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Editorial

14th International Conference on Finite Elements in Flow Problems

GUEST EDITORS: Mark A. Christon[1,*,†] and Alvaro L. G. A. Coutinho[2]

[1]*Chief Technology Office, Dassault Systémes Simulia Corporation, Providence, RI, U.S.A.*
[2]*Center for Parallel Computing and Department of Civil Engineering, COPPE/Federal University of Rio de Janeiro, Rio de Janeiro, Brazil*

SUMMARY

This special issue is dedicated to the Fourteenth Finite Elements in Flow Problems Conference held in Santa Fe, New Mexico, on March 24–28, 2007. The papers in this special issue were selected to represent the broad cross-section of computational fluid dynamics topics ranging from discontinuous Galerkin and stabilized methods to fluid–structure interaction and viscoelastic flows at the 14th meeting. Copyright © 2008 John Wiley & Sons, Ltd.

KEY WORDS: adaptivity; discontinuous Galerkin; discontinuity capturing; divergence free; edge based; error estimation; extended FEM; finite calculus; fluid–structure interaction; incompressible; Lagrangian; large-eddy simulation; least squares; mixture model; multifluid; multimaterial; multiscale; Navier–Stokes; NURBS; projection method; RANS; sensitivity; stabilized; subgrid; supersonic; thermal comfort; transonic; viscoelastic

The Finite Elements in Flow (FEF) Problems Conference has a rich history that closely parallels the development and maturation of the finite element method and its application to computational fluid dynamics problems. The FEF meetings began in Swansea (U.K.) in 1972 and are the principal forum for the exchange of research results in all aspects of flow simulation using the finite element method. The scope of the conference is intentionally broad with coverage of theory, implementation, assessment and application in all of the major and emerging areas of fluid dynamics and flow-related phenomena. The purpose of the 14th conference in the series continued to be the gathering of mathematicians, engineers, computer scientists and students for the exchange of the latest information on all aspects of flow modeling and simulation.

This special issue contains papers originally presented at the 14th FEF Conference held in Santa Fe, New Mexico, on March 24–28, 2007. The 19 peer-reviewed papers in this issue represent a cross-section of the conference and discuss advances in space–time discontinuous Galerkin

*Correspondence to: Mark A. Christon, Chief Technology Office, Dassault Systémes Simulia Corporation, Providence, RI, U.S.A.
†E-mail: mark.christon@3ds.com

methods, large-eddy simulation (LES), coupled physics, design sensitivity, stabilized methods and stability analysis.

The work by Sevilla *et al.* [1] considers the development of a hybrid NURBS-enhanced finite element method (NEFEM) blended with a discontinuous Galerkin formulation to solve the Euler equations. NURBS are used to provide exact geometry and accurate numerical fluxes. In addition, the use of p-refinement delivers exponential convergence.

The work by Montlaur *et al*. [2] uses an interior penalty method with a discontinuous Galerkin formulation for incompressible Stokes flow. This approach permits the velocity field to be split into div-free and curl-free spaces on an element-by-element basis. The resulting weak form permits the solution to proceed with two de-coupled problems with a hybrid (edge) pressure and an element-interior pressure. The additional penalty term permits the computation of solenoidal velocities without an explicit pressure computation.

Kanschat and Schötzau [3] develop an *a posteriori* error analysis of the discontinuous Galerkin method for the incompressible Navier–Stokes equations using Raviart–Thomas elements and an interior penalty. The discretely divergence-free elements are implemented in an h-adaptive framework.

Palaniappan *et al*. [4] present two methods for resolving shocks and discontinuities in a space–time discontinuous Galerkin framework. The first approach is an adaptation of the sub-cell shock-capturing technique, recently introduced by Persson and Peraire,[‡] to the space–time discontinuous Galerkin method with causal space–time grids. The second method relies on adaptive space–time meshing to track singular surfaces.

Elias *et al*. [5] develop an edge-based, stabilized finite element formulation to treat gravity-driven flows in lock-exchange problems. Validation is performed for head current position and velocity using experimental data, DNS and LES simulations. The ultimate goal is to demonstrate a scalable, parallel LES capability for simulating particulate-laden flows.

The work by Guermond [6] considers weak solutions for the Navier–Stokes solutions. The suitability of Faedo–Galerkin solutions is shown to depend on the use of finite-dimensional spaces with a discrete commutator property and satisfying the inf–sup conditions. This work investigates the connections between suitable weak solutions and LES and demonstrates a proposed closure model developed in the framework of 'suitable weak solutions'.

