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Comparison Between High order Schemes Related Convection Diffusion of Navier-Stokes Equations

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Abstract

In this paper, the cell-centered finite volume method with unstructured collocated meshes is applied to compare the accuracy of four schemes, the DC-CD, DC-SO, DCQ-QUICK and SGSD schemes are implemented for discrete convection. According to compare the numerical solutions with the analytical solutions, the impact of different formats for discrete numerical model calculation results are discussed. The results show the DCQ-QUICK scheme has the robust, accuracy and excellent convergence. Moreover, the DCQ-QUICK scheme is effective and trustable for solving complex regional problems.

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Keywords: unstructured; finite volume; DCQ-QUICK scheme Introduce

1. Introduction

The last two decades have witnessed a great advance in the area of computational fluid dynamics, and the motion law of viscous flow could be described by Navier-Stokes equations which to discretize the convective term is a big challenge [1]. Due to the nonlinearity of first derivative term of momentum equation(that is nonlinear of the convection coefficient), it has important theoretical and practical significance to look for a class of high precision and rapid convergence speed and strong robustness discrete format.

At present, the classic first upwind difference scheme (FUD)with good stability, which induces serious numerical dissipation in application. The central difference scheme(CDS) [3] generally satisfies the conditional stability, but

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when the Péclet number of grid exceeds the critical value that can lead to the iteration divergence. In addition, the power-law scheme [1] and [4] exponential scheme improve the shortages of CDS. But they still have great limitations in terms of stability and calculation precision. In recent years, composite difference schemes with the well stability and high precision are proposed by Darwish[5], while it is mainly due to less economy computation. However, the deferred correction theory [6] is successful in discretizing high scheme for convection.

In this paper, the cell-centered finite volume method with unstructured collocated meshes is applied for solving the Navier–Stokes equations. The computation discrete of the convection flux uses three high order schemes (deferred correction center difference (DC-CD), deferred correction symmetry and odd(DC-SO), deferred correction quasi-quadratic upwind interpolation of convective(DCQ-QUICK)) which are coupled with deferred correction method and high order scheme SGSD(stability guaranteed second-order difference) separately. We consider two types of numerical tests to examine the performance of different schemes for discrete numerical model, including a cavity driven flow with high Reynolds number and flow around a cylinder. By numerical comparison with the analytical solutions discussed the impact of different schemes for discrete numerical model calculation results. The results agree well with the analytical results reported in the previous studies. In additional.

2. Governing equations

Two dimensional steady incompressible viscous fluid equations are adopted, the continuity and momentum equations of motion can be written as follows:

$$\nabla \cdot \mathbf{u} = 0 \tag{1}$$

$$\nabla \cdot (\rho \mathbf{u} \phi) = \nabla \cdot (\Gamma \nabla \phi) + S_\phi \tag{2}$$

where $\boldsymbol{u} = (u, v)$ is velocity of fluid, ρ is the fluid density, a typical representative variable is denoted by ϕ, Γ is the coefficient of diffusion, and S_ϕ is the source term.

In this paper, the finite volume method discretize Eq.(2), triangulation is placed on the computational domain. The f interface of any triangle element p_i of convection denotes C_f then it can be finally written as

$$C_f = \int_{s_f} \rho \mathbf{u} \varphi \cdot d\mathbf{S} \approx (\rho \mathbf{u} \varphi)_f \cdot s_f = F_f \varphi_f \tag{3}$$

where S is a vector of the interface control, F_f is the convection coefficient, ϕ_f represents the average value in f interface of ϕ.

3. The discrete scheme of convection

Different discrete schemes of convection in solving NS equations obtain distinct results, thus that have a significant impact on results of numerical simulations. From (3), different approach arming at ϕ_f will directly affect the accuracy of the final numerical simulation. The discrete schemes of convection will be introduced as follows.

3.1. CD scheme[3] (Center Difference Scheme)

The CD is a second-order approximation of the convection term. The variable values at the interface proposes the values at the center of the adjacent cells based on a linear interpolation method, the equation can be expressed as follows.

$$\phi_f = \omega_1 \phi_j + \omega_2 \phi_i \tag{4}$$