Tech Science Press

ICCES, 2024, vol.31, no.1
DOI: 10.32604/icces.2024.012382

PROCEEDINGS

Direct Numerical Simulation for Transition and Turbulence Based on Nonlinear Coupled Constitutive Relation Model

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ABSTRACT

The study of boundary-layer transition and turbulence plays a crucial role in the development and design of high-speed aircrafts. Direct numerical simulation (DNS) is a numerical tool that enables the capture of flow phenomena across all scales, making it highly valuable for investigating the mechanism and process of transition and turbulence. In the DNS community, the prevailing approach involves directly resolving the Navier-Stokes (NS) equations. However, certain high-order effects lie beyond the capabilities of NS models when simulating compressible transition and turbulence under specific circumstances. To address this limitation, we have developed a DNS method of directly resolving the Nonlinear coupled constitutive relation (NCCR) equations in this work. The high-order shock capturing scheme and central difference scheme are employed for spatial discretization, and the third-order total variation diminishing Runge-Kutta method is used for time marching. Moreover, the undecomposed hybrid algorithm is used to solve the nonlinear algebraic equations. Subsequently, the supersonic flat-plate boundary-layer transition and turbulence are simulated by the DNS technology based on NCCR equations. Through these simulations, the insights into the mechanisms of boundary-layer transition are gained and the turbulent statistical characteristics are obtained. The numerical results also demonstrate good agreement with theoretical predictions and previous DNS results based on NS equations, which shows the reliability of the current framework for accurately simulating transition and turbulence.

KEYWORDS

Direct numerical simulations; transition and turbulence; nonlinear coupled constitutive relation

Acknowledgement: The authors are grateful to Prof. Xinliang Li from the University of Chinese Academy of Sciences.

Funding Statement: This research was supported by the National Natural Science Foundation of China (NSFC Grants No. 12002306, No. 92271204, and No. U20B2007).

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