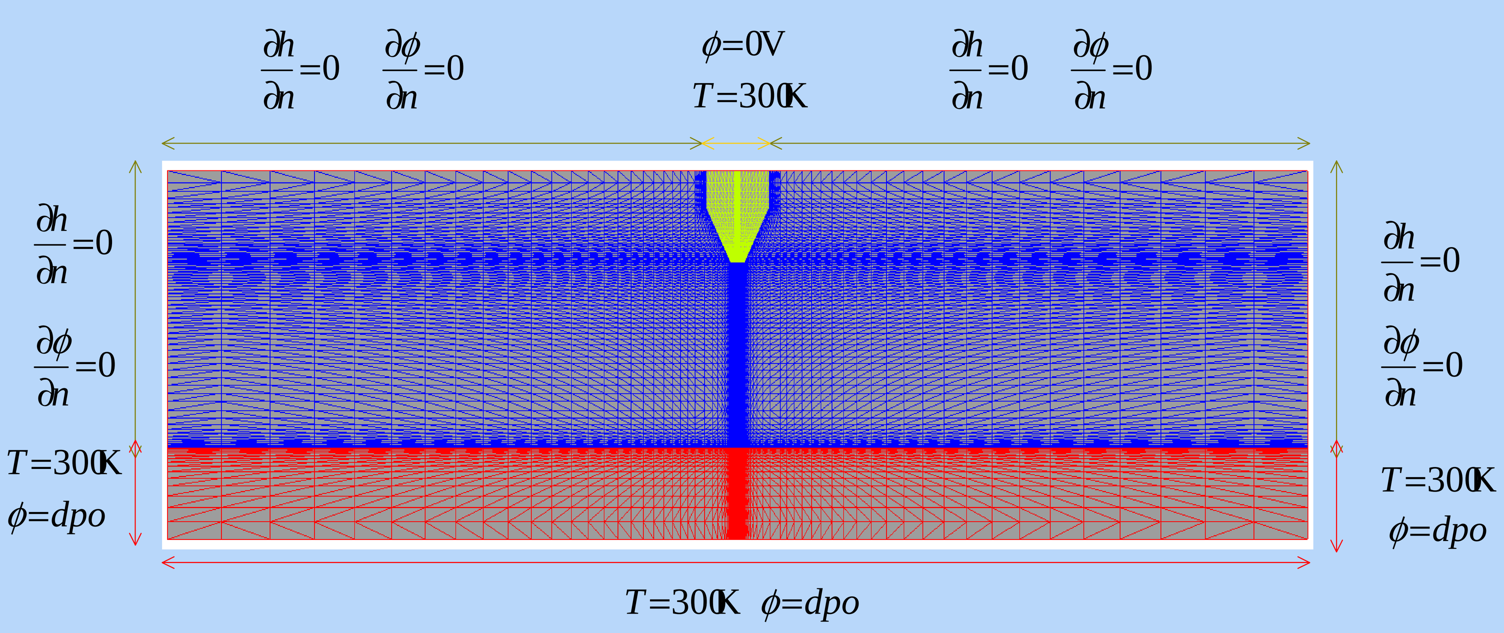
Arc plasma between a cathode and a anode also included in the computational domain ([2], [3], [4], [5])

***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

**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

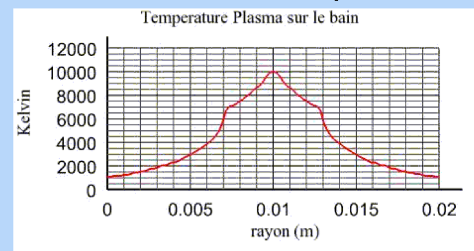



**Electrostatic sheaths :**

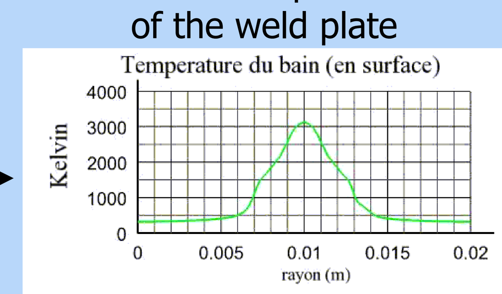
$$TS_{elec,cathode}=-j_e\left(\frac{2k_B}{e}T_{Wall}+W_{cathode}\right)+j_i\left(\frac{5k_B}{2e}T_{Wall}+\Delta\Phi_{cathode}+V_i\right)$$

$$TS_{elec,anode}=j_e\left(\frac{5k_B}{2e}(T_{Plasma}-T_{Wall})+W_{Anode}+\Delta\Phi_{Anode}\right)$$

