Tech Science Press

ICCES, 2024, vol.30, no.1
DOI: 10.32604/icces.2024.010890

PROCEEDINGS

Accelerating Convergence in Simulating Steady Flows Across All Regimes Using the Improved Discrete Velocity Method with Inner Iteration

Liming Yang[1,*] and Linchang Han[1]

[1]Department of Aerodynamics, College of Aerospace Engineering, Nanjing University of Aeronautics and Astronautics, Yudao Street, Nanjing 210016, China

[*]Corresponding Author: Liming Yang. Email: lmyang@nuaa.edu.cn

ABSTRACT

This work introduces an efficient improved discrete velocity method (IDVM) with inner iteration for simulating steady flows across all flow regimes. Building upon our prior implicit IDVM, this extension achieves a significantly enhanced convergence rate. In the previous method, simultaneous solution of the discrete velocity Boltzmann equation (DVBE) and corresponding macroscopic governing equations was performed. However, the computational cost was primarily driven by the DVBE calculations due to the substantial difference in the number of discrete distribution functions compared to macroscopic conservative variables. Additionally, the convergence rate was influenced by the predicted equilibrium state derived from the macroscopic governing equations' solution. To enhance the accuracy of the predicted equilibrium state for fully implicit discretization of DVBE, an inner iteration is incorporated into the solution of macroscopic governing equations. The flux Jacobian of these equations is evaluated through the difference of numerical fluxes from Navier-Stokes equations, diverging from the Euler equations-based flux splitting method used in the prior implicit IDVM. This refined prediction procedure significantly accelerates computation, particularly in the continuum flow regime. Numerical results demonstrate that, in the continuum flow regime, the presented method exhibits approximately one order of magnitude faster convergence compared to the previous implicit IDVM and one to two orders of magnitude faster than the conventional semi-implicit DVM.

KEYWORDS

Improved discrete velocity method; inner iteration; semi-implicit discrete velocity method; steady flows; all flow regimes

Funding Statement: This work is supported by the National Natural Science Foundations of China (92271103 and 12202191) and the Natural Science Foundation of Jiangsu Province (BK20210273).

Conflicts of Interest: The authors declare that they have no conflicts of interest to report regarding the present study.