NUMERICAL MODELING AND EXPERIMENTAL INVESTIGATION OF FINE PARTICLE COAGULATION AND DISPERSION IN DILUTE FLOWS

Bart Janssens, Belgium
Supervisor: Prof. T. Arts
Promoter: Prof. W. Bosschaerts (RMA, Belgium) and Prof. K. Limam (ULR, France)

One of the major factors in determining air quality is the level of pollution in the form of particles. In general, particles with an aerodynamic diameter inferior to 10 µm can penetrate into the human body, and constitute a potential health risk. Recently, the additional risks of nanoparticles have received much attention, so we will study particles in a range from about 5 nm to 10 µm. The goal of the present work is to arrive at a contribution to the numerical modeling of particle-laden flow, where the behavior of ultrafine particles is taken into account, as well as inter-particle collision and coagulation. This will be done in two phases: a model development phase, followed by an application phase. The target applications include flows in confined spaces that can be modeled using CFD. Particle loading should be such that the flow can be considered dilute, i.e. particle dynamics are dominated by the flow rather than inter-particle collisions.

The developed model must be able to capture both the flow and the particle behavior. In the class of problems studied here, the instantaneous fluid velocity is a major factor in determining particle behavior, so the accuracy of the fluid model will have a great impact on the results. The fluid will be modeled by discretizing the incompressible Navier-Stokes equations using the Finite Element Method, as implemented in COOLFluiD. The resulting method is of second order accuracy. In order to obtain a reliable velocity input for the particle equations, LES is used for the turbulence modeling. There is some discussion in the literature on the validity of using the LES results as instantaneous velocity input for the particle equation of motion. Some authors suggest that neglecting the small scales of turbulence may influence the results for the particle quantities. The added complexity of implementing a method to compensate this is considered to be beyond the scope of the current work, however, so we will attempt to work with LES solutions that are sufficiently resolved.

When modeling the behavior of the particles, a choice needs to be made between an Eulerian or a Lagrangian approach. Of the many Eulerian methods, the approach presented by Simonin seems most applicable to the current problem, especially since it has been extended to include collision effects. The Lagrangian approach seems more intuitive, as the particle equation of motion is solved directly, while different forces acting upon the particle can be modeled easily. The challenge is that from a computational point of view, it is impossible to track all particles, so statistical methods need to be used. The inclusion of collision effects further complicates matters: since not all particles are tracked directly, collisions can not be deduced directly either.

During the development of the model, it will be validated against simple test cases, using both literature data and small-scale experiments. As a validation of the fluid model, the classic DNS data for channel flow will of course be used. Channel flow data with dispersed particles is also widely available, and can be used for validation of the model including particles.

The final phase of the work consists of an application to industrial problems. Two cases will be considered: the acoustic agglomeration of industrial gases, and the evolution of particles through a turbine.

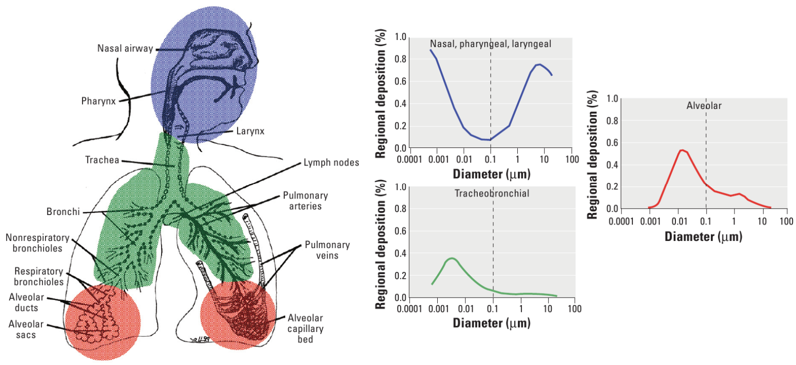

Illustration 1: Particle penetration into the human respiratory