Plasma temperature above the work piece

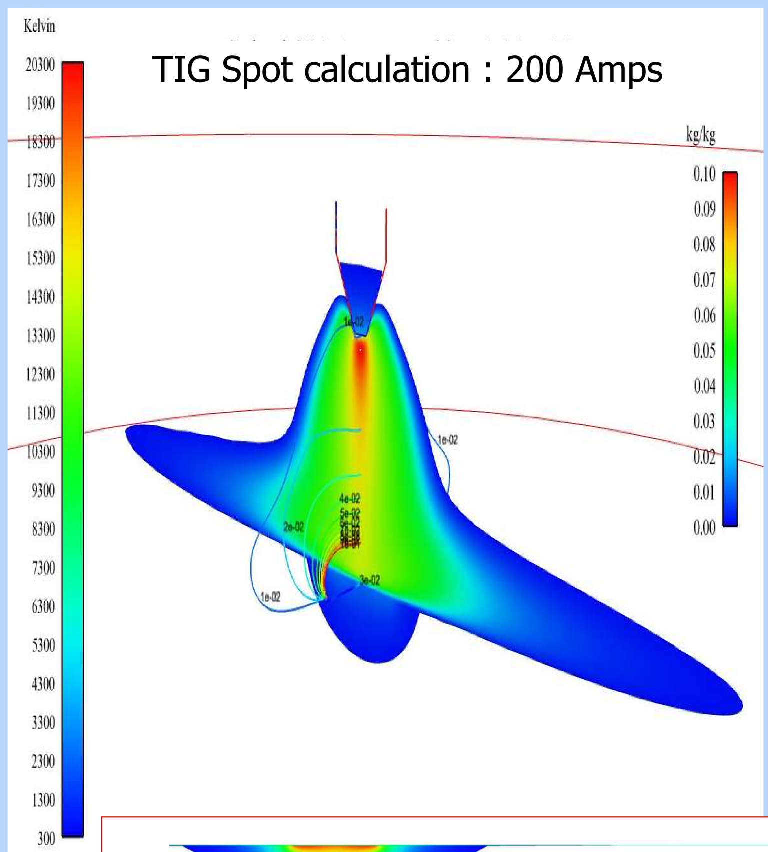


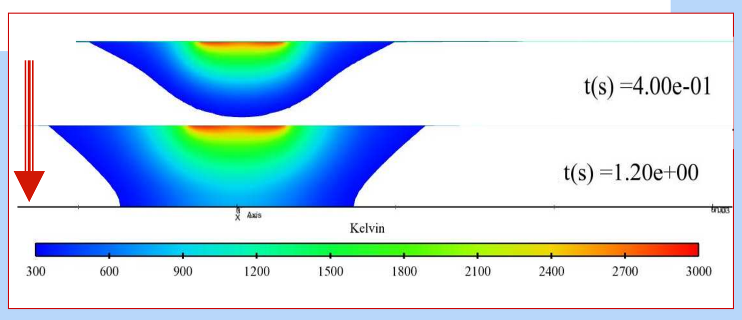

Surface temperature of the weld plate




## Numerical results

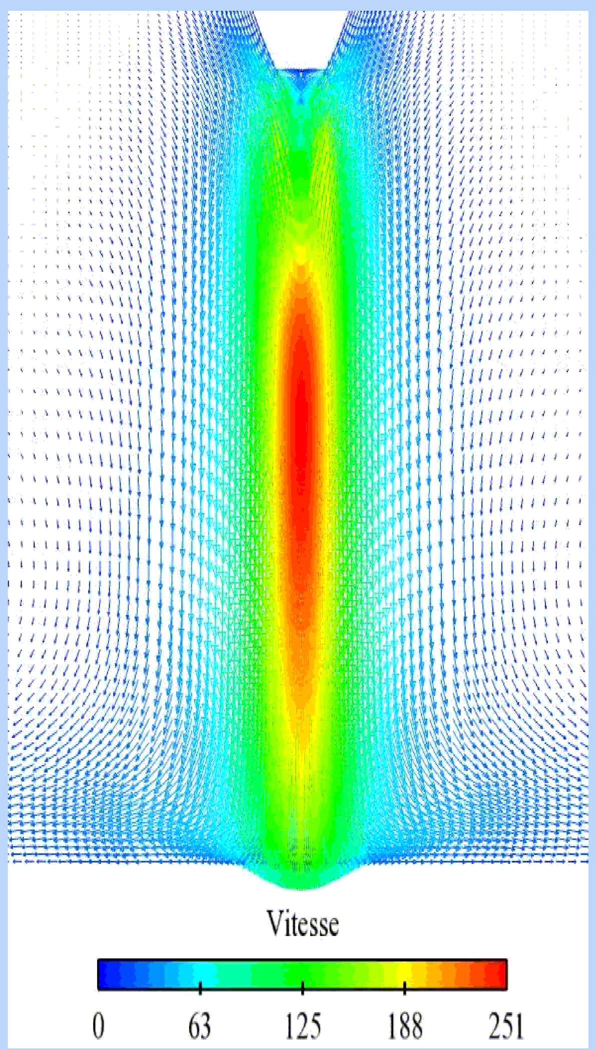
Temperature field in the plasma and electrodes and metallic vapor distribution in the plasma



