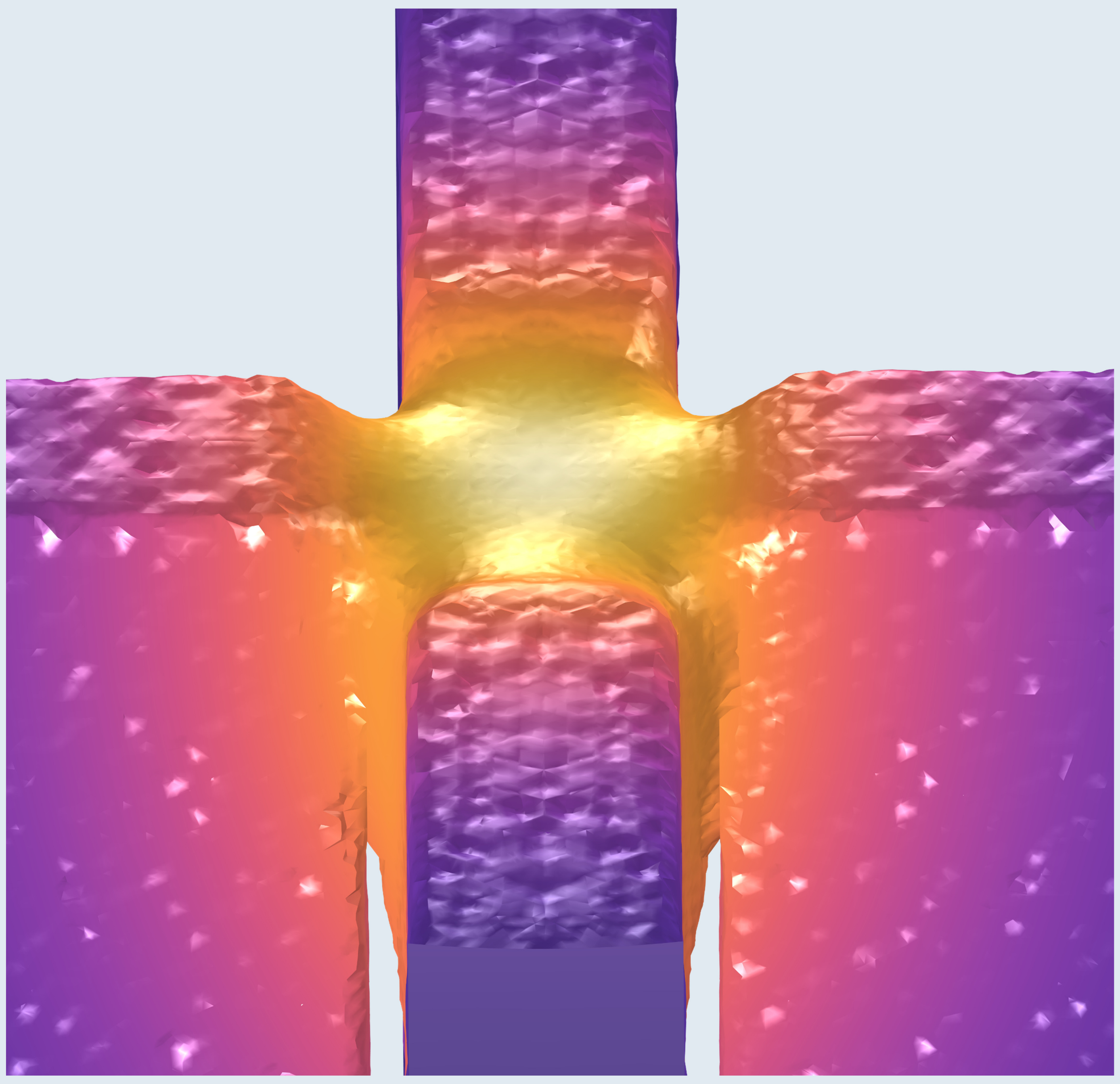


Numerical Simulation of Electron Beam Welding

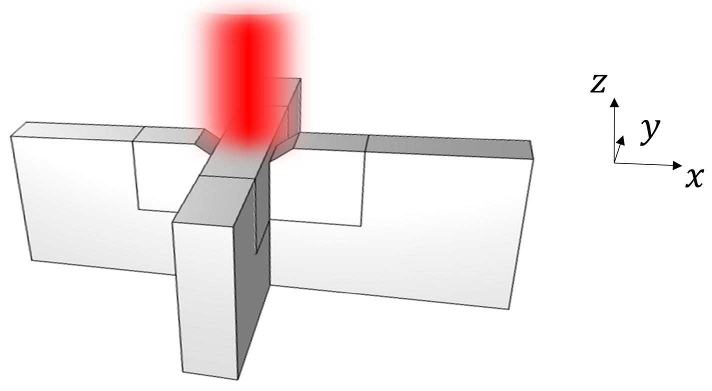
Understand physical phenomena in electron beam welding process to predict the size of the melted zone and optimize the operating conditions.

P. O. Barrioz[1], V. Bruyere[2], P. Namy[2], A. Brosse[1]
1. FRAMATOME, Lyon, France
2. SIMTEC, Grenoble, France

Introduction & Goals

Electron beam welding process is a high-energy welding technique that uses a focused beam of electrons to join metal components. It is widely used in various industries, due to its ability to produce high-quality welds with minimal distortion and heat input. However, this process involves numerous parameters that can affect the final weld quality, making it challenging to optimize and control.

A thermohydraulic model is developed to describe the dimensions of the melted zone and the resulting shape of the free surface on a geometry with chamfers. A level set approach is used to study the influence of surface tension and Marangoni effects on the shape of the weld pool. After adapting the solvers, the influence of the mesh and numerical parameters is studied, and results are discussed.

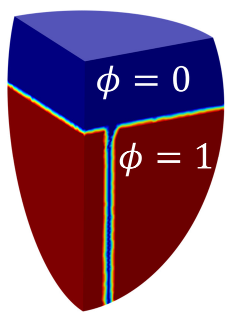


$$\nabla \cdot \boldsymbol{u} = 0$$

$$\rho \frac{\partial \boldsymbol{u}}{\partial t} + \rho(\boldsymbol{u} \cdot \nabla)\boldsymbol{u} = \nabla \cdot \left[-p\bar{\bar{I}} + \eta(\nabla \boldsymbol{u} + \nabla \boldsymbol{u}^T)\right] + \boldsymbol{F}$$

$$\rho C_p \frac{\partial T}{\partial t} + \rho C_p \boldsymbol{u} \cdot \nabla T = \nabla \cdot (k \nabla T) + Q$$

