低雷諾數壓縮流場的紊流模式之改進

朱思文、謝其源

E-mail: 9612396@mail.dyu.edu.tw

摘 要

本文主要是應用CFD(computational fluid dynamics)的方法，將低雷諾數壓縮流場的紊流模式與高雷諾數壓縮流場的紊流模式做一比較。在可壓縮流場的計算上，為了能準確的預估邊界層內複雜的情況，需選用適用性更廣的低雷諾數紊流模式，於是就採用了Chang and Hsieh 所發展出強健式低雷諾數紊流模式來進行流場的模擬。為了能充分解析層流次層（viscous sublayer）的變化，近壁處的格點分佈需非常細密，數值計算難度極高，所以在數值方法的選取及格點的產生極為重要。於數值方法中，本文在層流流場中選用了MUSCL Schem、LU-SSOR、時間前進法（time marching）、有限體積等數值方法；在紊流流場中使用有限差分法，顯式法（explicit）疊代求解每一時間步驟(time steps)，如此即可將紊流效應加入原流場的統御方程式之中，得到紊流效應的數值結果。而格點製作上，本文的幾何形狀為一個二維平板流場；格點採用正交交錯H型格點。因低雷諾數紊流模式的收斂情況需視邊界層內的格點數何近壁處的格點距離而定，所以需做疏密不同格點來比較，以期能找出於馬赫數大（超音速流場）也能收斂容易的格點。再將數值模擬的速度、阻力係數等流場性質與實驗值互相比較，希望能夠得到較好、令人滿意的低雷諾數壓縮流場的紊流模式。

關鍵詞 : 壓縮流場 ; 紊流 ; 強健式低雷諾數紊流模式 ; 紊流模式

目錄

參考文獻

[1] 魏大鈞, “ 壓縮流場的紊流模式研究 ” ,大葉大學碩士論文, 1998.

[2] 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.

[3] Cebeci,T.,etc., “ A General Method for Calculating Three-Dimensional Compressible Laminar and Turbulent Boundary Layer on Arbitrary Wings ” , NASA—CR—2777, 1997.

[4] Baldwin,B.S. and Lomax,H., “ Thin Layer Approximation and Algebraic Model for Separated Turbulent Flows. ” AIAA Paper No.78-257.Jan.1978.

[5] Agarwal,R.K. and Bower,W.W., “ Navier Stokes Computaions of Compressible 2D Impinging Jet Flowfield Using a Two Equation turbulent Model ” , AIAA paper,80-0007,1980.

[6] Agarwal,R.K. and Bower,W.W., “ Navier Stokes Computaions of Turbulent Compressible 2D Impinging Jet Flowfield ” , AIAA J,Vol.20,No.5,PP.577-584,1982.

[7] 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.

[8] Launder,B.E. and Spalding,D.B., “ The Numerical Computation of Turbulent Flows ” , Computer Methods in Applied Mechanics and Engineering Vol.3,pp269-280, 1974.

