Handbook of Numerical Analysis : Numerical Methods for Fluids (Part 3)

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This book-size article is dedicated to the numerical simulation of unsteady incompressible viscous flow modelled by the Navier-Stokes equations, or by non-Newtonian variants of them. In order to achieve this goal a methodology has been developed based on four key tools. Time discretization by operator-splitting schemes such as Peaceman-Rachford's, Douglas Rachford's, Marchuk-Yanenko's, Strang's symmetrized, and the so-called theta-scheme introduced by the author in the mid-1980s. Projection methods (in L2 or H1) for the treatment of the incompressibility condition div u = 0. Treatment of the advection by: either a centered scheme leading to linear or nonlinear advection-diffusion problems solved by least squares/conjugate gradient algorithms, or to a linear wave-like equation well suited to finite element-based solution methods. Space approximation by finite element methods such as Hood-Taylor and Bercovier-Pironneau, which are relatively easy to implement. conjugate gradient algorithms, least-squares methods for boundary-value problems which are not equivalent to problems of the calculus of variations, Uzawa-type algorithms for the solution of saddle-point problems, embedding/fictitious domain methods for the solution of elliptic and parabolic problems. In fact many computational methods discussed in this article also apply to non-CFD problems although they were mostly designed for the solution of flow problems. Among the topics covered are: the direct numerical simulation of particulate flow; computational methods for flow control; splitting methods for viso-plastic flow a la Bingham; and more. It should also be mentioned that most methods discussed in this article are illustrated by the results of numerical experiments, including the simulation of three-dimensional flow. easy to implement - as is demonstrated by the fact that several practitioners in various institutions have been able to use them ab initio for the solution of complicated flow (and other) problems.

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