

2次元静電場と正則関数: 静電誘導の簡単な例



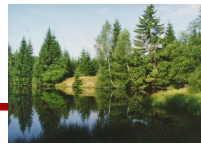
鈴木太郎, 中村九介

*Department of Mechanical Engineering
Sakura International University*



- Motivation: Dense Sprays and LES Calculations.
- Spatial Filtering of Multiphase Flow Equations.
- An Example of a Partly-Resolved Particle Model. 例
- Results for Various Particle Sizes. 種々の粒子サイズに対する結果
- Grid Requirements for Filtered Multiphase Calculations.
- Filtering and Point Particle Models.
- Conclusions.

Motivation



- Atomization models in combustion codes:



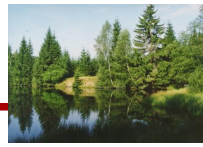
- Dense-region mass, momentum transfers are significant.
 - How much transfer should there be?
 - How should it be distributed?
- Multiphase models need to be consistent with LES.
- Filtered-Phase Method (FPM) provides analysis path.




What is the Filtered-Phase Method?



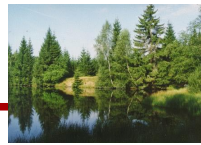
- Apply the turbulent LES methodology for fluid surfaces as well as turbulent eddies:
 - Rigorously extend fluid equations to cover entire domain, including regions outside the fluids.
 - Flow phases and variable fields are divided into large- and small-scale parts by spatial filtering.
 - Large-scale liquid features and gas-phase interaction appear directly in the resolved-scale calculation.
 - Small-scale effects such as individual droplets and secondary breakup are included by models.
- As in LES, the interaction between small scales and large scales can be derived explicitly.

Spatially-Filtered Multiphase Flow Equations



- Filtered momentum equation (simplified form):
- Simplifying assumptions: one phase (plus particles), incompressible flow, constant properties, no outflow.
- Unclosed terms:
 -  Correction terms for surface motion.
 -  Surface stress term.
 -  Subfilter-scale convection (LES model term).

Model Problem



- Laminar flow around a fixed cylindrical “particle”.
- Flow conditions: Uniform freestream, $Re_D = 26$.
 - Steady flow, with significant recirculation zone.
 - Wake continues for many diameters downstream.
 - Can be simulated with a 2-D calculation.

Parametric Particle Model



- Unclosed terms approximated by parametric models:
 - Surface force represented by a multi-point interpolation over the particle surface.
 - Subfilter-scale convection represented by three filtered point forces.

Initial Model Results



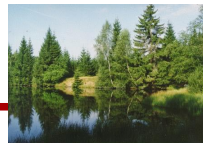
- Computation parameters (in units of $D_{particle}$):
 - 16×16 flow domain.
 - $\Delta x_{grid} = 1/16$, for grid-converged results.
- The resulting simulation is a close match for the exact filtered flow, both qualitatively and quantitatively.

Results from Partial Models



- With the subfilter-scale convection neglected:
 - Wake centerline velocity is higher.
 - Volume-displacement effects are greatly reduced.
 - Total wake momentum defect, however, is the same.

Results from Partial Models



- With the drag force uniformly distributed over the particle's surface (and without the subfilter term):
 - The wake is offset downstream because the centroid of the force is in the wrong place.
 - The results are otherwise nearly identical.

Initial and Partial Model Results



Momentum flux defects (in units of ρU_0^2).

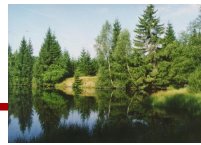
- The wake defect consists of two parts:
 - Momentum loss due to drag force (all models).
 - Momentum flux temporarily “hidden” in subfilter scales (with subfilter convection term).
- The surface force distribution has very little effect.

Results for Various Particle Sizes



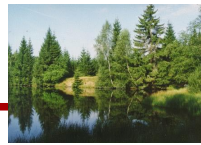
- Filter = 0.5 particle diameter:
 - Results are still very good.
 - Some minor effects from limited sfs-term coverage.

Results for Various Particle Sizes



- Filter = 0.1 particle diameter:
 - No sfs term (three-point is insufficient)
 - Results close, but sfs term still needed even at this fine resolution.

Results for Various Particle Sizes



- Filter = 4.0 particle diameter:
 - Still reasonably good results (comparable to 1.0 case).
 - Some domain-size issues.

Results for Various Particle Sizes



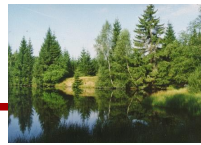
- SFS momentum term increases with increasing filter.
- Net wake defect is constant.
- Wake width converges to same size downstream..

Results for Grid Resolution Study



- Grid = 0.5 filter radius:
 - Qualitatively very good results
 - Some primary grid-coarsening effects. (Max wake defect slightly washed-out.)

Results for Grid Resolution Study



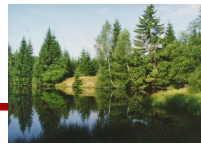
- Grid = 1.0 filter radius:
 - Expected to be ill-resolved.
 - Qualitatively still reasonable.
 - Wake defect very “smeared out”.

Results for Grid Resolution Study



- Wake width results are good over all grid range, even for most ill-resolved case.

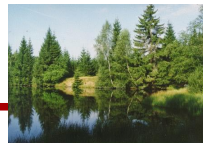
Filtering and the Point Particle Model



- Even for a case where the particle is two orders of magnitude smaller than the filter, the subfilter-scale convection term is a significant fraction (around 25%, at peak) of the filtered surface force.

りんご	110 円
なし	70 円
みかん	90 円

Summary and Conclusions



- We have derived LES-compatible equations for multiscale, multiphase flow by spatial filtering, and used these equations to develop models for typical partly-resolved particles.
- The particle models produce accurate results over a range of scales.
- Grid resolution requirements are comparable to requirements for turbulence LES.
- Subfilter-scale term is important over a wide range of scales, well into the “resolved” and “point-particle” regimes.
- This provides clear, rigorous guidance for distributing particle forces in particle-laden LES computations.