

Modelling of FSW

Nordic FSW Group meeting

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For members of Nordic FSW group only!
Do not distribute!

Why modelling FSW?

- To evaluate temperature history
- To predict microstructure evolution
- To predict residual stress and distortions
- To understand the basic mechanism for shear layer formation and deposition
- To investigate influence of different welding parameters
- To investigate influence of e.g. backing plate properties, cooling, clamping, tool design.
- Final goal:
 - To optimize final properties
 - To optimize the process window/process parameters
 - To understand the process (...even more)

Overview of FSW activities

- Analytical expression for heat generation
- Thermal models
- Thermo-mechanical models
 - Material flow and heat generation
 - Residual stress and distortion
- CFD
 - 2D
 - 3D
- Experimental investigation of material flow using marker material

We try to answer questions

- How is heat generated?
 - Frictional dissipation
 - Plastic dissipation
- How much heat is generated?
- Where is heat generated?
 - Shoulder
 - Probe sides and tip
- Where does the heat flow?
 - Efficiency
- What happens if RPM is doubled?

Analytical model for heat generation

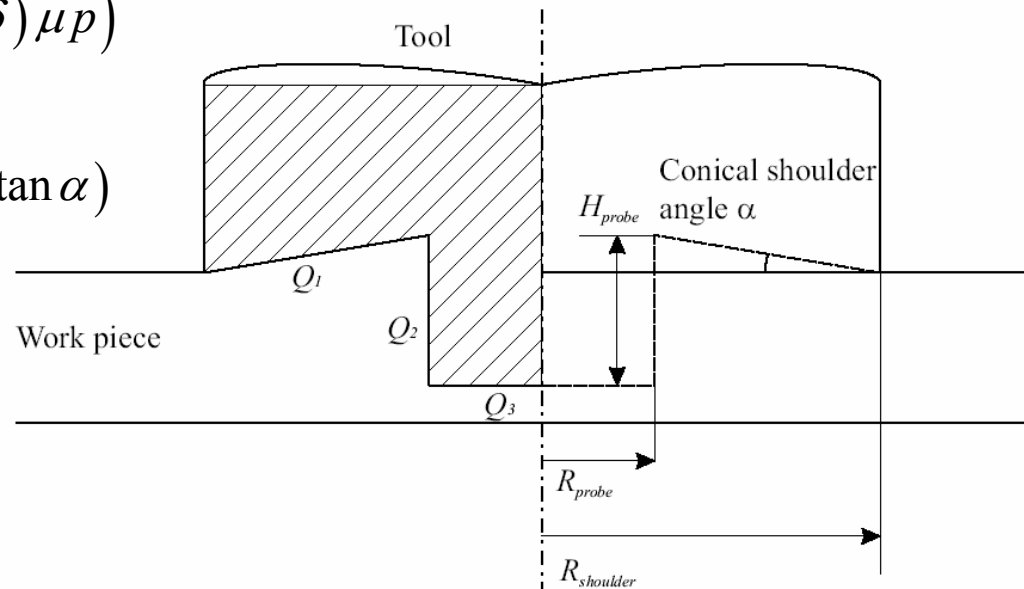
$$\frac{dQ}{dA}(r) = \omega r \tau_{contact} = \omega r (\delta \tau_{yield} + (1 - \delta) \mu p)$$

$$Q_1 = \frac{2}{3} \pi \omega \tau_{contact} (R_{shoulder}^3 - R_{probe}^3) (1 + \tan \alpha)$$

