Presented at the COMSOL Conference 2010 Boston

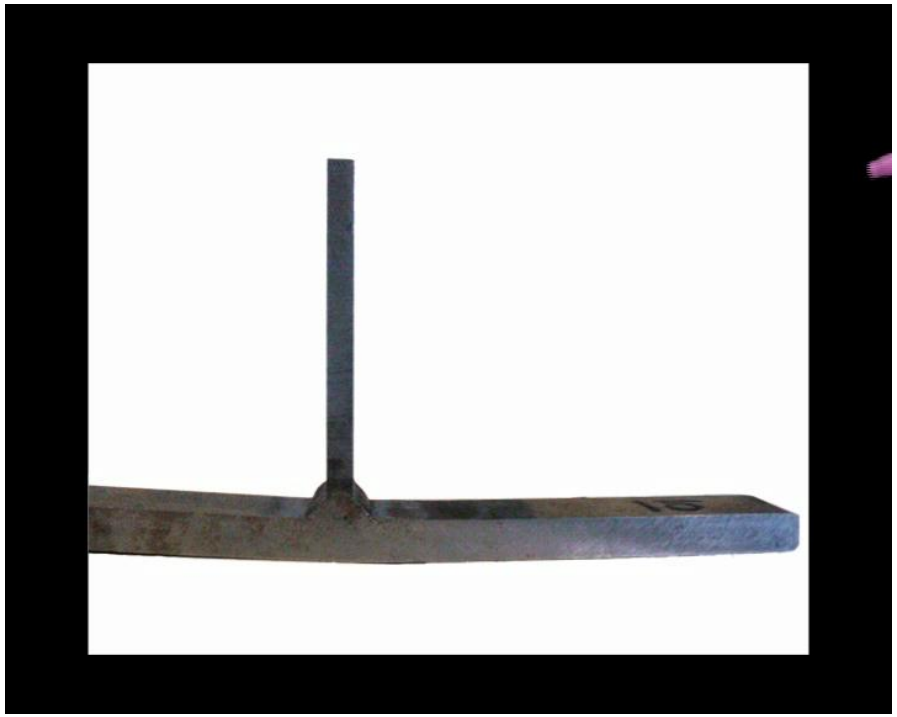
Modeling residual stresses in Arc Welding

