

NAFNoise User's Guide

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Introduction

NAFNoise, which stands for NREL AirFoil Noise, is a program that predicts the noise of any airfoil shape for five different types of noise sources: turbulent boundary layer trailing-edge noise, separated flow noise, laminar boundary layer vortex-shedding noise, trailing-edge bluntness noise, and turbulent inflow noise. The models in the program are based on the work of others and recently performed research at NREL. Empirical models for the first four noise sources (everything except turbulent inflow noise) were originally developed by Brooks, Pope and Marcolini [1], based on their detailed measurements of noise from NACA 0012 airfoils. An empirical model for the turbulent inflow noise is based on the work of Amiet [2]. Recent improvement of these models, has included the modeling of any airfoil shape by using the boundary layer calculations of Xfoil, developed by Drela [3]. These boundary layer predictions can be used as inputs into the models of Brooks, Pope, and Marcolini or into a newly developed model for trailing edge noise by researchers at TNO [4]. Two final modifications to the empirical models are the introduction of a turbulent inflow noise correction developed by Guidati[5] and a simplified version of the same Guidati method [6] that is less computationally intensive. The Guidati method corrects the Amiet method for turbulent inflow noise to account for airfoil shape. The details behind the theory of each of these methods and also comparisons to measured data can be found in References 4-6.

Retrieving Files from the Archive

You can download the NAFNoise archive from NREL's design code Web site <http://wind.nrel.gov/designcodes/simulators/NAFNoise>. The file name will be something like this: **nafnoise_v100.exe**. You can create a folder for the application, copy the archive to the folder, and double-click to expand the contents or type "nafnoise_v100" (or the filename) at a command prompt with the NAFNoise folder as the current directory. This will create some files and folders. Please see Marshall Buhl's paper *Installing NWTC Design Codes* [7] for information on how to set up NAFNoise to run in any folder.

Distributed Files

The files contained in the CondorNTM archive include these:

ArcFiles.txt	The list of files written to the archive
Archive.bat	The batch file that creates the archive
ChangeLog.txt	The list of changes to the NAFNoise program
NAFNoise.doc	This user's manual in Word format
NAFNoise.pdf	This user's manual in PDF format
NAFNoise.ipt	Example input file
NAFNoise.out	Example output file
S809.dat	Example airfoil input file
Source/*.*	Source files

Running NAFNoise

To run NAFNoise, type “nafnoise <input filename>” at a command prompt, where the input filename is optional. If you do not supply NAFNoise with an input filename, it will use the default input filename, which is “nafnoise.ipt.” The output filename will be the root of the input filename with an extension of “.out.” For example, the output file for the default input file would be “nafnoise.out.”

Modifying the Input File

You will need to modify the input file to examine your own airfoil shape. Do not change the format of the lines or the number of lines given in the example input file or NAFNoise will not work correctly. Below is a line-by-line description of the various input parameters contained in the input file.

The first three lines of the input file are not used by the program, but serve as places to write comments about the data contained in the input file and its use.

The first section of the input file contains the atmospheric constants used by NAFNoise, which includes the speed of sound, the kinematic viscosity and the density of air. Note that all input parameters must be in SI units.

The next section of the input file describes the program settings that tell NAFNoise which noise sources to compute and how to compute them. The first variable, *ITRIP*, specifies the boundary layer tripping of the airfoil. If *ITRIP* is set to 0, the boundary layer will not be tripped. A setting of 1 indicates “heavy” tripping, while 2 is for “light” tripping. The difference between these last two tripping settings is only important if the user chooses to calculate the boundary layer thicknesses using the empirical relations of Brooks, Pope, and Marcolini (BPM) [1]. The “heavy” tripping setting will produce larger boundary layer thicknesses (as described in Ref. 1) and louder boundary layer noise. A “light” tripping setting of 2 is recommended when comparing to data from measurements different from those of BPM. If you are using Xfoil to calculate boundary layer properties, a value for *ITRIP* of 1 or 2 will produce an identical result for a tripped airfoil.

The next line in the input file, *X_BLMMethod*, indicates the method for calculating the boundary layer properties. A value of 1 will cause

NAFNoise to use the empirical relations BPM. A setting of 2 will result in Xfoil routines being used to calculate boundary layer properties based on the input airfoil shape.

The next line in the input file is for the parameter, *TBL_Method*. *TBL_Method* determines which method, if any, will be used to determine the turbulent boundary layer trailing-edge noise. If *TBL_Method* is set to 0, no turbulent boundary layer noise will be calculated. If it is set to 1, the BPM empirical relations will be used to calculate this noise source. And if the setting is 2, the TNO [6] method will be used. Note that if the TNO model is used, the boundary layer properties are automatically calculated using Xfoil.

The next line in the input file controls the setting for the *TI_Method* parameter. This parameter is used to determine the method of calculation for turbulent inflow noise. If *TI_Method* is set to 0, no turbulent inflow noise is calculated. If it is set to 1, the turbulent inflow noise is calculated using the method of Amiet [2] based on a flat plate response to turbulence (i.e. airfoil shape is not modeled). If *TI_Method* is 2, the full Guidati prediction method is employed [5]. This method uses a correction to the Amiet model based on the airfoil shape and will take a significant amount of computation time, dependent on the settings described below in the TI section. The final choice for *TI_Method* is 3, which will invoke a simplified linear version of the Guidati method [6]. This simplified method is much less computationally intensive, but for reasonable accuracy the method should be limited to Strouhal numbers (dimensionless frequency based on chord length) lower than about 75.

