

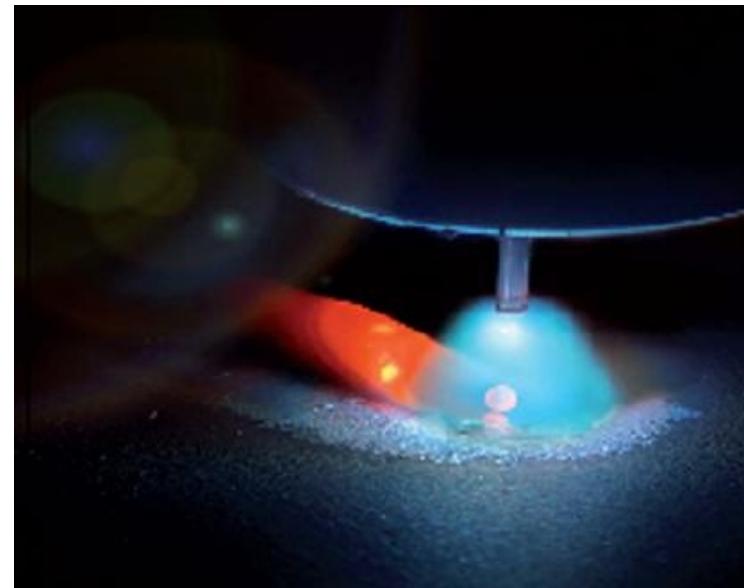
Magnetohydrodynamics and Gas Metal Arc Welding in ANSYS Fluent

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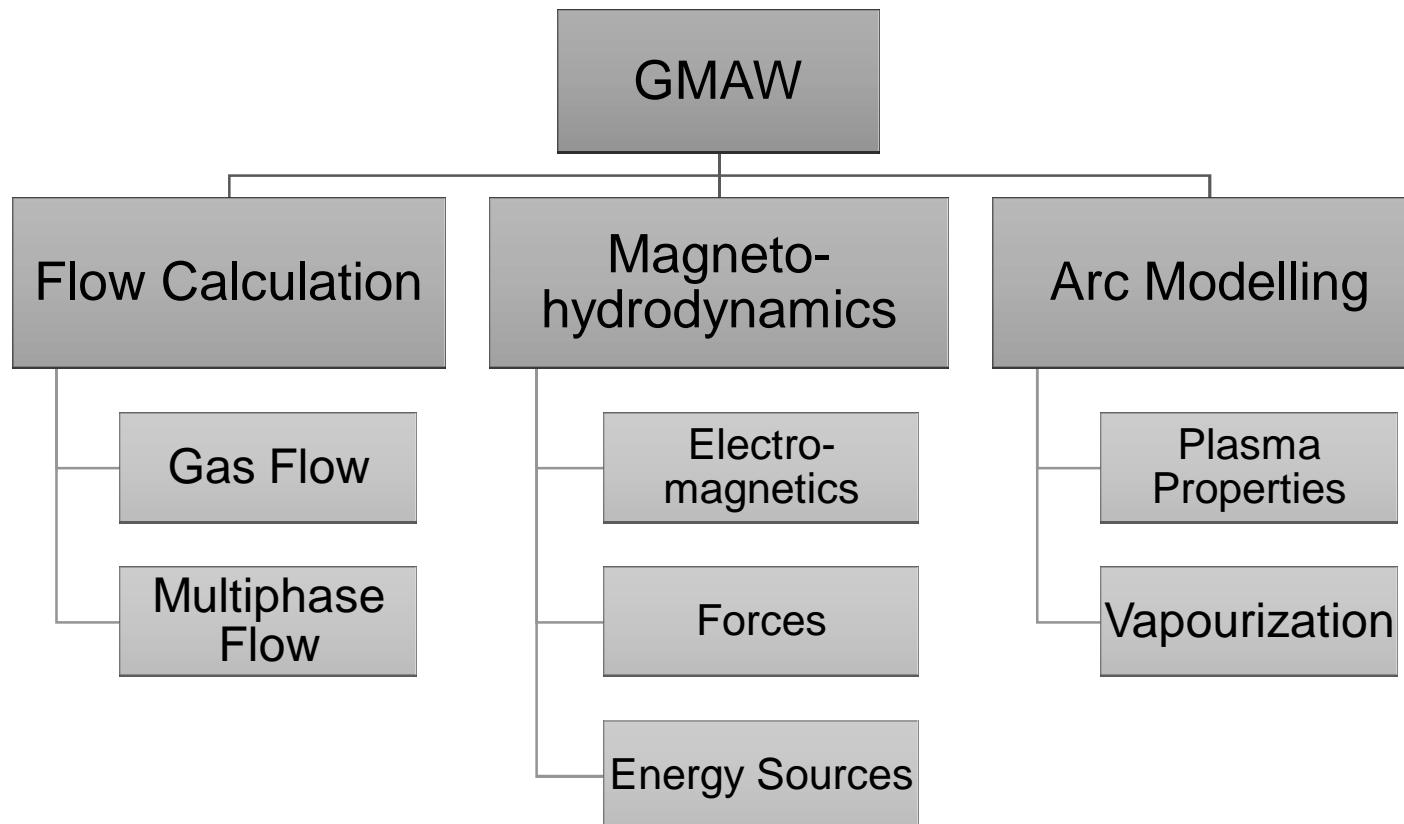
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Motivation

