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# 基于放大因子与Spalart-Allmaras湍流模型的转捩预测

# Transition prediction based on amplification factorand Spalart-Allmaras turbulence model

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**中文关键词:** 转捩 放大因子 输运方程 湍流模型 边界层 并行计算

**英文关键词:** transition amplification factor transport equation turbulence model boundary layer parallelized computation

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**中文摘要:**

为了验证放大因子输运方程与Spalart-Allmaras(S-A)湍流模型耦合对转捩现象的模拟精度,选取Schubauer and Klebanoff(S-K)平板、S809低速翼型、30p30n多段翼型以及复杂的三维HiLiftPW-1构型进行自由转捩计算,并将计算结果与实验进行比较分析,其中针对S809算例,还与Langtry-Menter(L-M)转捩模型进行了比较.算例结果表明:放大因子输运方程与S-A湍流模型的耦合能够较好的捕捉转捩位置以及转捩发展过程,对分离泡诱导的转捩的模拟相比L-M转捩模型更精确,转捩位置的捕捉精度提升了10%;对比实验,多段翼转捩位置的捕捉误差最大为6.5%;针对三维高升力增升构型,以实验作为参考,全湍流计算与考虑边界层转捩的对比显示考虑边界层转捩能够更加精确的模拟气动力系数,升力和表面摩擦阻力系数的模拟精度精度提升1%.

**英文摘要:**

To verify the simulation accuracy of current model coupling amplification factor transport equation with Spalart-Allmaras (S-A) turbulence model, Schubauer and Klebanoff flat plate (S-K), S809 low speed airfoil, 30p30n multi-element airfoil and complicated 3-D HiLiftPW-1 configure were selected for free transition calculation, and then, simulation results were compared with experimental results. Separately, current coupling model was compared with Langtry-Menter (L-M)transition model for S809 test cases. Test examples indicate that current coupling transition model can basically capture transition location and transition process, meanwhile, current coupling model performs better than L-M transition model in separated flow transition, and simulation accuracy increases by 10%; the maximum error of multi-element airfoil's transition position simulated is 6.5% compared with experiment data. For three dimensional high-lift configuration, comparison between full turbulence and free transition shows that considering boundary layer transition can simulate aerodynamic force coefficient more accurately and accuracy is promoted by 1%.



**参考文献(共19条):**

[1] Joslin R.Aircraft laminar flow control[J].Annual Review of Fluid Mechanics,1998,30(1):1-29.

[2] Green J E.Laminar flow control-back to the future[R].AIAA-2008-3738,2008.

[3] Greitzer E M,Bonnefoy P A,Blanco D R,et al.*N*+3 aircraft concept designs and trade studies[R].NASA CR-2010-216794,2010.

[4] Bradley M K,Droney C K.Subsonic ultra green aircraft research[R].NASA CR-2011-216847,2011.

[5] Kruse M,Wunderich T,Heinrich L.A conceptual study of a transonic NLF transport aircraft with forward swept wings[R].New Orieans,Louisiana:30th AIAA Applied Aerodynamics Conference,2012.

[6] Langtry R B,Menter F.Correlation-based transition modeling for unstructured parallelized computational fluid dynamics codes[J].AIAA Journal,2009,47(12):2894-2906.

[7] Grabe C,Krumbein A.Extension of $\gamma$-$Re_{\theta t}$ model for prediction of crossflow transition[R].National Harbor,MD:52th Aerospace Sciences Meeting,2014.

[8] Smith A M O,Gamberoni N.Transition,pressure gradient and stability theory[R].Segundo,California:ES 26388,1956.

[9] Ingen J V.A suggested semi-empirical method for the calculation of the boundary layer transition region[R].Netherlands:Delft University of Technology Internal Report UTH-74,1956.

[10] ZHANG Kun,SONG Weiping.Application of the full $e^N$ transition method to the infinite swept-wing\'s transition prediction[J].Journal of North West Polytechnical University,2011,29(1):142-147.

[11] Coder J G,Maughmer M D.A CFD-compatible transition model using an amplification factor transport equation[R].Grapevine,Texas:51st AIAA Aerospace Sciences Meeting Including the New Horizons Forum and Aerospace Exposition,2013.

[12] Drela M,Giles M B.Viscous-inviscid analysis of transonic and low Reynolds number airfoils.[J].AIAA Journal,1987,25(10):1347-1355.

[13] Mack L M.Transition and laminar instability[R].Pasadena,CA:California Institute of Technology,CR-153203,1977.