Frédéric Roger – Abderrazak Traidia

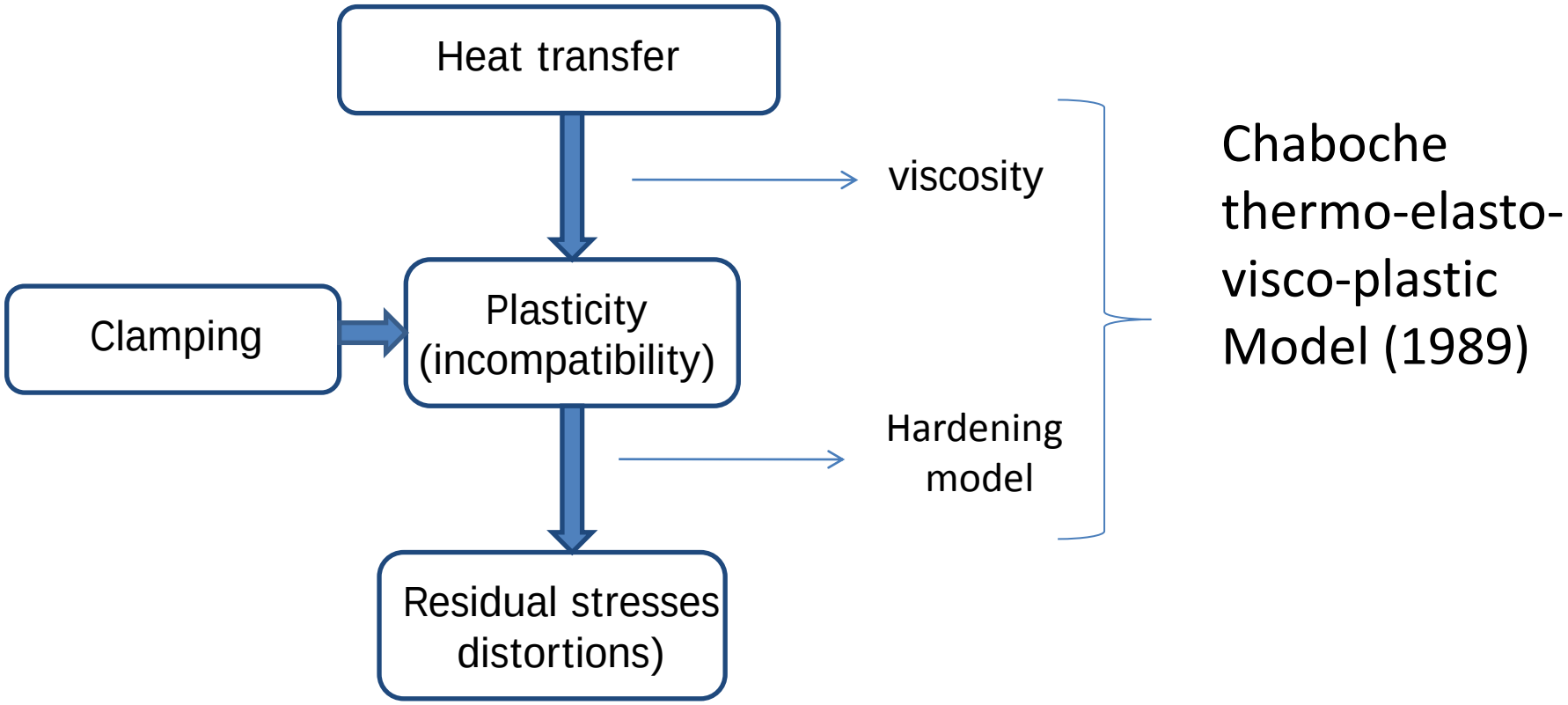
ENSTA Paristech

COMSOL CONFERENCE 2010
OCTOBER 7-9 2010, BOSTON, MA, USA

Consequences of Welding



Evaluation of (visco)plastic strains



Chaboche elastoviscoplastic model

Thermoelasticity with (visco)plastic strain

(visco)plastic strain time evolution

$$\dot{\varepsilon}_p = \frac{3}{2}\dot{p}\frac{\sigma' - X'}{J_2(\sigma - X)}$$

$$\dot{X} = \frac{2}{3}C\dot{\varepsilon}_p - \gamma X\dot{p}$$

$$\dot{p} = \left\langle \frac{J_2(\sigma - X) - R - k}{K} \right\rangle^n$$

$$R = Q(1 - \exp(-bp))$$

$$J_2(\sigma - X) = \sqrt{\frac{3}{2}(\sigma' - X'):(\sigma' - X')}$$

K, n, C, Q, γ and b
Temperature dependent

Comsol implementation

```
sr_smaxi=
4*G_smaxi*(er_smaxi-epr_smaxi)/3
-2*G_smaxi*(ephi_smaxi-epphi_smaxi)/3
-2*G_smaxi*(ez_smaxi-epz_smaxi)/3
-p
```

```
sz_smaxi=
4*G_smaxi*(ez_smaxi-epz_smaxi)/3
-2*G_smaxi*(er_smaxi-epr_smaxi)/3
-2*G_smaxi*(ephi_smaxi-epphi_smaxi)/3
-p
```

```
sphi_smaxi=
4*G_smaxi*(ephi_smaxi-epphi_smaxi)/3
-2*G_smaxi*(er_smaxi-epr_smaxi)/3
-2*G_smaxi*(ez_smaxi-epz_smaxi)/3
-p
```

```
srz_smaxi=
2*G_smaxi*(erz_smaxi-eprz_smaxi)
```

```
p=
-K_smaxi*(evol_smaxi-epr_smaxi-epphi_smaxi-epz_smaxi
-3*mat1_alpha*(Temp_smaxi-Tempref_smaxi))
```

Comsol implementation

$$\dot{\varepsilon}_p = \frac{3}{2}\dot{p}\frac{\sigma' - X'}{J_2(\sigma - X)}$$

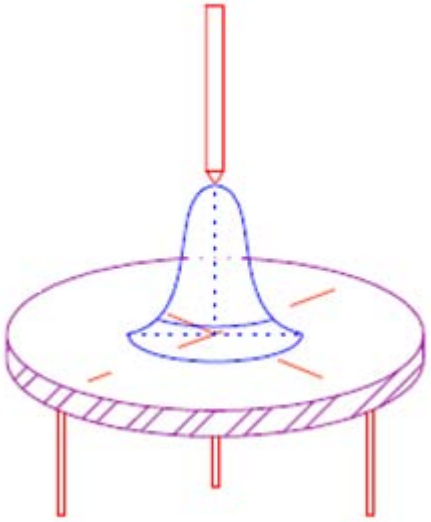
$$\dot{X} = \frac{2}{3}C\dot{\varepsilon}_p - \gamma X\dot{p}$$