- Numerical description of electromagnetics in ANSYS Fluent
- Simulation of welding processes
 - Extending process comprehension
- Multiphase simulation and electromagnetics
 - Welding processes considering material transition



Models needed for Gas Metal Arc Welding

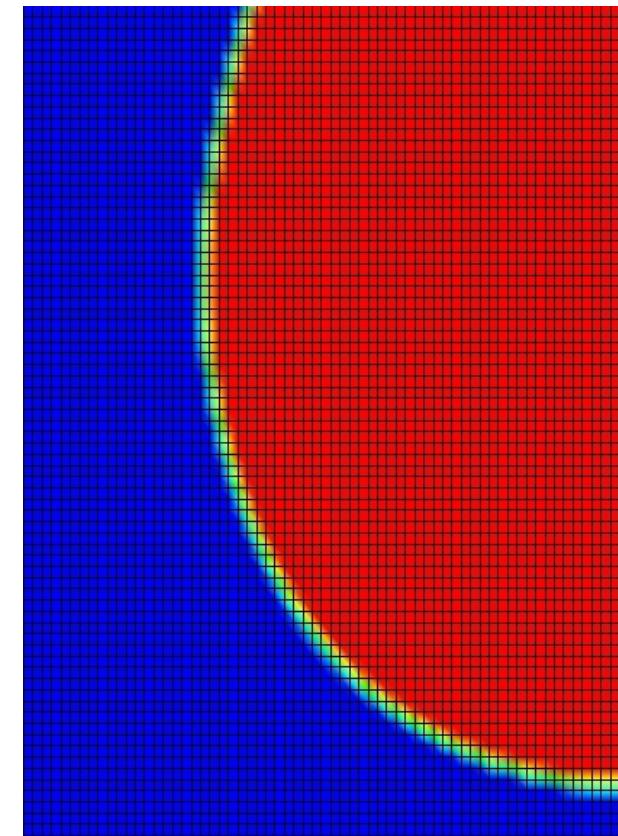


Agenda

- Simulation of multiphase flow
 - Volume of Fluid
 - PLIC and Compressive
- Magnetohydrodynamics in ANSYS Fluent
 - MHD-Module provided by ANSYS Fluent
 - Improved model
- Simulation of Welding processes
 - Comparison to ANSYS CFX
 - Multiphase welding process

Multiphase Simulation

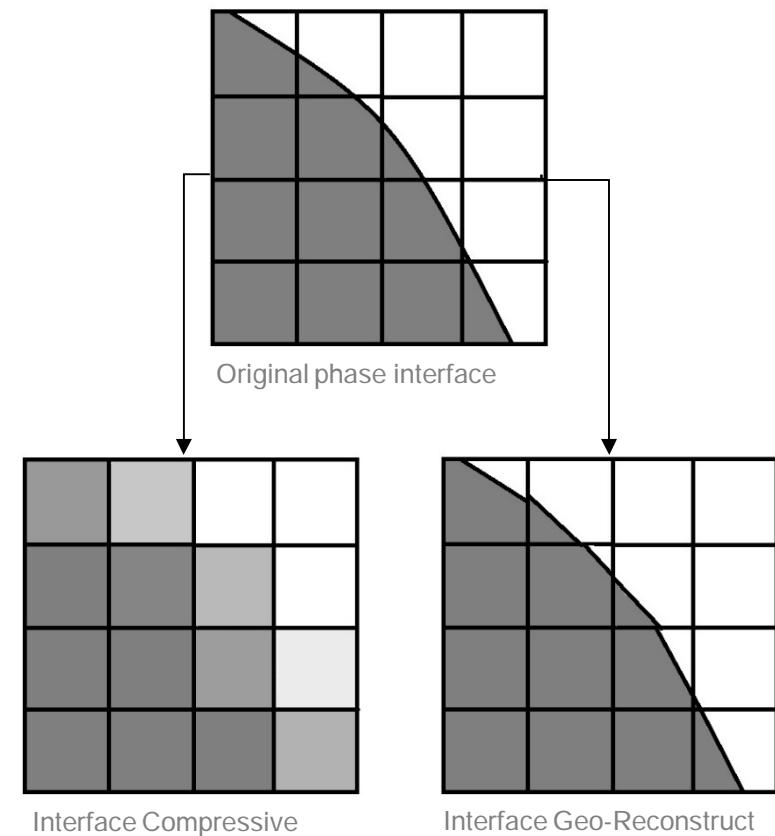
- Volume of Fluid method
- Each phase described by volume fraction F_i
transport equation for F_i :
$$\frac{\partial F_i \rho_i}{\partial t} + \nabla \cdot (F_i \rho_i \vec{u}) = -M_{Vap}$$
- Implicit or explicit calculation possible
- Changing topology on steady mesh
 - No remeshing
 - Nearly every topology possible
- Surface tension



