Proceedings of the Canadian Society for Mechanical Engineering International Congress
32nd Annual Conference of the Computational Fluid Dynamics Society of Canada
Canadian Society of Rheology Symposium
CSME-CFDSC-CSR 2025
May 25–28, 2025, Montréal, Québec, Canada

A NOVEL POLYDISPERSE GAUSSIAN-MOMENT MODEL FOR THE AIR DISPERSION OF VIRUS-LADEN AEROSOLS

Francois Forgues[1*], Benoit Allard[2], J. G. McDonald[2], Lucian Ivan[1,2]

[1]Canadian Nuclear Laboratories, Chalk River, Canada
[2]Mechanical Engineering, University of Ottawa, Ottawa, Canada
*francois.forgues@cnl.ca

Abstract

Active concerns about environmental health and airborne transmission of respiratory viruses have highlighted the need for a deep understanding of virus spreading to better estimate infection risk and develop effective mitigation strategies. Numerical models describing the transport of virus-containing aerosol play a central role in this effort. Although Lagrangian-based models have been widely adopted for predicting bio-aerosol dispersion, they remain prohibitively expensive to generate statistically relevant predictions, often requiring an excessive number of particles and numerical experiments. Alternatively, Eulerian approaches have the potential to improve the computational efficiency of particle-laden multiphase flows, but classical methods are prone to modelling artifacts stemming from the lack of proper treatment of the local statistical dependence between particle properties, such as particle velocity and size. This limitation is further exacerbated as the physical processes describing the evolution of the infectious droplet are more complex, such as accounting for droplet evaporation and the natural virus decay. This work proposes a new member of the polydisperse Gaussian-Moment Model (PGM) family, PGM-V, that provides an Eulerian treatment for the evolution of virus-laden aerosols. Notably, the model provides a direct treatment for local higher-order statistics such as variance and covariance related to particle velocity and particle distinguishable properties (i.e., diameter, viral load, and amount of non-volatile solute). Derived within an entropy-maximization moment-closure formulation, the new model yields a set of first-order robustly-hyperbolic balance laws which are efficiently solved with a high-order, massively parallel, discontinuous-Galerkin-Hancock method. This talk provides a summary of the model derivation and its mathematical properties and illustrates the predictive capabilities for several scenarios of bio-aerosol dispersion. This work shows that the new PGM-V model can accurately replicate published experimental results related to the temporal evolution of the saliva droplet-phase evaporation process for different particle-size and ambient conditions, thereby validating the approach. Furthermore, to illustrate the predictive capabilities of the new PGM-V model, a one-dimensional particle sedimentation demonstration with a typical cough or sneeze droplet distribution is performed. This is a particularly challenging problem for Eulerian-type model, which requires capturing the different relaxation times of the particle phase subject to evaporation, which lead to a variable terminal velocity. The presentation shows that the PGM-V can efficiently predict the physical phenomena present in this problem due to its capability to track a range of particle size, viral load content, and non-volatile solute amount. Finally, a comparison to a widely adopted direct-particle tracking method demonstrates the approach viability.