International Journal of Technical Research and Applications e-ISSN: 2320-8163,
www.ijtra.com Special, Issue 43 (March 2017), PP. 71-75

TRAILING EDGE SIMULATIONS OF NACA 0012 AIRFOIL IN ANSYS FLUENT© AND OPENFOAM

[1]Jim Joseph Kurian, [2]Don Augusty Plackal, [3]Ganesh Chandrababu
[1,2,3] Fr.C.R.I.T, Vashi
[1]namejimjk94@gmail.com, donaugusty@gmail.com, ganesh2595@gmail.com

Abstract— **Aircraft noise is an issue of enormous environmental and technological impact. Projected growth in significant development of quiet modern engines has brought renewed attention to the non propulsive component of aircraft noise. Flow induced noise is one of the major contributors in the noise generation in various industrial applications. Trailing edge noise is an important component of aircraft airframe noise, in particular during landing and approach. Moreover trailing edge is also a noise generation mechanism for wind turbine rotor blades and helicopter blades. Due to stronger regulations with respect to noise pollution, the implementation of wind turbines will tend to hamper. To ensure its further development, it is important to reduce this noise mechanism and therefore requires better modeling.**

Computing trailing edge noise is complex since it is inherently connected with turbulence. The trailing edge noise is caused by the interaction of turbulent structures with the trailing edge. Large Eddy Simulations (LES) has proven to be a reliable method for the calculation of aero-acoustic problems. Although it provides sufficient accuracy and is less expensive than DNS, the higher computational cost compared to Reynolds Averaged Navier Stokes (RANS) makes it less attractive. A combination of sufficient accuracy and cost savings is found in the hybrid RANS-LES approaches. Herein the boundary layers are solved in full RANS mode. The price to pay with such models is found in the uncertainties in the transition zone between both modes.

The project aims at trailing edge simulations of NACA 0012 airfoil using RANS in OpenFOAM and ANSYS FLUENT©. The reference pressure taken is 2 x 10-5 Pa which corresponds to a sound pressure level (SPL) value of 0 dB. The graph of SPL v/s location and SPL v/s curve length has been plotted for angle of attack of 00 and 70.

Index Terms— **noise, Trailing edge, RANS, NACA 0012, airfoil.**

I. INTRODUCTION

With the development of new technology for noiseless and quiet machines, Flow induced noise is one of the major contributors in the noise generation of various industrial applications. Aero-acoustics has gained a lot of importance and it can be used in various fields. In aerospace industry, noise generated from high-lift devices, landing gears, flap and slats etc. are of great importance. Noise generated in turbine blade is some of the other application.

The project will concentrate on noise generated due to turbulent flow from the trailing edge of the airfoil; unfortunately, enough computer power is not available within the specified budget to carry out simulations for a 3D model. Therefore, the 2D turbulent model using RANS shall be utilized, in which it is important to identify and predict the most important noise sources.

The continued success achieved by various researchers in engine noise reduction, airframe noise has emerged as a potentially significant contributor to overall acoustic emissions, particularly at landing or when an aircraft touches down. The dominant sources of airframe noise are known to be associated with unsteadiness of separated and/or vortex flow regions around the high-lift system (i.e., flaps and slats) and the aircraft undercarriage (i.e. landing gear). Due to the complexity of three dimensional vortices that may contribute to flow unsteadiness and the importance of surface geometry in scattering these vortex structures into sound, airframe noise is an extremely complex and challenging problem.

