Simulating mushy zone resolidification for multiphase and multicomponent alloys using ChemApp

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mushy zone resolidification

\[ \frac{dT}{dx} \rightarrow \frac{d\xi_{Li}}{dx} \]

experimental set-up

\[ T_L (c_0) \]

\[ 700^\circ C \]

\[ T_S (c_0) \]

\[ 500^\circ C \]

phase diagram
binary systems

- measured concentration
- measured local temperature
- corresponding solidus concentration

other effects documented in literature
- TGZM
- LFM
- thermo migration
- coarsening
- ...

analytical model by Combeau et al.
- resolidification in binary alloys with single solid phase forming in mushy zone
multiphase resolidification

Al-60% Cu
→ quenched after 2 min holding time
model

\[ \frac{\partial c_{\text{tot}}}{\partial t} = \frac{\partial}{\partial x} \left( D_L f_L \frac{\partial c_L}{\partial x} \right) \]

- constant temperature gradient assumed
- \( c_0, T, D_L \) known
- calculate liquidus concentration \( (c_L) \), liquid fraction \( (f_L) \), phase fractions and concentrations in solidified phases using \textbf{ChemApp}
- solve diffusion equation using Finite Differences Method to obtain new \( c_{\text{tot}} \)
results: Al-3.8 % Cu

holding time: 10 min
temperature gradient: 10 K/mm
multiphase case: Al-60 wt.% Cu

→ solute flux $j^+ \neq j^-$
→ solute concentration at $T_p$ changes
results: Al-60 wt.% Cu

2 min, 55 K/mm
Al-60 wt.% Cu – liquid fraction

380 min

2 min
10 min
20 min
30 min
180 min

liquid fraction [g/g]

600 620 640 660 680

temperature [°C]
results: Al-60 wt.% Cu - concentrations

Temperature gradient: 55 K/mm

- Concentration Al [g/g]
- Distance from solidus [mm]
- 2 min
- 30 min
- 180 min
results: Al-5 wt.% Si- 1 wt.% Mg, 30 K/mm
conclusions

➢ a model for mushy zone resolidification was presented:
  – temperature dependent local equilibria calculated using thermodynamic software package ChemApp
  – diffusion equation solved numerically

➢ multiphase and multicomponent alloys

➢ verification via temperature gradient annealing experiments in Al-Cu and Al-Mg-Si alloys