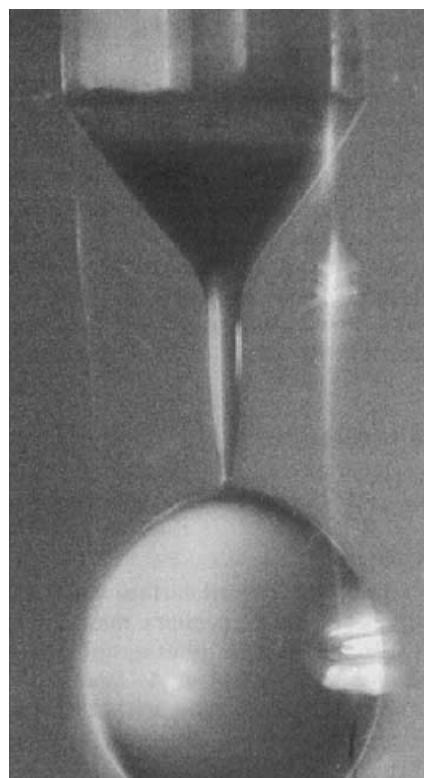
Vof function in flow field

Implicit and explicit multiphase calculation

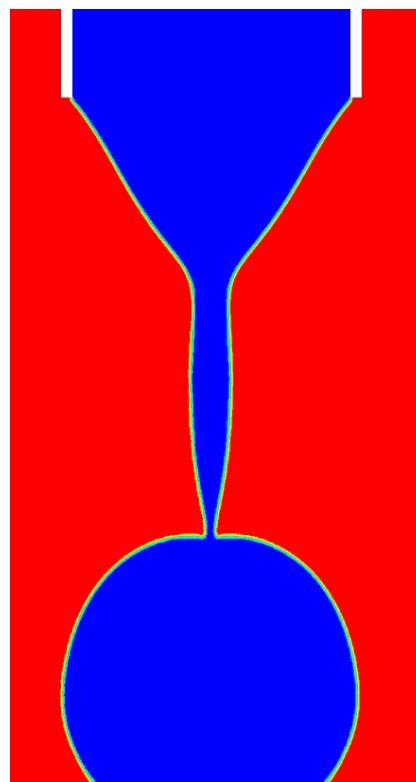
- Explizite
 - Fast and precise
 - Geometric phase interface reconstruction possible (Geo-Reconstruct / PLIC)
 - Small timestep
- Implizite
 - Large timestep
 - Compressive phase interface calculation
- Compared to experiments of D. H. Peregrine