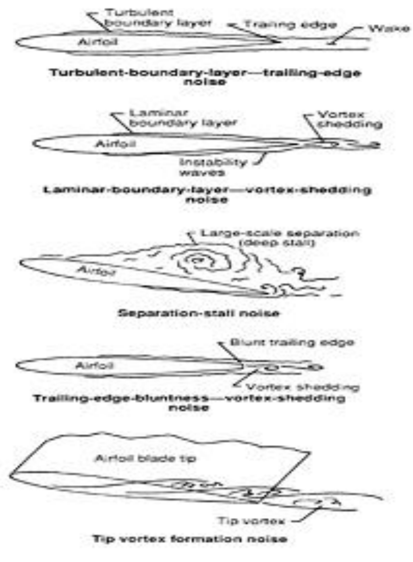


Fig 1- Different noise source generation [1]

II. AIM AND OBJECTIVES

Aim: The aim of the project is to perform trailing edge simulations of NACA 0012 airfoil using RANS in OpenFOAM and ANSYS Fluent ©.
Objective: The goal of project is to simulate the noise emanating from an airfoil with a special emphasis on trailing edge noise .Additionally the effect of a blunt trailing edge on the noise production should be quantified.
Therefore the following objectives that are inevitable and essential for completing our study are listed below:

- To identify modelling errors by using RANS approach.
- To compare boundary layer profiles of the flow of airfoil with reference data and ANSYS Fluent©.
- To compare the results obtained for various angle of attacks.
- To simulate the trailing edge noise emanating from an airfoil.
- To identify the location of high frequency noises.

III. PROBLEM DEFINITION

With the introduction of advanced noiseless engines, flow induced noises have become major contributors for noise generation. The source of noise generation and airfoil simulations of a sharp trailing edge will be studied and analyzed to determine the location of noise generation for a turbulent model for the following specifications:-

- A symmetric NACA0012 is chosen to be the test airfoil.
- A free-stream velocity of 70m/s is considered.
- Reference Pressure of 2 x 10-5 Pa is chosen.
- A Reynolds number of 1 million is chosen.
- Angle of attack considered is 00 and 70.

IV. SIMULATIONS PERFORMED

A. ANSYS FLUENT©

Simulation is the imitation of any real world phenomenon by developing a model, applying real world condition .The aim of the performed simulations is to showcase the trailing edge noise emanating from an airfoil and to identify the location of high frequency noises.

The steps are divided in following categories as follows:-

- Geometry
- Mesh Model
- Boundary Conditions
- Solution

1) Geometry:-

The geometry of NACA 0012 airfoil is created. The first step followed is to input the coordinate file of NACA 0012 airfoil from airfoil tools website. Twenty points were taken into consideration to make the airfoil shape. The angle of attack is kept as 00 and 70 .Figure 3.1 and 3.2 shows geometric model of the NACA 0012 airfoil at 00 and 70 angle of attack.

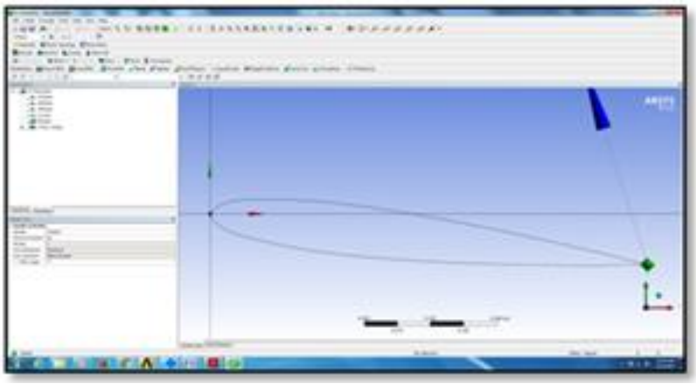


Fig 4.1- Geometric modelling of NACA 0012 airfoil for 00 angle of attack.

