Transport and Deposition of Small Particles in Turbulent Flows

Particle deposition from turbulent flows is a fascinating and complex subject with a large number of applications. For example, in steam turbines the deposition of submicron droplets onto the blades provides the coarse water responsible for downstream blade erosion. Techniques developed for computing deposition by inertial impaction [1988a] and turbulent diffusion [1987] culminated in an experimental programme which, for the first time, linked measurements of fog and coarse water via a theory of deposition [1988b]. At the time, it was believed that deposition theory was inadequate for this task and that other physical processes were involved. Studies of ash particle deposition and erosion in coal-fired gas turbines were also carried out using similar methods [1993, 1994].

In the course of this work, it emerged that the 'free-flight' theories of turbulent deposition which had dominated the literature for forty years were inadequate. By a combination of physical intuition and more rigorous mathematical modelling, a theory of deposition was devised which encompassed the three regimes which had previously been treated separately and empirically. The phenomenon of 'turbophoresis' (particle transport down a turbulence gradient) emerged as the dominant transport mechanism in the near-wall region. The initial analysis concentrated on pipe-flow [1997] and turbulent boundary layers [2003] but subsequent work has extended the approach to more complex flows involving streamline curvature [2004] and thermophoresis due to temperature gradients [2010]. A reassessment of the theory for the thermophoretic force on a spherical particle has resulted in a new prescription for transition regime thermophoresis [2011].

Practical calculation methods for depositing gas-particle flows have also been developed. A fully-Eulerian method [2001] overcame problems associated with boundary conditions, concentration discontinuities and particle-free zones. In some cases Lagrangian-based methods are still preferable despite their notoriety in calculating particle concentration fields. A method which does this elegantly by calculating the Jacobian of the Eulerian-Lagrangian transformation along particle path lines should have an impact on the calculation of gas-particle flows in more complex situations [2005].

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