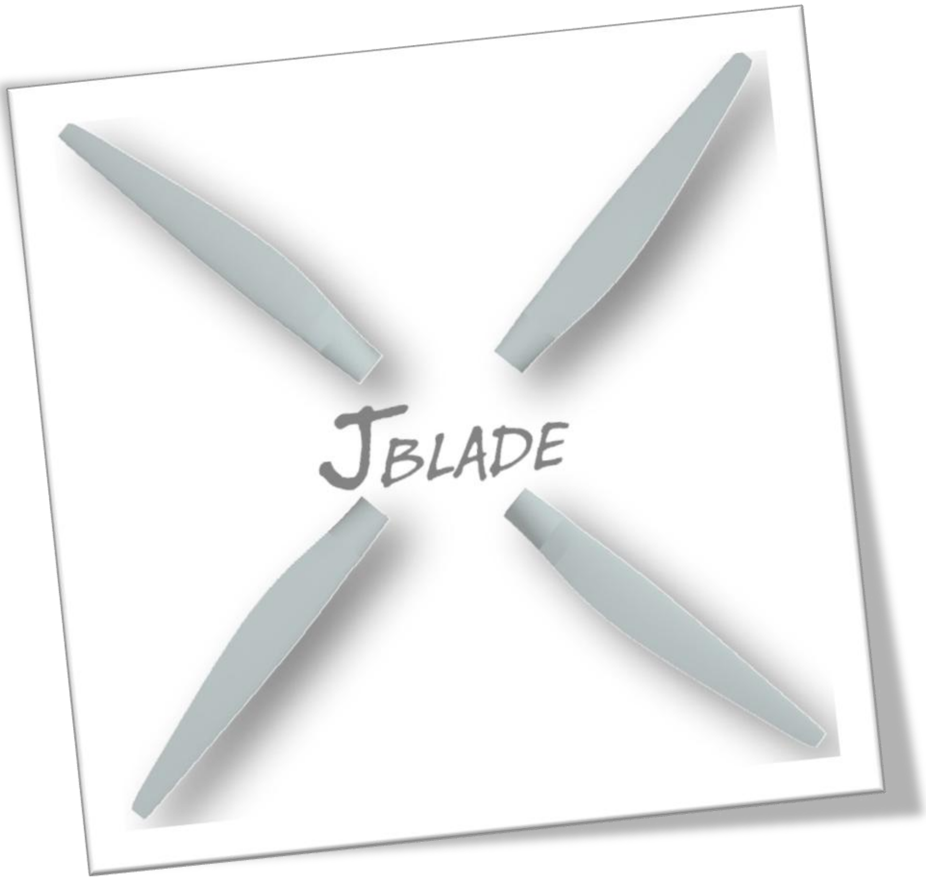
UNIVERSIDADE DA BEIRA INTERIOR
Covilhã | Portugal

JBLADE v17 Tutorial



João Morgado

September 20, 2013

Email: jmorgado@ubi.pt

Centre for Aerospacial Science and Technologies

The MAAT Project -
Multibody Advanced Airship for Transport
MAAT

Index

1. Introduction

The problems caused by growth in the transportation sector, e.g. the rise of fuel consumption and cost, as well as pollution and consequent climate change led to a reconsideration of the transportation systems by the most economically advanced nations. Nowadays, despite all technologic developments, as we proceed in the 21st century, we may be about to witness the return of slower transportation as a mean of increasing energy efficiency and business profitability. Regarding air transportation, open rotors propulsion systems are being considered for future airliners in the past, unducted fans have been developed that delivered better specific fuel consumption (SFC) than the ultra high bypass ratio turbofans being developed today. In both cases, the noise is an issue. Reducing the tip speed of these devices is an obvious solution for noise but requires a reduction of cruise speed and disk loading and the side effects are further reductions in drag and SFC. All of this means that we may well witness the return of propellers for future commercial aviation.

A. The Software Project

JBLADE [1] [2], is being developed as part of a PhD thesis at Aerospace Sciences Department in University of Beira Interior, Covilhã, Portugal under the supervision of Professor Miguel Silvestre.

This software is an open-source propeller design and analysis code written in the Qt® programming language. The code is based on QBlade code developed at TU Berlin [3], [4], [5], [6], [7] and André Deperrois' XFLR5 [8].

The airfoil performance figures needed for the blades simulation come from QBLADE's coupling with the open-source code XFOIL. This integration, which is also being improved, allows the fast design of custom airfoils and computation of their lift and drag polars.

JBLADE uses the classical Blade Element Momentum (BEM) theory modified to account for the 3D flow equilibrium. Its methodology and theoretical formulation for propeller analysis are detailed presented in [4] and [5]. The code can estimate the performance curves of a given propeller design for off-design analysis. The software has a graphical interface making easier to build and analyze the propeller simulations.

The long term goal of the JBLADE is to provide a user-friendly, accurate, and validated open-source code that can be used to design and optimize a variety of propellers.

B. Code Structure

An overview of the data objects storing polars, blades, propellers, and simulation data as well as their relation to XFOIL can be found in Figure 1. This figure was obtained based on the QBlade's structure since the main structure remains the same.