The next line in the input file is for the variable *IBLUNT*, which controls the trailing edge bluntness calculation. If *IBLUNT* is 0 no bluntness noise will be calculated, but if the parameter is set to 1, NAFNoise will estimate the bluntness noise using the empirical relations of BPM.

The final parameter in this section of the input file, *ILAM*, controls the laminar boundary layer vortex-shedding noise. If the value of *ILAM* is 0, no laminar boundary layer noise will be calculated, but if the *ILAM* is to 1, NAFNoise will estimate the laminar boundary layer noise using the empirical relations of BPM. Note that if calculation of laminar boundary layer noise is desired, the boundary layer must not be tripped and therefore the parameter *ITRIP* must be 0.

The next section of the input file is reserved for the airfoil properties. These properties include the airfoil chord length, the airfoil span (normal to

chord), the freestream velocity, the angle of attack, the trailing edge thickness, and the trailing edge angle. All of the angles are in units of degrees. The one quantity that requires definition is the trailing edge angle, which is the angle between the upper and lower surface at the trailing edge.

The section after airfoil properties specifies the input variables for the Xfoil input. These parameters are important for users using Xfoil to calculate the boundary layer properties, for either the BPM or TNO trailing edge noise model or for users implementing the Guidati turbulent inflow noise model. The first two input variables of this section are the locations of the trip on the lower and upper surface of the airfoil measured by the distance from the leading edge and normalized by the chord length. The next line of the input file is reserved for a logical variable that specifies whether the airfoil of interest is a NACA series airfoil. Xfoil has the ability to generate both 4-digit and 5-digit NACA airfoil shapes and there is no need for a separate airfoil input file. If this input line is "TRUE", the next line should be the number of the NACA airfoil. If the *ISNACA* variable is "FALSE", the next line should be the name of the airfoil input file. The format of this secondary input file should be readable by Xfoil [8], which typically is a two-column format with normalized (by chord) x- and y- positions of the upper and lower surface. See the example s809.dat airfoil file supplied in the NAFNoise archive. The first line of this airfoil file should be the name of the airfoil and if it is not, NAFNoise will ask for a name from the user.

The next section of primary input file is dedicated to the turbulent inflow noise parameters. If the user does not want to calculate turbulent inflow noise, this section can be ignored. The first line of this section is the turbulence intensity of the incoming flow in the streamwise direction. Typically, this is defined as the RMS velocity divided by the mean velocity of the oncoming flow. The next line of this section is for the turbulent length scale, or more specifically, the integral turbulent length scale of the streamwise turbulence. This length scale is defined in most turbulence textbooks and empirical relations exist if the quantity is unknown. The length should be input in meters. The next two lines in the input file are the airfoil thickness at 1% and 10% chord respectively. These parameters are used for the simplified linear Guidati model and are normalized by the chord length. After the thickness parameters, the next two lines in the input file are used by the full Guidati method. The first line is the number of streamlines used by the Guidati method to convect vorticity past the airfoil [5]. The higher this number, the more accurate the relationship will be at higher frequencies, but also the longer the computation time. Typically, the

number should be 400 or more to obtain accurate results at frequencies greater than 10 kHz. The user may wish to perform a sensitivity study on this parameter before converging on a final answer. The final line in this section is the distance between streamlines in the Guidati model. Similar to the number of streamlines, the distance between streamlines must be smaller for higher frequencies, but a smaller number increases the computational overhead.

When using the Guidati model, note that the screen will show a lift coefficient that is higher than the one predicted by Xfoil in the same window. This is because the Guidati method uses an inviscid solution of the airflow around the airfoil, while Xfoil uses a viscous solution.

The final section of the input file contains the observer location variables. The first line is the absolute distance of the observer from the trailing edge of the airfoil in meters. The last two lines are angular positions of the observer relative to the trailing edge. The first angle, *PHI*, is relative to a line running parallel to the span of the airfoil and is positive on the upper surface and right-hand side when looking upstream (see [1] or [4] for a diagram). The second angle, *THETA*, is relative to the chordline running from the leading edge through the trailing edge and is positive on the upper surface of the airfoil. The units of these angle inputs are degrees.

NAFNoise Output

The output file produced by NAFNoise is relatively straightforward. The first three lines of the output file are a description of the run including the time and date. Below this are eight columns of data. The first column is the frequency in one-third octave bands. The next two columns are turbulent boundary layer noise predictions for both sides of the airfoil. The fourth column is separating flow noise, which is important at higher angles of attack. The fifth column is the laminar boundary layer vortex-shedding noise. The sixth column is the trailing edge bluntness noise. The seventh column is the turbulent inflow noise. And finally, the eighth column is the total of all noise sources combined.

References

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- [4] Moriarty, P. and Migliore, P., *Semi-Empirical Aeroacoustic Noise Prediction Code for Wind Turbines*, NREL/TP-500-34478, National Renewable Energy Laboratory, Golden, CO, 2003.
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Known Bugs

None.

Caveats

The National Renewable Energy Laboratory (NREL) cannot guarantee the usefulness or accuracy of NAFNoise, which is essentially a beta code. NREL does not have the resources to provide full support for this program. *You may use NAFNoise for evaluation purposes only.*

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Feedback

If you have problems with NAFNoise, please contact Pat Moriarty, who will respond as time permits. Please send comments and bug reports to:

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