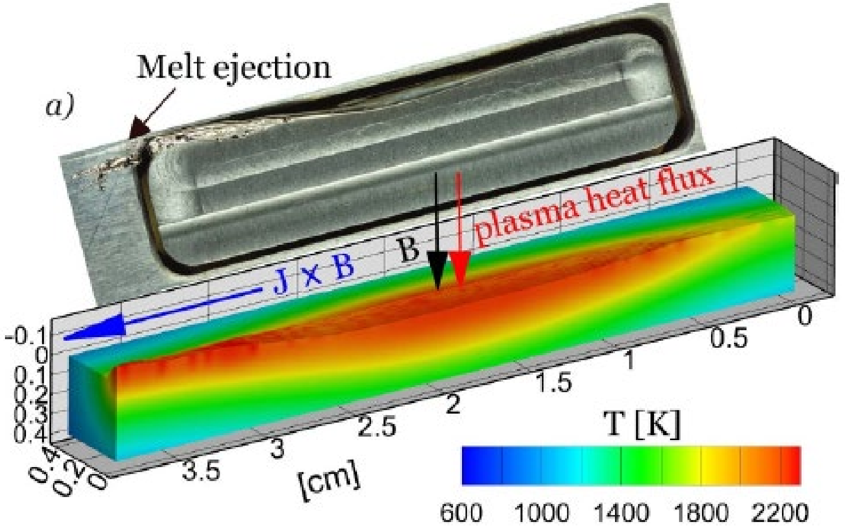
MEMOS-U describes macroscopic metallic melt motion in large-deformation long-displacement regimes, where melts spill onto progressively colder solid surfaces

Treatment of free-surface MHD flows with phase transitions

S. Ratynskaia, E. Thorén, P. Tolias *et al.*, *NF* **60**, 104001 (2020).
E. Thorén, S. Ratynskaia, P. Tolias *et al.*, *PPCF* **63**, 035021 (2021).
E. Thorén 2020 *PhD Thesis* KTH Royal Institute of Technology



MEMOS-U as per TSVV project application time

"Employs the finite difference method solving coupled Navier-Stokes and heat convection-diffusion equations. The code is already parallelized and runs on IO clusters, but would benefit from further parallelization and optimization"

Retained original MEMOS-3D architecture, lack of documentation and adaptive meshing

Currently is beeing re-written

in AMReX - open source framework for adaptive mesh refinement)

Zhang et al., (2019) Journal of Open Source Software, 4(37), 1370

- Some versions of heat and fluid solvers exist, not coupled yet
- Testing of current heat solver version (with all surface cooling fluxes and phase change) is being carried out
- No attempts of parallelization have been undertaken yet (AMReX does have build-in possibilities)

MEMOS-U model

$$\frac{\partial h}{\partial t} + \nabla_{\mathrm{t}} \cdot (hU) = \frac{\partial b_1}{\partial t} - \dot{x}_{\mathrm{vap}} \,,$$

$$\rho_{\mathrm{m}} \left[\frac{\partial U}{\partial t} + (U \cdot \nabla_{\mathrm{t}}) U \right] = \langle (J \times B)_{\mathrm{t}} \rangle - \nabla_{\mathrm{t}} P - 3\frac{\mu}{h^2} U + \mu \nabla_{\mathrm{t}}^2 U + \frac{3}{2h} \left(\frac{\partial \gamma}{\partial T} \nabla_{\mathrm{t}} T_{\mathrm{s}} + f_{\mathrm{d}} \right) ,$$

$$\rho_{\mathrm{m}} c_{\mathrm{p}} \left[\frac{\partial T}{\partial t} + U \cdot \nabla_{\mathrm{t}} T \right] = \nabla \cdot (k \nabla T) + \rho_{\mathrm{e}} |J|^2 - T \frac{\partial S}{\partial T} J \cdot \nabla T \,,$$

$$\nabla \cdot (\sigma_{\mathrm{e}} \nabla \psi) = 0 \quad \text{with } J = -\sigma_{\mathrm{e}} \nabla \psi \,,$$

(U) depth-averaged fluid velocity,
(h, P) melt column height, ambient pressure
$(\boldsymbol{J}, \boldsymbol{B})$ current density, magnetic flux density,
$(b_1, \dot{x}_{vap})$ solidification interface, rate of change of interface position due to vaporization,
(T, T_s) bulk and surface temperature
(ρ_m, c_p) mass density, heat capacity
(k, S) thermal conductivity, thermoelectric power,
(μ, γ) dynamic viscosity, surface tension
(σ_e, μ_0) electrical conductivity, vacuum permeability

Liquid-solid phase transition: heat integration method
(the enthalpy budget is kept by an extra set of algorithms)

Boundary conditions:

$(k \nabla T - STJ) \cdot \hat{n} = q_{\mathrm{inc}} - q_{\mathrm{cool}} \,,$ q_{inc} is the incident heat flux and and q_{cool} is the surface cooling fluxes

$\sigma_{\mathrm{e}} \frac{\partial \psi}{\partial n} = J_{\mathrm{surf}} \,,$ J_{surf} is the current density on the surface

External input: $q_{inc}, J_{surf}, \boldsymbol{f}_d, \nabla \mathrm{P}_{plasma}$ + geometry and B field