Recent Development in Hydraulic Modelling - Bolzammn Kinetic Theory

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Abstract:

This talk introduces the fundamental equation of kinetic theory (the Boltzmann equation) and highlights some of its potential usefulness in hydraulics and fluid mechanics. The potential of using kinetic theory to construct computational models for hydraulic applications is summarized and illustrated. Examples from the fields of both free surface and pressurized flows are used in the illustration. In addition, the usage of kinetic theory to formulate turbulence models is briefly described.

Boltzmann Kinetic theory recognizes that matter is made up of an enormous number of tiny units, called molecules and atoms, that bounce around and interact with one another and provides the link between the gross properties of matter and the motion of its parts. The basic concepts of Boltzmann Kinetic theory are called upon whenever one explains the macroscopic behavior in terms of molecular motion. Textbooks in fluid mechanics and hydraulics often relate pressure, temperature, compressibility, viscosity, conductivity, diffusion, surface tension, cavitation and other properties of both the fluid and the flow to the motion of the molecules that make up the fluid. In addition, Prandtl's mixing length was developed by drawing analogy between eddies and molecules so that one could use the concepts of kinetic theory to replace the mean free path by the mixing length, the kinematic viscosity by the eddy viscosity and viscous stresses by the Reynolds stresses. Moreover, the continuum hypothesis, which is the very foundation of all fluid and hydraulic modeling, is rooted in kinetic theory.

The talk is arranged as follows. A brief description of the historical development of kinetic theory and the interesting controversies that this development faced is summarized. Then, the Boltzmann equation and its connection to fluid mechanics and hydraulics are demonstrated and how this connection has been exploited to devise Boltzmann-based models for hydraulic applications is explained and demonstrated. The talk concludes by discussing the potential that this theory holds to make headway in outstanding problems such as turbulence modeling and other flow instabilities.