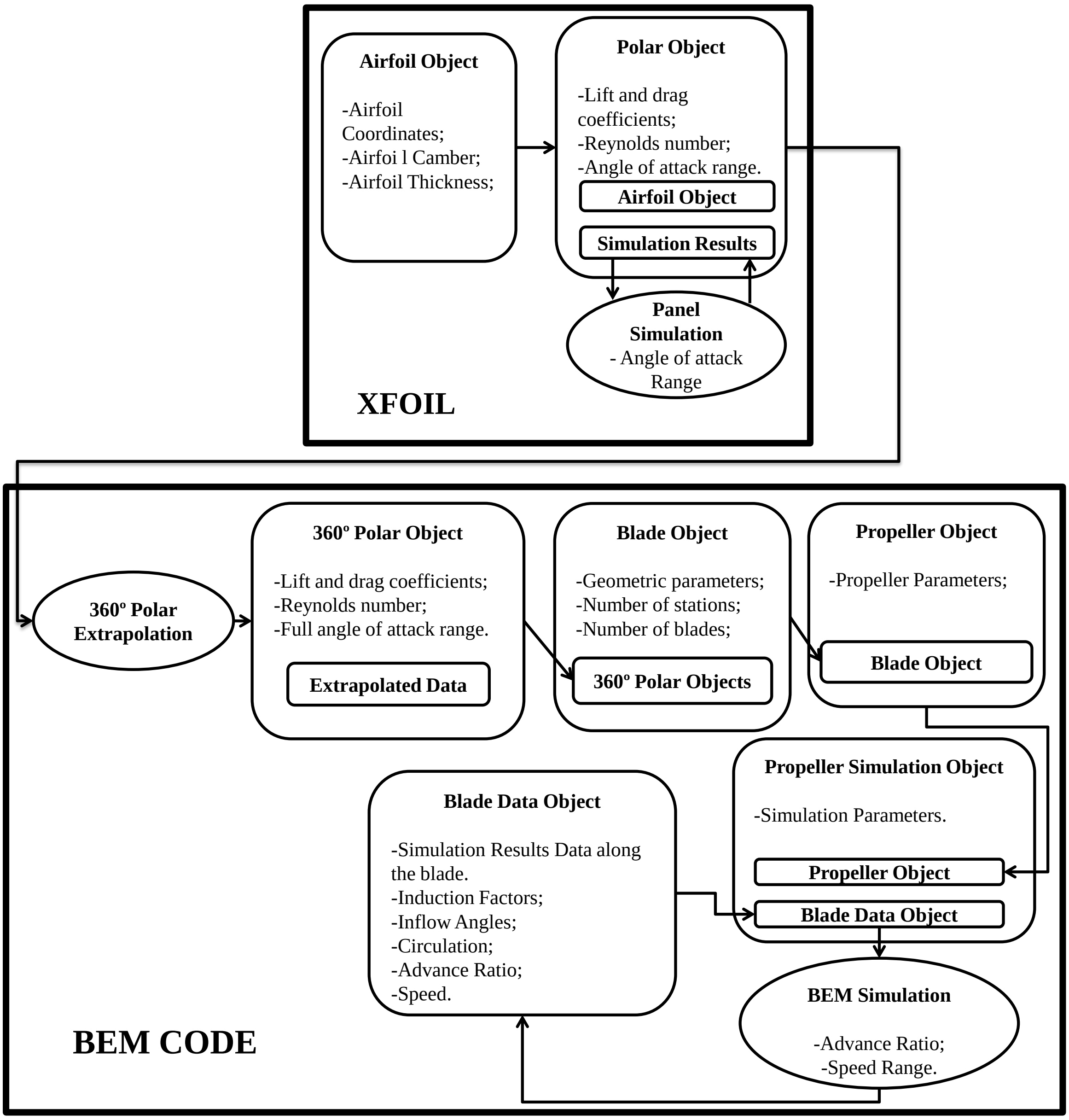


Figure 1 - JBLADE code structure.

C. Code Limitations

Like the original XFOIL written by Mark Drela, XFLR, written by Andre Deperrois and QBlade developed by David Marten, JBLADE has been developed and released according to the principles of the General Public License. One important point about the GPL is that this program is distributed without any warranty (neither the warranty of merchantability nor the warranty of fitness for a particular purpose). The resulting software is not intended as a professional product and does not offer any guarantee of robustness or accuracy. It is distributed as a personal use application only. This software may not be faultless and there will certainly be more bugs discovered after the distribution. However, a validation against other BEM software permits some trust in the provided results.

1. Tutorial Guide

A. Overview

In this section it will be presented a short introduction about how to design and simulate a propeller using JBLADE. Just the basic functions will be mentioned along the tutorial and this document not intends to be a formal help guide of the software. Just the succession of the modules and sub-modules needed to create propeller blade and simulate it will be covered. All the functions not mentioned in this part are more or less self-explanatory and the user may experiment them freely.

B. Direct Foil Design

When user select the **Direct Foil Design** next screen will appear.

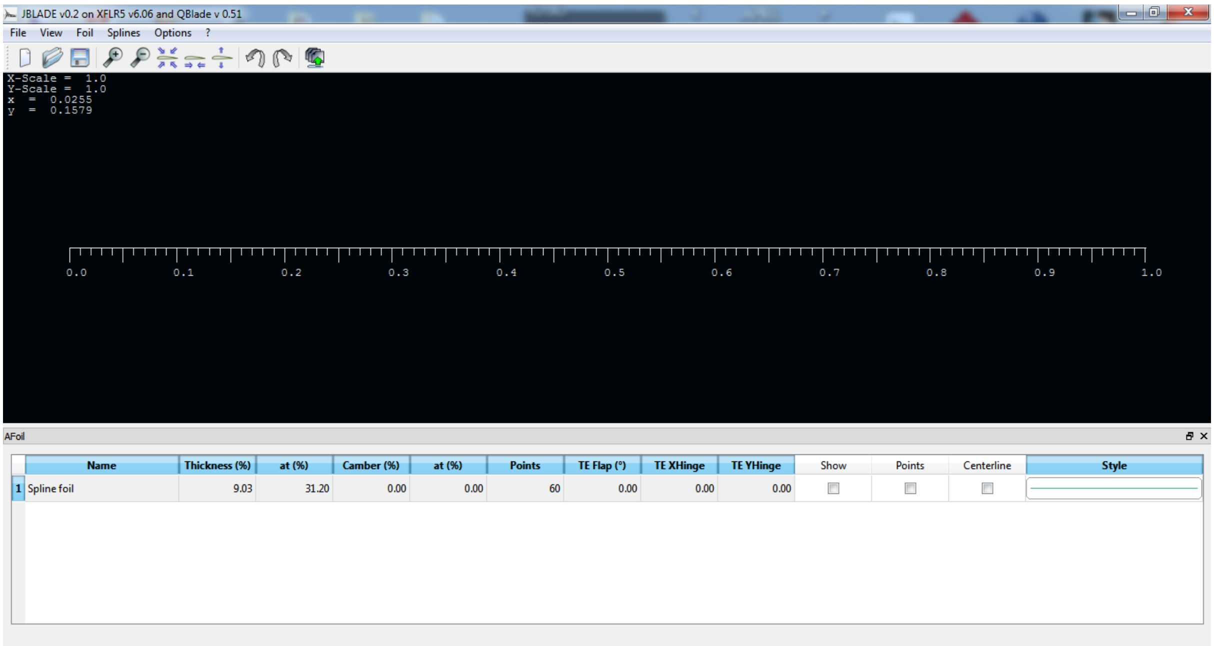


Figure 1 - Direct Foil Design Screen.

To create a propeller simulation it is need to import or create its airfoils. This can be done by 3 different ways: using splines, using the NACA airfoil generator or import an airfoil through a function originally created in XFLR5[8]. For complete this tutorial only one airfoil will be used. It is the NACA 0010 which was created through the second option presented above . If a modification of the airfoil is needed, it is possible to do it with right click on the airfoil name row, and select the desired option. In Figure 2 is possible to observe the available modifications.