$$Q_2 = \frac{2}{3} \pi \omega \tau_{contact} R_{probe}^3$$

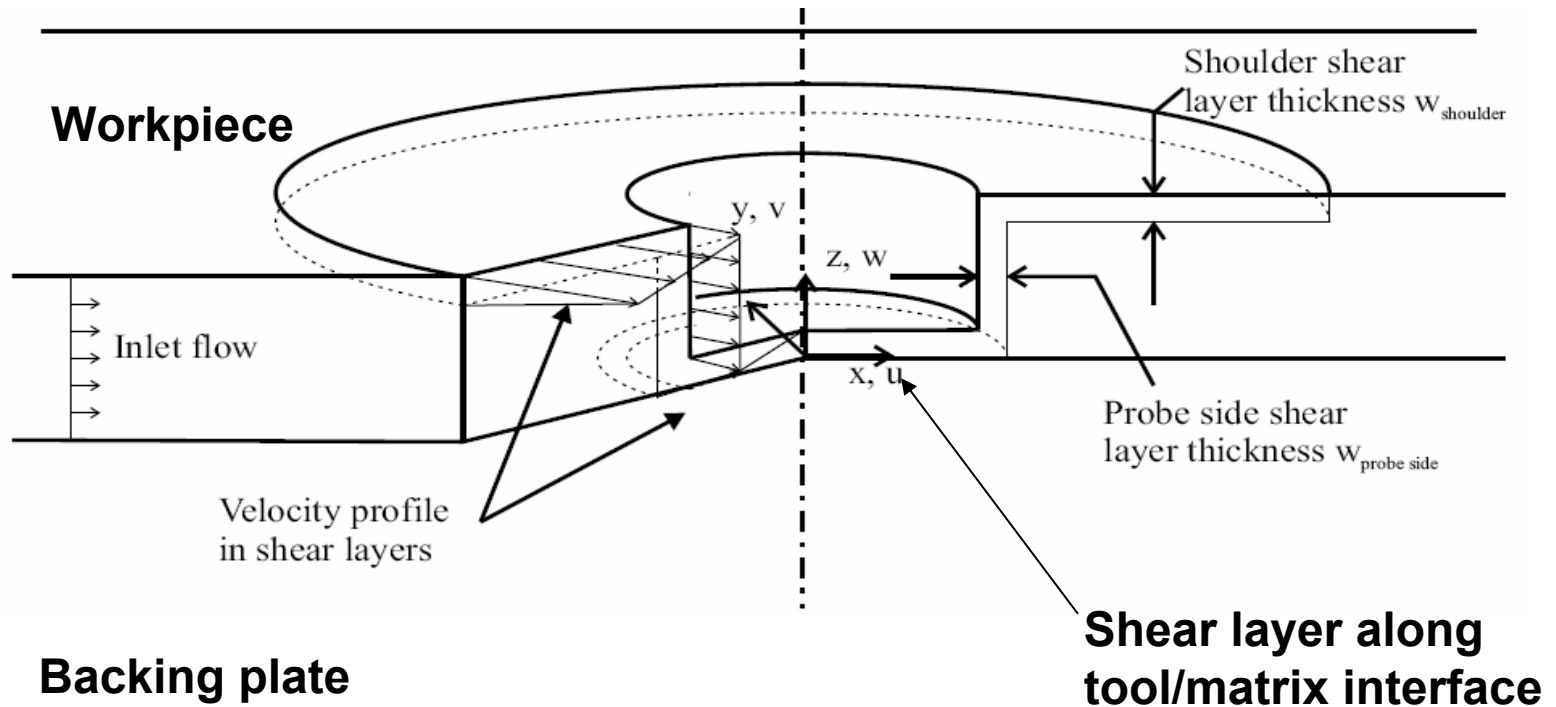
$$Q_3 = 2 \pi \omega \tau_{contact} R_{probe}^2 H_{probe}$$

$$Q_{total} = \frac{2}{3} \pi \omega (\delta \tau_{yield} + (1 - \delta) \mu p) \left((R_{shoulder}^3 - R_{probe}^3) (1 + \tan \alpha) + R_{probe}^3 + 3 R_{probe}^2 H_{probe} \right)$$



Schmidt, Hattel and Wert (2004)

Thermal model



Schmidt and Hattel (2005)