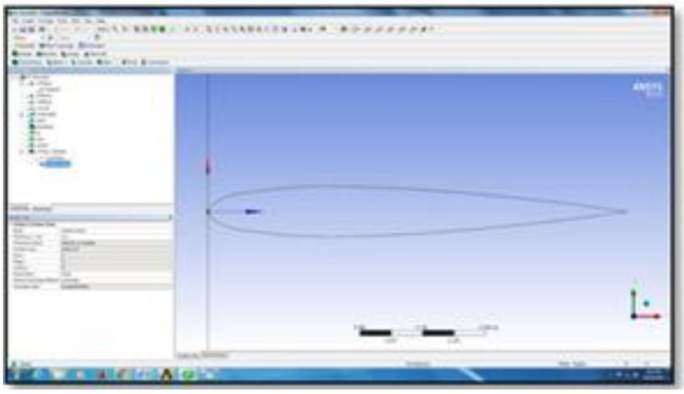
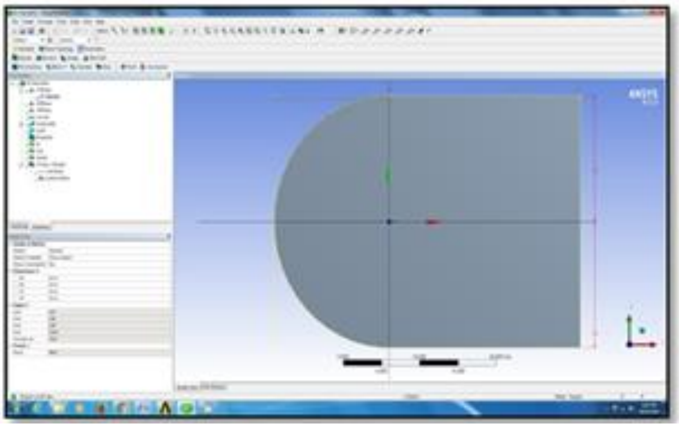


Fig 4.2- Geometric modelling of NACA 0012 airfoil for 70 angle of attack

Next, the domain in which the flow is simulated is created. It consists of a rectangle having dimensions as H1=15m, H2 = 25m, V1 =15m and V2= 15m and the inlet for the



profile is semi-circular

Fig 4.3- Domain modelling (00)

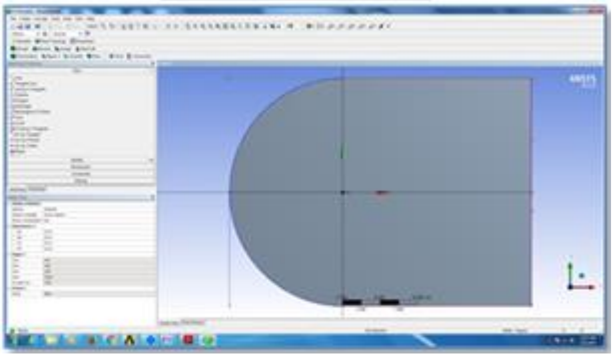


Fig 4.4- Domain modelling (70)

2) Mesh Model:-

The mesh model is created in ICEM CFD which is another component of ANSYS Workbench. The Meshing performed is a coarse mesh for the semi-circular domain and semi fine mesh for airfoil. The elements are 1020 and 3080 for 00 and 70 in numbers respectively.

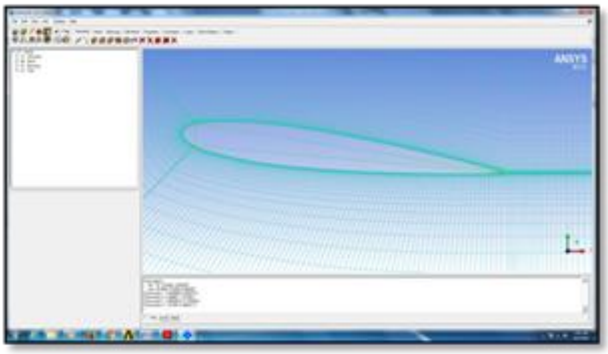


Fig 4.5- Mesh model of airfoil- semi fine mesh (00)