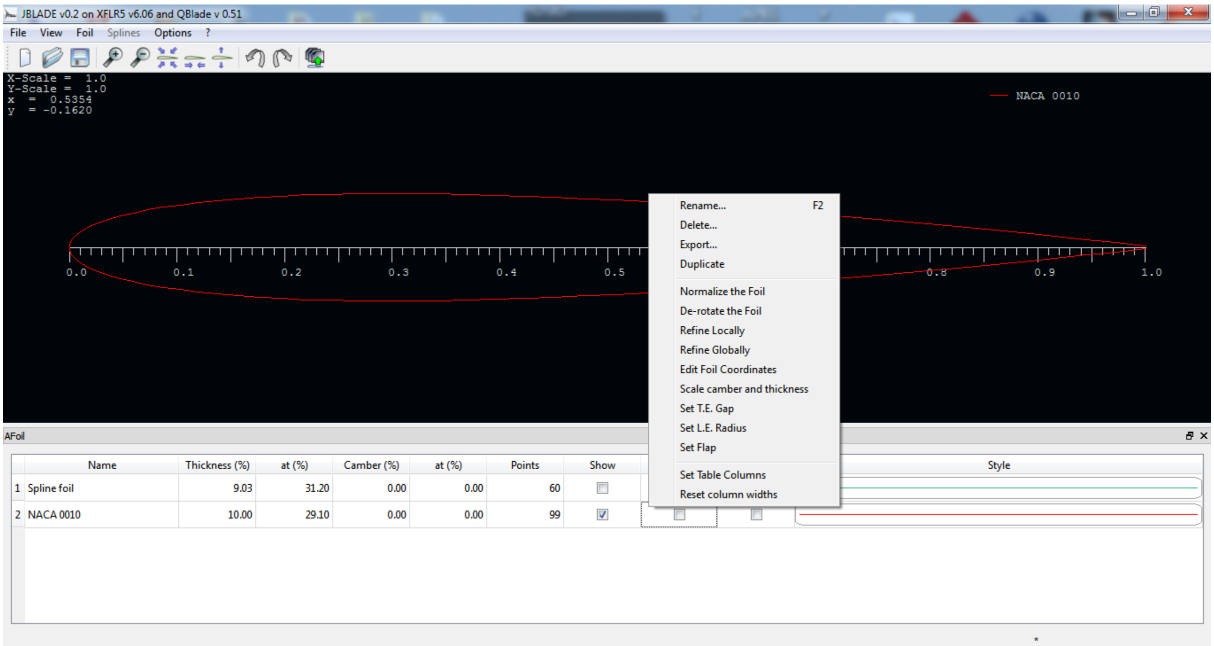


Figure 2 - Available options to modify or refine an airfoil [4].

An advice to new users is that airfoils should be defined at least with 250 points, to avoid numerical errors during airfoil calculations. This could be done trough "Refine Globally" Option [1].

C. XFOIL Direct Analysis

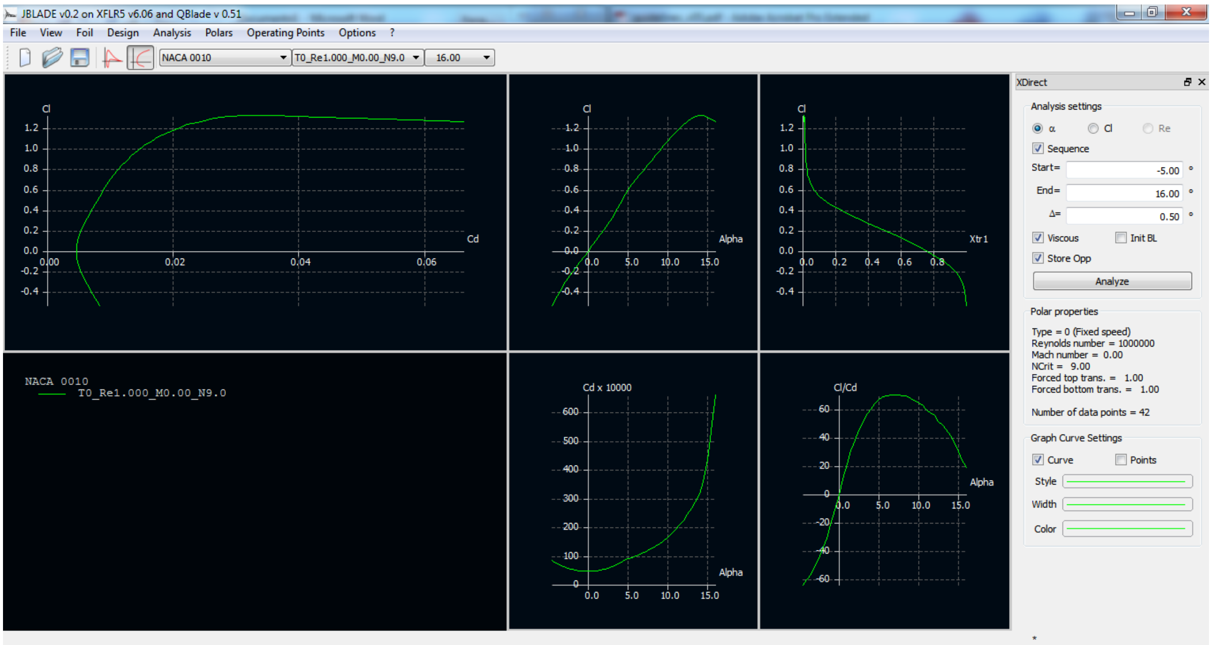


Figure 3 - XFOIL Direct Analysis Screen in JBLADE [4].

Inside the **XFOIL Direct Analysis** sub-module, the airfoils are simulated and their polar are created. An analysis can be defined under the menu point **Analysis** as presented in Figure 4 , and the simulation can be performed.

