Wilcox Turbulence Modeling For Cfd Solution Manual

Turbulence Modeling for CFDStatistical Theory and Modeling for Turbulent FlowsFundamentals Of Turbulence ModellingTurbulence Modeling for Steady Three-dimensional Supersonic FlowsModeling Complex Turbulent FlowsApplied Computational Fluid Dynamics and Turbulence ModelingTurbulence Modeling for Compressible FlowsTurbulence Modeling for Free-Surface FlowsTurbulence Modeling for Shock Wave/Turbulent Boundary Layer InteractionsProgress in Turbulence Modeling for Complex Flow Fields Including Effects of CompressibilityTurbulence Modeling for Hypersonic FlowsTurbulence ModelingAlgebraic Turbulence Modeling for Unstructured and Adaptive MeshesAtmospheric Turbulence Modeling for Aero Vehicles: Fractional Order FitsAdvanced Approaches in TurbulenceTurbulence Modeling for CFDTurbulence Modelling ApproachesTurbulence Modeling for Hypersonic FlowsThree-dimensional Turbulence Modeling for Free Surface FlowsNumerical Computations of Supersonic Base Flow with Special Emphasis on Turbulence Modeling David C. Wilcox P. A. Durbin Ching Jen Chen James E. Danberg Manuel D. Salas Sal Rodriguez Joseph G. Marvin Dave Walker National Aeronautics and Space Admini David C. Wilcox Joseph G. Marvin D. J. Mavriplis National Aeronautics and Space Adm Nasa Paul Durbin Konstantin Volkov National Aeronautics and Space Administration (NASA) Junying Qu Jubaraj Sahu

Turbulence Modeling for CFD Statistical Theory and Modeling for Turbulent Flows Fundamentals Of Turbulence Modelling Turbulence Modeling for Steady Three-dimensional Supersonic Flows Modeling Complex Turbulent Flows Applied Computational Fluid Dynamics and Turbulence Modeling Turbulence Modeling for Compressible Flows Turbulence Modeling for Free-Surface Flows Turbulence Modeling for Shock Wave/Turbulent Boundary Layer Interactions Progress in Turbulence

Modeling for Complex Flow Fields Including Effects of Compressibility Turbulence Modeling for Hypersonic Flows Turbulence Modeling Algebraic Turbulence Modeling for Unstructured and Adaptive Meshes Atmospheric Turbulence Modeling for Aero Vehicles: Fractional Order Fits Advanced Approaches in Turbulence Turbulence Modeling for CFD Turbulence Modelling Approaches Turbulence Modeling for Hypersonic Flows Three-dimensional Turbulence Modeling for Free Surface Flows Numerical Computations of Supersonic Base Flow with Special Emphasis on Turbulence Modeling *David C. Wilcox P. A. Durbin Ching Jen Chen James E. Danberg Manuel D. Salas Sal Rodriguez Joseph G. Marvin Dave Walker National Aeronautics and Space Admini David C. Wilcox Joseph G. Marvin D. J. Mavriplis National Aeronautics and Space Adm Nasa Paul Durbin Konstantin Volkov National Aeronautics and Space Administration (NASA) Junying Qu Jubaraj Sahu*

providing a comprehensive grounding in the subject of turbulence statistical theory and modeling for turbulent flows develops both the physical insight and the mathematical framework needed to understand turbulent flow its scope enables the reader to become a knowledgeable user of turbulence models it develops analytical tools for developers of predictive tools thoroughly revised and updated this second edition includes a new fourth section covering dns direct numerical simulation les large eddy simulation des detached eddy simulation and numerical aspects of eddy resolving simulation in addition to its role as a guide for students statistical theory and modeling for turbulent flows also is a valuable reference for practicing engineers and scientists in computational and experimental fluid dynamics who would like to broaden their understanding of fundamental issues in turbulence and how they relate to turbulence model implementation provides an excellent foundation to the fundamental theoretical concepts in turbulence features new and heavily revised material including an entire new section on eddy resolving simulation includes new material on modeling laminar to turbulent transition written for students and practitioners in aeronautical and mechanical engineering applied mathematics and the physical sciences accompanied by a website housing solutions to the problems within