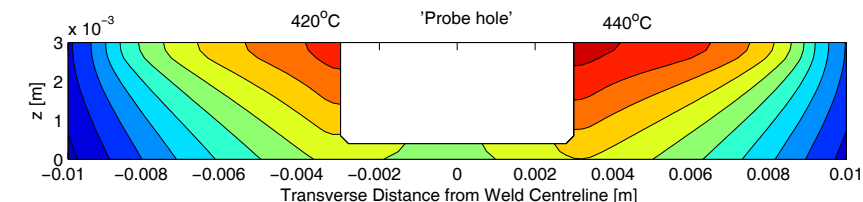
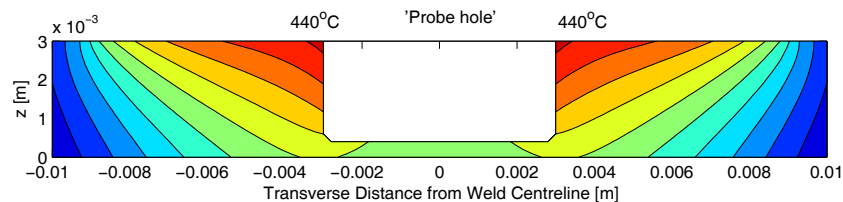
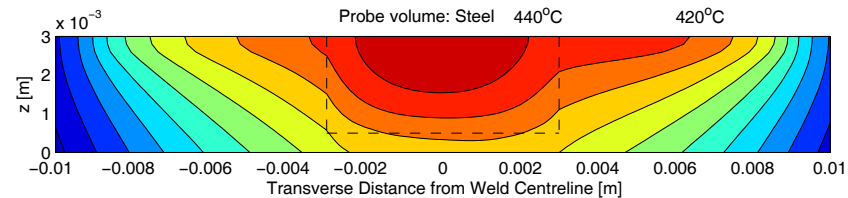
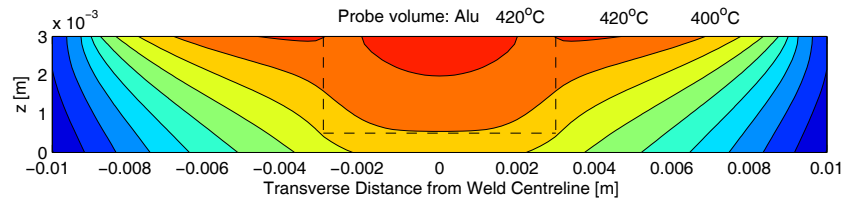
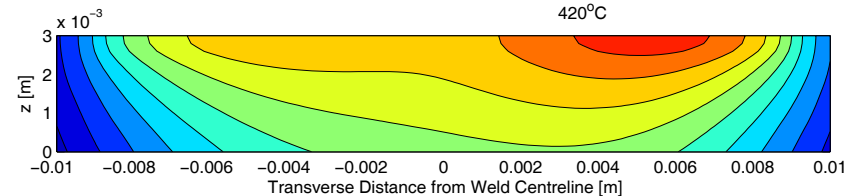
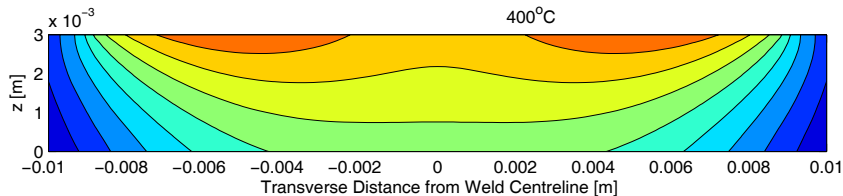
Different heat sources

**Retreating
Left**

**Advancing
Right**

**Retreating
Left**

**Advancing
Right**

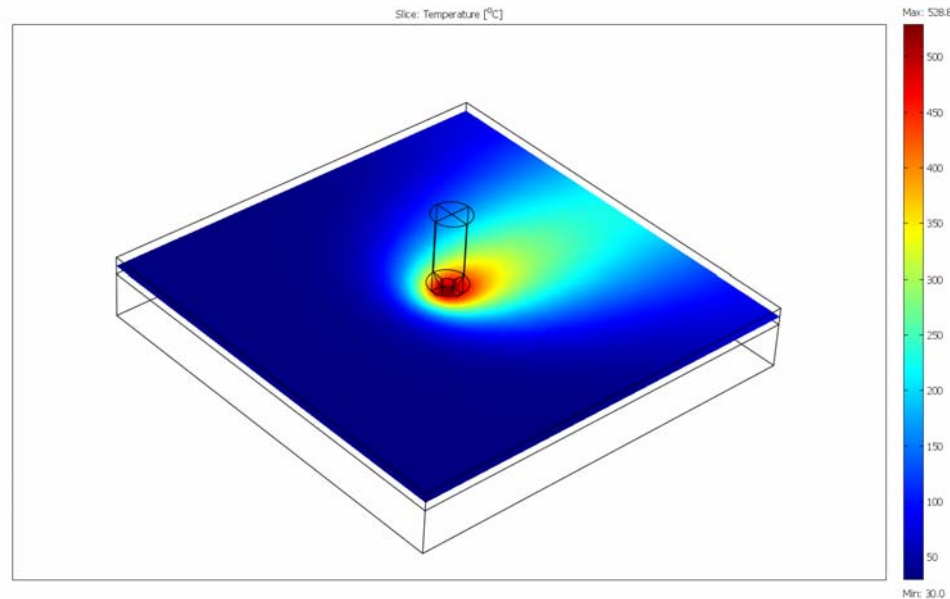
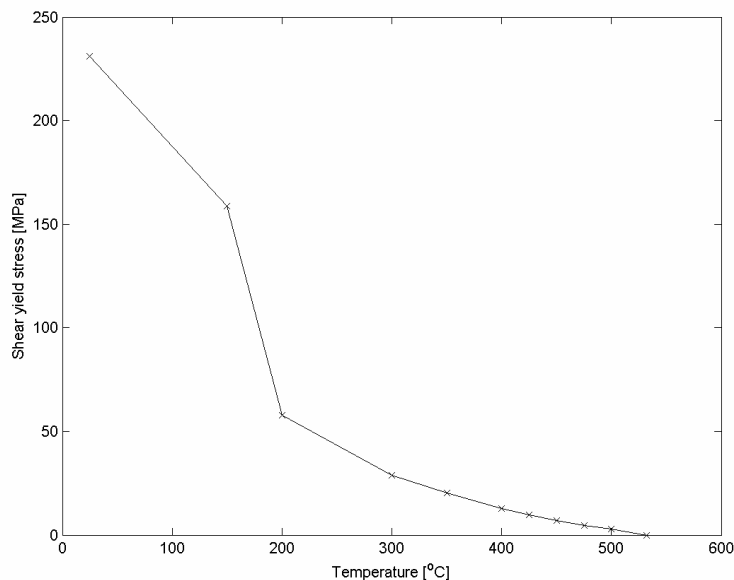


