Undergraduate Project Summary MSE398

IIT Kanpur

Shrinkage and Segregation Modelling

Submitted By

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Submitted To

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Objective

Solidification in binary alloys such as Al-5%Cu is accompanied by phenomena like segregation (composition variation due to solute redistribution) and shrinkage (volume reduction during phase transition). OpenFOAM provides tools for modelling such processes, with segregation already implemented in the solidificationFoam solver. The next step is to integrate shrinkage effects, which involve accounting for mass conservation and flow dynamics induced by density changes during solidification.

1. *Linux Command Line Basics*

Acquired foundational skills in Linux command-line operations, an essential prerequisite for using Open FOAM effectively.

2. Open FOAM Basics

Case Setup and Execution : Configuring and running simulation cases.

Post-Processing : Extracting and analysing simulation results.

Solver and Library Modifications : Learning to modify solvers and libraries to meet specific simulation requirements.

3. Density vs Temperature Relations for Al-6%Cu

Using Mixture theory and data from the references, deduced the density and temperature equation for the implementation in Open FOAM shrinkage simulations. The summary of the result found is attached below.

Detailed report can be accessed from the link → Detailed Report

Density and Temperature Relations

$$f_s = \frac{T_l - T}{T_l - T_s}$$ [*from the reference 2*]

$$\frac{g_\alpha \rho_\alpha}{\rho} = \frac{T_l - T}{T_l - T_s}$$

$$\left(\frac{\rho_l - \rho}{\rho_l - \rho_\alpha}\right)\frac{\rho_\alpha}{\rho} = \frac{T_l - T}{T_l - T_s}$$

T_l and T_s are the liquidus and solidus temperatures of Al-6%Cu.

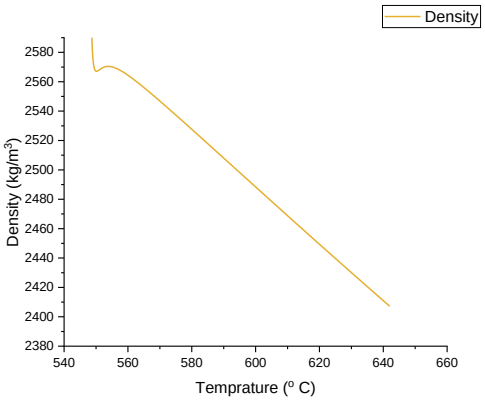
$$T_l = 642^o\ C$$

$$T_s = 548^o\ C$$

$$\rho_l = 2583.8 - 0.316 * T + 16.567 * C_l + 0.2689 * C_l^2$$

$$\rho_l = 2800.0 - 0.369 * T + 1.279 * C_s$$

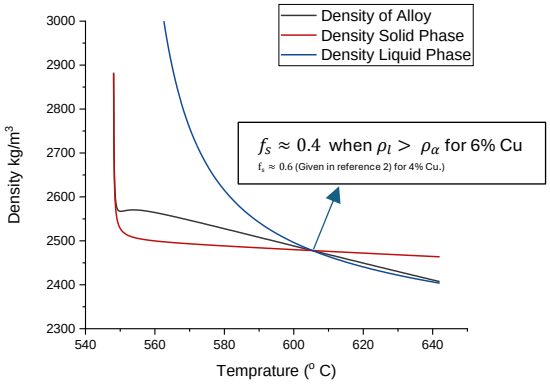
$$k = 0.17$$

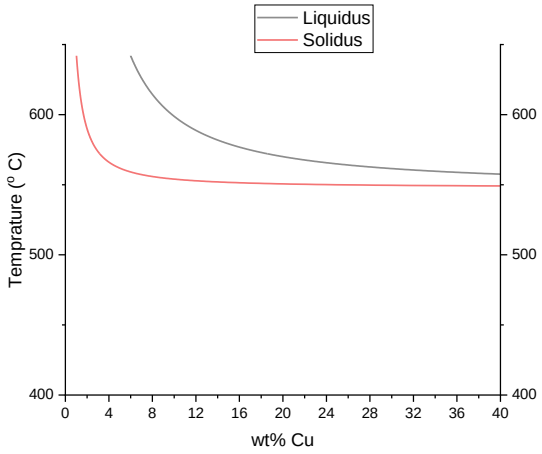


References

1. A continuum model for momentum, heat and species transport in binary solid-liquid phase change systems- I. Model formulation. *W. D. BENNON and F. P. INCROPERA*