THE BOOK

FOCUSES ON THE SECOND ORDER TURBULENCE CLOSURE MODEL AND ITS APPLICATIONS TO ENGINEERING PROBLEMS TOPICS INCLUDE TURBULENT MOTION AND THE AVERAGING PROCESS NEAR WALL TURBULENCE APPLICATIONS OF TURBULENCE MODELS AND TURBULENT BUOYANT FLOWS

THE JONES AND LAUNDER TWO EQUATION MODEL OF TURBULENCE HAS BEEN FORMULATED AND APPLIED TO THE SOLUTION OF SUPERSONIC THREE DIMENSIONAL FLOW AND THE RESULTS COMPARED TO EXPERIMENTAL DATA TWO SOLUTION TECHNIQUES WERE STUDIED THE BOUNDARY LAYER THEORY APPROACH AND THE PARABOLIZED NAVIER STOKES METHOD FORMULATED IN A BODY FITTED COORDINATE SYSTEM THE K E TURBULENCE MODEL RESULTS WERE COMPARED WITH AN ALGEBRAIC TURBULENCE MODEL AS APPLIED TO THE PREDICTION OF FLOW ABOUT A SPINNING OGIVE CYLINDER BOATTAIL CONFIGURATION THE K E MODEL GAVE SLIGHTLY SUPERIOR RESULTS IN BOTH THE BOUNDARY LAYER AND PNS COMPUTATIONS ROTTA S NON ISOTROPIC THEORY FOR THE REYNOLDS STRESSES WAS INCORPORATED INTO THE FORMULATION RESULTS FOR THE SMALL ANGLE OF ATTACK CONFIGURATION SHOWED LITTLE EFFECT OF NON ISOTROPY THE CROSS FLOW PROPERTIES ARE THE MOST STRONGLY AFFECTED BRADSHAW S STREAMLINE CURVATURE THEORY WAS ALSO CONSIDERED AND THE RESULTS SHOW NEGLIGIBLE INFLUENCE FOR THE PRESENT CASE

TURBULENCE MODELING BOTH ADDRESSES A FUNDAMENTAL PROBLEM IN PHYSICS THE LAST GREAT UNSOLVED PROBLEM OF CLASSICAL PHYSICS AND HAS FAR REACHING IMPORTANCE IN THE SOLUTION OF DIFFICULT PRACTICAL PROBLEMS FROM AERONAUTICAL ENGINEERING TO DYNAMIC METEOROLOGY HOWEVER THE GROWTH OF SUPERCOM PUTER FACILITIES HAS RECENTLY CAUSED AN APPARENT SHIFT IN THE FOCUS OF TUR BULENCE RESEARCH FROM MODELING TO DIRECT NUMERICAL SIMULATION DNS AND LARGE EDDY SIMULATION LES THIS SHIFT IN EMPHASIS COMES AT A TIME WHEN CLAIMS ARE BEING MADE IN THE WORLD AROUND US THAT SCIENTIFIC ANALYSIS ITSELF WILL SHORTLY BE TRANSFORMED OR REPLACED BY A MORE POWERFUL PARADIGM BASED ON MASSIVE COMPUTATIONS AND SOPHISTICATED VISUALIZATION ALTHOUGH THIS VIEWPOINT HAS NOT LACKED AR TICULATE AND INFLUENTIAL ADVOCATES THESE CLAIMS CAN AT BEST ONLY BE JUDGED PREMATURE AFTER ALL AS ONE COMPUTATIONAL RESEARCHER LAMENTED THE COM PUTER ONLY DOES WHAT I TELL IT TO DO AND NOT WHAT I WANT IT TO DO IN TURBULENCE RESEARCH THE

INITIAL SPECULATION THAT COMPUTATIONAL METH ODS WOULD REPLACE NOT ONLY MODEL BASED COMPUTATIONS BUT EVEN EXPERIMEN TAL MEASUREMENTS HAVE NOT COME CLOSE TO FULFILLMENT IT IS BECOMING CLEAR THAT COMPUTATIONAL METHODS AND MODEL DEVELOPMENT ARE EQUAL PARTNERS IN TURBULENCE RESEARCH DNS AND LES REMAIN VALUABLE TOOLS FOR SUGGESTING AND VALIDATING MODELS WHILE TURBULENCE MODELS CONTINUE TO BE THE PREFERRED TOOL FOR PRACTICAL COMPUTATIONS WE BELIEVED THAT A SYMPOSIUM WHICH WOULD REAFFIRM THE PRACTICAL AND SCIENTIFIC IMPORTANCE OF TURBULENCE MODELING WAS BOTH NECESSARY AND TIMELY