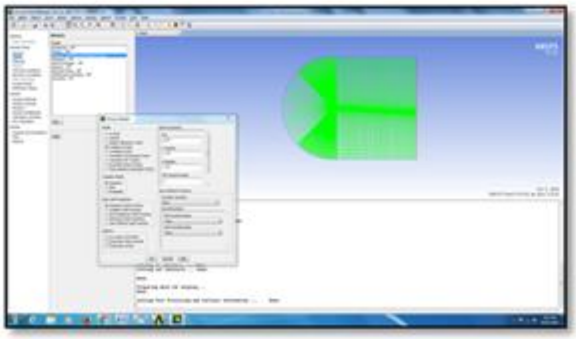


Fig 4.6- Mesh model of airfoil- semi fine mesh (70)

3) Boundary conditions:-

This mesh model is an input to the Fluent and sets it up for applying boundary conditions and getting the simulations.

The assumed acoustics boundary conditions for broadband noise sources are as given below:

Far-Field Density= 1.225 kg/m3
Far-Field Speed =300 m/s
Reference Acoustic Power = 1 e-12 W
Number of Realizations= 25

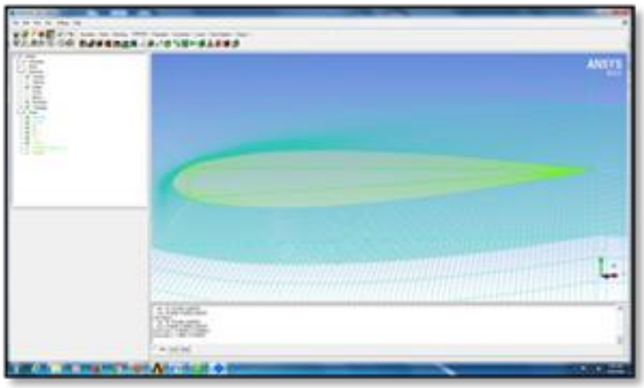


Fig 4.7 Boundary conditions in K-Epsilon (RANS) model for 00

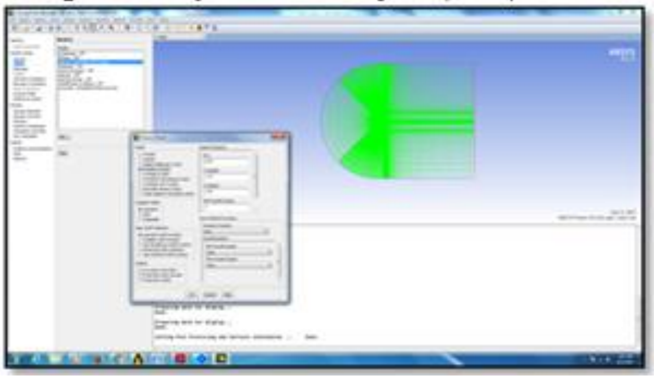


Fig 4.8 Boundary conditions in K-Epsilon (RANS) model for 70

4) Solution:

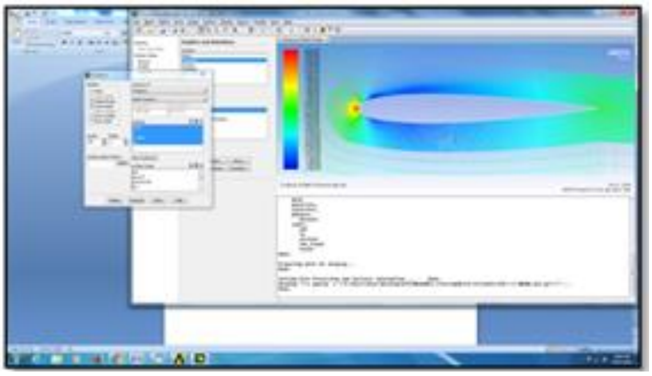


Fig 4.9 contours of static pressure for 00

The contours of static pressure having minimum of -1579.982 Pa and a maximum of 3011.911 Pa are shown at edges of airfoil and tip or start of leading edge respectively, as in Fig 4.9

