PROPAGATION OF SOUND WAVES BY LINEARIZED EULER EQUATIONS USING RESIDUAL DISTRIBUTION SCHEMES

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In computational aeroacoustics (CAA) the Linearized Euler Equations (LEE) are used to model sound propagation in steady, non-uniform flows. As part of a more extensive project, work on an LEE solver for COOLFluiD, the multiphysics simulation software of the VKI, had already been started before. However, the implementation of proper boundary conditions for the LEE module was still missing from COOLFluiD. The main problem caused by using improper boundary conditions at inflow/outflow boundaries is that outgoing acoustic waves are partially reflected back into the domain and spoil the solution. The main goal of this project was to implement two new kinds of boundary treatment for the LEE solver, in order to reduce unphysical reflections at the boundaries.

As a first step it was decided to implement a so-called damping zone. The damping zone is not a boundary condition in the strict sense. It is applied to those regions of the computational domain immediately adjacent to the boundaries. Here, an additional source term in the LEE is activated which works to attenuate all types of outgoing and incoming acoustic waves. If applied properly it helps to reduce the reflection of such outgoing waves close to the boundaries, while interfering as little as possible with the solution in the interior, unmodified part of the domain. A parametric study was conducted on two different test cases to obtain a better understanding of the behavior of the damping zone. It was concluded that this approach can be useful in suppressing the appearance of reflected waves, but is comes with an additional computational cost, because of the increased mesh size needed to accommodate the damping zone.

The second part of the project dealt with the implementation of so-called 1D-characteristic boundary conditions. They have the peculiarity that one does not impose specific values of the solution at the boundaries. Instead, the amplitude of waves expressed in terms of the characteristic variables entering the domain normal to the boundary is specified. This type of boundary condition is well-posed in the mathematical sense, but also provides a good approximation of the physical behavior at the boundaries. In particular, both a subsonic outflow and inflow boundary condition were implemented. They were tested using a classic benchmark case for aeroacoustic simulations. Finally, also a reflective wall boundary condition was implemented and tested. A comparison of using an ill-posed boundary condition (left) and the newly developed 1D-characteristic boundary condition (right) is shown below.

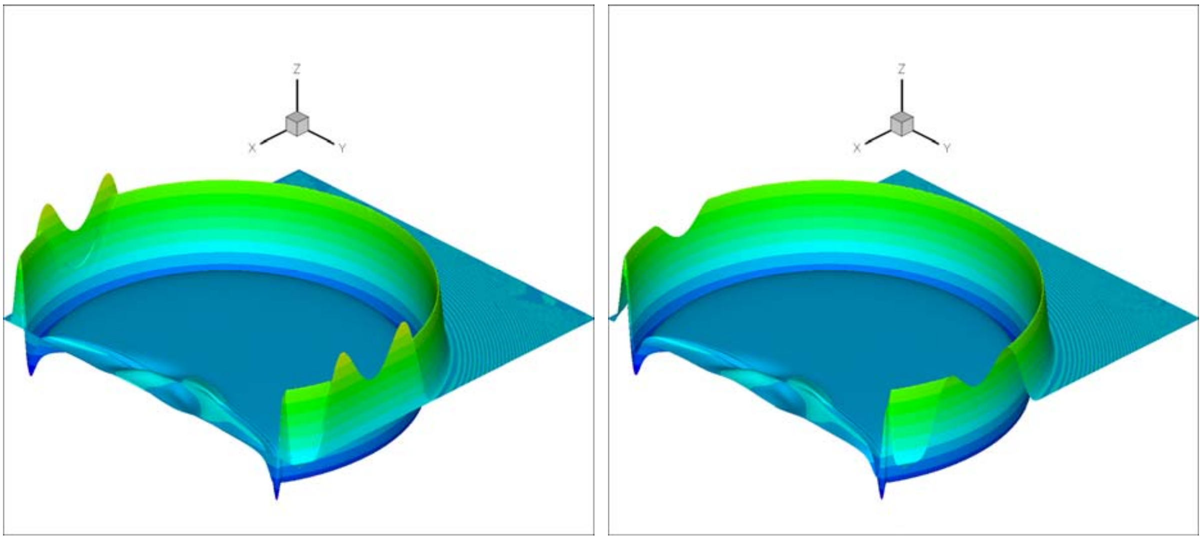

Figure 1: Acoustic pulse in uniform flow using Ill-posed boundary condition (left) and well-posed boundary condition (right) at domain boundaries