THIS UNIQUE TEXT PROVIDES ENGINEERING STUDENTS AND PRACTICING PROFESSIONALS WITH A COMPREHENSIVE SET OF PRACTICAL HANDS ON GUIDELINES AND DOZENS OF STEP BY STEP EXAMPLES FOR PERFORMING STATE OF THE ART RELIABLE COMPUTATIONAL FLUID DYNAMICS CFD AND TURBULENCE MODELING KEY CFD AND TURBULENCE PROGRAMS ARE INCLUDED AS WELL THE TEXT FIRST REVIEWS BASIC CFD THEORY AND THEN DETAILS ADVANCED APPLIED THEORIES FOR ESTIMATING TURBULENCE INCLUDING NEW ALGORITHMS CREATED BY THE AUTHOR THE BOOK GIVES PRACTICAL ADVICE ON SELECTING APPROPRIATE TURBULENCE MODELS AND PRESENTS BEST CFD PRACTICES FOR MODELING AND GENERATING RELIABLE SIMULATIONS THE AUTHOR GATHERED AND DEVELOPED THE BOOK S HUNDREDS OF TIPS TRICKS AND EXAMPLES OVER THREE DECADES OF RESEARCH AND DEVELOPMENT AT THREE NATIONAL LABORATORIES AND AT THE UNIVERSITY OF NEW MEXICO MANY IN PRINT FOR THE FIRST TIME IN THIS BOOK THE BOOK ALSO PLACES A STRONG EMPHASIS ON RECENT CFD AND TURBULENCE ADVANCEMENTS FOUND IN THE LITERATURE OVER THE PAST FIVE TO 10 YEARS READERS CAN APPLY THE AUTHOR S ADVICE AND INSIGHTS WHETHER USING COMMERCIAL OR NATIONAL LABORATORY SOFTWARE SUCH AS ANSYS FLUENT STAR CCM COMSOL FLOWNEX SIMSCALE OPENFOAM FUEGO KIVA BIGHORN OR THEIR OWN COMPUTATIONAL TOOLS APPLIED COMPUTATIONAL FLUID DYNAMICS AND TURBULENCE MODELING IS A PRACTICAL COMPLEMENTARY COMPANION FOR ACADEMIC CFD TEXTBOOKS AND SENIOR PROJECT COURSES IN MECHANICAL CIVIL CHEMICAL AND NUCLEAR ENGINEERING SENIOR UNDERGRADUATE AND GRADUATE CFD AND TURBULENCE MODELING COURSES AND FOR PROFESSIONALS DEVELOPING COMMERCIAL AND RESEARCH APPLICATIONS

THE PURPOSE OF THIS EFFORT WAS TO ESTABLISH THE ABILITY OF EXISTING ENGINEERING

TURBULENCE MODELS TO PREDICT FREE SURFACE TURBULENT FLOWS AND TO LAY THE GROUNDWORK FOR IMPROVED MODELING OF THESE FLOWS THE EFFORT HAD AN EXPERIMENTAL COMPONENT A MODELING COMPONENT AND A INSTRUMENTATION DEVELOPMENT COMPONENT DATA WERE ACQUIRED TO INITIALIZE AND VALIDATE REYNOLDS AVERAGED NAVIER STOKES RANS CALCULATIONS OF FREE SURFACE JET FLOWS THIS DATA HAS BEEN MADE AVAILABLE TO THE COMMUNITY VIA THE INTERNET AN EXISTING SURFACE SHIP RANS CODE WAS ADAPTED TO THE JET PROBLEM AND USING THE ACQUIRED DATA AS INITIAL CONDITIONS THE EVOLUTION OF THE JETS WAS PREDICTED USING A STANDARD K EPSILON TURBULENCE MODEL THIS MODEL WAS EVALUATED FOR ITS ABILITY TO PREDICT THE FEATURES OF THE FREE SURFACE JETS AND FOUND INCAPABLE OF PREDICTING THE RAPID SPREADING OF THE JET NEAR THE SURFACE THIS WAS TRACED TO ITS INABILITY TO REPRESENT THE TURBULENCE ANISOTROPY WHICH DEVELOPS NEAR THE FREE SURFACE IN LOW FROUDE NUMBER FLOWS TO SUPPORT THE EXPERIMENTAL COMPONENT OF THE PROGRAM AS WELL AS FUTURE EFFORTS A SINGLE POINT HIGH RESOLUTION LASER INDUCED FLUORESCENCE SURFACE ELEVATION MEASUREMENT SYSTEM WAS DEVELOPED AND NEW LASER VELOCIMETER SIGNAL PROCESSING HARDWARE WAS ACQUIRED THE SURFACE ELEVATION MEASUREMENT SYSTEM WAS SUCCESSFULLY COMPLETED AND IS CURRENTLY BEING BROUGHT ON LINE