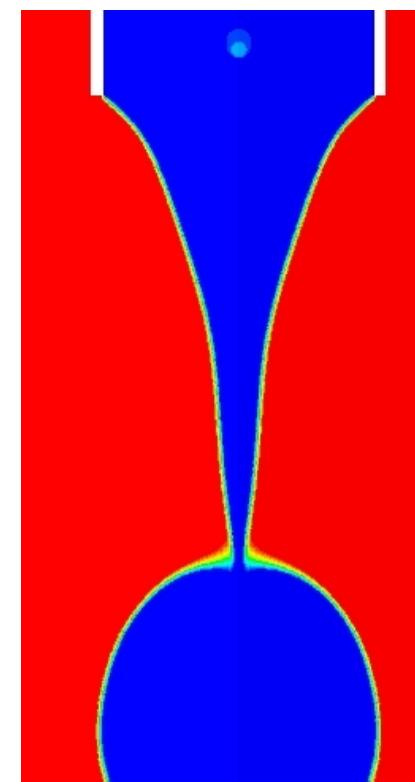
1.2 ms



experiment

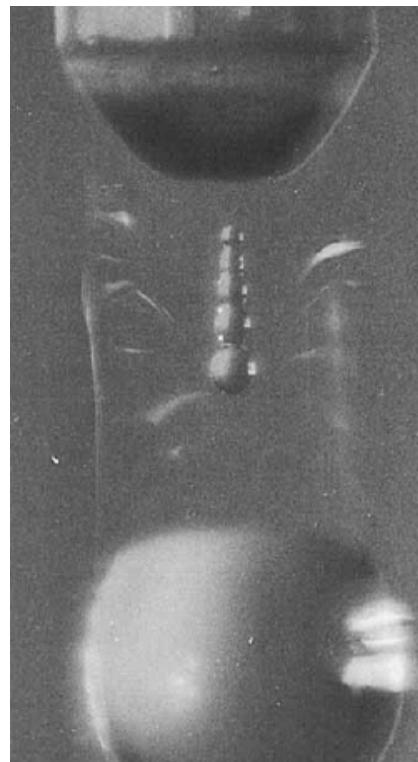


explicite

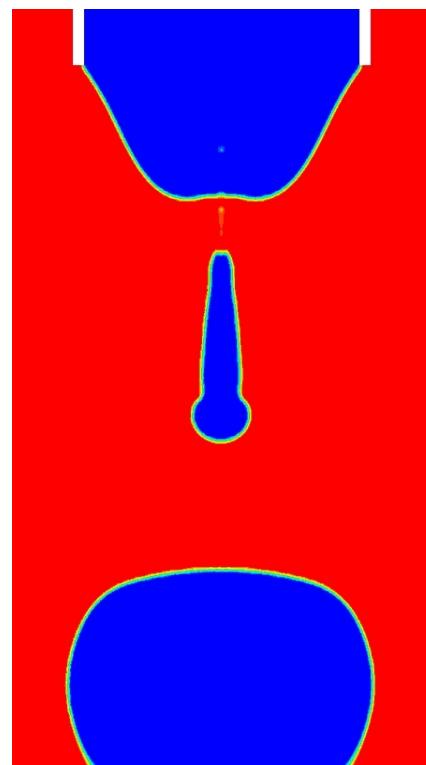


implicite

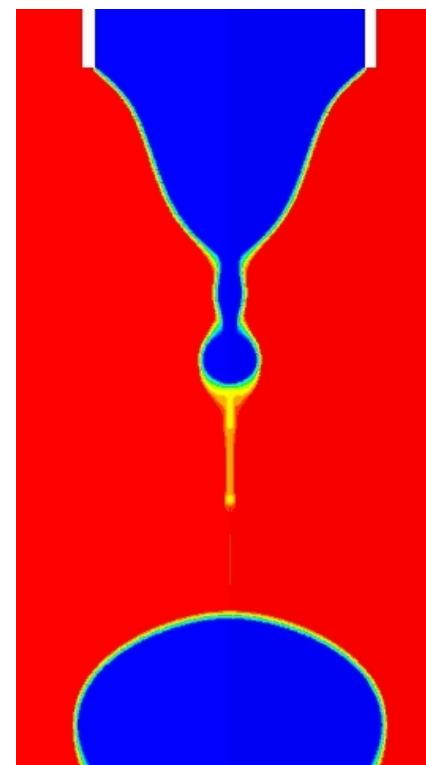
3.5 ms



experiment



explicite

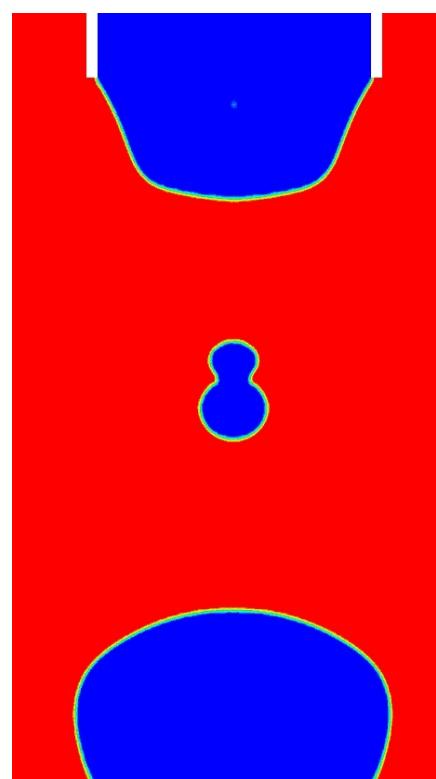


implicite

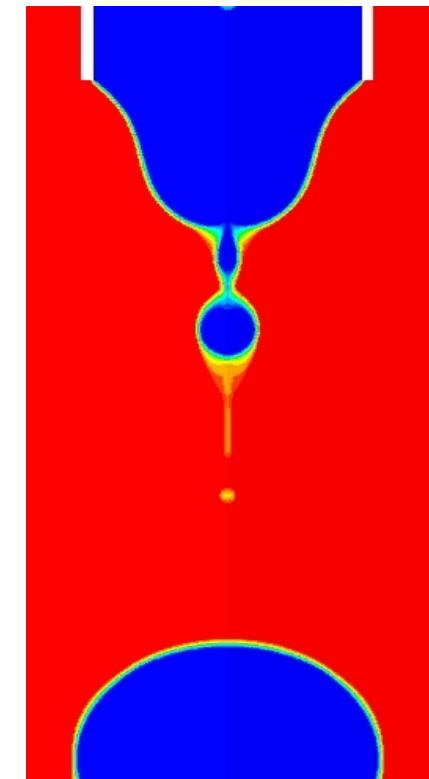
4.2 ms



experiment



explicite



implicite

Magnetohydrodynamics - Equations

- Maxwell equations

$$\nabla \cdot \vec{B} = 0$$

$$\nabla \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$$

$$\nabla \cdot \vec{D} = \rho_e$$

$$\nabla \times \vec{H} = \vec{J} + \frac{\partial \vec{D}}{\partial t}$$

- Ohmic law

$$\vec{J} = \sigma(-\nabla \varphi + \vec{U} \times \vec{B})$$

- Lorentz force

$$\vec{f}_L = \vec{J} \times \vec{B}$$

Magnetohydrodynamics in Fluent

Magnetohydrodynamics in Fluent

Magnetic Induction
Method

Electric Potential
Method

Equations for
magnetic field

Boundaries:
Magnetic boundary
condition

Equation for
electric field

Boundaries:
Electric boundary
condition

Electric Potential Method

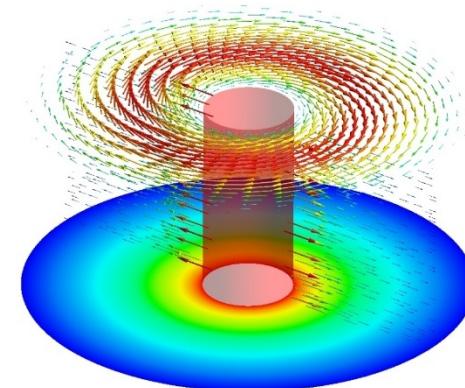
- Equations

$$\nabla \sigma \nabla \varphi = \nabla \cdot (\vec{U} \times \vec{B}_0)$$

$$\vec{j} = \sigma(-\nabla \varphi + \vec{U} \times \vec{B}_0)$$

$$\vec{f}_L = \vec{j} \times \vec{B}_0$$

$$q_e = \frac{1}{\sigma} |\vec{j}|^2$$



MHD Motor with external magnetic field

- No magnetic field due to electric current density
- Applicable for problems with dominating extern magnetic field or without one
- Example: Hartmann flow, heating due to electric current