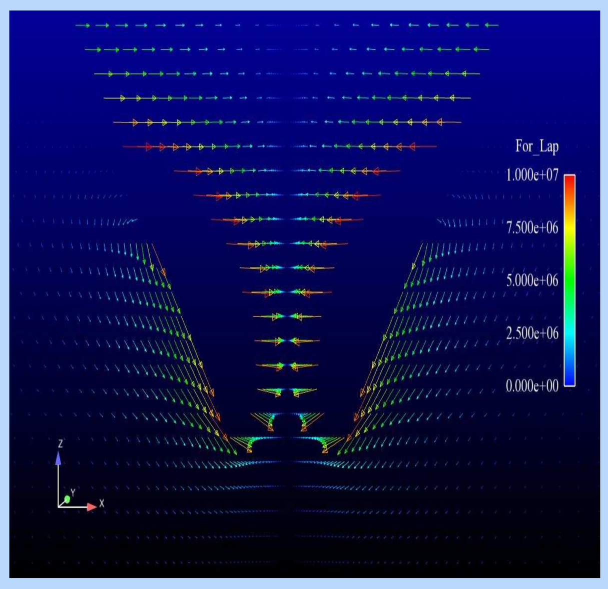




Time evolution of the workpiece temperature (at 0.4 s and 1.2 s)

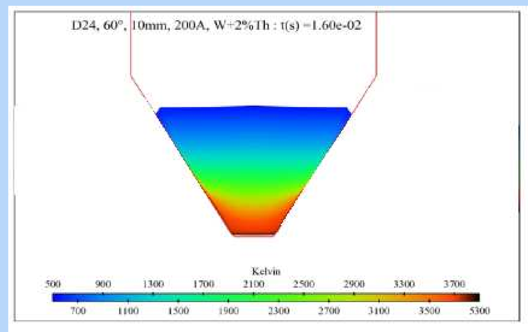
Velocities are oriented from electrode toward anode (work piece) with a maximum value of 250 m/s, for a 1mm and 200A plasma