ACCURATE AERODYNAMIC COMPUTATIONAL PREDICTIONS ARE ESSENTIAL FOR THE SAFETY OF SPACE VEHICLES BUT THESE COMPUTATIONS ARE OF LIMITED ACCURACY WHEN LARGE PRESSURE GRADIENTS ARE PRESENT IN THE FLOW THE GOAL OF THE CURRENT PROJECT IS TO IMPROVE THE STATE OF COMPRESSIBLE TURBULENCE MODELING FOR HIGH SPEED FLOWS WITH SHOCK WAVE TURBULENT BOUNDARY LAYER INTERACTIONS SWTBLI EMPHASIS WILL BE PLACED ON MODELS THAT CAN ACCURATELY PREDICT THE SEPARATED REGION CAUSED BY THE SWTBLI THESE FLOWS ARE CLASSIFIED AS NONEQUILIBRIUM BOUNDARY LAYERS BECAUSE OF THE VERY LARGE AND VARIABLE ADVERSE PRESSURE GRADIENTS CAUSED BY THE SHOCK WAVES THE LAG MODEL WAS DESIGNED TO MODEL THESE NONEQUILIBRIUM FLOWS BY INCORPORATING HISTORY EFFECTS STANDARD ONE AND TWO EQUATION MODELS SPALART ALLMARAS AND SST AND THE LAG MODEL WILL BE RUN AND COMPARED TO A NEW LAG MODEL THIS NEW MODEL THE REYNOLDS STRESS TENSOR LAG MODEL LAGRST WILL BE ASSESSED AGAINST MULTIPLE WIND TUNNEL TESTS AND CORRELATIONS THE BASIS OF THE LAG AND LAGRST MODELS ARE TO PRESERVE THE ACCURACY OF THE STANDARD

TURBULENCE MODELS IN EQUILIBRIUM TURBULENCE WHEN THE REYNOLDS STRESSES ARE LINEARLY RELATED TO THE MEAN STRAIN RATES BUT CREATE A LAG BETWEEN MEAN STRAIN RATE EFFECTS AND TURBULENCE WHEN NONEQUILIBRIUM EFFECTS BECOME IMPORTANT SUCH AS IN LARGE PRESSURE GRADIENTS THE AFFECT THIS LAG HAS ON THE RESULTS FOR SWBLI AND MASSIVELY SEPARATED FLOWS WILL BE DETERMINED THESE COMPUTATIONS WILL BE DONE WITH A MODIFIED VERSION OF THE OVERFLOW CODE THIS CODE SOLVES THE RANS EQUATIONS ON OVERSET GRIDS IT WAS USED FOR THIS STUDY FOR ITS ABILITY TO INPUT VERY COMPLEX GEOMETRIES INTO THE FLOW SOLVER SUCH AS THE SPACE SHUTTLE IN THE FULL STACK CONFIGURATION THE MODEL WAS SUCCESSFULLY IMPLEMENTED WITHIN TWO VERSIONS OF THE OVERFLOW CODE RESULTS SHOW A SUBSTANTIAL IMPROVEMENT OVER THE BASELINE MODELS FOR TRANSONIC SEPARATED FLOWS THE RESULTS ARE MIXED FOR THE SWBLI ASSESSED THIS WORK HAS BEEN SELECTED BY SCHOLARS AS BEING CULTURALLY IMPORTANT AND IS PART OF THE KNOWLEDGE BASE OF CIVILIZATION AS WE KNOW IT THIS WORK WAS REPRODUCED FROM THE ORIGINAL ARTIFACT AND REMAINS AS TRUE TO THE ORIGINAL WORK AS POSSIBLE THEREFORE YOU WILL SEE THE ORIGINAL COPYRIGHT REFERENCES LIBRARY STAMPS AS MOST OF THESE WORKS HAVE BEEN HOUSED IN OUR MOST IMPORTANT LIBRARIES AROUND THE WORLD AND OTHER NOTATIONS IN THE WORK THIS WORK IS IN THE PUBLIC DOMAIN IN THE UNITED STATES OF AMERICA AND POSSIBLY OTHER NATIONS WITHIN THE UNITED STATES YOU MAY FREELY COPY AND DISTRIBUTE THIS WORK AS NO ENTITY INDIVIDUAL OR CORPORATE HAS A COPYRIGHT ON THE BODY OF THE WORK AS A REPRODUCTION OF A HISTORICAL ARTIFACT THIS WORK MAY CONTAIN MISSING OR BLURRED PAGES POOR PICTURES ERRANT MARKS ETC SCHOLARS BELIEVE AND WE CONCUR THAT THIS WORK IS IMPORTANT ENOUGH TO BE PRESERVED REPRODUCED AND MADE GENERALLY AVAILABLE TO THE PUBLIC WE APPRECIATE YOUR SUPPORT OF THE PRESERVATION PROCESS AND THANK YOU FOR BEING AN IMPORTANT PART OF KEEPING THIS KNOWLEDGE ALIVE AND RELEVANT