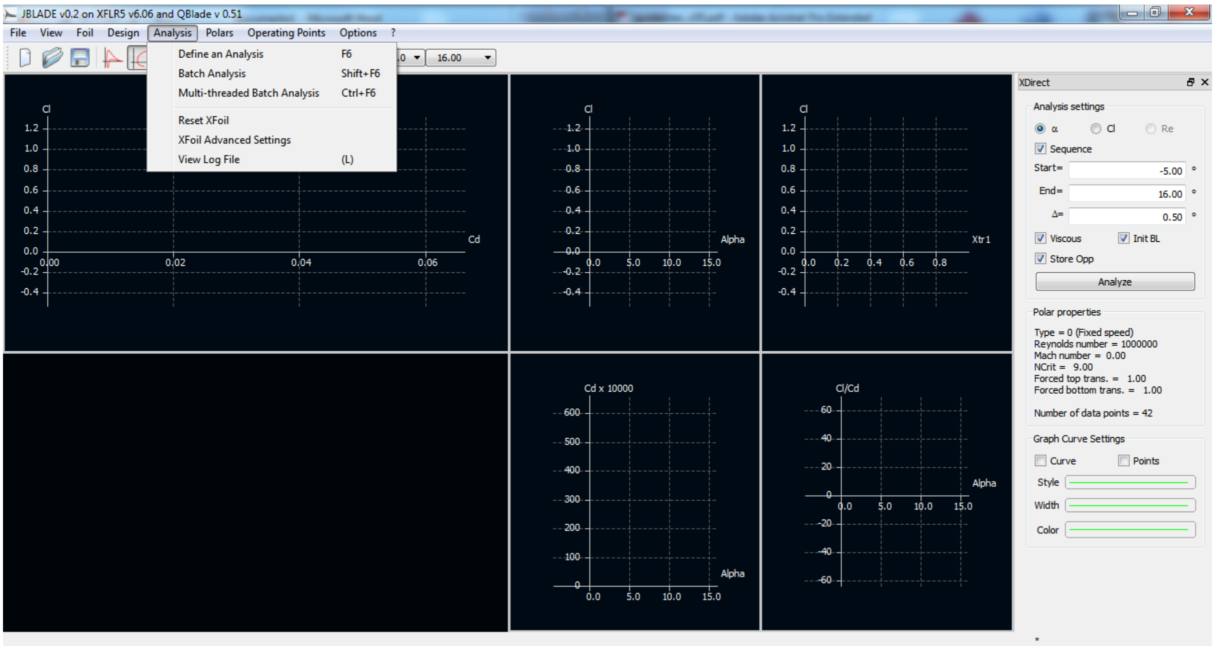


Figure 4 - Define menu under XFOIL Direct Analysis sub-module [4].

There are 2 different ways to do an airfoil simulation: 1- Define an Analysis; 2- Batch Analysis. There are several different types of analysis (see [8]). The most common type of analysis is a variation in angle of attack. This type of analysis will only converge for a limited range of AoA values, typically from about -5º to +25º [9].

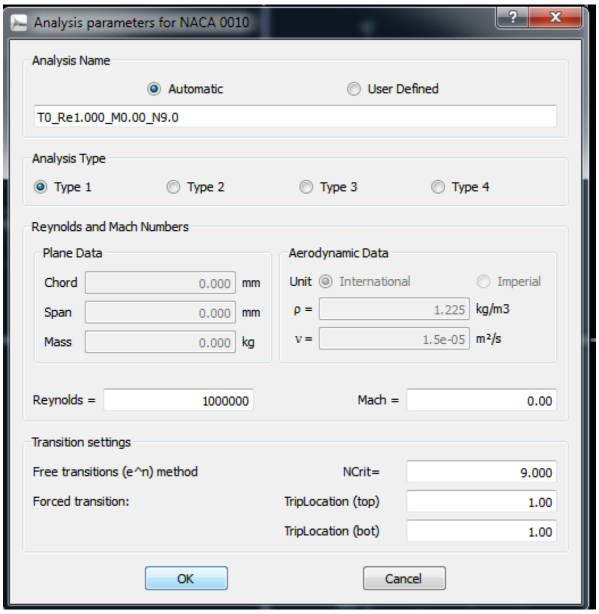


Figure 5 - Define an Analysis Dialog [4].

Any number of polars can be created and associated to a given airfoil. By default, the transition number is set to 9, and the trip locations are set at the trailing edge [8].

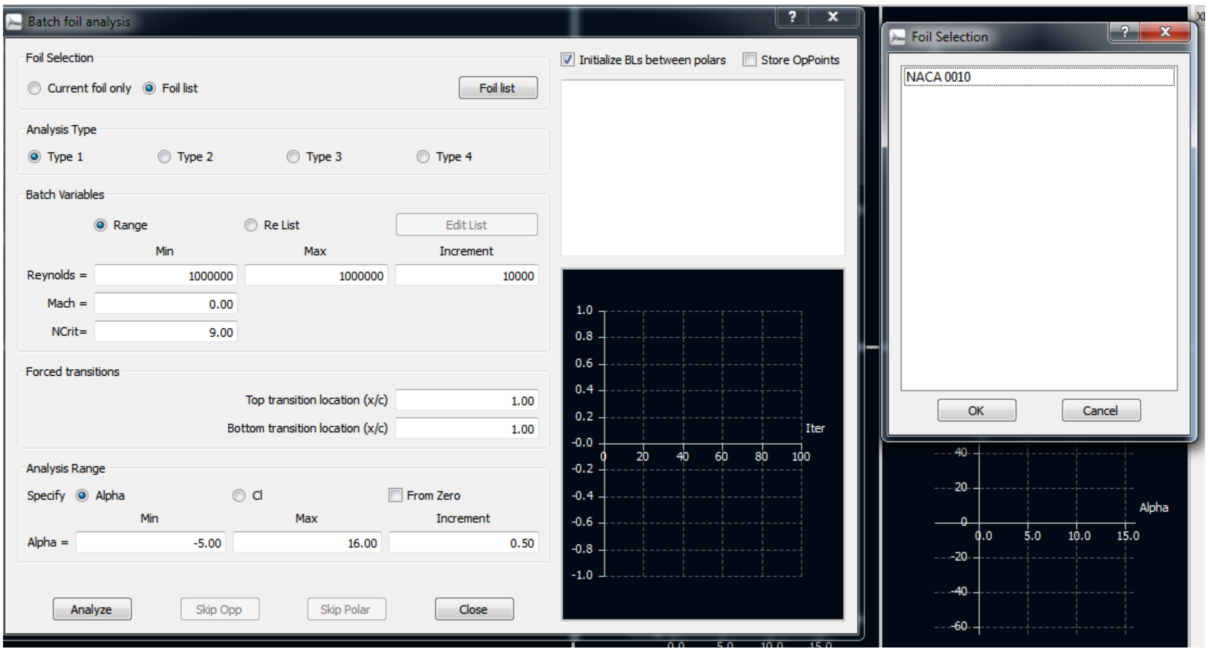


Figure 6 - Batch Analysis Dialog [4].

The Batch Analysis allows that the user choose a Reynolds Number Range and even a list of airfoils. This could be useful for a first attempt of simulate a propeller.

It is also possible to import polar data in this module, whenever importing polar data, an arbitrary airfoil with exactly the same name as the imported polar data needs to be created to connect the polar data with this airfoil. Under the menu **Polar** it is possible to **Edit** and **Export** the polar.

D. 360 Polar Sub-Module

Under the menu **File** → **Rotor and Propeller Design** is possible to analyze a new propeller. The XFOIL calculated polar will be to be extrapolated to 360º [2], [4], [5], since during normal operation propellers can attain high angles of attack. The sliders on the left side of Figure 7 can be used to achieve the best match between extrapolation function and XFOIL computed polar data. The positive extrapolation can be manipulated using the sliders A+ and B and the negative extrapolation can be manipulated with sliders A- and B-.

The extrapolation is carried out exactly as described in Methods for Root Effects, Tip Effects and Extending the Angle of Attack Range to +-100º, with Application to Aerodynamics for Blades on Wind Turbines and Propellers [10].