Magnetic Induction Method

- Equations

$$\frac{\partial \vec{B}}{\partial t} + (\vec{U} \cdot \nabla) \vec{B} = \frac{1}{\mu\sigma} \nabla^2 \vec{B} + (\vec{B} \cdot \nabla) \vec{U}$$

$$\vec{j} = \frac{1}{\mu} \nabla \times \vec{B}$$

$$\vec{f}_L = \vec{j} \times \vec{B}$$

$$q_e = \frac{1}{\sigma} |\vec{j}|^2$$

- No electric field due to electric current density
- No electric boundary condition possible
- Applicable for problems with dominating extern magnetic field and without electric boundary conditions
- Example: Magnetohydrodynamic stirring

New Approach

- Equations

$$\nabla \sigma \nabla \varphi = \nabla \cdot (\vec{U} \times \vec{B}_0)$$

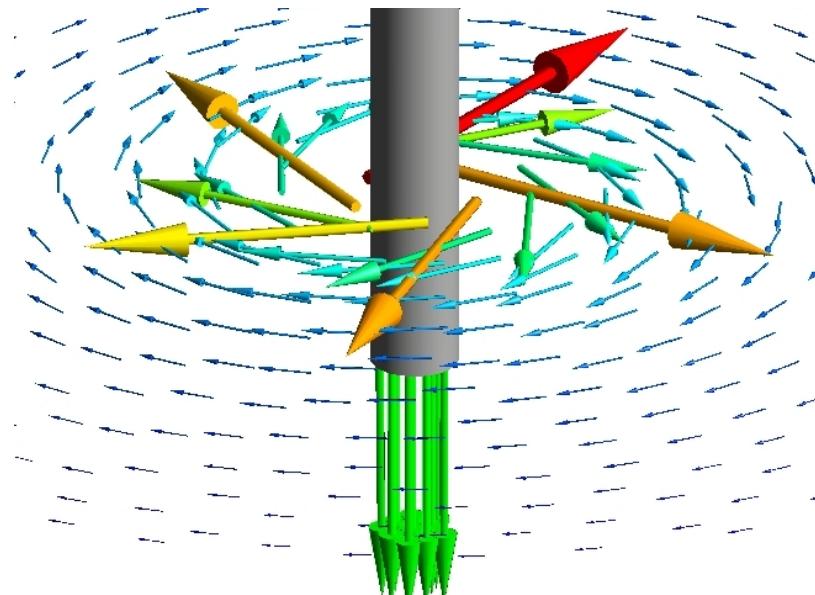
$$\nabla \cdot \nabla \vec{A} = -\mu \vec{j}$$

$$\vec{B} = \nabla \times \vec{A} + \vec{B}_0$$

$$\vec{j} = \sigma (-\nabla \varphi + \vec{U} \times \vec{B}_0)$$

$$\vec{f}_L = \vec{j} \times \vec{B}$$

$$q_e = \frac{1}{\sigma} |\vec{j}|^2$$

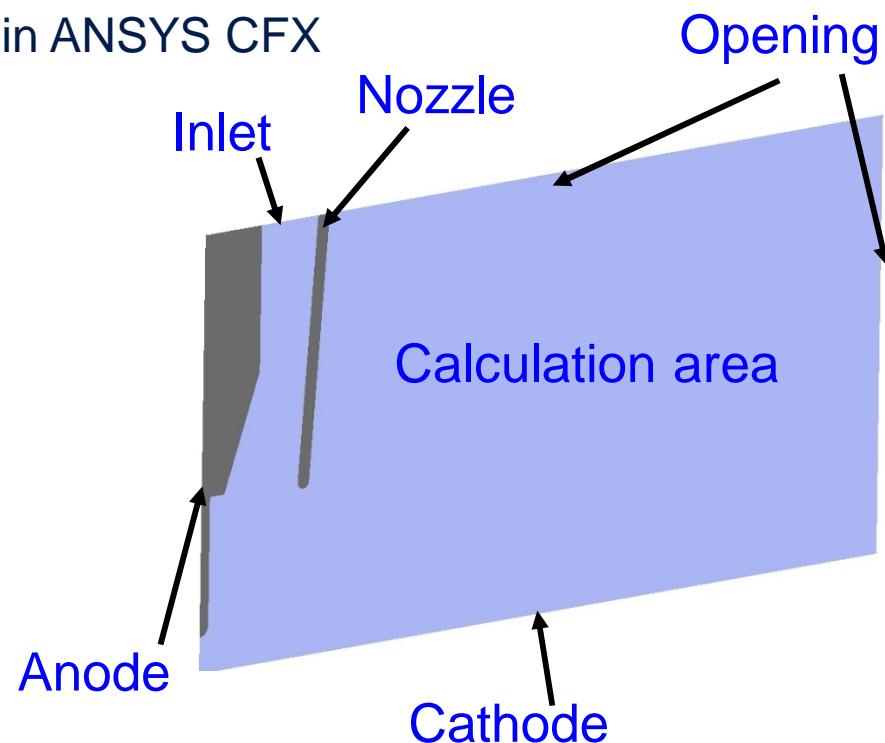


Magnetic field due to current in conductor, „Right Hand Rule“

- Equations and boundary conditions for magnetic field and electric potential
- Calculates magnetic field due to electric current density
- Using the methods for UDS and UDM in ANSYS Fluent

