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The Equation of Motion and Energy Equation for Particles - A Historical Perspective

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Abstract

Energy and momentum exchange between spherical particles and a fluid is a fundamental problem that has excited the intellectual curiosity of many scientists for more than two centuries. The development of the energy equation of spherical particles in a fluid can be traced back to the work of Laplace and Fourier that appeared early in the 19th century. It is now little known that Peclet formulated the no-slip condition at a solid boundary, by observing the transfer of heat, approximately ten years before the concept of viscosity was conceived. Towards the middle of the 19th century Poison derived the hydrodynamic force on a sphere in an inviscid fluid and a few years later, Stokes formulated what is now known "the Stokes drag" for the steady-state hydrodynamic force acting on a spherical particle in a viscous fluid. Boussinesq and Basset developed a form for the transient equation of motion of the particles with very low inertia towards the end of the 19th century. The mathematical advances of the early 20th century are reflected in developments in mechanics and on the equation of motion of particles. Oseen and Faxen used asymptotic methods to derive improved our knowledge on the behavior of particles with inertia and in close proximity to boundaries. Experimentation contributed very useful correlations on the hydrodynamic force and the heat transfer from particles. The experimentally derived data helped also in the development of semi-empirical equations for the transient hydrodynamic force. Regular and singular perturbation methods have been used more recently to derive expressions for the transient hydrodynamic force and the heat transfer from particles during time-dependent processes, both under creeping flow conditions and at low Reynolds or Peclet numbers. The recent advances on computational methods and the exponential increase in computer power enable us to simulate the motion and energy exchange of groups of particles and complex particle interactions.

This presentation gives a historical perspective on the development of our knowledge on particle motion and heat transfer inside a viscous or conducting fluid. Emphasis is given on the exposition of the lesser-known works of the 19th century that have placed the foundation for many concepts and methods that are still used today. The presentation concludes with the most recent contributions of the numerical studies and a short exposition of the voids in our knowledge on energy and momentum exchange processes between particles and a fluid.