

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

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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 2×10^{-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.

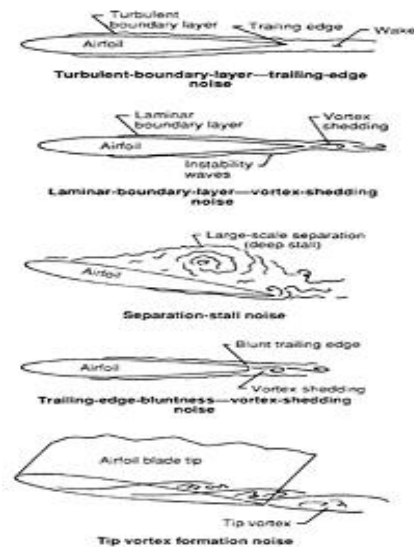


Fig 1- Different noise source generation [1]

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 2×10^{-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.

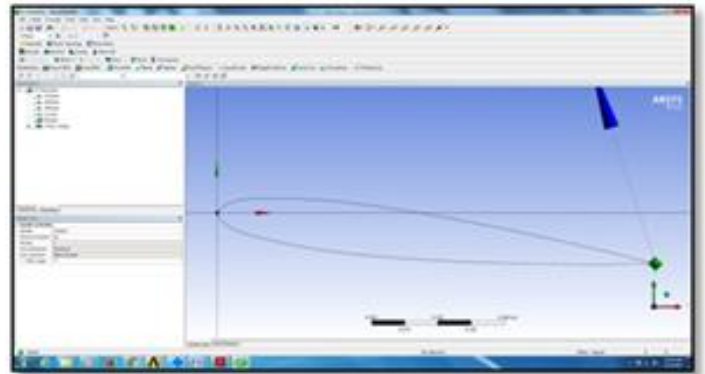


Fig 4.1- Geometric modelling of NACA 0012 airfoil for 00 angle of attack.

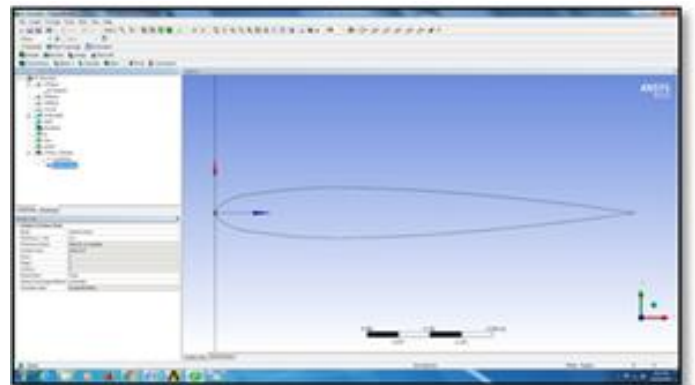
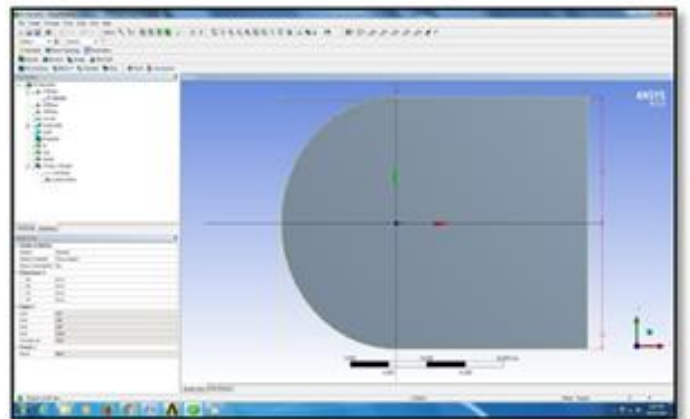


Fig 4.2- Geometric modelling of NACA 0012 airfoil for 70 angle of attack

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)