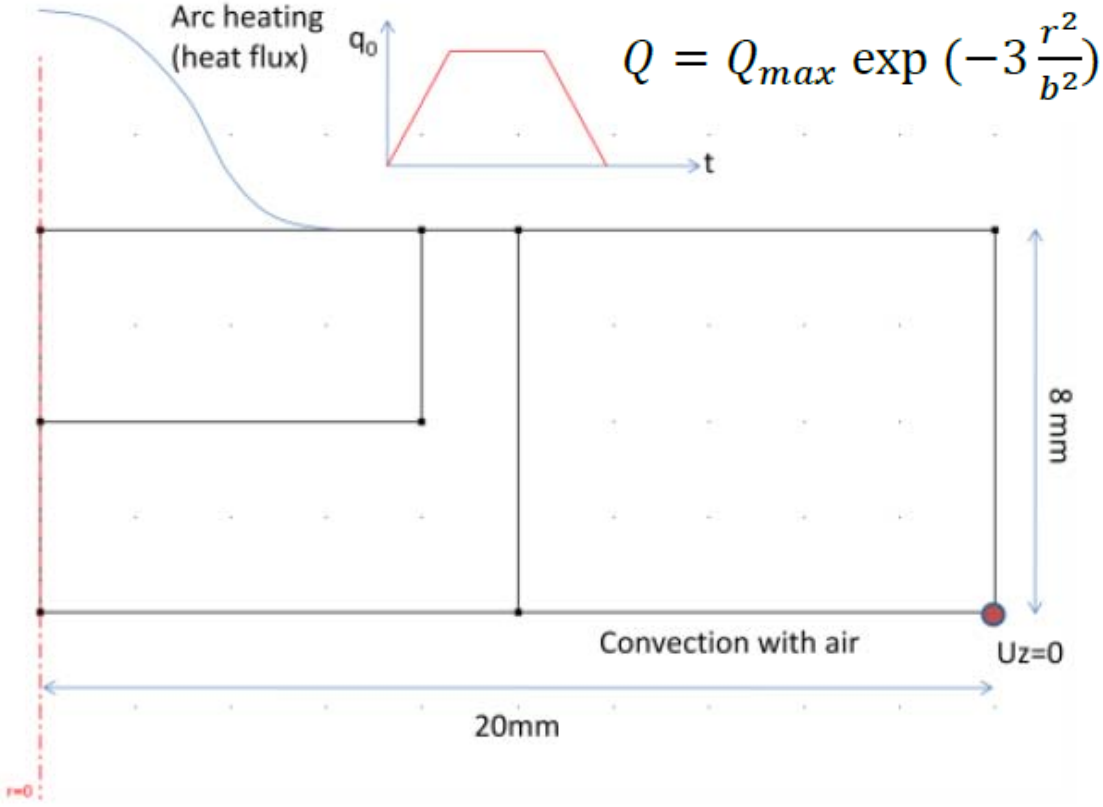
$$\dot{p} = \left\langle \frac{J_2(\sigma - X) - R - k}{K} \right\rangle^n$$