2. A Model for Macro segregation and Its Application to Al-Cu Castings. *S. CHANG and D.M. STEFANES.*



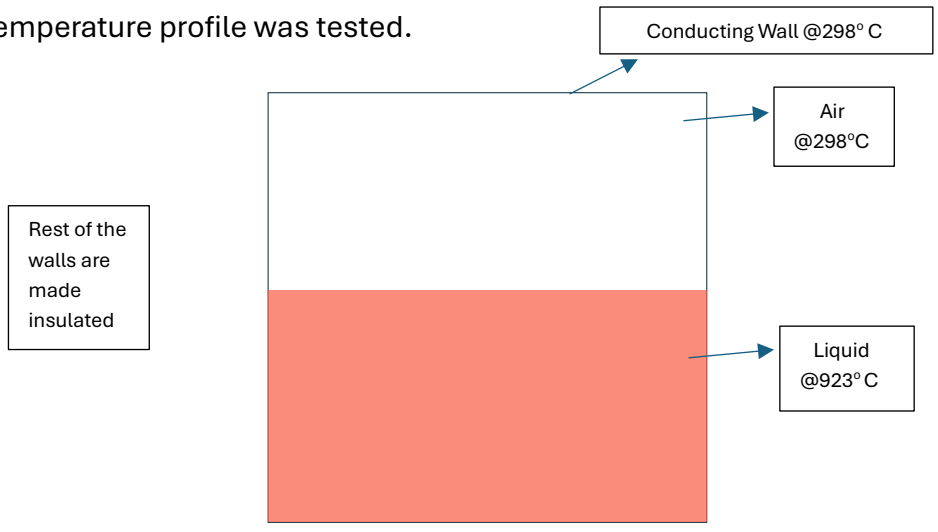


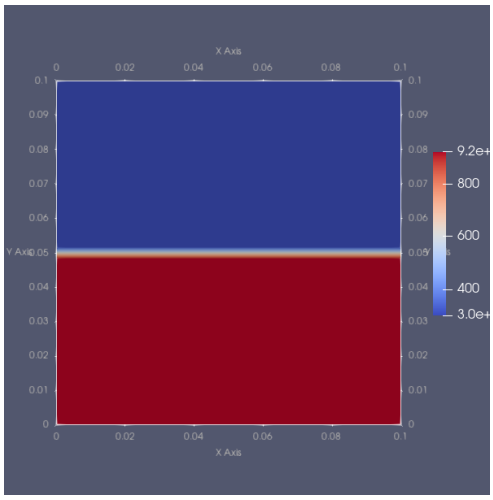
4. **ThermoLoop and Species Equation Compilation in InterFoam**:
   - Addition of the thermal Loop of solidification is added into the species transport and VoF solver.
   - The solver compiled correctly.
   - The case was developed to test the solver.
   - The solver must be significantly improved in upcoming days.

GitHub Link for the solver along with case developed “sFoam”:

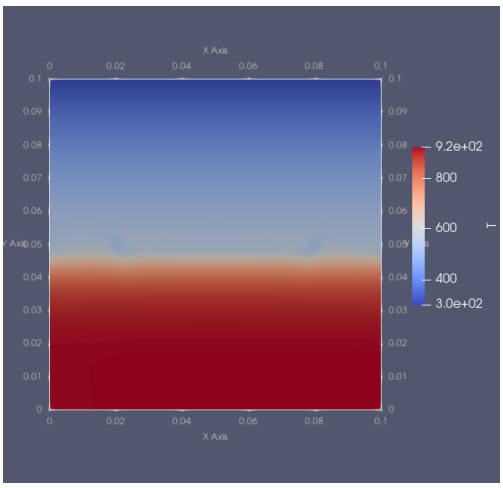
https://github.com/neo-global/mpcFoam_base.git

