Multidimensional Characteristics Non Reflecting Boundary Conditions With HO DG methods

Vincent Couaillier, Marta de la Llave Plata, Florent Renac
Onera The French Aerospace Lab
F-92322 Châtillon, France
vincent.couaillier@onera.fr

Abstract

The development of numerical methods and increasingly available computing power has led engineers to use CFD as an every day tool for component design in aeronautical industry. In particular, problems related to noise generation and propagation are a topic of great importance in most industrial projects. This makes the noise prediction a subject of major interest, especially to the aerospace industry.

However, most of the industrial CFD codes used today for the solution of the Navier-Stokes equations are based on second-order methods, which appear not to be sufficiently accurate to predict noise radiation. As a consequence, a number of various strategies have been developed in order to couple low-order (generally second-order) non-linear solvers used for the simulation of noise source generation induced by turbulence, rotating shock waves, etc, …, close to the bodies with propagation linearized solvers using high-order methods in the far field region.

With the aim of overcoming the limitations of second-order approaches, Onera has started the development of a DG solver called Aghora [1],[2],[3]. The main goal is to develop a new demonstrator able to integrate efficient high-order schemes based on Discontinuous Galerkin methods using hybrid meshes (tetrahedra, hexahedra, prisms and pyramids) for the simulation of turbulent flows using different levels of modelling. 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.

Another topic of major importance for the simulation of noise propagation simulations concerns the implementation of accurate non reflecting conditions at the artificial boundaries. In this paper we will present a multidimensional non-reflecting boundary condition treatment based on a DG discretization scheme for the non-linear Navier-Stokes equations. The methodology is based on a characteristic relation approach in which the projection vector is chosen to be by the local normal to the wave front instead of the normal to the boundary [4]. This wave propagation direction is evaluated at the boundary using a normalized pressure gradient.

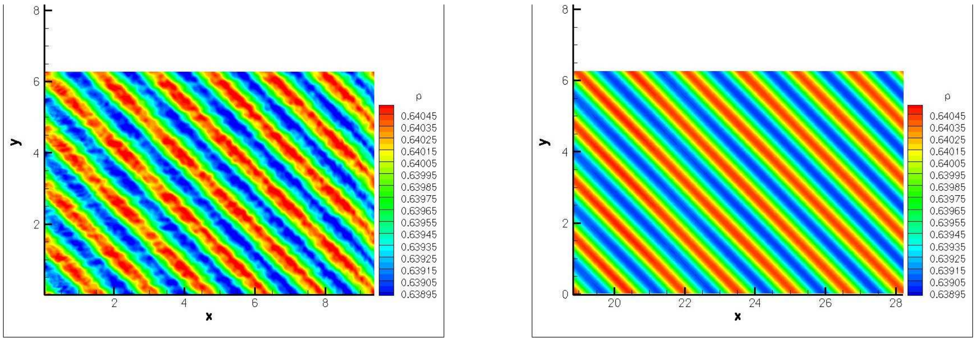
The DG methods, in addition to their properties of accuracy for wave propagation simulation, allow the precise evaluation of the gradient with respect to other methods. This is due to the fact that the formal order of accuracy is conserved locally throughout the domain, and in particular at the boundaries, which is not the case in most finite volume or finite difference schemes.

Oblique Plane wave

In order to demonstrate the capacity of the new non reflecting boundary condition treatment, we consider a test case which was used in the European Project TurboNoiseCFD. The numerical simulation is performed with the non-linear Euler equations for a two-dimensional plane wave propagating obliquely to the boundary. In this case the static pressure imposed downstream is a function of time t and of the coordinate y:

$$P_S(t) = P_{Sm} + \Delta P \sin\left(2\pi\left(\frac{t}{T} + \frac{y}{L_y}\right)\right)$$

The outlet average static pressure P_{Sm} is obtained from the Mach number equal to $M = 0{,}4$ and the stagnation pressure $Ptot = 101\,KPa$. The amplitude ΔP is equal to $89\ Pa$ and the period T is defined as: $T = N\Delta x / c$, where c is the speed of sound and Δx the space step (here $\Delta x = \Delta y$). The length L_y is defined as: $L_y = N\Delta y$, being N the wave number. The calculations presented here were carried out with $N = 20$, and corresponds to the propagation of a wave inclined with 45° in the grid.



nref_cell NREF_grdp

Fig. 1 : Numerical simulation of an oblique plane wave propagation :

Two characteristic non reflecting boundary conditions presented in Fig. 1, have been applied at the inlet boundary: the classical condition using the cell face (nref_cell) and the new one based on the pressure gradient (nref_grdp). The improvement of the solution obtained by using the new non reflecting treatment is clearly observed. Results from additional tests will be presented in the final version of this paper as for example a cylindrical wave problem.

References

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