

非正交格點系統的壓縮流場之紊流模式研究

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摘要

本文主要目的是應用CFD(computational fluid dynamics)數值模擬方法，來探討非正交格點系統的壓縮流場之紊流模式。為了能更準確的模擬複雜的幾何形狀，在此採用三種不同的楔形角(wedge angle)來進行流場的分析。為了能充分瞭解震擊波(shock waves)及層流次層(viscous sublayer)上的變化，楔形角的頂端及近牆處需特別處理，數值計算難度極高，所以在格點的產生上極為重要。本文在層流流場中採用有限差分法(finite difference method)、LU Scheme及MUSCL Scheme；在紊流流場中則是使用中央差分法(central difference method)、顯式法(explicit)、LU Decompositions疊代求解每一時間步驟(time steps)的紊流黏滯係數，如此即可將紊流效應加入原流場的統御方程式之中，使分析的流場成為一紊流流場，得到紊流效應的數值結果。幾何形狀為二維非正交楔形的流場，並以邊牆函數(wall function)為本流場邊界上之處理。最後，將數值模擬的速度、溫度等流場性質與理論流場性質比較，並針對震擊波的產生點做一比較，其所得的結果相當接近。

關鍵詞：壓縮流場；計算流體力學；非正交格點系統；紊流效應；紊流模式；震擊波

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參考文獻

- [1] Cebeci, T., et al., "A General Method for Calculating Three- Dimensional Compressible Laminar and Turbulent Boundary Layer on Arbitrary Wings", NASA-CR-2777, 1997.
- [2] Baldwin, B.S. and Lomax, H., "Thin Layer Approximation and Algebraic Model for Separated Turbulent Flows", AIAA Paper No. 78-257, Jan, 1978.
- [3] Agarwal, R.K. and Bower W.W., "Navier Stokes Computations of Compressible 2D Impinging Jet Flowfield Using a Two Equation Turbulent Model", AIAA Paper, 80-0007, 1980.
- [4] Agarwal, R.K. and Bower W.W., "Navier Stokes Computations of Turbulent Compressible 2D Impinging Jet Flowfield", AIAA J., Vol.20, No.5, pp.577-584, 1982.
- [5] Looney, M.K. and Walsh, J.J., "Mean Flow and Turbulent Characteristics of Free and Impinging Jet Flows", J.F.M., 147, pp.397-429, 1984.
- [6] Launder, B.E. and Spalding, D.B., "The Numerical Computation of Turbulent Flows", Computer Methods in Applied Mechanics and Engineering Vol.3, pp.269-280, 1974.
- [7] Launder, B.E., Pridden, C.H., and Sharna, B.I., "The Calculation of Turbulent Boundary Layers on Spinning and Curved Surfaces", ASME J., Fluid Eng, Vol.99, pp.231-239, 1997.
- [8] Lin, R.S. and Chang, K.C., "Predictions of Free Jet Flow Field Using Various Turbulence Models", CSME J., Vol.10, No.3, pp.159-167, 1989.
- [9] Yu, etc. "Three-Dimensional Calculation of Supersonic Reacting Flows Using an LU Scheme", Sverdrup Technology, Inc. NASA Lewis Research Center Cleveland, Ohio, 1989, 7.
- [10] Demirzic, I.A., "A finite volume method for computation of fluid flows in complex geometries", PhD thesis, University of London, 1982.
- [11] Rhie, C.M. and Chow, W.L., "Numerical study of turbulent flow past an airfoil with trailing edge separation", AIAA J., Vol.21,

pp.1525-1532, 1983.