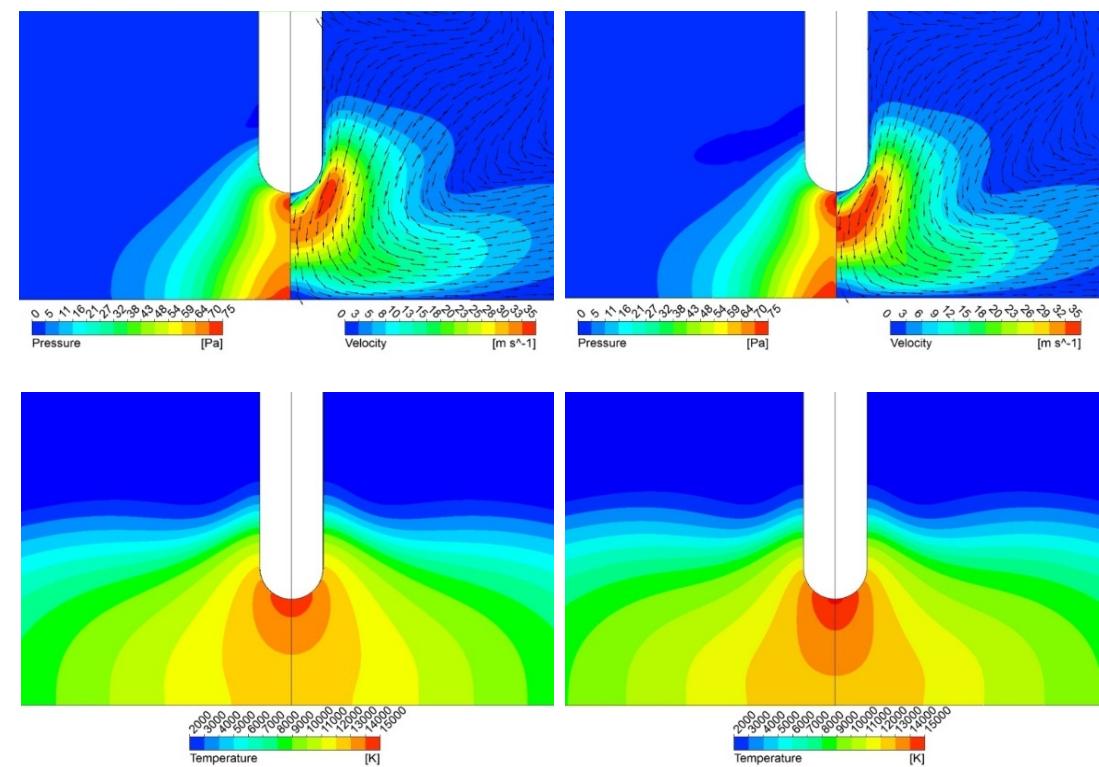
Simulation of welding processes

- Simplified GMAW process with solid geometry
- Comparison to the MHD module in ANSYS CFX
- Rotational symmetry
 - 2D geometry in Fluent
 - 6° geometry in CFX
- Boundary conditions
 - Electric potential: 3 V
 - Gas flow rate: 12 l

