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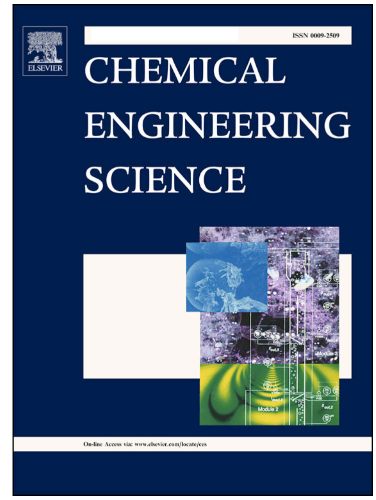

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Development and verification of anisotropic solids stress closures for filtered Two Fluid Models

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Abstract

Models for predicting flows in large scale fluidized beds, such as filtered Two Fluid Models (fTFMs), must account for meso-scale phenomena that manifest spontaneously in sedimenting gas-particle suspensions. Next to the closures for interphase momentum exchange, the filtered solids stresses also require closure in such models. A budget analysis reveals that, for large filter sizes, the meso-scale solids stresses, which arise due to the particles' sub-grid velocity fluctuations, are the most important contribution to these stresses. Previously, closures for meso-scale stresses have commonly adopted a Boussinesq approach where (i) a filtered solids pressure is used to close the mean normal stress, and (ii) a filtered solids viscosity is modelled to close the deviatoric stress components. The present study highlights that such a Boussinesq approach fails to accurately predict the forces arising from the meso-scale stresses. This is primarily due to the fundamental inability of a viscosity-based formulation to approximate deviatoric stress components in sedimenting gas-particle suspensions. The present study proposes a novel anisotropic approach in which both normal (i.e., diagonal) and shear (i.e., off-diagonal) stress components are modelled individually. The proposed anisotropic closure explains resolved stress data significantly more reliably (i.e., with a correlation coefficient of $R^2 \approx 0.62$) compared to a conventional Boussinesq-based approach ($R^2 \approx -0.65$) using a single model equation. Finally, these findings are confirmed by evaluating different stress closures in fTFM simulations of bubbling and turbulent fluidization. These simulations indicate that the novel anisotropic stress closure leads to improved model generality and better grid independence. Most important, it is found that a classical Boussinesq-based closure leads to worse predictions compared to a complete neglect of meso-scale solids stresses. Thereby, the present study underlines that it is essential to account for anisotropy when closing the meso-scale solids stress in fTFMs.

Keywords: Gas-particle flow, Fluidised bed, Meso-scale stresses, Filtered Two Fluid Model, Coarse grid simulations