2D Galerkin finite volume solution of steady inviscid artificial compressible flow on triangular meshes

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Abstract

Contribution to develop an accurate and efficient incompressible two dimensional flow solver is presented in this paper. The incompressible form of the mass and momentum conservation equations are solved in a coupled manner using artificial compressibility Method. In this work, two dimensional incompressible forms of the continuity and momentum equations are converted to discrete form by application of Galerkin Finite Volume algorithm on triangular unstructured meshes. Using triangular unstructured meshes provides great flexibility for modeling the flow in geometrically complex domains. In order to verify the accuracy of the numerical model, computed results are compared with the analytical solutions of potential flow problems.

Keywords: Artificial Compressibility Technique, Galerkin Finite Volume Method, Steady Incompressible Inviscid Flow, Triangular Unstructured Meshes.

1. INTRODUCTION

The availability of high performance digital computers and development of efficient numerical models techniques have accelerated the use of Computational Fluid Dynamics. The control over properties and behavior of fluid flow and relative parameters are the advantages offered by CFD which make it suitable for the simulation of the applied problems. Consequently, the computer simulation of complicated flow cases has become one of the challenging areas of the research works. In this respect, many attempts have been made to develop several efficient and accurate numerical methods suitable for the complex solution domain. The assumption of incompressibility is valid for common civil and environmental engineering problems. For the incompressible flow condition, the time derivative of the density vanishes from the continuity equation. If the boundary layer thickness is negligible in the flow domain, the inviscid form of the equations of motion can be used in desired dimensions. These set of equations which consists of time-independent velocity and the time-dependent equations of motion, mathematically represent the behavior of fluid flow. For steady state problems, adding a pseudo time derivative of pressure to the continuity equation removes the troublesome problem of coupling pressure-independent equation of continuity to the pressure-dependent equations motion. This method has been widely applied, mostly with the use of explicit schemes. The computational procedure is to choose the pressure field such that continuity is satisfied at each time-step. This procedure normally requires a relaxation scheme iterating on pressure until the divergence free condition is reasonably realized. The method using artificial compressibility was initially proposed by Chorin to achieve an efficient computation. Note that, when the solution converges to the steady state condition, the pseudo time derivative tends to zero and the computations results in the incompressible flow solution [1].

In present work, the Galerkin Finite Volume Method is used to derive the discrete formulas of the governing equations on triangular meshes. The problem of growing up numerical errors, which usually disturbs the explicit solution of the formulations are overcome by adding artificial dissipation terms suitable for the triangular meshes. These extra terms are used to damp out the unwanted errors and stabilize the numerical solution procedure while preserving the accuracy of the solution. In order to increase the computational efficiency, some numerical technique such as Runge-Kutta multi-stage time stepping, residual smoothing and the edge-base algorithm are applied. In this paper, the described Galerkin finite volume algorithm, in which, artificial dissipation for triangular meshes are utilized for stabilizing of the explicit solution of incompressible steady state flow cases is described, and the accuracy of model is assessed for various flow conditions.