Journal of Engineering Mathematics **32:** 101–102, 1997.

Introductory remarks

In many technological and natural systems the flow of fluids plays an important role. A detailed knowledge of the dominant mechanisms is often essential in order to understand the functioning of these systems and to be able to optimise specific aspects. The large diversity of basic phenomena associated with the flow of fluids makes this field of study both intriguing and challenging. Since the work of Navier and Stokes, the equations describing the motion of the most common fluids like water and air are known. The physical basis of these Navier–Stokes equations is in fact simple; they describe conservation of mass, momentum and energy. The nonlinear nature of these equations, however, seriously complicates the analysis in spite of the considerable effort of several generations of researchers. Until a few decades ago solution methods for the equations of fluid flow were restricted to some special cases, where approximations in the physics lead to mathematically simpler problems. Well-known examples are potential flow or the boundary-layer equations. For many practically relevant technological applications, such as the design of large water works and aircraft, the basic design tool remained a physical scale experiment.

During the last decades, the continuing growth of computers with respect to both computational speed and memory has enabled numerical simulations of flows based on the Navier-Stokes equations in gradually more complex situations. The increase in computing power also provided an additional stimulation of research which resulted in a considerable increase in the efficiency and accuracy of numerical methods for viscous-flow simulation. Due to the favourable interplay of these two developments, the approximations made in the physics of the flow could be relaxed and a new design tool, complementary to the physical experiment, originated. Laminar-flow simulations and modelled turbulent-flow simulations have become possible for complex flows, e.g. in complicated geometries, which resulted in the widespread use of commercial codes in the design and optimisation of technological applications. This interplay also facilitated the application of numerical simulation to turbulence, which is regarded as one of the most difficult problems in classical physics. Nowadays, direct numerical simulation and large-eddy simulation of turbulent flow in still rather simple examples are used to study the fundamental properties of turbulence and to improve turbulence models which are used in approximations to the Navier–Stokes equations.

In this special issue of the Journal of Engineering Mathematics an overview is given of the present-day possibilities of numerical simulation of flows with the Navier–Stokes equations by state-of-the-art contributions. They involve studies of aspects of turbulent flow by means of direct numerical simulation or large-eddy simulation. Other contributions deal with modelled flows in more complex geometries, including free-surface flow and illustrate the applicability of large-scale computations to practically relevant problems. For all large-scale flow calculations the first rough result is an enormous amount of data. In order to capture the basic flow phenomena and to increase the understanding of the flow, an extensive post-processing of these data is essential. The properties and the quality of the numerical solution can best be appreciated if use is made of modern visualisation tools. Most contributions to this special issue show the possibilities for visualisation in Computational Fluid Dynamics. Although essential progress in the understanding of fluid flow has proven to be a slow and difficult process, we hope that this special issue will contribute in an inspiring way to the ongoing research in this field.

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