Non linear Ordinary differential equations =

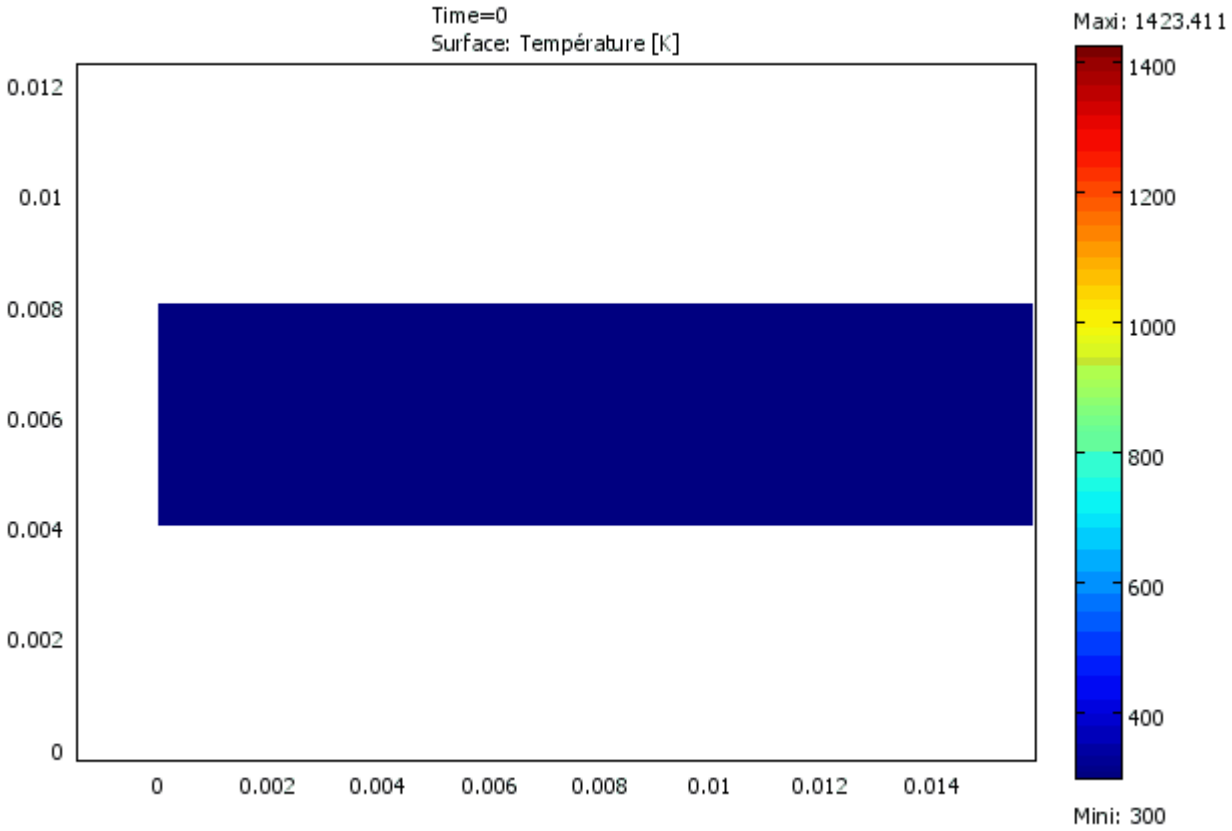
Mode PDE, General form without spatial derivatives

