VI International Conference on Adaptive Modeling and Simulation
ADMOS 2013
J. P. Moitinho de Almeida, P. Díez, C. Tiago and N. Parés (Eds)

DEVELOPMENT OF A 3D NAVIER-STOKES DG SOLVER FOR ADAPTIVE SCHEME AND MODELLING

VINCENT COUAILLIER, FLORENT RENAC, MARTA DE LA LLAVE PLATA EMERIC MARTIN, JEAN-BAPTISTE CHAPELIER, MARIE-CLAIRE LE PAPE

Onera The French Aerospace Lab
F-92322 Châtillon, France
vincent.couaillier@onera.fr

Keywords. Discontinuous Galerkin method, hybrid mesh, turbulent flow, High-order discretization methods

Abstract. Over the years, the development of new and increasingly powerful CFD simulation tools has helped manufacturers in the aerospace industry gain a greater understanding of the operating performance of their products. This has allowed them to progress through the design life cycle in a more timely and cost-effective manner by supplementing or replacing experimental testing with CFD computations.

The industrial demand for CFD predictions at an ever-increasing level of detail is the driving force for the development of highly accurate simulation techniques able to predict not only overall flow features, but also local values of the quantities of interest. This will allow engineers to expand the range of flow conditions to which CFD can be applied.

Nevertheless, most of the industrial CFD codes used today are based on second-order methods, which appear not to be sufficiently accurate to reach these goals. With the aim of overcoming the limitations of second-order approaches, Onera has launched the development of a DG solver called Aghora [1], [2]. The main goal is to develop a new demonstrator able to integrate efficient high-order schemes based on Discontinuous Galerkin methods using hybrid type meshes (tetrahedral, hexahedra, prisms and pyramids) for the simulation of turbulent flows using different levels of modelling, i.e. RANS [2], LES, hybrid RANS/LES and DNS. Adaptive techniques based on local HPM methods (H for grid, P for accuracy of shape function, M for model) will be used in order to represent accurately the flow physics.

However, these methods require the solution of very large discrete systems. This leads to long execution times and high memory requirements. Consequently, in order to tackle such challenges, the project focuses on the implementation of efficient algorithms for modern multi-core architectures with highly-scalable parallel strategies. The paper will present the status of the modal DG schemes implemented in Aghora as well as representative test cases illustrating the adaptability capacity of DG methods.

In order to illustrate the interest of DG approach with high order polynomial degrees, a convergence analysis in terms of number of Degrees of Freedom (DOFs) is presented hereafter. The calculations are performed with the compressible Navier-Stokes equations for the simulation of a manufactured solution of a Poiseuille flow (M=0.1). Fig. 1 shows the evolution of the L^2 norm of the error vs. the characteristic size of the elements h, represented here by the Degrees of Freedom. The slopes obtained by the computations, compared to the theoretical slopes,

demonstrate the effective accuracy of the implemented Navier-Stokes DG scheme in Aghora.

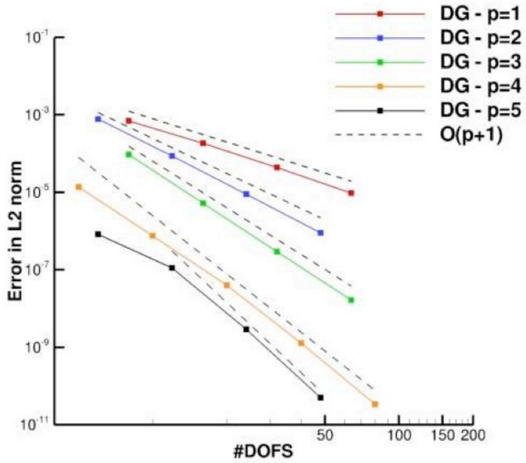

Figure 1: Convergence analysis in DoFs – Manufactured solutions for Navier-Stokes equations Aghora (laminar flow) - L2-norm on the error between numerical and exact solutions

Mesh convergence analysis (*h*) and polynomial degree convergence analysis (*p*) for turbulent flow computations will be presented. Fig. 2 illustrates the solution of a transonic flow around the Onera M6 wing for a DGP1 computation performed with the Kω Wilcox model.

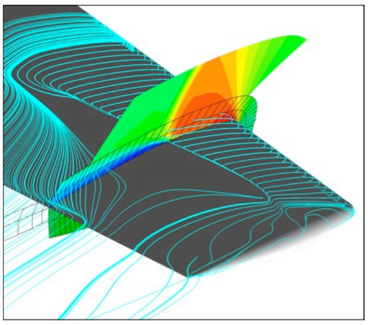

Figure 2: Turbulent flow around the Onera M6 wing – DGP1 computation with a RANS/Kω model

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