- [12]魏大鈞, “ 壓縮流場的紊流模式研究 ”, 大葉大學碩士論文, 1998.
- [13]邱聖葵, “ 壓縮流場的低雷諾數紊流模式分析 ”, 大葉大學碩士論文, 1999.
- [14]Chang, K.C., Hsieh, W.D., and Chen, C.S., “ A Modified Low- reynolds-Number Turbulence Model Applicable to Recirculation Flow in Pipe Expansion ”, ASME Journal of Fluids Engineering , Vol.117,pp.417-423,1995.
- [15]朱思文, “ 低雷諾數壓縮流場的紊流模式之改進 ”, 大葉大學碩士論文, 2000.
- [16]Gordon, Sandford, and McBride, Bonnie J., “ Computer Program for the Calculation of Complex Equilibrium Compositions, Rocket Performance, Incident and Reflected Shocks, and Chapman- Jouguet Detonations ”, NASA SP-273 Interim Revision, 1976.
- [17]Reid, R.C., Prausnitz, J.M., and Sherwood, T.K., “ The Properties of Gases and Liquids ”, McGraw-Hill Publishing Co., New York, NY, 1977.
- [18]Reynolds, W.C., “ Computation of Turbulent Flows ”, 1976.
- [19]Hoffmann, Klaus A., and Chiang, Steve T., “ Computational Fluid Dynamics for Engineers-Volume ”, 1993.
- [20]Yang, S.L., “ Development and Application of Computational Methods in Fluid Dynamics ”, July 1995.
- [21]Amsden, A.A., O ' Rourke, P.J., and Butler, T.D., “ Turbulent Boundary Layer Treatment in KAVA- ”.
- [22]莊書豪、鄭東辰, “ 壁面效應對翼剖面黏性流場之影響分析 ”, 中國機械工程學會第十屆學術研討會論文集, 1993.
- [23]Shapiro, A.H., “ The Dynamics and Thermodynamics of Com- pressible Fluid Flow ”, New York, 1953.
- [24]James, E.A., John, “ Gas Dynamics ”, pp.384-395, 1985.
- [25]陳偉雄, “ 紊流迴流近牆區模擬傳輸過程之研究 ”, 成功大學碩士論文, 1995.
- [26]陳伯欽, “ 運用非正交非交錯網格於複雜幾何形狀流場 ”, 清華大學碩士論文, 1994.
- [27]蘇泓瑜, “ 運用非正交非交錯網格方法配合雷諾應力模式於複雜幾何形狀流場 ”, 清華大學碩士論文, 1996.
- [28]吳文忠, “ 超音速空穴流抑制壓力震盪之數值研究 ”, 成功大學碩士論文, 1994.
- [29]謝其源、溫志湧, “ 前翼尾翼組合的地效氣動力分析 ”, 交通部計畫結案報告, 1996.
- [30]Lin Heng, and Chieng Ching Chang, “ Efficient Reynolds- Averaged N-S Solver with Two-Equation Model of Turbulence ”, Dissertation for Doctor of Philosophy, Graduate School of Power Mechanical Engineering, National Tsing Hua University, 1992.
- [31]Chun Chuang Che, and Chieng Ching Chang, “ A Comparative Study of Higher-Order Turbulence Models on the high Speed Separated Flows ”, Dissertation for Doctor of Philosophy, Graduate School of Power Mechanical Engineering, National Tsing Hua University, 1994.
- [32]Tokunaga H., Ichinose K., and Satofuka N., “ Direct Simulation of Transient Turbulent Flows Using Generalized Method of Lines ”, FED-Vol. 117, Advances in Numerical Simulation of Turbulent Flows ASME, 1991.
- [33]Kato Chisachi, and Ikegawa Masahiro, “ Large Eddy Simulation of Unsteady Turbulent Wake of a Circular Cylinder Using the Finite Element Method ”, FED-Vol.117, Advances in Numerical Simulation of Turbulent Flows ASME, 1991.
- [34]Jameson Antony, and Yoon Seokkwan, “ Lower-Upper Implicit Schemes with Multiple Grids for the Euler Equations ”, Vol.25, No.7, July 1987.
- [35]Jameson, A., Schmidt, W., and Turkel, E., “ Numerical Solution of the Euler Equations by Finite Volume Methods Using Rung-Kutta Time Stepping Schemes ”, AIAA paper 81-1259, AIAA Fluid and Plasma Dynamics Conference, Palo Alto, June 1981.