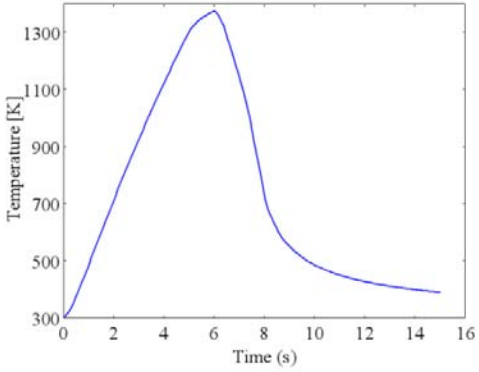
Application : spot arc welding





Numerical results

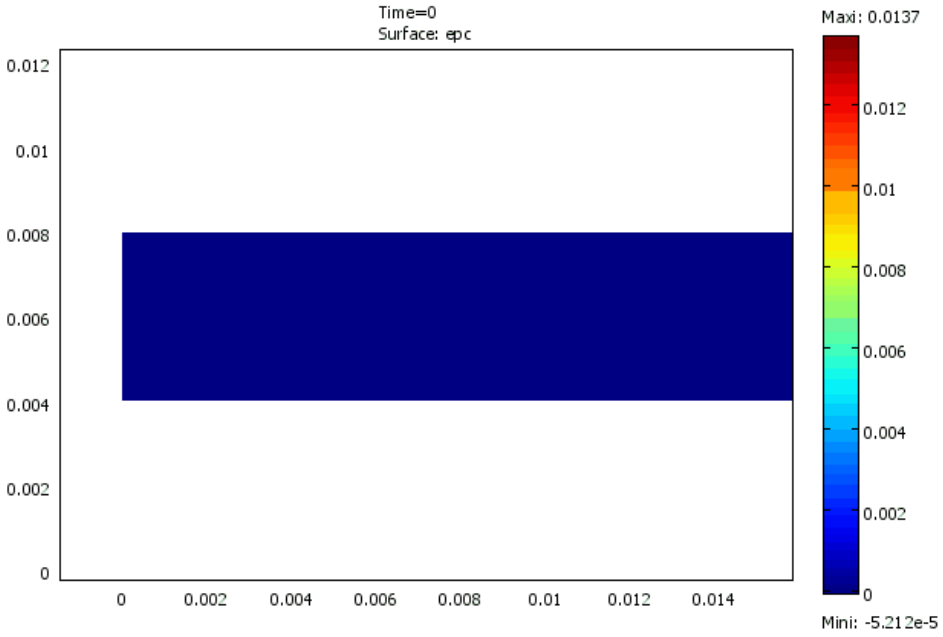




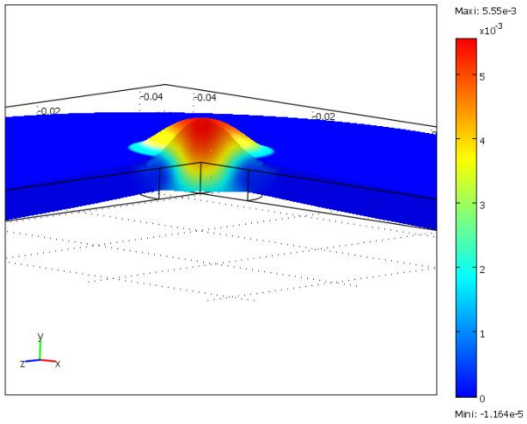
Temperature field during welding

Numerical results

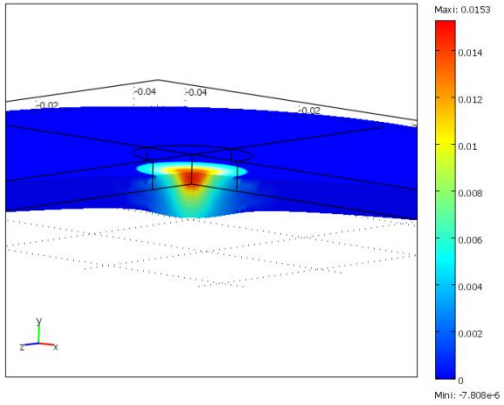
Equivalent plastic strain



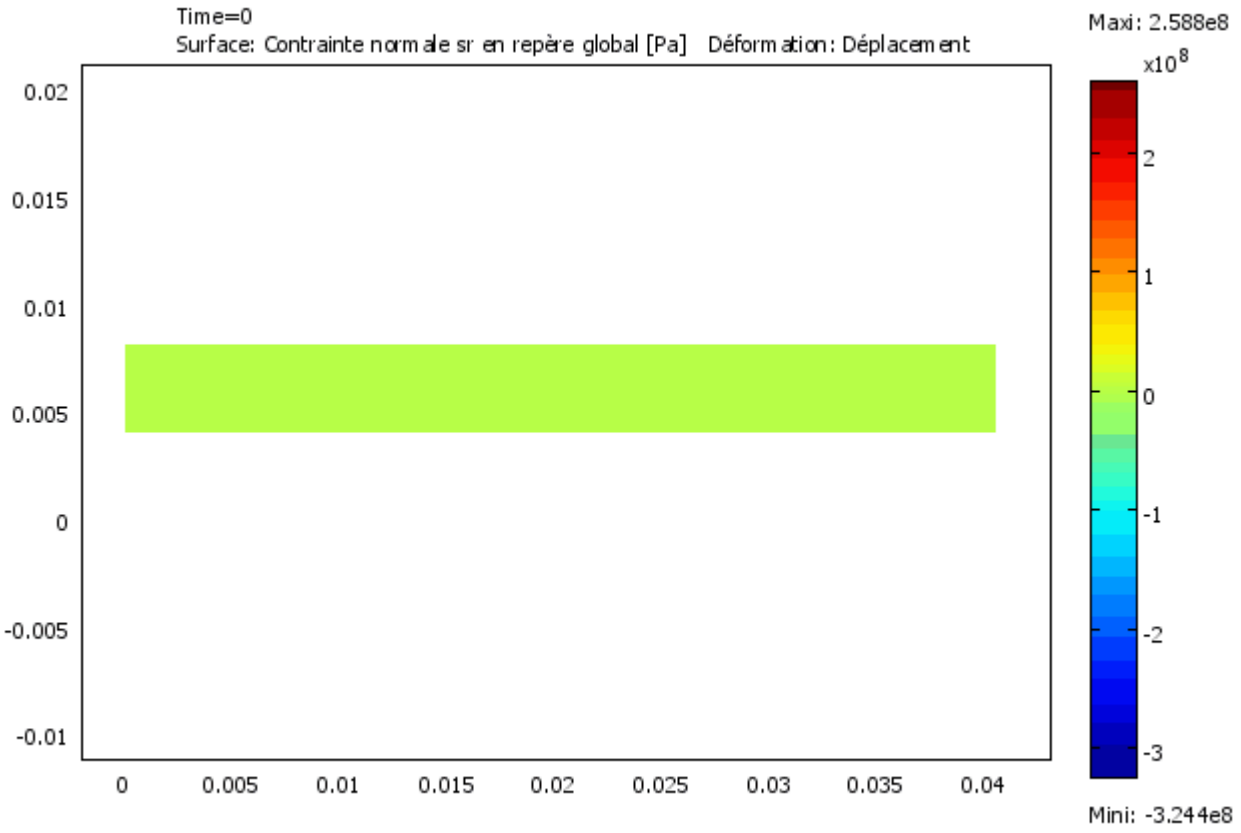
