Convection phenomena: moving grains

GRADECET meeting Cologne

Dr. Gyula Tóth and Dr. György Tegze

Hungarian Academy of Sciences
Wigner Research Centre for Physics
Budapest

June 14, 2012

Outline

Decision about numerical procedure for convection modeling

- approximations
- Convection term in scalar equations: finite volume vs. spectral
- accuracy
- Rigid body constraint

Implementation

- moving grid method
- fluid-structure interaction (FSI)

Demo

- shear flow
- sedimentation

Goals

- quantitative scale phase field
- multiple phases (peritectic)
- convection: Navier-Stokes equation
- gravity effect
- moving solid (fluid structure interaction)
- break off
- interacting particles

Central problem: convection and rotation

mathematical form:

- convection term: $\nabla \cdot (\phi \vec{v})$
- rotational term: $\nabla \times (\vec{v})$

Why important?

- artificial diffusion if $J_{DIFF} << J_{CONV}$
- "boundedness" : e.g. cc values outside [0,1] range (unphysical oscillations)

Tested: FVM vs. Spectral

- 1D uniform velocity with periodic boundaries
- finite volume: CDS, upwind, CUS, QUICK etc schemes.
  low order: bounded but numerical diffusion
  higher order: not bounded with lower numerical diffusion
- spectral: not bounded but exponential convergence

No satisfactory result obtained!

Eliminating convection terms from scalar equations

deforming grid

- grid deforming with fluid flow
- unstructured grid
- remeshing
- all fields are convected the same way
- convective terms canceling in the scalar equations (PF and cc)

overlapping grid

- subgrid moving + interpolations among grids
- structured grid
- no remeshing
- separating solid and liquid transport
- convective terms (partially)canceling in the scalar equations (PF and cc)

Our choice: summary

Model

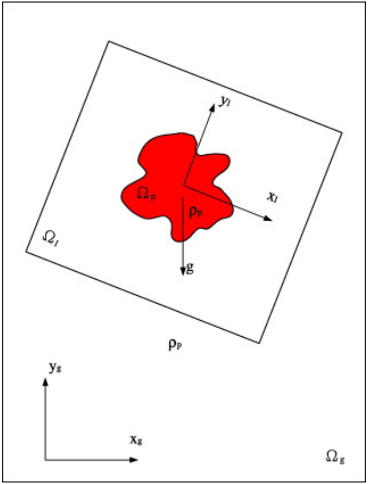
- Quantitative (meaningful size for gravity driven motion)
- Kim-Kim-Suzuki/Steinbach type model (separate phase-field and concentration fields for each grain)
- Multi-phase-field (peritectic)
- Boussinesq approximation for gravity driven flow

Numerical implementation

- finite difference/volume spatial discretization scheme
- overlapping grid
- structured grid
- convective terms are fully cancelling in the scalar equations
- particle interaction via collision forces

Convection: overlapping grid

Overlapping grid (G. Amberg)



Update scheme

- calculating velocity field in the whole domain
- enforcing incompressibility
- calculating angular and translational monentum over solid particle
- updating velocity over solid particle
- enforcing incompressibility again
- translate solid grain

Shear flow demo: the local grid

Shear flow demo: the global grid

Shear flow demo: streamlines

Sedimentation demo

Under development

Convection

- upscaling: multigrid pressure solver
- particle-wall interaction
- multi-particle simulations
- particle collision
- particle agglomeration
- break off condition
- gravity (composition dependence)

Phase field model

- 1 grain - 2 phase field (Peritectic)
- solid cc + liquid cc = cc (Kim-Kim-Suzuki)
- quantitative