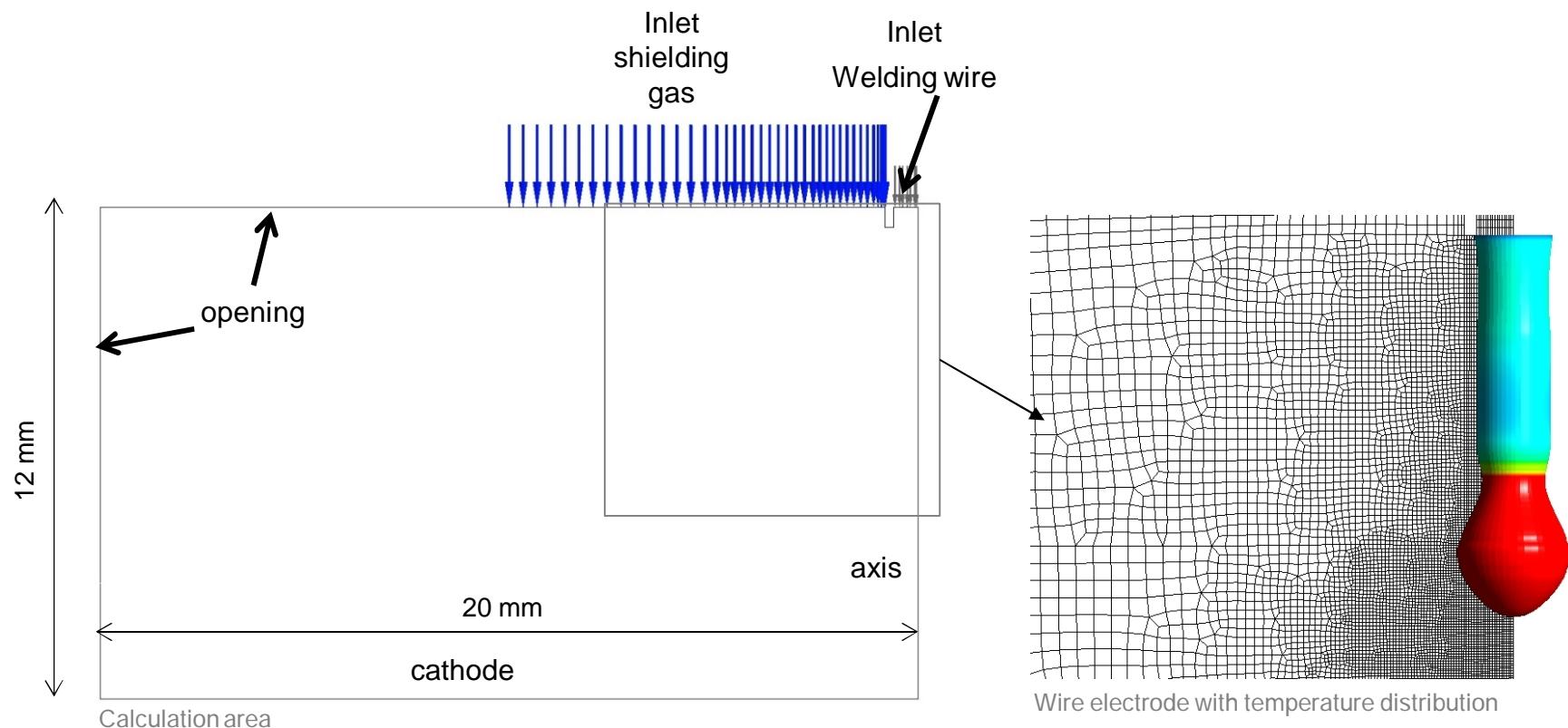


Simulation of welding processes

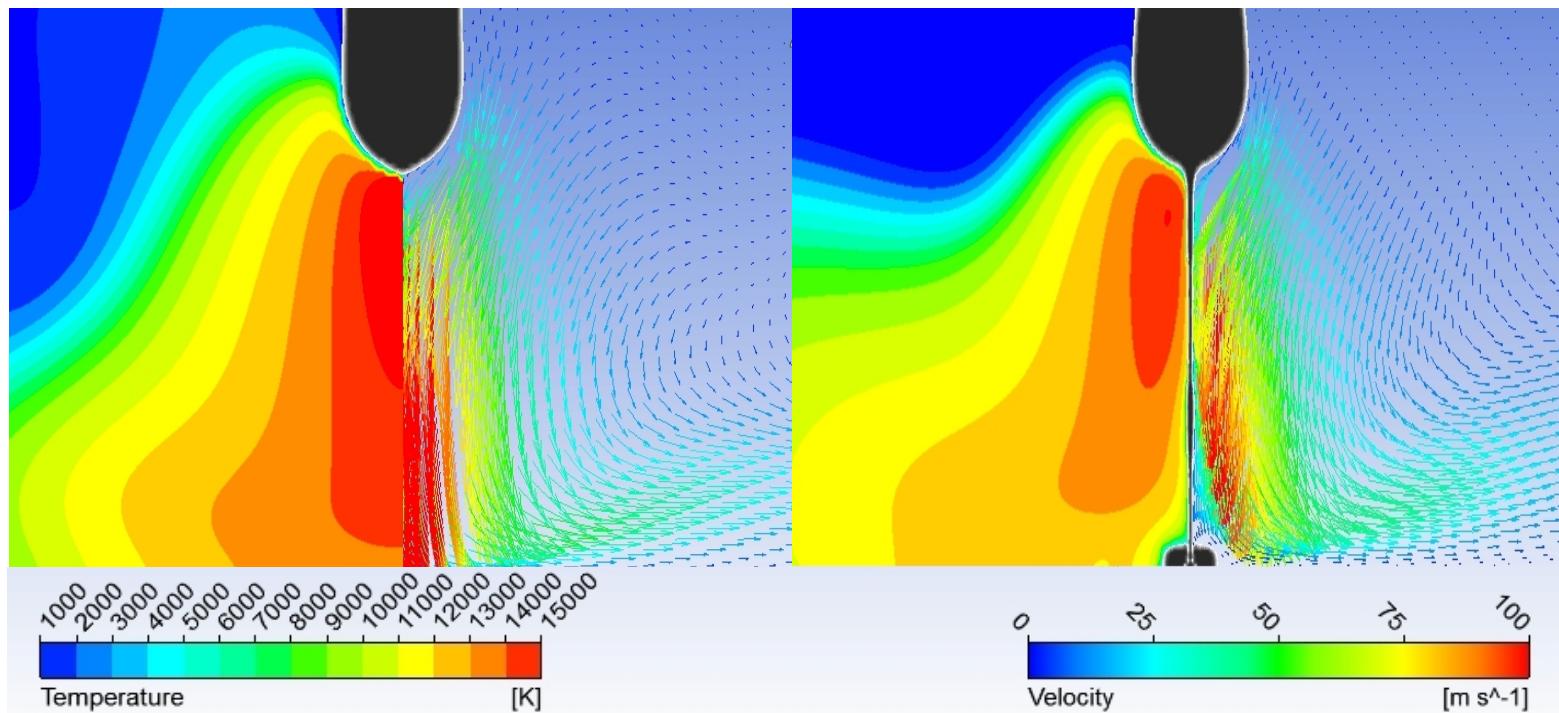
	CFX	Fluent
Current [A]	94.57	93.05
Force Workpiece[N]	0.0017747	0.001822
Ohmic Loss [W]	283.1	279.8
Power[W] = U^*I	283.71	279.15
Resistance [Ohm]	0.0317	0.326
radiation [W]	153.8	155.2