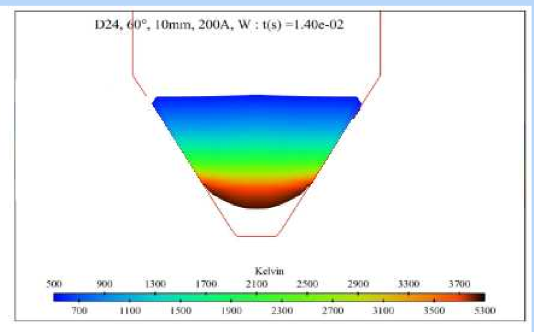

Electromagnetic forces near the electrode



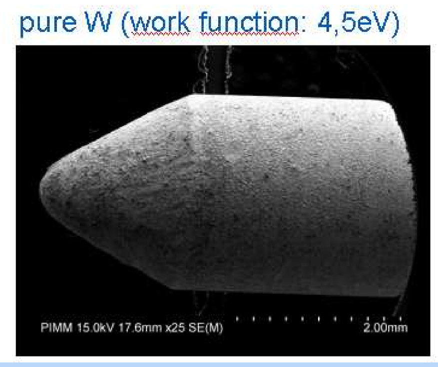
Influence of work function ($W_{cathode}$) and cathodic voltage drop ($\Delta\Phi_{cathode}$) on the electrode temperature

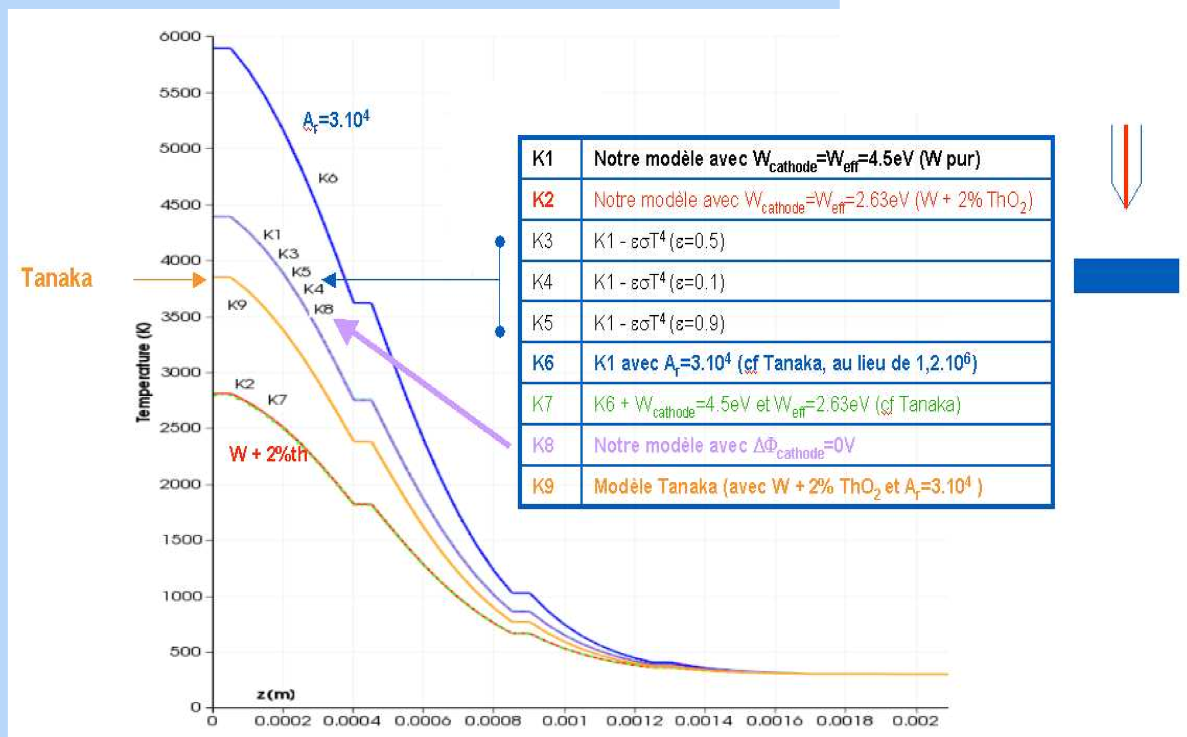


W + 2% Th (work function : 2,63eV)



pure W (work function: 4,5eV)






Influence of cathodic model parameters on the temperature inside the electrode

Results about the electrode model indicate:

-Major influence of the thermoelectronic 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