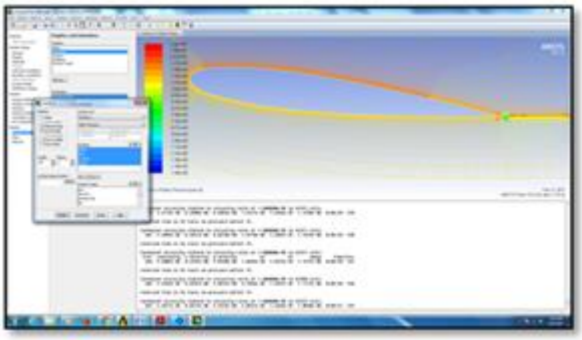


Fig 4.10 contours of static pressure for 70

The contours of static pressure having minimum of -1475.39 Pa and a maximum of 2336.09 Pa are shown at edges of airfoil and tip or start of leading edge respectively, as in Fig 4.10

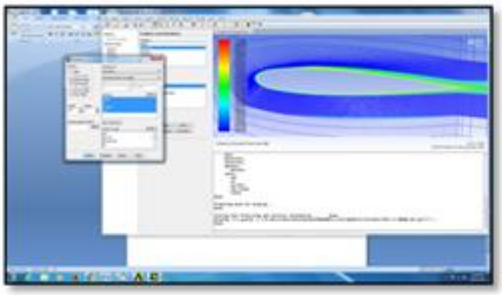


FIG 4.11 CONTOURS OF ACOUSTIC POWER LEVEL FOR 00

The contours of Acoustic Power level has a minimum value of 2e-5 Pa which corresponds to 0 dB and maximum value of 113.3476 dB at farfield and near the profile of airfoil respectively.

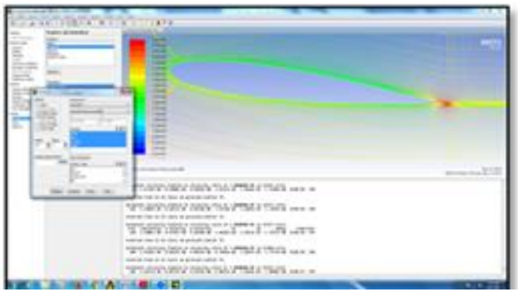


Fig 4.12 Contours of acoustic power level for 70

The contours of Acoustic Power level has a minimum value of 26.69 dB and maximum value of 287.48 dB at farfield and near the profile of airfoil respectively.

B. OPENFOAM

The solution obtained for pressure contours are shown and compared with ANSYS FLUENT©.

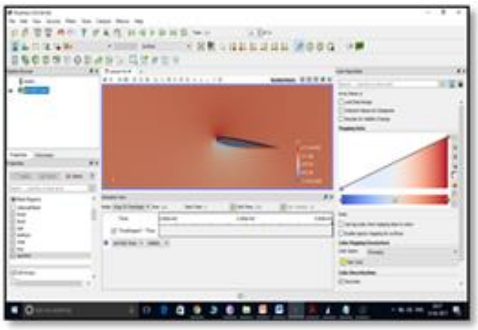


Fig 4.13 Contours of static pressure for 00

The contours of static pressure having minimum of -1376 Pa and a maximum of 4171 Pa are shown at edges of airfoil and tip or start of leading edge respectively, as in Fig 4.13

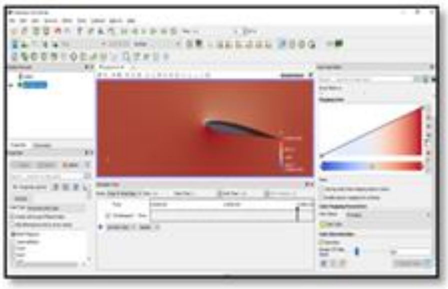


Fig 4.14 Contours of static pressure for 70

The contours of static pressure having minimum of -2854Pa and a maximum of 3055 Pa are shown at edges of airfoil and tip or start of leading edge respectively, as in Fig 4.14