AN INVESTIGATION OF THE EMBODIED PHYSICS IN TURBULENCE CLOSURE MODELS WAS MADE THAT FOCUSED ON COMPRESSIBLE TURBULENT FLOWS BOUNDARY LAYER AND FREE SHEAR LAYERS INCLUDING WALL EFFECTS SUCH AS ROUGHNESS BLOWING CURVATURE A HYBRID K 3 TURBULENCE MODEL WAS SELECTED THAT CONSISTS OF THE STANDARD TWO EQUATION MODEL FOR THE OUTER LAYER AND A ONE EQUATION MODEL FOR THE INNER VISCOUS LAYER THIS MODEL WAS

chosen due to its success in analyzing compressible flows including interactions as well as the experience base using k e models to treat a wide range of engineering problems while also being adaptable to industrial codes the baseline model will consider the sarkar and zeman compressible dilatation terms together with the hybrid k e turbulence model a phase ii building block approach is recommended that provides a dial a model menu from a matrix of turbulence closure coefficients generated from the baseline compressible hybrid k e model and a multi zone navier stokes solver a direct result of this effort will be the technology transfer to the government industrial sector and the commercialization of a turbulence tutorial the tutorial will consist of a boundary layer code turbulence models and a database adaptable to a pc to provide researchers teachers students with guidance to explore turbulence issues

atmospheric turbulence models are necessary for the design of both inlet engine and flight controls as well as for studying coupling between the propulsion and the vehicle structural dynamics for supersonic vehicles models based on the kolmogorov spectrum have been previously utilized to model atmospheric turbulence in this paper a more accurate model is developed in its representative fractional order form typical of atmospheric disturbances this is accomplished by first scaling the kolmogorov spectral to convert them into finite energy von karman forms and then by deriving an explicit fractional circuit filter type analog for this model this circuit model is utilized to develop a generalized formulation in frequency domain to approximate the fractional order with the products of first order transfer functions which enables accurate time domain simulations the objective of this work is as follows given the parameters describing the conditions of atmospheric disturbances and utilizing the derived formulations directly compute the transfer function poles and zeros describing these disturbances for acoustic velocity temperature pressure and density time domain simulations of representative atmospheric turbulence can then be developed by utilizing these computed transfer functions together with the disturbance frequencies of interest kopasakis george glenn research center nasa tm 2010 216961 e 17566

advanced approaches in turbulence theory modeling simulation and data analysis for