$$\frac{\partial \phi}{\partial t} + \boldsymbol{u} \cdot \nabla \phi = \gamma \nabla \cdot \left(\varepsilon \nabla \phi - \phi(1-\phi)\frac{\nabla \phi}{|\nabla \phi|}\right)$$



Methodology

Navier-Stokes and heat equations are solved together to describe the liquid metal flow at high temperature. To predict the resulting free surface shape, and due to change of topology, a two-phase flow approach is required, as proposed in [Ref. 1]. Both "Level Set" and "Phase Field" methods have been studied in this work to carefully consider surface tension effect. Numerical investigations have been performed to obtain the correct numerical parameters (ε and γ), in the Level Set equation, that guarantee mass conservation. Giving convincing results this approach has been chosen. The influence of the mesh has also been investigated to reduce the computational time and ensure the precision of the results of this 3D modelling.

Results

The temperature evolution is shown in Figure 1 in solid and liquid phases, delimited by magenta melting isotherm, at four different instants τ during the heating phase. After formation of the melted zone, the free surface is moving and forms a domed surface at $t = 2\tau$ due to tension surface effect. By increasing the absorbed energy, the melted zone volume increases, and the liquid metal fills the gap between both pieces. The joining is performed and the final shape of the melted zone, as well as the resulting free surface shape, can be observed at $t = 4\tau$. The results have been compared qualitatively with experimental data, providing a first validation of this numerical approach. More quantitative experimental data are in progress to confront the numerical results in a forthcoming study.

