Efficient and non-reflecting far-field boundary conditions for incompressible flow calculations

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ABSTRACT

Traditionally, the artificial compressibility (AC) method of Chorin is used for simulation of low-speed and incompressible flows. In this method, the difficulty of continuity and momentum equations decoupling is removed by adding an artificial time derivative of pressure to the continuity equation. For the first time, a fully two-dimensional upwind scheme was presented for AC equations by using characteristic structure of equations by the authors. In this paper, a new remote boundary calculation method is presented by using the idea of characteristics for these equations. Instead of simple boundary conditions which usually are employed for incompressible flows, the flow quantities at the far-field boundaries are evaluated by compatibility relations of characteristic equations. This is implemented by assuming a row of ghost cells outside of the far-field boundary and using the flux calculation method based on characteristics similar to the inside of computational domain. The idea in conjunction with multidimensional characteristic based scheme was tested for incompressible flow around circular cylinder in comparison with conventional far-field boundary condition and showed good improvements in the terms of accuracy and convergence speed.

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1. Introduction

The method of solving low-speed or incompressible flows by the artificial compressibility (AC) correction was first introduced by Chorin [1] in obtaining steady state solutions. In this method, a time derivative of the pressure is added to the continuity equation and a coupling system of equations for pressure and velocity is obtained. Due to coupled nature of AC equations (like compressible flow equations), it is possible that the incompressible flow equations can be solved by similar methods which are used in the case of compressible flows. By reviewing the literature in this case, it is found that different schemes for discretization of AC equations have been used. They include central schemes [2], Godunov-type schemes [3–6] or characteristic based schemes [7–12].

By using the multidimensional characteristic structure of AC equations and their compatibility relations, the first multidimensional characteristic based scheme (MCB) for incompressible flows was introduced by the author [13,14]. Because of using multidimensional characteristic paths which the information is propagated along them, the MCB scheme takes into account the real two-dimensional nature of flow and presents remarkable superiority in the case of numerical accuracy and convergence speed [13,14].

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