1. Temperature profile was tested.

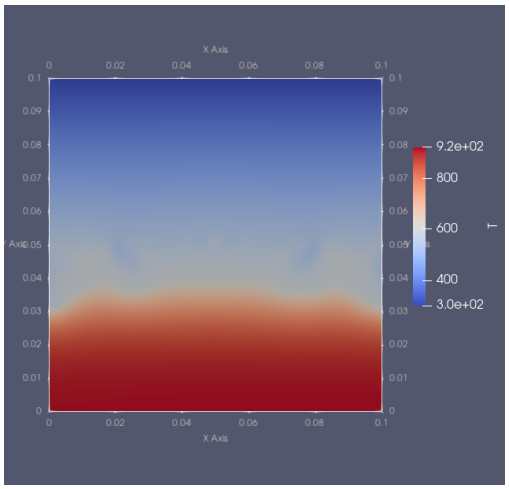




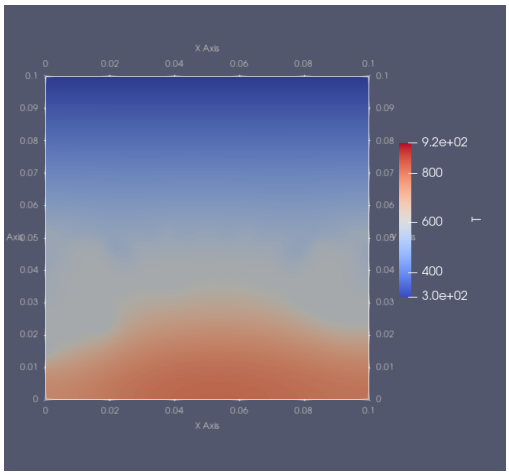
t=0



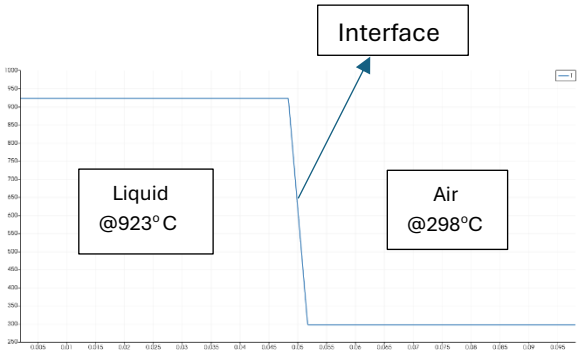
t=0.1



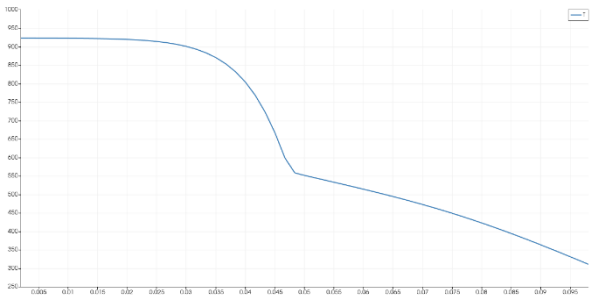
t=0.2



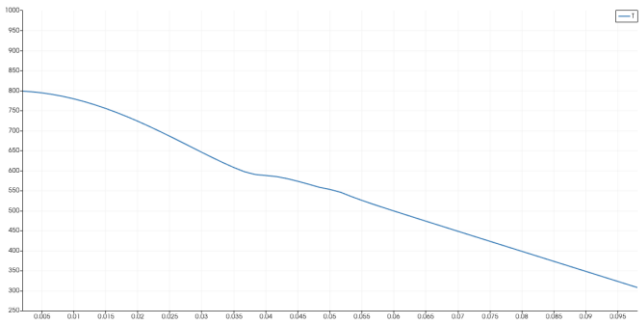
t=0.5



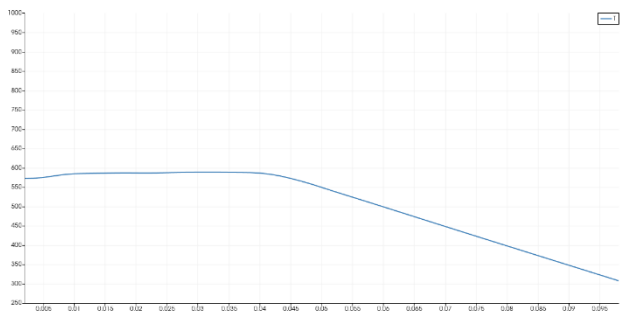
Temperature about central vertical axis at t=0 s



Temperature about central vertical axis at t=0.1 s



Temperature about central vertical axis at t=0.5



Temperature about central vertical axis at t=1 s