End of heating



After cooling

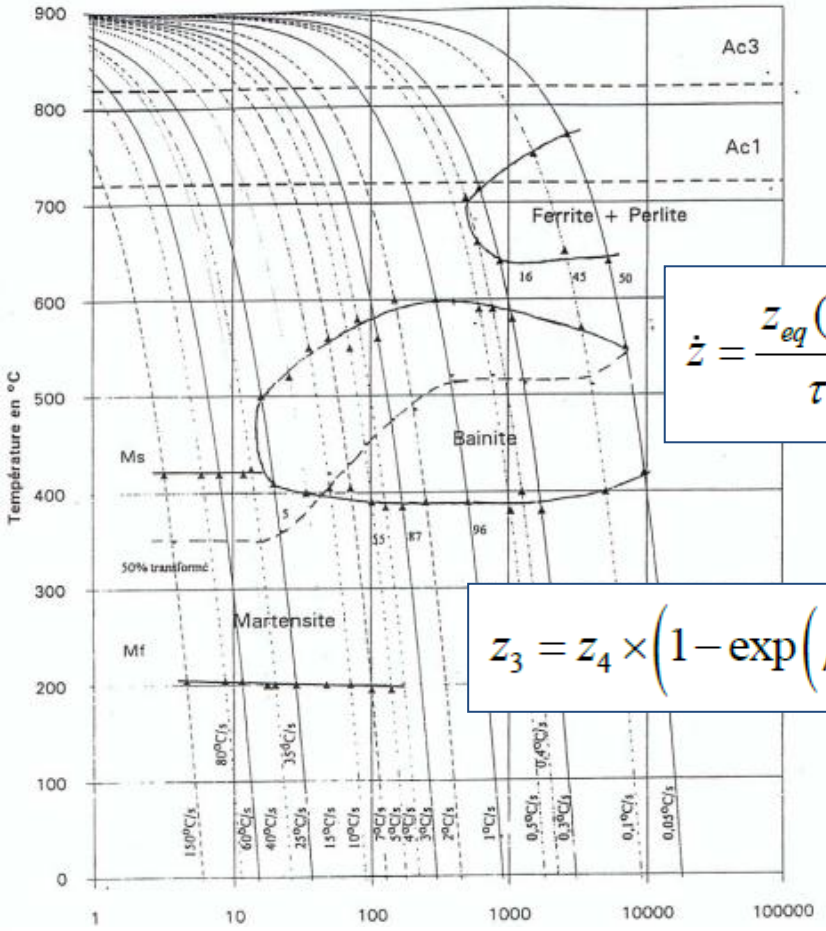


Numerical results



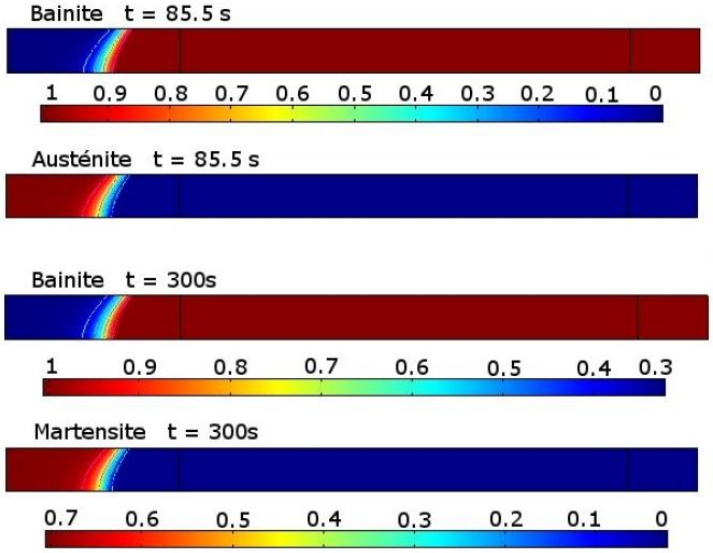
Residual stresses and distortions

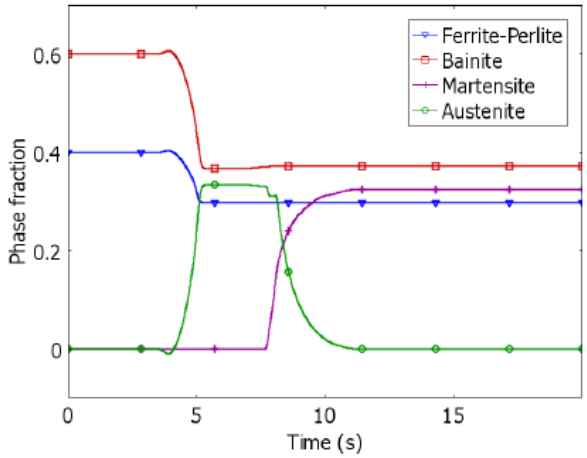
Extension of the model : metallurgical transformation



$$\dot{z} = \frac{z_{eq}(T) - z}{\tau(T)}$$

