Wing Designer

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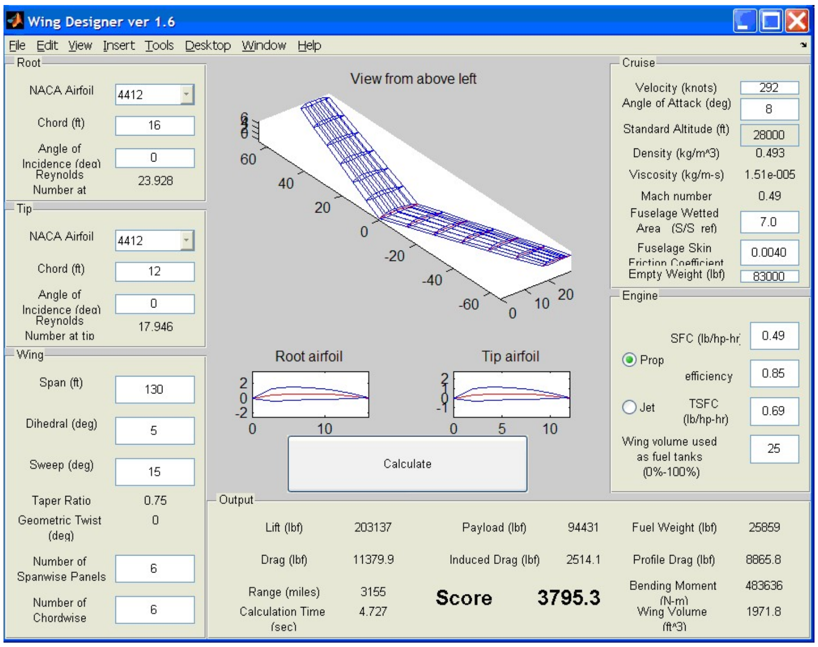

1 Introduction

Wing Designer is a MATLAB Graphical User Interface (GUI)-based program intended to demonstrate to undergraduate aerodynamic students the impact of engineering trade-offs in basic wing design. Students can vary numerous design parameters to include NACA airfoils, chord, span, dihedral, twist, sweep, cruise conditions, and engine parameters. To limit the design space and to simplify the GUI, Wing Designer limits the aerodynamic and geometric twist and chord distributions to be linear across the span. Within these contraints, students can vary the chordwise and spanwise panel distributions to discover the trade-off between model fidelity and computation time. The program also boasts the following features:

- Each airfoil available in the drop-down menu has been analyzed at eight different Reynolds numbers from 100,000 to 50,000,000 to determine profile drag at each. Thus the profile drag at any station is a function of both Reynolds number and angle of attack, α.
- The above analysis also determines the stall angle of attack, α_{stall} for each airfoil at each Reynolds number. Thus, increasing the local α beyond α_{stall} results in a large drag penalty mimicking reality.

- The program displays the wing panel geometry from a number of different viewpoints.
- Educators can tailor the program to focus on tapered wing design or incorporate performance metrics such as range and maximum payload. Extending the existing code to predict stability derivatives is trivial although not currently implemented.
- Educators can change the design objectives to offer a fresh design challenge to subsequent classes and prevent students from recycling past designs.
- The standard atmosphere model is accurate beyond 100,000 ft.

The following known limitation prevent the program from achieving higher fidelity.

- The post stall drag model reflects the general trend for both thick and thin airfoils, but is not specific to each particular airfoil.
- The profile drag model is an integration of the 2D profile drag at numerous stations along the span, but it does not account for any 3D relaxation.
- The drag model does not incorporate any wave drag or compressibility effects beyond a Prandtl-Glauert correction to modify the wing geometry.
- There is particular noise in the results of the analytical 2D airfoil analysis between similar airfoils at similar Reynolds numbers.
- The current selection of airfoils is limited to NACA 4 and 5-digit airfoils that are admittedly less than ideal for transonic applications.

2 Sample Cadet Report

The following is an excerpt from a sample cadet final Wing Designer report.

> Using the MATLAB Wing Designer program, I was able to design a wing for a C-130 Hercules with the mission of achieving a high total score. In order to design the wing, I first submitted weekly updates for several weeks in order to get an understanding of how the program worked and gain some general insight for maximizing the total score. In designing the final wing, I chose reasonable values (based on my previous submissions) for all of the design boxes. Then, I started the process of maximizing my total score. I went through, parameter by parameter, altering the value in one direction until I achieved the highest possible score for the configuration. Next, I moved down the list to the next variable and repeated the process. I cycled through all of the parameters several times, because as one variable changes the best value for the remainder of the parameters will be different. After several cycles, I was confident that I had designed a pretty good wing.

3 Function Summaries

The following are summaries of the subfunctions implemented in the latest version of Wing Designer.

Contents.m Similar outline of high-level function summary and necessary files

Main.m Top level file that establishes GUI and runs Wing Designer

InitializeGUI.m Initializes the GUI and establishes callback functions

StandardAtmosphere.m Reads in altitude and output viscosity, density, and speed of sound

GetGeometryfromGUI.m Gets parameters from the GUI and create geometry structure "geo"

DeterminePanelGeometry.m Finds coordinates for horseshoe vortices and control points and plots points to GUI

VortexStrength.m Implements Vortex Lattice Method and determines horseshoe vortex strengths

LiftCoeff.m Determines the lift coefficient given the vortex strengths

SpanLoading.m Determines center of pressure and spanwise loading

InducedDrag.m Calculates far field induced drag estimate

NacaCoord.m Determines airfoil skin and camber coordinates from NACA designation

NACAdata.txt Drag Polar Coefficients from XFOIL for each airfoil at numerous Reynolds numbers

parseNACAairfoildata.m Parses the text file NACAdata.txt into a structure

PerformRegression.m Relates the coefficients of the drag polar to Reynolds number as parabolic functions.

DetermineProfileDrag.m Determine the wing profile drag estimate from the 2D section airfoils' drag polars

ZeroOutput.m Nulls output to GUI when error checking is not satisfied

FinalOutput.m Calculates score and other outputs and posts these parameters to the GUI