[9] Lauder,B.E., Prdden,C.H. and Sharna,B.I., “ The Calculation of Turbulent Boundary Layers on Spinning and Curved Surfaces ”, ASME J,Fluid Eng,Vol.99,pp231- 239,1997.
[10] Lin,R.S. and Chang,K.C., “ Predictions of Free Jet Flow Field Using Varios Turbulence Models ”, CSME J., Vol.10,No.3,pp.159-167,1989.
[11] 伍湘杰、廖祥旭、苗君易、周榮華, “ 紊流效應對渦輪機串 聯葉片邊界層發展之影響 ”,1995.
[12] Yu,etc. “ Three-Dimensional Calculation of Supersonic Reacting Flows Using an LU Scheme ”, Sverdrup Technology,Inc.NASA Lewis Research Center Cleveland, Ohio,1989,7.
[13] Degani,D. and Schiff,L.B., “ Computation of Supersonic Viscous Flows Around Pointed Bodies at Large incidence ”, AIAA paper 83-0034,1983.
[14] Launder,B.E. and Sharma,B.I., “ Application of the Energy Dissipation Model of Turbulence to the Calculation of Flow Near a Spinning Disc ”, Letter in Heat and Mass Transfer,Vol.1,No.2,1974,pp.131-138.
[15] Goldberg,U.C., “ Exploring a Three-Equation R-κ-ε Turbulence Model ”, Journal of Fluids Engineering, Vol.118,1996,pp.795-799.
[16] Yakhot,V., Orszag,S.A., Thangam,S., Gatski,T.B. and Speziale,C.G., “ Development of Turbulence Models for Shear Flow by a Double Expansion Technique ”, Phys. Fluids,Vol.4,No.7,1992,pp.1510-1520.
[17] Hirsch,C., “ Numerical Computation of Internal and External Flow ”, John Wiley and Sons Ltd.,Vol.2, 1990, ch.21.
[18] Goldberg,U.C., “ Toward a Pointwise Turbulence Model for Wall-Bounded and Free Shear Flow ”, ASME Journal of Fluids Engineering,Vol.116,No.1,1994,pp.72-76.
[19] Jameson,A., Schmidt,W. and Turkel,E., “ Numerical Solutions of the Euler Equations by a Finite Volume Method Using Runge-Kutta Time-stepping Schemes, ” AIAA Paper 81-1259,1981.
[20] Gordon, S. and McBride,B.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.
[21] Reid,R.C., Prausnitz,J.M. and Sherwood,T.K., “ The Properties of Gases and Liquids ”, McGraw-Hill Publishing Co.,New York,NY,1977.
[22] Reynolds,W.C., “ Compuation of Turbulent Flows ”,1976.
[23] Klaus A.Hoffmann and Steve T.Chiang, “ Computational Fluid Dynamics for Engineers-Volume Ⅱ ”,1993.
[24] Yang,S.L., “ Development and Application of Computational Methods in Fluid Dynamics ”,July 1995.7.
[25] Amsden,A.A., O ’ Rourke,P.J. and Butler,T.D., “ Turbulent Boundary Layer Treatment in KAVA-Ⅱ ”.
[26] 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.
[27] Yoon,S. and Jameson ,A., “ An LU-SSOR Scheme for the Eular and Navier-Stoke Equation, ” AIAA Paper 87-0600, January 1987.
[28] Bussing,T.R. and Murman,E.M., “ A Finite Volume Method for the Calculation of Compressible Chemically Reacting Flows, ” AIAA paper 85-0331.January 1985.
[29] White,F.M., Fluid Mechanics, McGraw-Hill, New York, 1986.
[30] Van Driest , “ Investigation of Laminar Boundary Layer Copressible Fluids Using the Crocco Method ”, NACA Technical Note 2597,1952.
[31] Magid H. Rizk and Donald R.Lovell, “ Euler procedure for Correcting Two-Dimensional Transonic Wind-Tunnel Wall Interference ”,1988.
[32] 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.
[33] 陳伯欽, “ 運用非正交非交錯往格點於複雜幾何形狀流場 ”, 清華大學碩士論文,1994.
[34] Lai Chen Chien and Yiin-Kuen Fuh, “ Pressurd Based Navier-Stokes Calculation for All Speeds Flows ”,第 三屆全國計算流體力學研討會論文集,1995.
[35] Suhas V. Patankar, “ Numerical Heat Transfer and Fluid Flow ”.
[36] Frank M. White, “ Viscous Fluid Flow ”.
[37] Wieselberger C., “ Wing Resistance Near the Ground ”, 1992.
[38] Anon, “ Wind Tunnel Invesigation of Single and Tandem Low-Aspect Ratio Wings in Ground Effect ”,1946.
[39] Lenorovitz,J.M., “ Russians completing New Ground- EffectVehicle ”,1993.
[40] Lange,R.H. and Moore,J.W., “ Large Wing-in-Ground Effect Transport Aircraft ”,1980.
[41] Shigenori Ando, “ Some Thoughts on Power-Augmented-Rem Wing-in-Ground Effect Vehicle ”,1988.
[42] Janes, “ Wing-in-Ground-Effect Craft ”,1992.
[43] Launder,B.E. and Spalding,D.B. “ The Numerical Computation of Turbulent Flow ”,1974.
[44] S.H. Chuang and C.Y. Wei, “ Computations of an Oblique Jet Impingement on a Flat Surface ”,1991.
[45] Yu,S.T., Peer Tsai,Y.L. and Shuen,J.S. “ Three- Dimensional Calculation of Supersonic Reacting Flows Using an LU-Scheme ”, Sverdrup Technology, 1nc. NASA Lewis Research Center Cleveland,Ohio,1989.7.
[46] Wilke,C.R., “ A Viscosity Equation for Gas Mixture ”, J. Chem. Phys.,Vol.18,No.4,Apr.1950,p.517.
[47] Shuen,J.S. and Yoon,s., “ Numerical Study of Chemically Reacting Flow Using an LU Scheme ”, AIAA paper 88-0436, Jan.,1988.
[48] Van Leer,B., “ Flux-Vector Splitting for the Euler Equations ”, Lecture Notes in Physics,Vol.170,1982, pp.507-512.
[49] Van Leer,B., “ Towards the Ultimate Conservative Difference Scheme V. A Second-Order Sequel to Gudonov ’ s Method ”, J. Comput.Phys.,Vol.32,1979, pp.101-136.

[50] 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.
[51] Shuen,J.S., Liou,M.S. and Van Leer, B., " Inviscid Flux-Splitting Algorithms for Real Gases with Non- Equilibrium Chemistry " , J. Cmput. Phy.,1989.
[52] Hsieh,K.C., Shuen,J.S., Peter Tsai,Y.L. and Yu,S.T., " Rplus2D/3D Call " , Sverdrup Technology, Ins., NASA Lewis Research Center Cleveland, Ohio 44135, 1990.3.
[53] Shapiro, A.H., " The Dynamics and Thermodynamics of Compressible Fluid Flow " , New york,1953.