Geometry multiphase GMAW

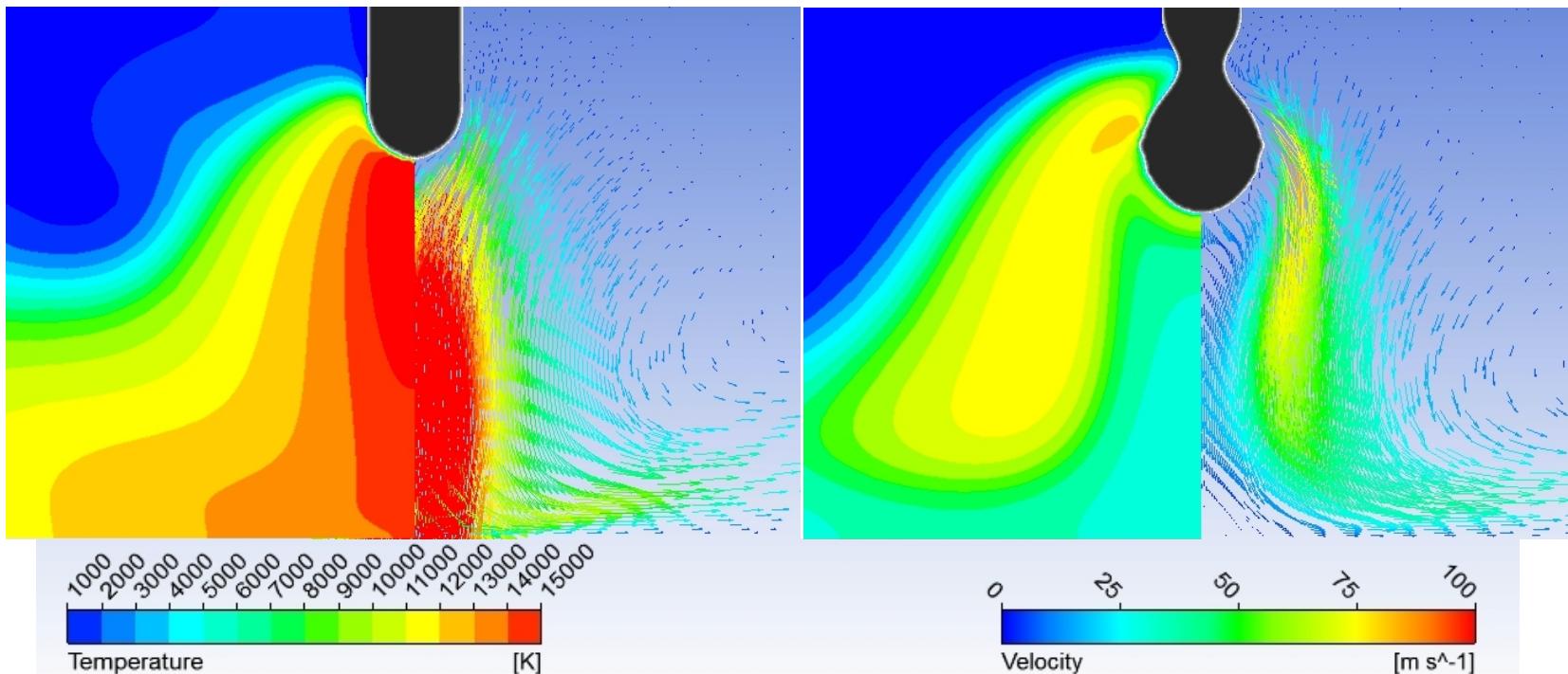


GMAW with multiphase



Simulation of a multiphase GMAW model, arc after ignition (left), arc after melting (right)

Influence of metal vapour



Simulation of a multiphase GMAW model considering metal vapour,
arc after ignition (left), arc after melting (right)

Conclusion and lookout

- Implementation of a new module for MHD
- Successfully calculated welding arc
- Welding arc combined with multiphase simulation
- Considering vapourization for realistic temperature distribution and droplet formation
- Future:
 - Coupled model with workpiece
 - Predict the impact of the plasma gas on the seam quality
 - Predict the impact of the power source on the seam quality

Thank you for your attention