High Performance Computation for DNS/LES

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ABSTRACT

The lecture focuses on high order scheme and parallel computation for direct numerical simulation and large eddy simulation for flow separation, transition, wakes, and flow control. A detailed description is given for several fundamental issues such as high quality grid generation, high order scheme for curvilinear coordinates, CFL condition for complex geometry, relation of pseudo-time marching and Richardson iteration, and high-order weighted compact scheme for shock capturing and shock-vortex interaction. The computation examples include DNS for K-type and H-type transition, DNS for flow separation and transition around airfoil with attack angle, control of flow separation by using paused jets, LES simulation for wakes behind juncture of wing and flat plate with wing tip vortex. For DNS of flow transition on flat plate, the calculation has been well validated including friction coefficients and log law of velocity profile. The direct numerical simulation (DNS) for flow separation and transition around a NACA 0012 airfoil with an attack angle of 4^0 and Reynolds number of 100,000 has been carried out. The details of the flow separation, formation of the detached shear layer, Kelvin-Helmoholtz instability (inviscid shear layer instability) and vortex shedding, interaction of non-linear waves, breakdown, and re-attachment are obtained and analyzed. Though no external disturbances are introduced in the baseline case study, the self-excited mechanism is observed, which may reveal the origin of the disturbance for airfoil with attack angle. The power spectral density of pressure shows the low frequency of vortex shedding caused by the Kelvin-Helmoholt instability dominates from the leading edge to trailing edge. The simulation shows that the nonlinear wave interaction and breakdown is driven by the generation and growth of the stream-wise vortex which leads to the deformation, stretching, and eventually breakdown of the shedding prime vortex. DNS for flow separation control by blowing jets (steady, pulsed, and pitched and screwed jets) is also tested. The effects of unsteady blowing on the surface at the location just before the separation points on the transition and separation are also studied. The separation zone is significantly reduced (almost removed) after unsteady blowing technology is applied. For the case of juncture of wing and flat plate, the wing tip vortex and wakes behind the juncture are well simulated. The computation also shows almost linear growth in efficiency is obtained by using multiple processors.

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EDUCATION

Doctor of Philosophy (December, 1989) , Applied Mathematics, University of Colorado at Denver

Master of Science (1981), Computational Fluid Dynamics, Tsinghua University, Beijing, China

Bachelor of Science (1967), Fluid Mechanics, Tsinghua University, Beijing, China

EXPERIENCE

8/2000-present, Professor, Department of Mathematics, University of Texas at Arlington
9/98-8/2000, Professor and Director of Center for Numerical Simulation & Modeling, Louisiana Tech University
2/96-8/98, Associate Professor, Department of Mathematics and Statistics, Louisiana Tech University
1/90-1/96, Adjunct Professor, Department of Mathematics, University of Colorado at Denver

Courses Taught

Calculus, Numerical Analysis, Numerical PDE, Computational Fluid Dynamics.

FIELDS OF INTEREST

Multigrid, DNS/LES, CFD, High-order Discretization, Flow Control, Flow Transition and Turbulence.

GRANT HISTORY

4/1/03-4/1/06, ONR Principal Investigator, Project Title: LES for near field wakes behind juncture of wing and plate, Grant No. N00014-03-1-0492 for $179,997.

6/17/03-3/31/04, NASA Langley Principal Investigator, Project Title : Numerical Simulation of Laminar-Turbulent Transition in a Compressible Boundary Layers, Sole Source Purchase Order No. L-16516 for $39,998.

7/01-9/02, Rockwell International Principal Investigator, Additional Funding, Project Title: Advanced Cooling Technology, Grant No. B1U442201 and B1U442201 for $83,358.55.

5/21/00-1/21/01, NASA Langley Principal Investigator, Project Title : Numerical Simulation of Laminar-Turbulent Transition in a Subsonic Boundary Layers, Sole Source Purchase Order No. L-14360 for $24,999.

12/00 - 12/03 US Air Force Principal Investigator, Project Title: Parallel Multigrid DNS/LES Methods for Time-Dependent Compressible Turbulent Flow Around Simplified Air Force Vihecles, Grant No. F49620-01-1-0065 for $250,000.

12/00 - 12/01 US Air Force Principal Investigator, Project Title: Proposal for AFOSR Sponsorship to the Third AFOSR International Comference on DNS/LES, Grant No. F49620-01-1-0065 for $15,000.

10/00 - 06/01, US Navy Principal Investigator, Project Title: Efficiency Improvement for IFLOW RANS Code, Grant No. N00167-00-M-0631 for $60,000.

3/00 - 3/01, DoD DURIP (Defense University Reseach Instrument Program) Principal Investigator, Project Title:Upgrade of the Computing and Visualization System for DNS/LES Resarch, Grant No. F49620-00-1-0220 for $400,000.

Other 25 research grants have been received since 1990 and the total amount is $4,280,490.

PUBLICATIONS

[1] Direct numerical simulation for flow separation control with pulsed vortex generator jets, AIAA Paper 2003-0611, 41st AIAA Reno Conference, Jan. 6-9, 2003, with Li Jiang.
[2]Weighted Compact Scheme for Shock Capturing, International Journal of Computational Fluid Dynamics, Vol. 15, pp. 147-155, 2001, with Jiang, L. and Shan, H. [3] Numerical Investigation of Compressible Separated Flow around a NACA 0012 Airfoil at 12 Degree Angle of Attack, International Journal of Computational Fluid Dynamics , Vol. 9, No. 2, pp84-92, 2000, with Shan, H. and Jiang, L.
[4] Large eddy simulation of flow transition in a compressible flat-plate boundary layer at Mach number 4.5, International Journal of Computational Fluid Dynamics, Vol. 13, pp25-41, 1999, with Shan, H. and Jiang, L. [5] Direct numerical simulation of leading edge receptivity in a flat-plate boundary layer, International Journal of Computional Fuild Dynamics, Vol 3, pp470-480, 1999, with Shan, H. and Jiang, L.
[6] Study of flow transition in a supersonic flat-plate boundary layer: Large eddy simulation and validation, International Journal of Computational Fluid Dynamics, Vol 8, pp208-219, 1999, with Shan, H. and Jiang, L. [7] Direct numerical simulation of three-dimensional flow around a Delta wing, AIAA Paper 2000-0402, AIA Reno Meeting, Jan., 2000, with Shan, H. and Jiang, L.

Another 75 papers and books have been published in professional journals or conference proceedings.