[14] Langtry R B.A correlation-based transition model using local variables for unstructured parallelized CFD codes[D].Mount Pleasant,MI:Universit┌t Stuttgart,2006.

[15] Somers D M.Design and experimental results for the S809 airfoil[R].NREL/SR-440-6918,1997.

[16] Klausmeyer S M,Lin J C.Comparative results from a CFD challenge over a 2D three-element high-lift airfoil[R]. Hampton,Virginia:NASA Technical Memorandum 112858,1997.

[17] Rumsey C L,Gatski T B,Ying S X,et al.Prediction of high-lift flows using turbulent closure models[J].AIAA Journal,1998,36(5):765-774.

[18] Suluksna K,Dechaumphai P,Juntasaro E.Correlations for modeling transitional boundary layers under influences of free stream turbulence and prssure gradient[J].International Journal of Heat and Fluid Flow,2009,30(1):66-75.

[19] WANG Gang,LIU Yi,WANG Guangqiu,et al.Transitional flow simulation based on $\gamma$-$Re_{\theta t}$ transition model[J].Acta Aeronautica et Astronautica Sinica,2014,35(1):70-79.

**相似文献(共20条):**

[1] 符松,王亮.湍流转捩模式研究进展[J].力学进展,2007,37(3):409-416.

[2] 杨中,杜建一,徐建中.基于湍流模型的转捩流动数值计算研究[J].工程热物理学报,2010(2).

[3] 李广宁,李杰,李凤蔚.S-A湍流模型在N-S方程求解中的应用研究[J].弹箭与制导学报,2006,26(2):1180-1182.

[4] 侯祎华,齐学义,张静,敏政.Spalart-Allmaras湍流模型在混流式长短叶片转轮流场计算中的应用[J].水力发电学报,2010,29(1).

[5] 马威,王丹华,陆利蓬.提高Spalart-Allmaras湍流模型对分离模拟能力的研究[J].航空动力学报,2008,23(8):1474-1479.

[6] 郑健,周长省,鞠玉涛,张家仙.Spalart-Allmaras湍流模型在弧形翼超音速流场数值模拟中的应用[J].重庆工学院学报,2008,22(12):34-39.
[7] 宁方飞,徐力平.湍流模型在内流流场数值模拟中的应用[J].工程热物理学报,2001,22(3):304-306.
[8] 周志军,林震,周俊虎,刘建忠,岑可法.不同湍流模型在管道流动阻力计算中的应用和比较[J].热力发电,2007,36(1):18-23.
[9] 夏刚,程文科,秦子增.Spalart-Allmaras湍流模型在高超声速气动加热计算中的应用[J].国防科技大学学报,2002,24(6):15-18.
[10]何枫,谢峻石,郝鹏飞,姚朝晖.应用S-A模型的自由射流和冲击射流数值模拟[J].推进技术,2001,22(1):43-46.
[11]曹旭,詹浩,叶正寅.基于湍流模型的转捩预测方法研究[J].航空计算技术,2008,38(3):39-41.
[12]杨小权,杨爱明,孙刚.一种强耦合Spalart-Allmaras湍流模型的RANS方程的高效数值计算方法[J].航空学报,2013,34(9).
[13]张玉伦,王光学,孟德虹,王运涛.γ-Re_θ转捩模型的标定研究[J].空气动力学学报,2011,29(3).
[14]王亮,符松.一种适用于超音速边界层的湍流转捩模式[J].力学学报,2009,41(2).
[15]徐星仲,朱斌,蒋洪德.一种新的k方程转捩湍流模型[J].工程热物理学报,1998(1).
[16]王刚,王光秋,王光秋,单肖文.模型的转捩流动计算分析简[J].航空学报,2014,35(1):70-79.
[17]涂国华,燕振国,赵晓慧,马燕凯,毛枚良.SA和SST湍流模型对高超声速边界层强制转捩的适应性[J].航空学报,2015,36(5):1471-1479.
[18]李 楠,倪 原,李聚峰,牛佳慧,田 华.基于Fluent的飞行器气动参数计算方法[J].现代电子技术,2014(16):68-70.
[19]严明,宿兴远,魏然,盛春华.应用改进的低雷诺数湍流模型预测转捩流动[J].航空动力学报,2009,24(12):2683-2688.
[20]杨立,蒋小勤,周福国,杜先之.加热对自然转捩湍斑产生影响的实验研究[J].工程热物理学报,1997(4).