NOVEL NUMERICAL TECHNIQUES FOR PROBLEMS IN ENGINEERING SCIENCE

A Dissertation Presented

by

Francesco Fedele

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Dissertation Examination Committee:

______________________________ Advisor
Jeffrey P. Laible, Ph.D. .

______________________________ co-Advisor
Margaret Eppstein, Ph.D.

____
George F. Pinder, Ph.D.

______________________________ Chairperson
Darren L. Hitt, Ph.D.

______________________________ Vice President for Research and Dean of Graduate Studies
Frances E. Carr, Ph.D.

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Abstract

In this thesis novel numerical techniques are proposed for application to different problems in engineering science. Three categories of numerical techniques are investigated: collocation methods, finite element methods (FEM) and boundary element methods (BEM).

In the context of collocation methods a new numerical technique called LOCOM (LOcalized COllocation Method) has been proposed. This method is able to reduce the degrees of freedom of the classical Hermite collocation to one single degree for each collocation node, still maintaining higher order accuracy. This new methodology has been applied to an existing Hermite Collocation Fortran code that solves multiphase flow problems.

In the context of the Finite Element Method, a special form of the Petrov-Galerkin method has been formulated for the sub-grid stabilization of advection-diffusion partial differential equations on triangular meshes. This new method is able to damp out the spurious oscillations occurring near a sharp front when the standard finite element method is applied. An adjoint FEM has been developed in the context of fluorescence tomography and a Galerkin technique has been formulated to investigate the hydrodynamic stability of pulsatile Poiseuille flow in a pipe.

Finally, a 3D boundary element method is presented for the numerical solution of general coupled elliptic differential equations. This methodology has application in some areas of optical tomography where small heterogeneities immersed in a homogenous domain need to be detected.

Citations

Material from this dissertation has been published in the following form:

Fedele F., Hitt D., Prabhu R.D. Revisiting the stability of Pulsatile pipe flow. European Journal of Mechanics - B/Fluids 2004, in press

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Fedele F., Laible J. P. & Eppstein M. Coupled complex adjoint sensitivities for frequency-domain fluorescence tomography: theory and vectorized implementation " Journal of Computational physics Vol. 187, Issue 2, pp. 597-619, 2002

Fedele F.,Laible J. P., Pinder G. F. Localized-Adjoint-Finite-Element-Method for Sub-Grid Stabilization of Convection-dominated Transport on a Triangular Mesh. XIV International Conference on Computational Methods in Water Resources June 23-28, 2002 Delft University of Technology The Netherlands

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