Schmidt and Hattel (2005)

Thermo-pseudo-mechanical model

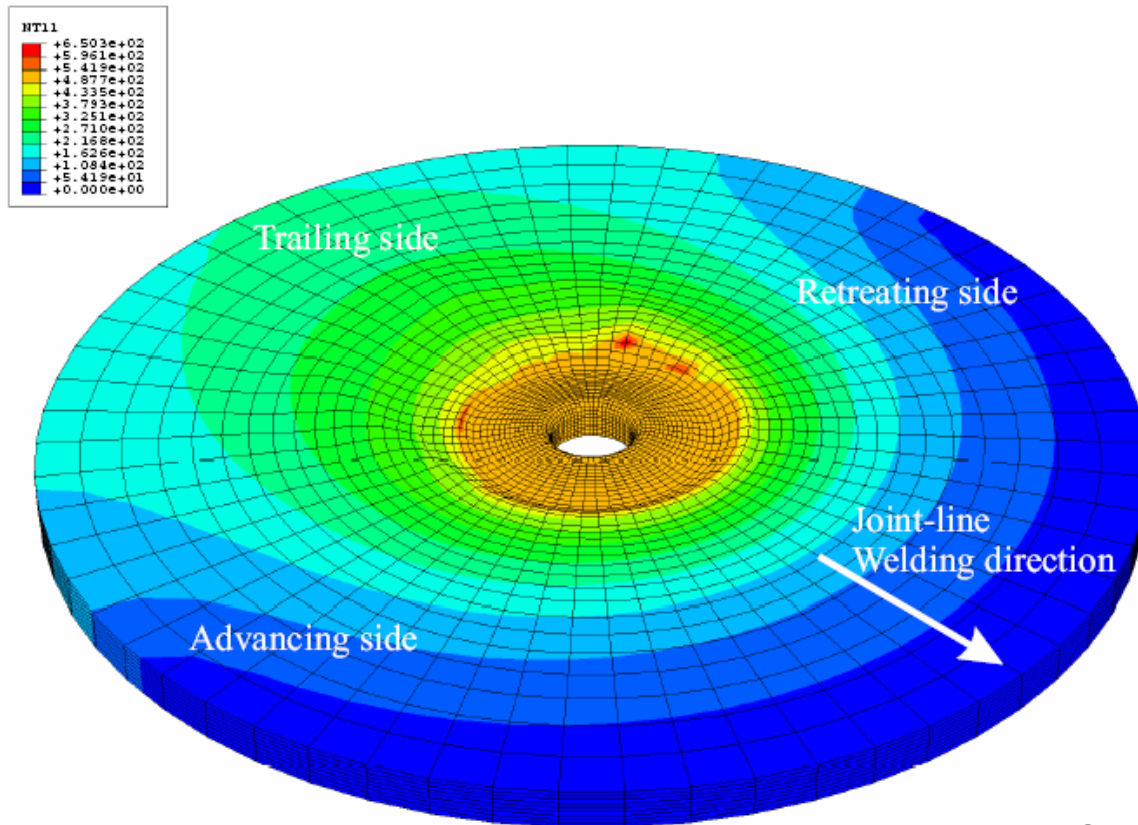
Using a temperature dependent shear stress as the driver for the local generation.