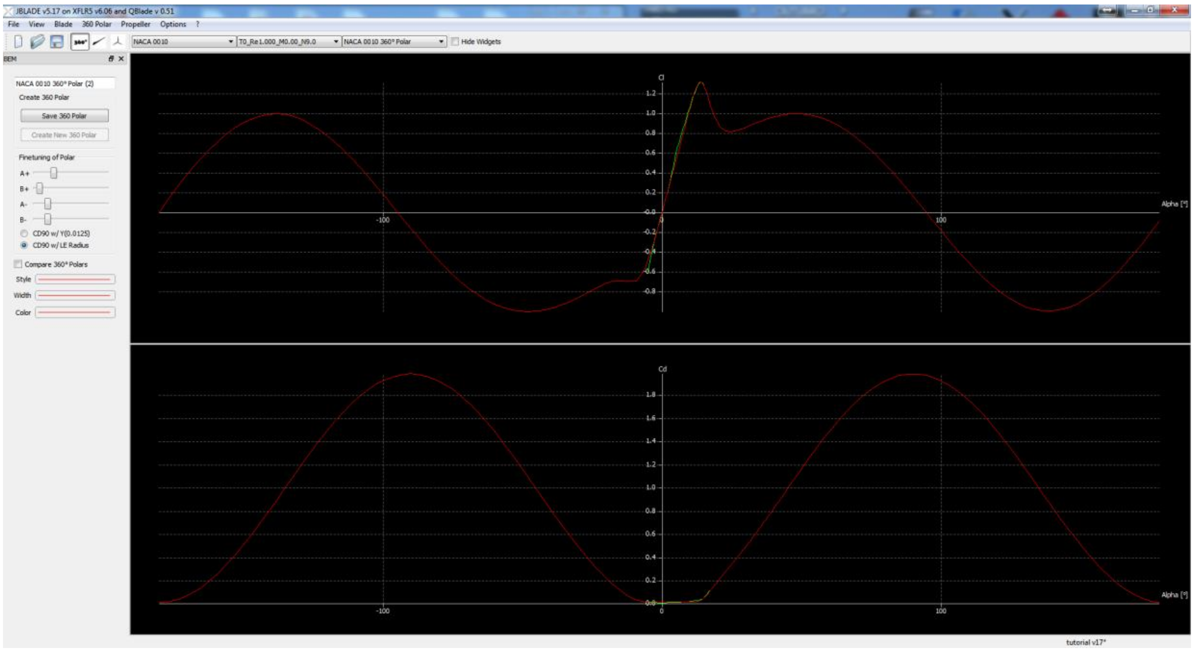


Figure 7 - 360 Polar Extrapolation Sub-Module Screen.

Bellow the sliders the value for CD90 can be estimated by 2 different methods: use the airfoil's leading edge radius or use the airfoil y-coordinate at x/c=0.0125 [2] . Under the **360 Polar** menu, it is possible to load a cylindrical foil [4]. This foil has zero lift and a drag value that can be specified by the user. Cylindrical foils can be used in the root region of the propeller blades in order to facilitate the connections with hub and also due to structural reasons.

E. Blade Geometry Sub-Module

When at least one 360º polar was created, a new blade can be designed. The number of stations can be increased or decresead since one airfoil and one polar are specified at each section. The number of Blades should also be defined in this module. To ensure consistency, when a blade from the database is deleted or overwritten all associated simulations and propellers are deleted as well [4].

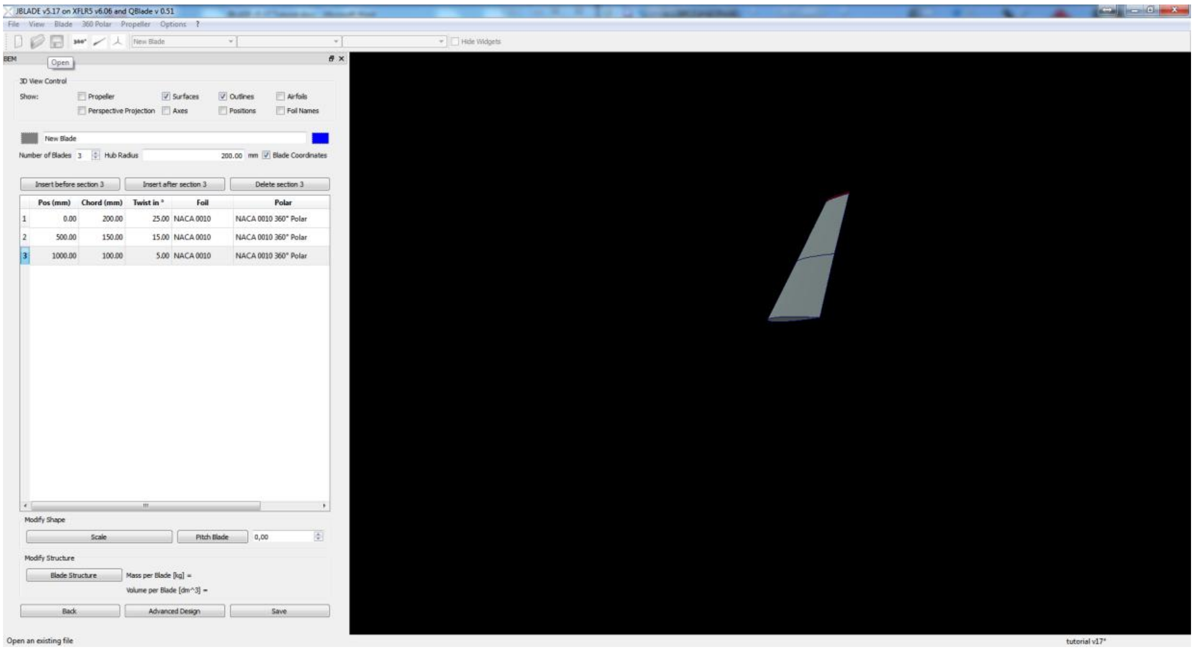


Figure 8 - Blade Design Sub-Module.

The Scale button opens the corresponding dialog window as it is shown in Figure 9. The scale button allows to the user scale the chord, twist and span by a scaling factor and it was originally implemented in QBlade [4]. The Hub Radius represents the distance between the origin and the beginning of the blade.