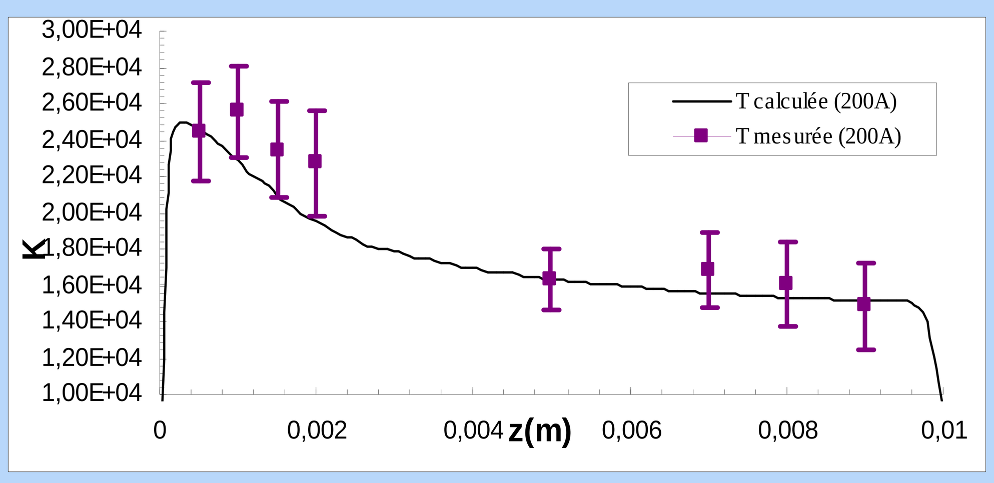
**Spectroscopic tests :** - Parallelepipedic specimen (300x30x20 mm)
- 304L Stainless steel

| I (A) | Arc length (mm) | Tip angle (°) | Electrode diameter (mm) | Electrode composition |
|---|---|---|---|---|
| 200 | 10 | 60 | 2.4 | W+2%th |
| 100 | 10 | 60 | 2.4 | W+2%th |
| 200 | 5 | 60 | 2.4 | W+2%th |
| 200 | 10 | 30 | 2.4 | W+2%th |
| 200 | 10 | 60 | 3.2 | W+2%th |
| 200 | 10 | 60 | 2.4 | W |

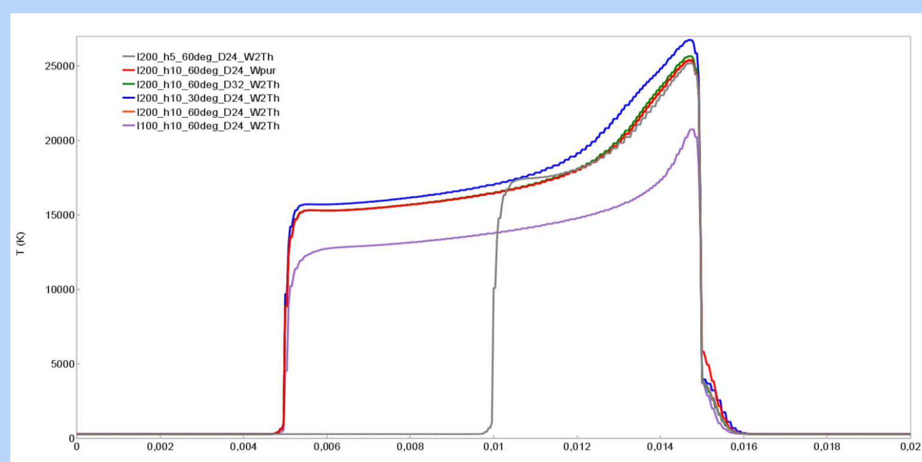
**OBJECTIVES :** - To obtain plasma temperature and electronic density fields

- To study the effect of different set of welding parameters

COMPARISON EXPERIMENTAL - CFD CALCULATION




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



Axial temperature (K) of the plasma for the six configurations.

Picture of the plasma (1cm long, 200A)

- Electric current has the most Influence
- Electrode tip angle as a least influence
- The model seems to be unsensitive to the other parameters

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

## References

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[2] Kaddani A., Delalondre C., Simonin O., Minoo H., *Thermal and electrical coupling of arc electrodes*, High Temp. Chem. Processes Vol 3, pp.441-448, 1994

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[5] Chemartin L., Lalande Ph., Delalondre C., Cheron B., Lago F., *Modelling and simulation of unsteady dc electric arcs and their interactions with electrodes*, J. Phys D : Applied Phys, Vol 44, 2011