Liu and Nithiarasu [7] use a fully explicit characteristic-based method to calculate the viscoelastic flows with an upper-convected Maxwell model. An equal-order u–P interpolation is used with an artificial damping method to produce a method capable of treating high Deborah number flows.

A direct-coupling technique for coupled thermal-flow problems is presented by Tezduyar *et al.* [8]. The formulation relies on streamline upwind and pressure stabilization in a Petrov–Galerkin framework with discontinuity-capturing directional dissipation. A series of 2D and 3D natural convection problems are used to demonstrate the method.

The work by Heinrich *et al.* [9] focuses on the development of a projection method for the simulation of dendritic solidification in flows where large local density gradients are present. The modified projection method used in this work preserves the pressure gradient–body force coupling. The computational efficiency of the projection method results in significant reduction in computational complexity for this class of problems.

An accurate approach to treating 'fixed-grid' fluid–structure interaction problems is investigated by Gerstenberger and Wall [10]. The goal is to avoid complex re-meshing techniques either by local mesh refinement near the fluid–structure interface or by a hybrid ALE technique. They ultimately

[‡]Persson PP, Peraire J. Sub-cell shock capturing for discontinuous Galerkin methods for hyperbolic conservation laws. *Forty-fourth AIAA Aerospace Sciences Meeting and Exhibit*. AIAA: New York, 2006.

demonstrate that the hybrid ALE method is essentially a variation of the XFEM/Lagrange multiplier scheme.

Codina and co-workers [11] present a stabilized finite element formulation based on the variational multiscale approach for the modified Boussinesq equations, i.e. the shallow-water equations. A new approach to obtaining a stabilized equal-order interpolation is achieved with the splitting between resolved-scale and subgrid-scale terms. They also describe the consistent treatment of the high-order derivatives in the model.

Lube *et al.* [12] apply the stabilized FEM to the prediction of ventilation and thermal comfort in buildings. A k–ε–ϕ–f turbulence model is used for time-dependent RANS simulations of flow in a building. The application of this approach to thermal comfort is demonstrated. Their approach also permits the direct calculation of the age of the air.

A detailed analysis of consistency recovery in the context of stabilized methods for convection–diffusion is undertaken by Nadukandi *et al.* [13]. This work addresses the relative trade-offs associated with consistently recovering the high-order terms in the discrete residual that is an integral part of stabilized methods. A spectral analysis of semi-discrete and fully discrete systems is presented to quantify the effects of consistent residual recovery.

Masud and Kwack [14] develop a stabilized mixed FEM for the first-order form of advection–diffusion equation. The new approach uses the fine-scale variational problem to derive stabilization terms that do not rely on the mesh length scale and physical parameters in the problem. Optimal convergence rates are demonstrated for both structured and unstructured meshes.

The treatment of design sensitivities (shape and value) is considered by Ilinca *et al.* [15]. A general method for computing first- and second-order accurate flow sensitivities is developed and applied to steady and transient problems. The method is applied to estimate parameter sensitivity in terms of Reynolds number and also to shape sensitivity.

A high-order least-squares spectral element method is developed by Gerritsma *et al.* [16] for the Euler equations. The formulation takes advantage of the inherently stable properties and optimal convergence rates of the least-squares method. In this work, the detailed treatment of curved walls is considered. The method is evaluated using flows ranging from subsonic to supersonic.

The topic of adaptivity and *a posteriori* error estimation for coupled heat-transfer fluid flow is treated in the work by Larson *et al.* [17]. The error estimator is based on a duality technique and applied to the heat flux at an immersed boundary. An h-adaptivity algorithm is developed around a dual error estimator for the coupled problem.

Behr [18] presents a unique method for generating simplex space–time meshes with arbitrary temporal refinement in portions of the space–time slabs. Both tetrahedral (2D) and pentatope (3D) space–time meshes are tested with advection–diffusion problems using local refinement in the time domain.

The use of a ‘timestepper’s approach’ for absolute and convective stability analysis is presented in the work by Barkley *et al.* [19]. The approach to converting a time-accurate Navier–Stokes solver to provide an evolution operator for the adjoint linearized equations is discussed with the concomitant tools for the eigenvalue extraction. The approach suggests the possibility of solution strategies with embedded stability analyses.

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