11th World Congress on Computational Mechanics (WCCM XI)
5th European Conference on Computational Mechanics (ECCM V)
6th European Conference on Computational Fluid Dynamics (ECFD VI)
July 20–25, 2014, Barcelona, Spain

IMPLEMENTATION AND NUMERICAL STABILISATION OF ADJOINT FLOW AND TURBULENCE MODEL IN OPENFOAM

Hrvoje Jasak[1,2], Mirza Popovac[3] and Henrik Rusche[4]

[1] Faculty of Mechanical Engineering and Naval Architecture, University of Zagreb, Ivana Lučića 5, 10000 Zagreb, Croatia, e-mail: {hrvoje.jasak, zeljko.tukovic, damir.rigler}@fsb.hr
[2] Wikki Ltd, 459 Southbank House, SE1 7SJ, London, United Kingdom, e-mail: h.jasak@wikki.co.uk
[3] AIT Austrian Institute of Technology GmbH, Vienna, Austria, e-mail: Mirza.Popovac@ait.ac.at
[4] Wikki GmbH. Görgesstrae 24, 38118 Braunschweig, Germany, e-mail: h.rusche@wikki-gmbh.de

Key words: *Continuous Adjoint, Shape Derivative, Cell-centred Finite Volume Method, RANS, Adjoint Wall Functions*

AbstractIn adjoint-based sensitivity simulations based on the continuous adjoint equations on industrial geometries two main problems arise. Firstly, the formulation of the continuous adjoint equation set must be consistent with the physics of the problem in order to reliably capture the shape gradient for further use in optimisation. Giannakoglou and co-workers have recently shown that for Reynolds Averaged Navier-Stokes equations this should involve the solution of the adjoint turbulence model, since the established practice of "frozen turbulence" in adjoint equations leads to inaccurate shape derivative. Secondly, for accurate shape derivative both the forward and adjoint equation set need to be solved to a high tolerance and typically require meshes of very high quality: a local numerical error or lack of convergence in parts of domain may seriously pollute the adjoint model solution and the shape derivative. To make the problem more difficult, adjoint equation sets, have proven difficult to solve to high accuracy, bringing into doubt the usefulness of the method in shape optimisation. In this paper we shall present the implementation of the turbulent incompressible steady equation set for the continuous adjoint using the adjoint k-epsilon turbulence model with wall function near-wall treatment in OpenFOAM. Shape derivative results for the adjoint k-epsilon model will be compared with the frozen turbulence approach on a series of complex geometries. Particular attention is given to the stability of implementation of the adjoint flow boundary conditions, which have proven to be the main factor for poor stability and rate of convergence of early simulations. Stabilised implementation of adjoint boundary conditions for the flow uniformity and minimum dissipation objective will be presented in detail.

REFERENCES

[1] C. Othmer *A continuous adjoint formulation for the computation of topological and surface sensitivities of ducted flows*, Int. J. Numer. Meth. Fluids **58**, 861–877, 2008.

[2] A.S. Zymaris, D.I. Papadimitriou, K.C. Giannakoglou, C. Othmer *Adjoint wall functions: A new concept for use in aerodynamic shape optimization*, J. Comp. Physics. **229**, 5228–5245, 2010.