$$\frac{dQ}{dA} = \omega r \tau(T)$$



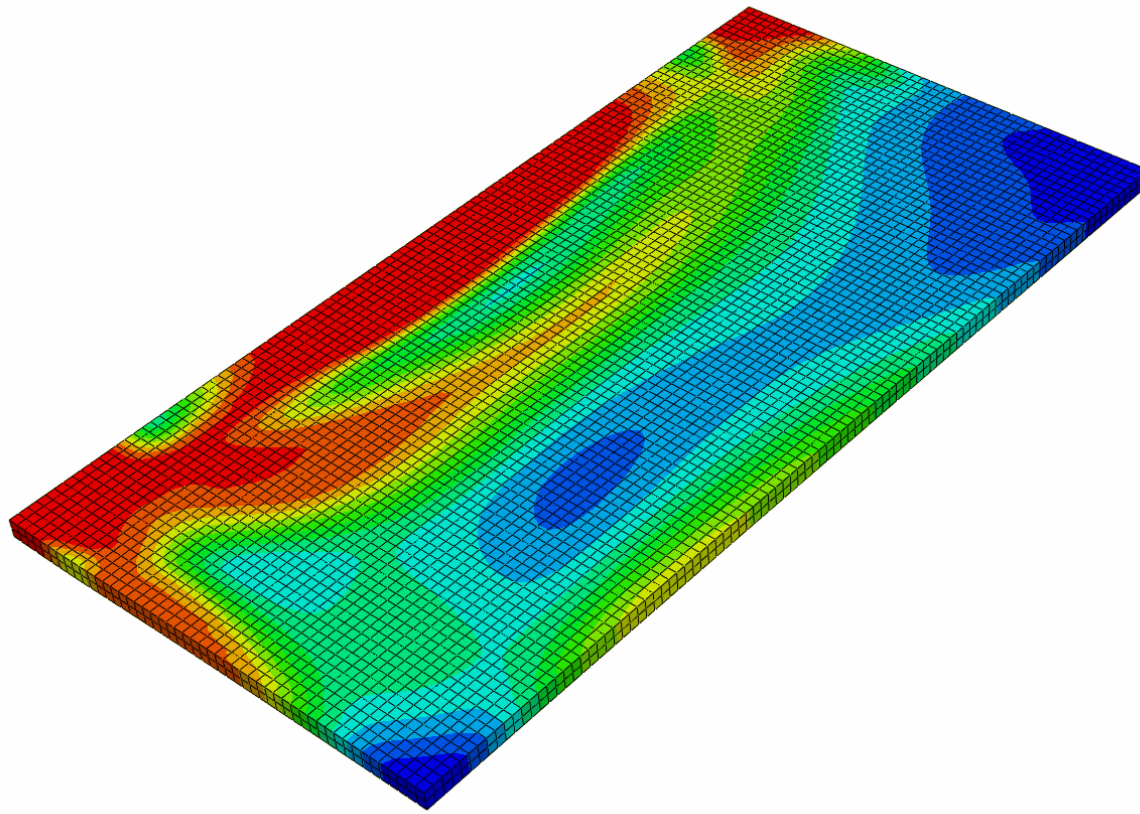
Schmidt and Hattel (2007)