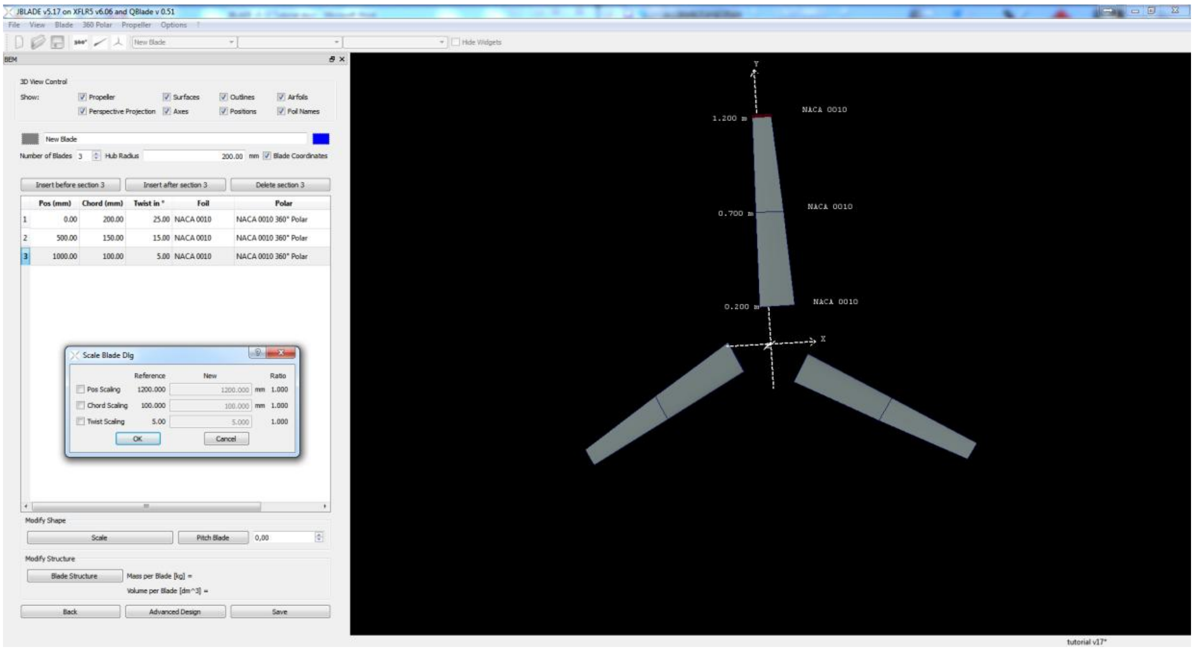


Figure 9 - Optimize Dialog [4].

F. Propeller Simulation

In the "Propeller Definition and Simulation" module it is possible to define a new propeller. The user specifies all propeller parameters, as presented in Figure 10. Then a propeller simulation, over a range of speeds, can be conducted.

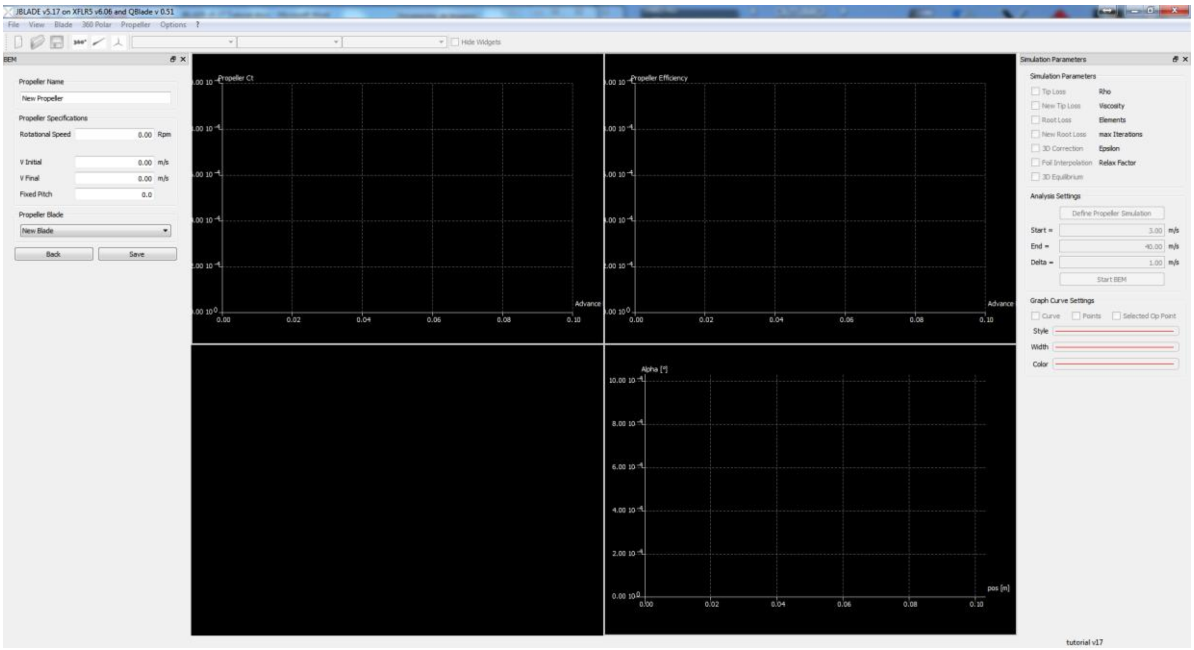


Figure 10 – Propeller Sub-Module Screen

The Tip and Root Losses, Foil Interpolation, 3D Correction are explained in ref. [4]. The 3D Equilibrium is explained in ref. [1].

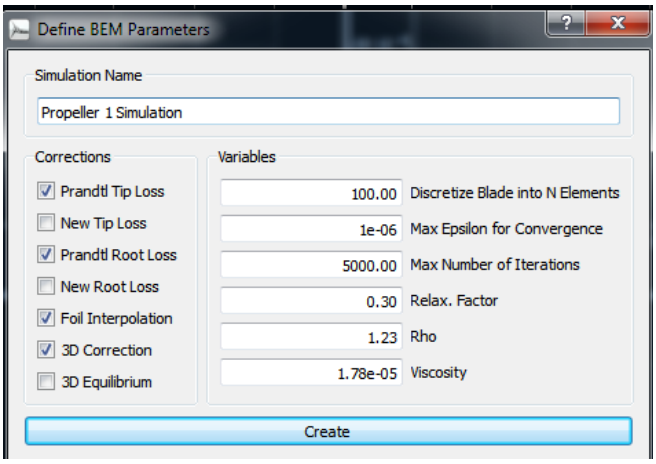


Figure 11 - Simulation Parameters .

After choose the adequate parameters for the propeller simulation the user just needs to introduce the initial and final values of velocity.

After analyze the propeller, the graph variables of each axis can be modified, in order to provide to the user a better view of propeller performance. In Figure 12 are presented the variables for the top graphs.

If more than one analysis is present, it will appear, making easy the comparison between different simulations.