TURBULENT FLOWS FOCUSES ON THE UPDATED THEORY SIMULATION AND DATA ANALYSIS OF TURBULENCE DEALING MAINLY WITH TURBULENCE MODELING INSTEAD OF THE PHYSICS OF TURBULENCE BEGINNING WITH THE BASICS OF TURBULENCE THE BOOK DISCUSSES CLOSURE MODELING DIRECT SIMULATION LARGE EDDY SIMULATION AND HYBRID SIMULATION THE BOOK ALSO COVERS THE ENTIRE SPECTRUM OF TURBULENCE MODELS FOR BOTH SINGLE PHASE AND MULTI PHASE FLOWS AS WELL AS TURBULENCE IN COMPRESSIBLE FLOW TURBULENCE MODELING IS VERY EXTENSIVE AND CONTINUOUSLY UPDATED WITH NEW ACHIEVEMENTS AND IMPROVEMENTS OF THE MODELS MODERN ADVANCES IN COMPUTER SPEED OFFER THE POTENTIAL FOR ELABORATE NUMERICAL ANALYSIS OF TURBULENT FLUID FLOW WHILE ADVANCES IN INSTRUMENTATION ARE CREATING LARGE AMOUNTS OF DATA THIS BOOK COVERS THESE TOPICS IN GREAT DETAIL COVERS THE FUNDAMENTALS OF TURBULENCE UPDATED WITH RECENT DEVELOPMENTS FOCUSES ON HYBRID METHODS SUCH AS DES AND WALL MODELED LES GIVES AN UPDATED TREATMENT OF NUMERICAL SIMULATION AND DATA ANALYSIS

ACCURATE PREDICTION OF TURBULENT FLOWS REMAINS A CHALLENGING TASK DESPITE CONSIDERABLE WORK IN THIS AREA AND THE ACCEPTANCE OF CFD AS A DESIGN TOOL THE QUALITY OF THE CFD CALCULATIONS OF THE FLOWS IN ENGINEERING APPLICATIONS STRONGLY DEPENDS ON THE PROPER PREDICTION OF TURBULENCE PHENOMENA INVESTIGATIONS OF FLOW INSTABILITY HEAT TRANSFER SKIN FRICTION SECONDARY FLOWS FLOW SEPARATION AND REATTACHMENT EFFECTS DEMAND A RELIABLE MODELLING AND SIMULATION OF THE TURBULENCE RELIABLE METHODS ACCURATE PROGRAMMING AND ROBUST WORKING PRACTICES THE CURRENT SCIENTIFIC STATUS OF SIMULATION OF TURBULENT FLOWS AS WELL AS SOME ADVANCES IN COMPUTATIONAL TECHNIQUES AND PRACTICAL APPLICATIONS OF TURBULENCE RESEARCH IS REVIEWED AND CONSIDERED IN THE BOOK

TURBULENCE MODELING FOR HIGH SPEED COMPRESSIBLE FLOWS IS DESCRIBED AND DISCUSSED STARTING WITH THE COMPRESSIBLE NAVIER STOKES EQUATIONS METHODS OF STATISTICAL AVERAGING ARE DESCRIBED BY MEANS OF WHICH THE REYNOLDS AVERAGED NAVIER STOKES EQUATIONS ARE DEVELOPED UNKNOWN AVERAGES IN THESE EQUATIONS ARE APPROXIMATED USING VARIOUS CLOSURE CONCEPTS ZERO ONE AND TWO EQUATION EDDY VISCOSITY MODELS ALGEBRAIC STRESS MODELS AND REYNOLDS STRESS TRANSPORT MODELS ARE DISCUSSED COMPUTATIONS OF SUPERSONIC AND HYPERSONIC FLOWS OBTAINED USING SEVERAL OF THE MODELS ARE DISCUSSED

and compared with experimental results specific examples include attached boundary layer flows shock wave boundary layer interactions and compressible shear layers from these examples conclusions regarding the status of modeling and recommendations for future studies are discussed marvin j g and coakley t j ames research center rtop 505 60 11

a zonal implicit time marching navier stokes computational technique has been used to compute the turbulent supersonic base flow over cylindrical afterbodies a critical element of calculating such flows is the turbulence model various eddy viscosity turbulence models have been used in the base region flow computations these models include two algebraic turbulence models and a two equation k epsilon model the k epsilon equations are developed in a general coordinate system and solved using an implicit algorithm calculations with the k epsilon model are extended up to the wall flow field computations have been performed for a cylindrical afterbody at m 2 46 and at angle of attack alpha 0 the results are compared to the experimental data for the same conditions and the same configuration details of the mean flow field as well as the turbulence quantifies have been presented in addition the computed base pressure distribution has been compared with the experiment in general the k epsilon turbulence model performs better in the near wake than the algebraic models and predicts the base pressure much better

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