Thermo-mechanical Material flow and heat generation

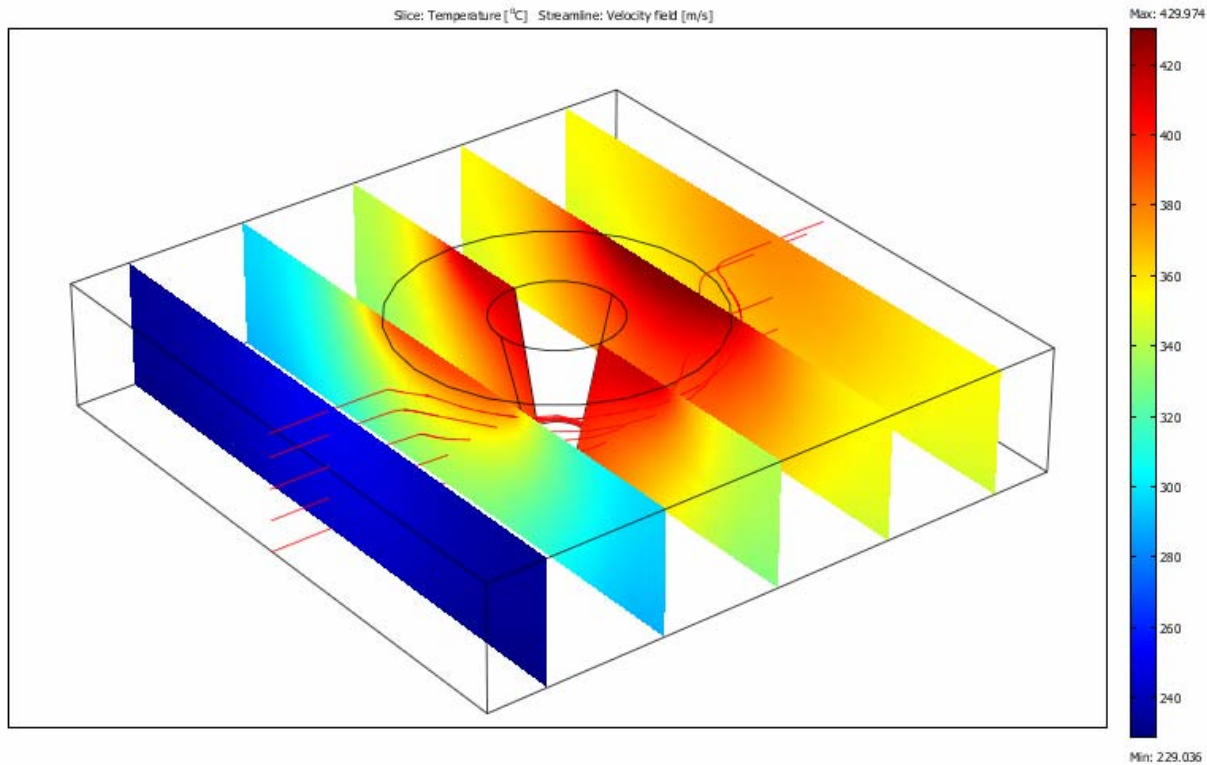


Schmidt and Hattel (2005)