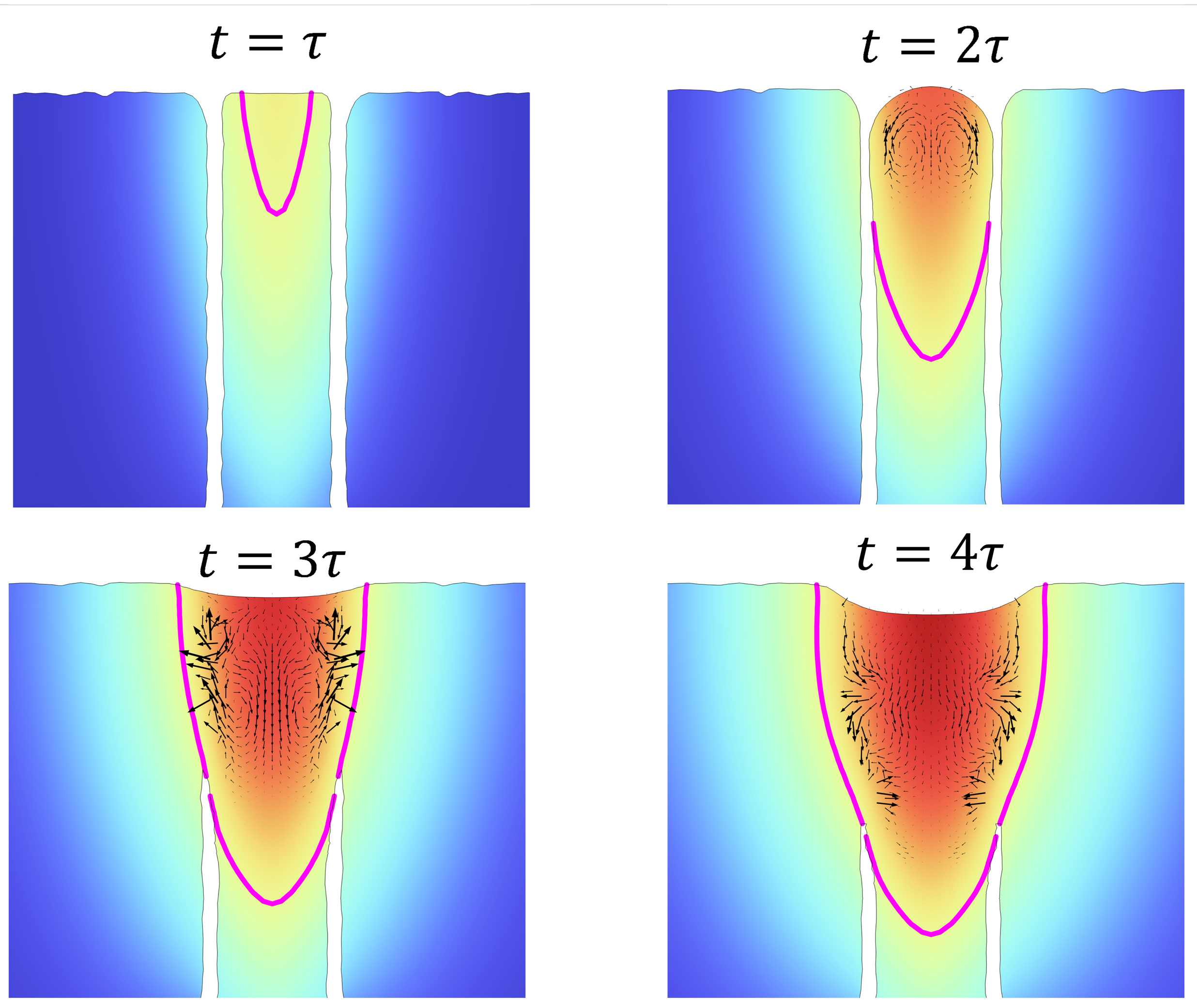


FIGURE 1. Temperature (color) and velocity field (with arrows) in xz cut

REFERENCES

1. C. Touvrey, "A Phase Field Approach to Model Laser Power Control in Spot Laser Welding", *COMSOL Conference in Cambridge*, 2014.

framatome

SIMTEC