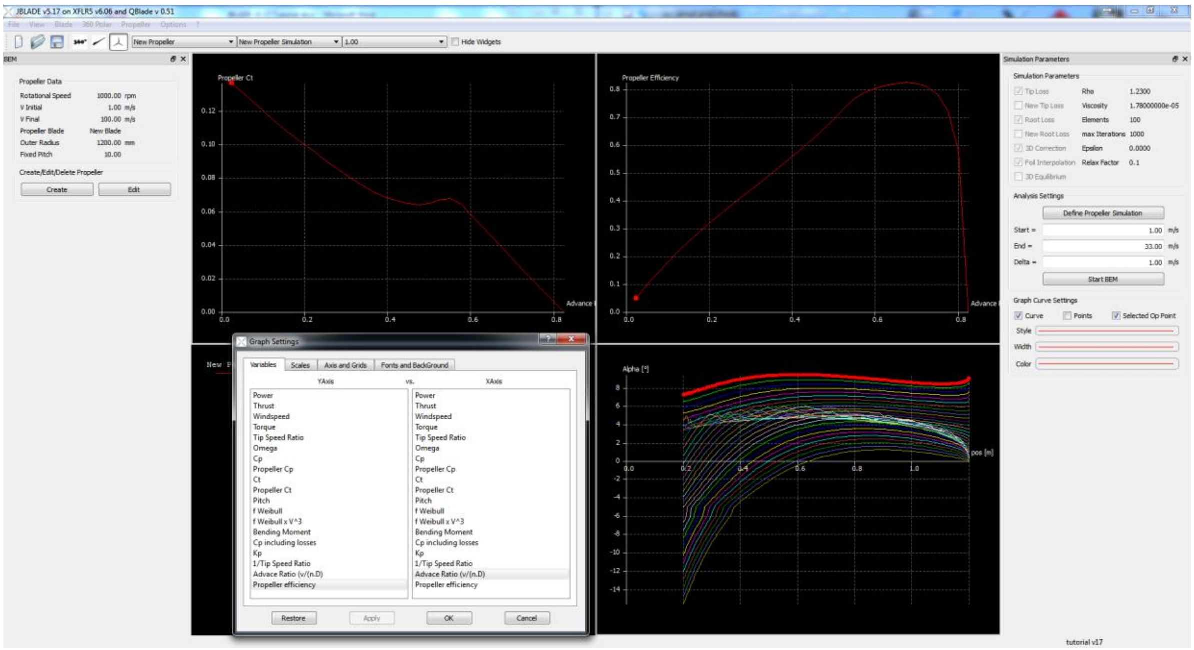


Figure 12 - Top Graph available variables.

The available variables for low-right graph are shown in Figure 13. These variables can be useful as a complement to the top graphs variables. These variables were originally implemented in QBlade [4].

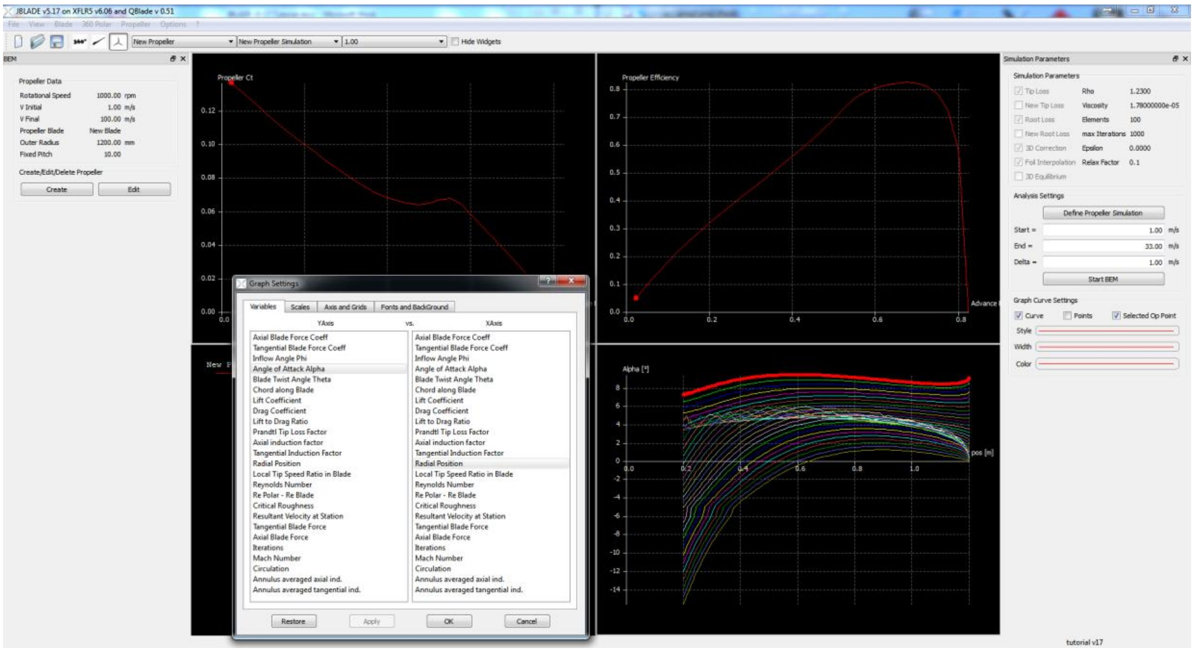


Figure 13 - Low-Right Graph available variables.

It is possible to export the Graphs as a *.txt or *.csv file. With a right click in the mouse, the menu shown in Figure 14 appears. The user just needs to choose the name and location of the file.

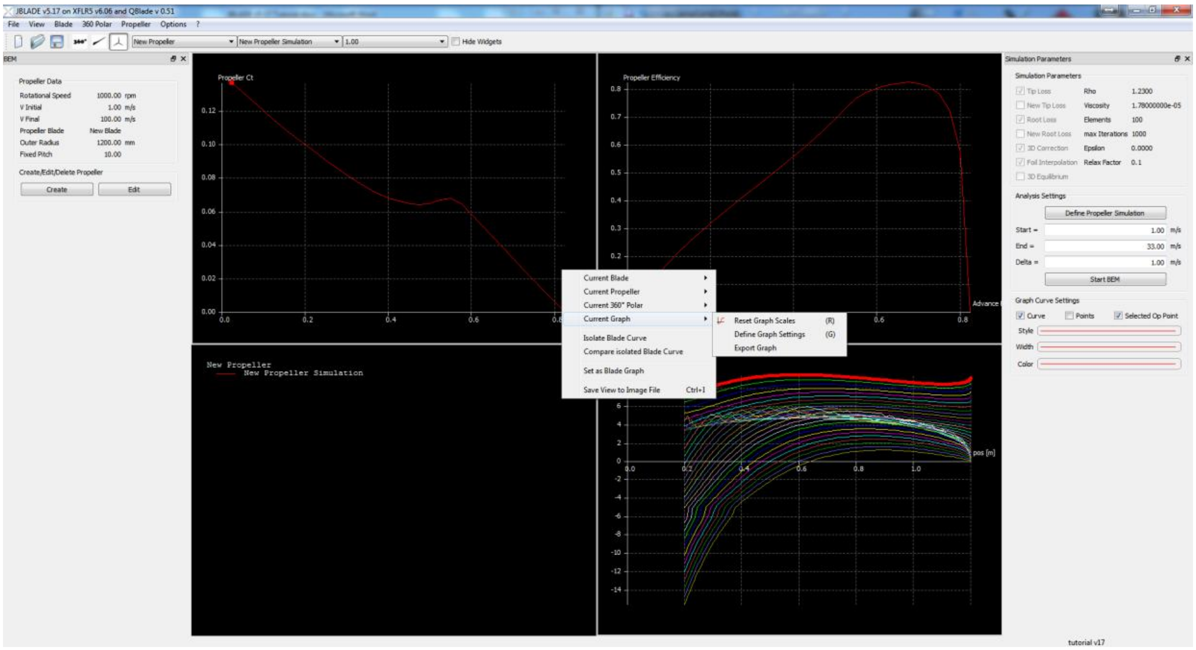


Figure 14 - Export Graphs.