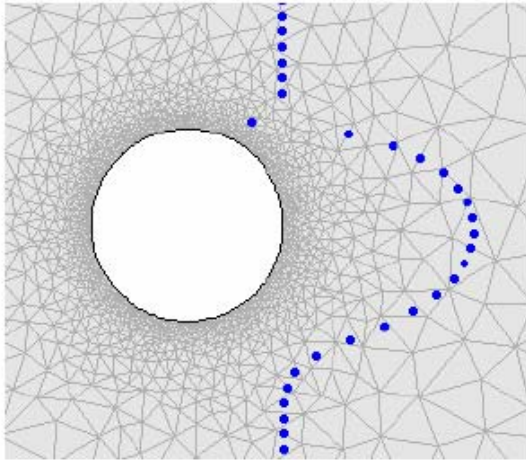
Thermo-mechanical Residual stress



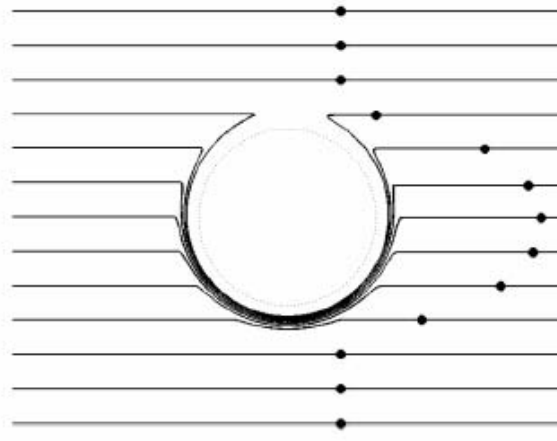
CFD 3D



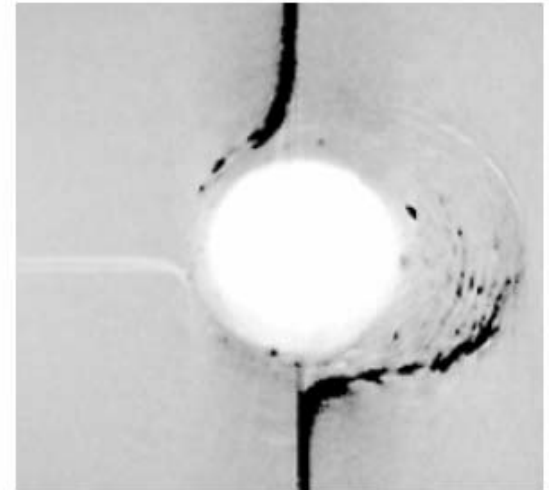
Comparison between CFD, analytical and experimental results



CFD



Analytical
(linear velocity profile)

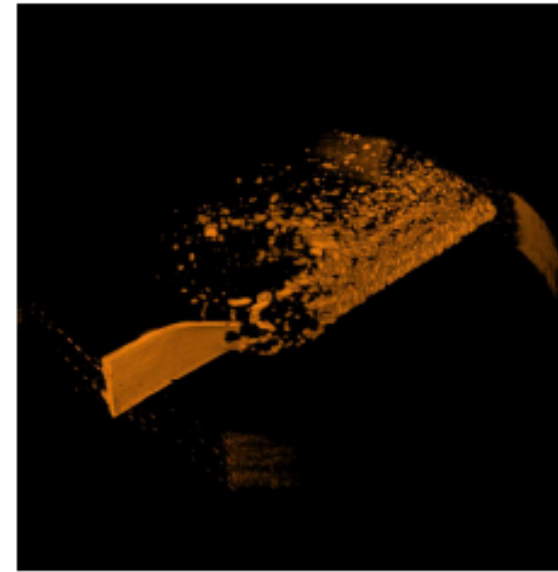
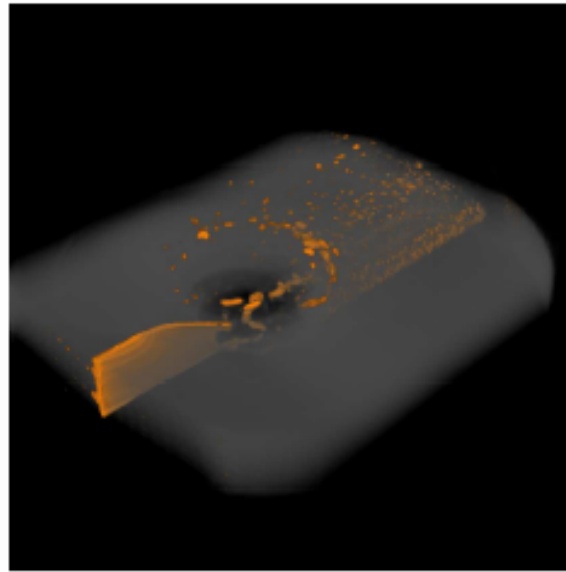
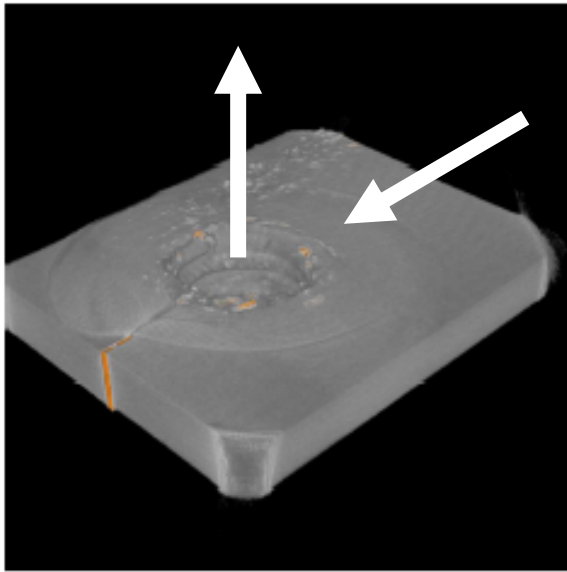


Experiment
(CT slide)

Schmidt and Hattel (2006)

Computational Tomography Model

MM inserted along the joint-line



Schmidt, Dickerson and Hattel (2006)

Future for FSW modelling

- Go hand in hand with welding experiments
- Use models to find welding parameters
- Go from convolute to real size welding geometries
- Development of new tool design
- New material combinations