V. RESULT

	OPENFOAM		ANSYS©	
Angle of attack	**Pressure (Pa) (Min)**	**Pressure (Pa) (Max)**	**Pressure (Pa) (Min)**	**Pressure (Pa) (Max)**
0^0	-1376	4171	-1579.982	3011.911
7^0	-2854	3055	-1475.5	2336.09

Table 1 Comparison of pressure between OPENFOAM and ANSYS FLUENT

CONCULUSTION

Thus results have been achieved for 0 degree angle of attack for pressure and the minimum and maximum values are -1376 Pa and 4171 Pa respectively. These values have been verified and validated with that of performed simulations in ANSYS© and have shown significant closeness. The differences in values are due to the following reasons:-

- Every software has its own methodology to obtain the results out of simulations performed.
- The RANS model used in ANSYS© is a K-epsilon model whereas K-Kl-w model has been used in OPENFOAM due to complexity involved in simulations.
- These errors are also known as modelling errors and their values are 2955.982 Pa and 1159.21 Pa for minimum and maximum respectively for 00.

- These errors are also known as modelling errors and their values are 1378.5 Pa and 718.91 Pa for minimum and maximum respectively.

ACKNOWLEDGMENT

A sincere gratitude to project guide Prof. Sanjay Rukhande and also, valuable inputs from Prof. Dr. Nilaj Deshmukh. A very heartfelt thanks to the college for support and guidance provided.

REFERENCES

[1] Olivier Verhoeven. Trailing edge noise simulations using IDDES in OpenFOAM.Delft University of Technology, 2011.

[2] T.F. Brooks, M.A. Marcolini, and D.S. Pope.Airfoil Self Noise and Prediction.NASA Reference Publication, 1989.

[3] S. Oerlemans and P. Migliore. Aero-acoustic Wind tunnel tests of wind turbine airfoils. American Institute of Aeronautics and Astronautics, 2004.

[4] Rongqian Chen, Yizhao Wu AND JianXia.Airframe noise prediction using SNGR method. 4th International Symposium on Physics of fluids, IJMP conference, 2012.

[5] Robert W. Stoker,YuepingGuo, Craig Streett and Nathan Burnside.Airframe noise source locations of a 777 aircraft in flight and comparisons with the past model scale tests. 9th AIAA/CEAS journal, 2003.

[6] Robert W. Stoker And Rahul Sen. An Experimental Investigation of Airframe Noise Using a Model-Scale Boeing 777.39th AIAA Aerospace Sciences journal, 2001.

[7] Robert W. Stoker And Rahul Sen.," An Experimental Investigation of Airframe Noise Using a Model-Scale Boeing 777," AIAA 2001-0987/ 39th AIAA Aerospace Sciences Meeting & Exhibit 8-11 January 2001 / Reno, NV

[8] KazuhideISOTANI,Kenji HAYAMA, Yuzuru YOKOKAWA, Mitsuhiro MURAYAMA, Hiroki URA, and KazuomiYAMAMOTO.,"An Aerodynamic Noise Reduction Study for Airframe Noise from Flap Tips," 19th AIAA/CEAS Aero-acoustics Conference May 27-29, 2013, Berlin, Germany

[9] SerhatHosder, Joseph A. Schetz, Bernard Grossman, and William H. Mason.," AIRFRAME NOISE MODELING APPROPRIATE FOR MULTIDISCIPLINARY DESIGN AND OPTIMIZATION", 42nd AIAA Aerospace Sciences Meeting and Exhibit 5 - 8 January 2004, Reno, Nevada

[10] M.Herr,"Design criteria for low noise trailing edges", 13th AIAA/CEAS Aero-acoustic Conference, 2007

[11] M.Herr, C.Appel, J. Dierke and R.Ewert, Trailing Edge Noise Quality Assessment for CAA Validation, 2010

[12] Michael Goody,"Emperical Spectral Model of surface pressure fluctuations", AIAA Journal Vol.42, No.9, Sept 2004

[13] D. Keith Walters, 2008 Title: A Three Equation Eddy viscosity model for RANS of Transitional flow

[14] W .Nikitin, 2000 Title: Wall modeling using LES.