$$z_3 = z_4 \times \left(1 - \exp\left(\beta \times \left[Ms - T\right]^{+}\right)\right)$$





Conclusion

Arc heating

Weld pool

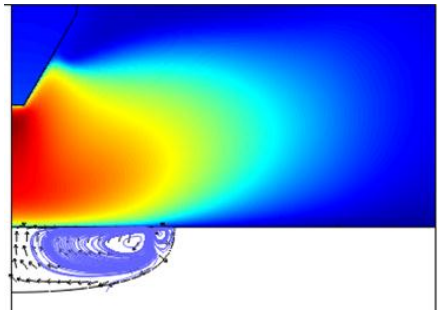
Heat transfer

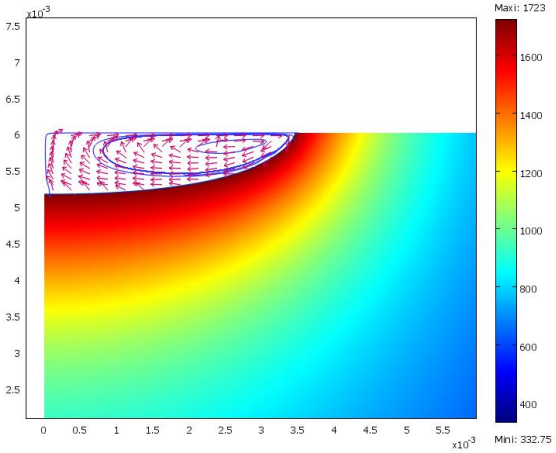
Clamping

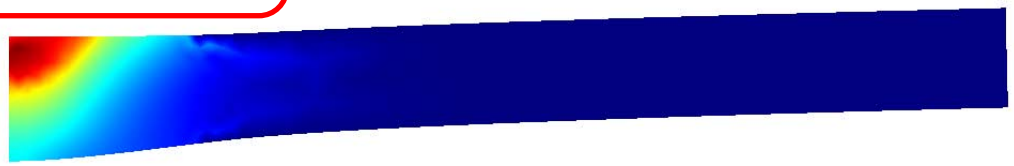
Metallurgical transformation

Plasticity (incompatibility)

Residual stresses distortions)