2. JBLADE Validation - NACA TR-594 - "PROP C"

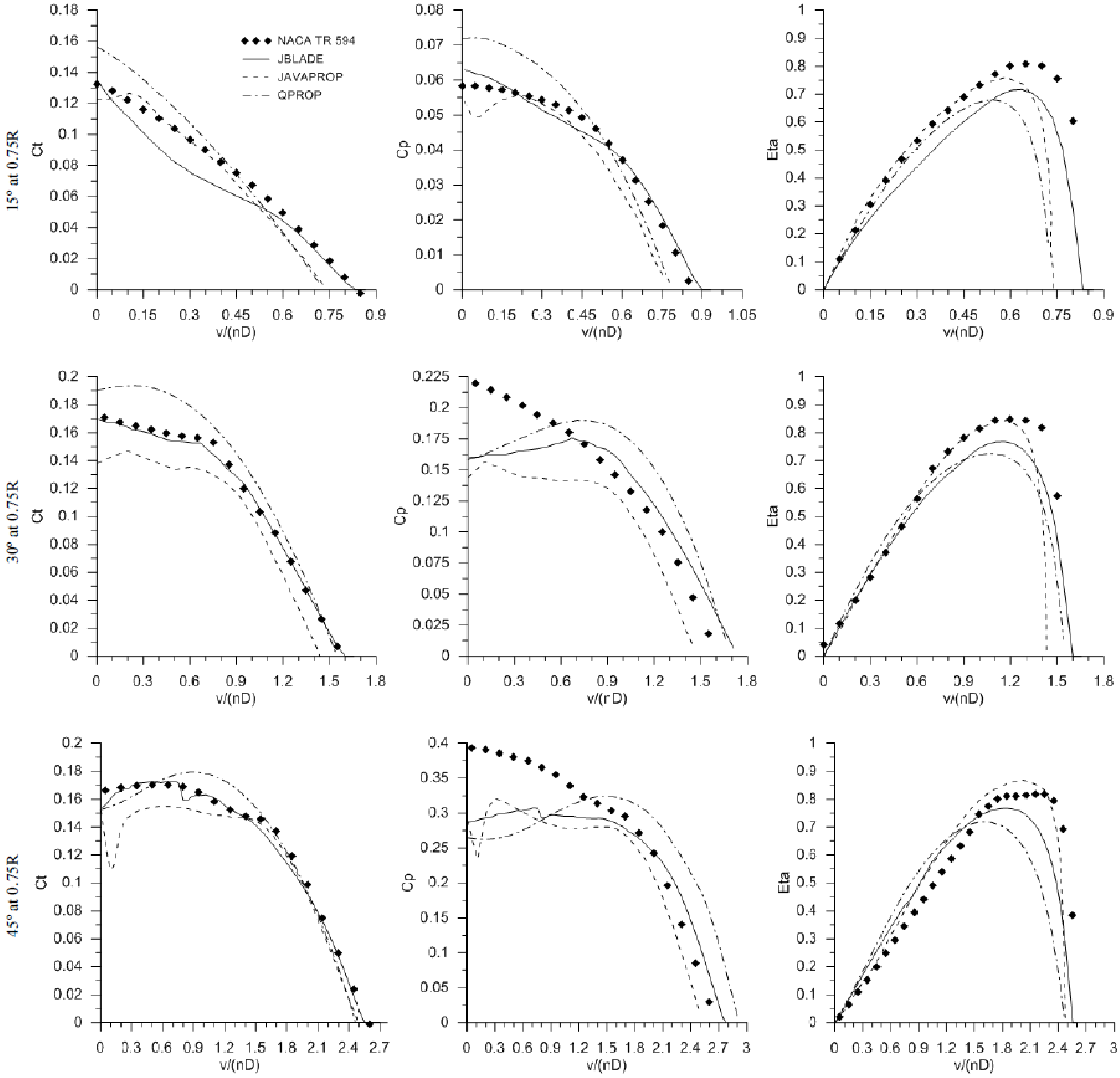


Figure 15 - Results of JBLADE Software Validation [1].

3. Bibliography

[1] M. A. R. Silvestre, J. Morgado, and J. C. Pascoa, “JBLADE: a Propeller Design and Analysis Code,” in *2013 International Powered Lift Conference*, 2013.

[2] J. P. Morgado, M. A. Silvestre, and J. Pascoa, “Full Range Airfoil Polars for Propeller Blade Element Momentum Analysis,” in *2013 International Powered Lift Conference*, 2013.

[3] D. Marten, G. Pechlivanoglou, C. N. Nayeri, and C. O. Paschereit, “INTEGRATION OF A WT BLADE DESIGN TOOL IN XFOIL/XFLR5,” vol. 49, no. 0, pp. 1–4.

[4] D. Marten, “QBlade Guidelines,” Berlin, Germany, 2012.

[5] D. Marten and J. Wendler, “QBlade Guidelines v0.6,” Berlin, 2013.

[6] D. Marten, J. Wendler, G. Pechlivanoglou, C. N. Nayeri, and C. O. Paschereit, “QBLADE : An Open Source Tool for Design and Simulation of Horizontal and Vertical Axis Wind Turbines,” *International Journal of Emerging Technology and Advanced Engineering*, vol. 3, no. 3, pp. 264–269, 2013.

[7] D. Marten, J. Wendler, G. Pechlivanoglou, C. N. Nayeri, and C. O. Paschereit, “DEVELOPMENT AND APPLICATION OF A SIMULATION TOOL FOR VERTICAL AND HORIZONTAL AXIS WIND TURBINES,” in *Proceedings of ASME Turbo Expo 2013: Turbine Technical Conference and Exposition - GT2013*, 2013.

[8] A. Deperrois, “Analysis of Foils and Wings Operating at Low Reynolds Numbers - Guidelines for XFLR5 v6.03,” 2011.

[9] M. Drela, “XFOIL - An Analysis and Design System for Low Reynolds Number Airfoils.pdf,” in *Low Reynolds Number Aerodynamics*, 1989, vol. 54, pp. 1–12.

[10] B. Montgomerie, “Methods for Root Effects, Tip Effects and Extending the Angle of Attack Range to +-180^{o}, with Application to Aerodynamics for Blades on Wind Turbines and Propellers,” Stockholm, 2004.