[15] Thomas Brooks, 1989 Title: Aircraft self-noise generation, Langley Research Center, Hampton, Virginia.

[16] M. Herr, C. Appel, J. Dierke, and R. Ewert. Trailing-Edge Noise Data Quality Assessment for CAA Validation. 16th AIAA/CEAS Aeroacoustics Conference, 2010.

[17] M.S. Howe. Acoustics of Fluid-Structure Interaction.Cambridge University Press, 1998.

[18] [18] Issa, R.I. Solution of the implicitly discretised fluid flow equations by operator-splitting, Journal of Computational Physics, 1986.

[19] H. Jasak. Error Analysis and estimation in the finite volume method with applications to fluid flows.PhD thesis, University of London, Imperial College, London, 1996.

[20] Lighthill, M.J. On sound generated aerodynamically. Part I. General theory.Proceedings of the Royal Society of London, 1952.

[21] FR Menter, M. Kuntz, and R. Langtry. Ten years of industrial experience with the SST turbulence model. Turbulence, heat and mass transfer, 4:625–632, 2003.

[22] NV Nikitin, F. Nicoud, B. Wasistho, KD Squires, and PR Spalart. An approach to wall modeling in large-eddy simulations.Physics of Fluids, 12:1629, 2000.

[23] A.A. Oberai, F. Roknaldin, and Hughes T.J.R. Computation of Trailing-Edge Noise due to turbulent flow over an airfoil.AIAA, 40(11), 2002.

[24] S. Oerlemans and P. Migliore.Aeroacoustic Wind tunnel tests of wind turbine airfoils. American Institute of Aeronautics and Astronautics, 2004.

[25] S. Oerlemans, P. Sijtsma, and B. Mendez Lopez.Location and quantification of noise sources on a wind turbine.Journal of Sound and Vibration, 2006.

[26] OpenCFD. User guide openfoam, http://openfoam.com/docs/user, June 2011.

[27] R. Parker and M.C. Welsh.Effects of sound on ow separation from blunt at plates.Int. J. Heat and Fluid Flow, 1983.

[28] [28] U. Piomelli, E. Balaras, H. Pasinato, K.D. Squires, and P.R. Spalart. The inner-outer layer interface in large-eddy simulations with wall-layer models. International Journal of heat and fluid flow.

[29] S.W Rienstra and H. Hirschberg.Introduction to Acoustics. Eindhoven University of Technology,2001.

[30] C.J. Roy. Review of code and solution verification procedures for computational simulation, Journal of Computational Physics, 2005.

[31] P. Schlatter and Orlu R. Assesment of direct numerical simulation data of turbulent boundary layers.Journal of Fluid Mechanics, 2010.

[32] U. Schumann. Subgrid scale model for finite difference simulations of turbulent flows in plane channels and annuli. J. Comp. Physics, 1975.

[33] R. E. Sheldahl and P. C. Klimas. Characteristics of Seven Airfoil Sections Through 180 Degrees Angle of Attack for Use in Aerodynamic Analysis of Vertical Axis Wind Turbines. report SANDIA national laboratories, 1981.

[34] M.L. Shur, P.R. Spalart, M.K. Strelets, and A.K. Travin.A hybrid rans-les approach with delayed-des and wall-modelled les capabilities. International Journal of Heat and Fluid Flow,

[35] Smagorinsky, J. General Circulation Experiments with the Primitive Equations. Monthly Weather Review, 1963.

[36] P.R. Spalart. Detached-Eddy Simulation.Annu.Rev. Fluid Mechanics, 2009.