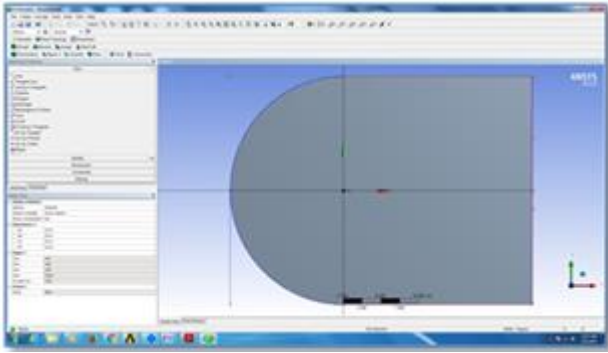


Fig 4.4- Domain modelling (70)

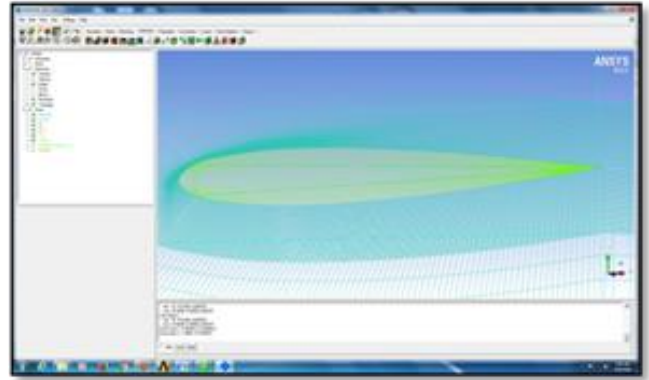


Fig 4.7 Boundary conditions in K-Epsilon (RANS) model for 00

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.

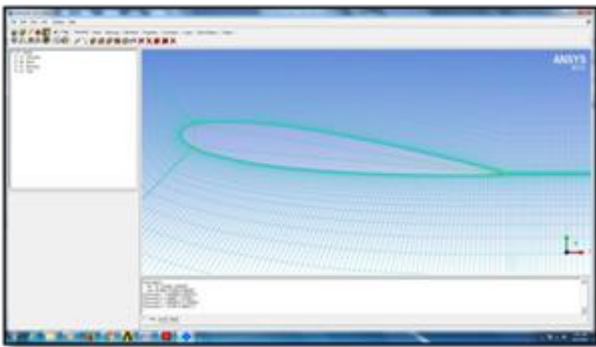


Fig 4.5- Mesh model of airfoil- semi fine mesh (00)

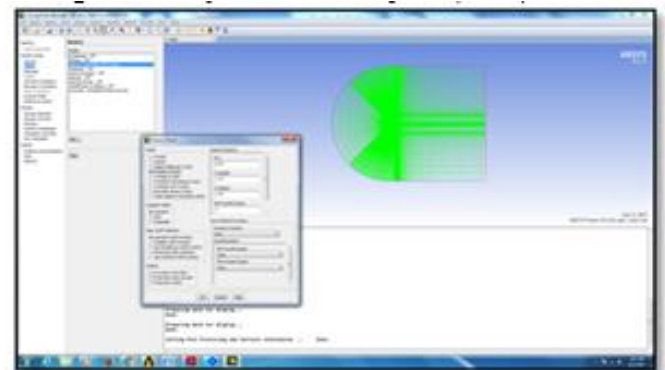


Fig 4.8 Boundary conditions in K-Epsilon (RANS) model for 70

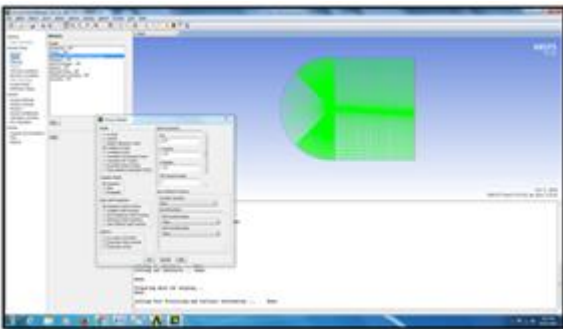


Fig 4.6- Mesh model of airfoil- semi fine mesh (70)

4) Solution:

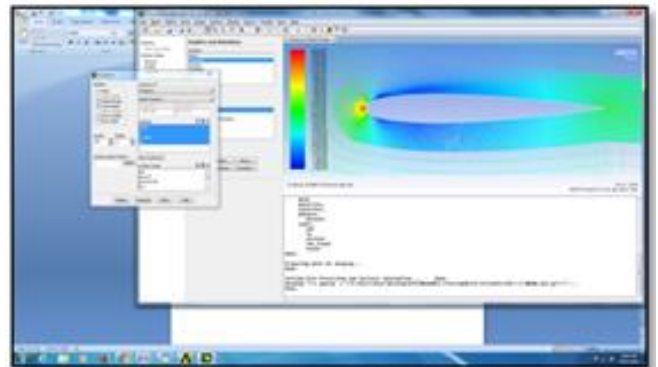


Fig 4.9 contours of static pressure for 00

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

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

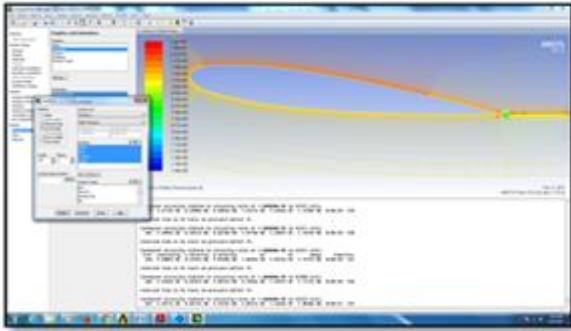


Fig 4.10 contours of static pressure for 70

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

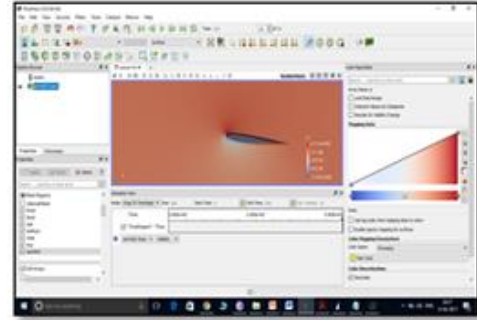


Fig 4.13 Contours of static pressure for 00

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

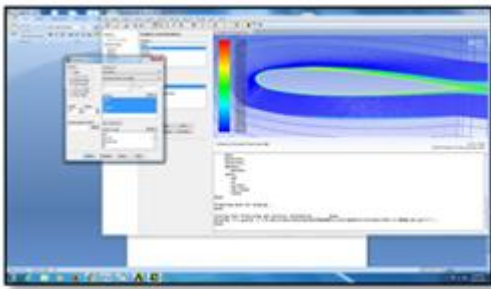


FIG 4.11 CONTOURS OF ACOUSTIC POWER LEVEL FOR 00

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.

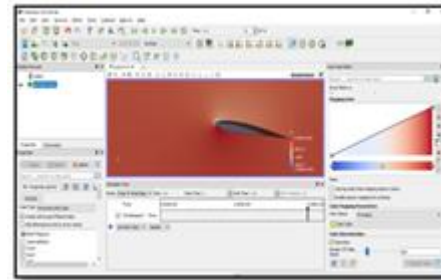


Fig 4.14 Contours of static pressure for 70

The contours of static pressure having minimum of -2854 Pa 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

Angle of attack	OPENFOAM		ANSYS®	
	Pressure (Pa) (Min)	Pressure (Pa) (Max)	Pressure (Pa) (Min)	Pressure (Pa) (Max)
0°	-1376	4171	-1579.982	3011.911
7°	-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-K1-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.

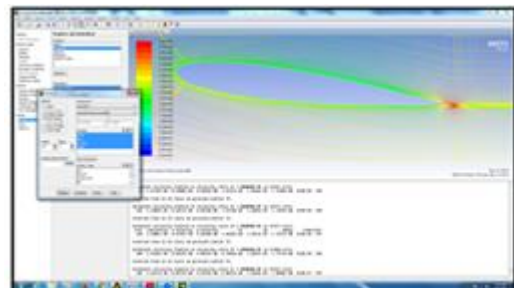


Fig 4.12 Contours of acoustic power level for 70

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®.

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

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