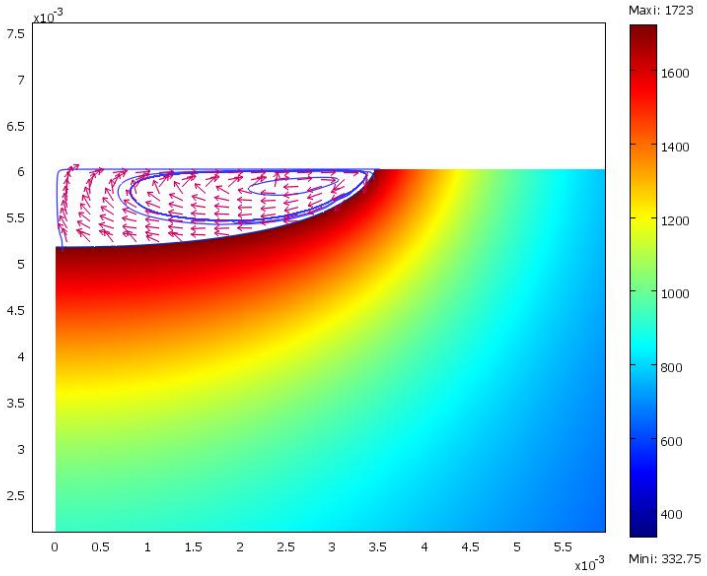




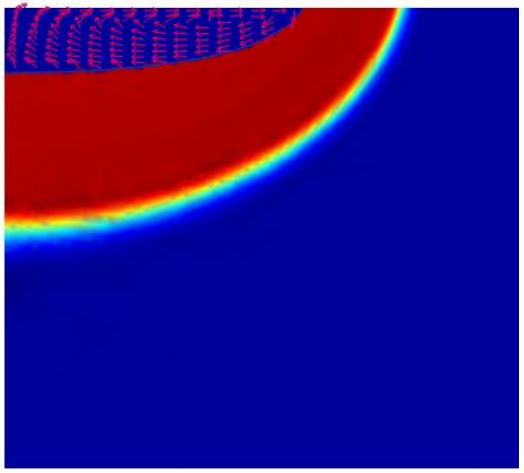
Thank you for your attention
Any questions ?

The authors: Frederic Roger And Abderrazak Traidia

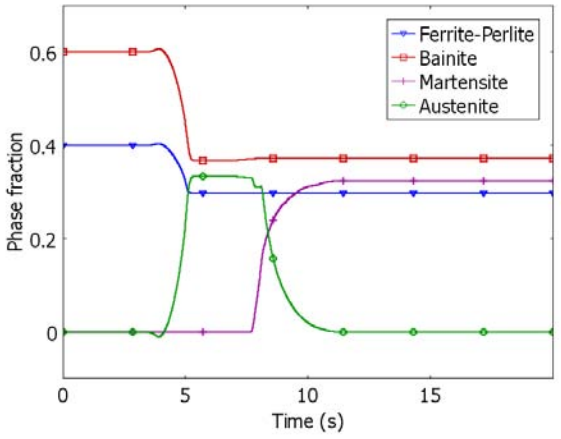
Extension of the model :Fluid flow and metallurgy



Fluid flow and thermal field



Austenite distribution after heating

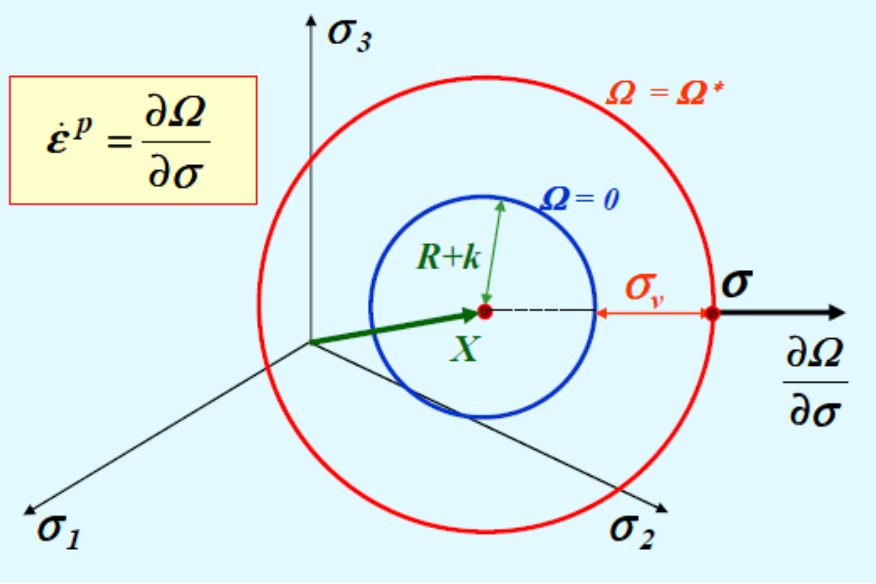


Phase fraction time evolution

Chaboche elastoviscoplastic model

Thermoelasticity with (visco)plastic strain

(visco)plastic strain time evolution



$$\dot{\varepsilon}_p = \frac{3}{2}\dot{p}\frac{\sigma' - X'}{J_2(\sigma - X)}$$

$$J_2(\sigma - X) = \sqrt{\frac{3}{2}(\sigma' - X'):(\sigma' - X')}$$

$$\dot{p} = \left\langle \frac{J_2(\sigma - X) - R - k}{K} \right\rangle^n$$

$$R = Q(1 - \exp(-bp))$$

$$\dot{X} = \frac{2}{3}C\dot{\varepsilon}_p - \gamma X\dot{p}$$