Instructions for the VLM_Camber Program

Introduction

VLM_Camber is a vortex lattice program for a single straight-tapered wing. Thus, wings have straight leading and trailing edges but allows for arbitrary sweep angles. A later version will allow other lifting segments to be added and will relax the straight wing requirement.

The program also allows the user to choose from a variety of camber functions for the root and tip chords. The camber function at intermediate spanwise stations is then found by linear interpolation.

The program also allows the user to select wing twist, sweep, aspect ratio, taper ratio, and geometric angle of attack. The Mach number may also be entered if compressibility effects are desired.

The program presents the user with a 3D graphic of the wing as it is being constructed so that the user may see the effects of varying all wing planform parameters. The user may also easily change the viewpoint of the wing and observe it rotating in to the new position. The user also has options to change what is seen in the 3D graphic. That is, the user may choose whether to see the vortex lattice control points, horseshoe vortex corners, vortex filaments, wing outline and the 3D axes.

A separate window opens when the user selects the camber functions. Two graphics show the root and tip camber. These graphics change dynamically with the user choices so that the user may see the different NACA camber functions and the effects of changing the various parameters associated with the function.

Since the computational power of modern PC's has improved, the vortex lattice algorithm in the program does not use many of the usual approximations. For instance, none of the thin airfoil approximations are used. Thus, the application of the tangency boundary condition takes place on the wing and not the x-y plane. The approximation of flat horseshoe vortices is also not taken. Each trailing filament follows the wing camber by being divided into segments between vortex corners. Thus all filaments leave the physical trailing edge to form a genuinely flat vortex sheet.

Output of the program includes wing CL, Cdi, CM about the root LE, and Cmac. In addition, the functions CL vs. alpha, CM vs. alpha, and Cdi vs. alpha squared are given. If vortex lift is present, a graphic showing the contributions of the inviscid and vortex lift is shown.

Main Window

When the user runs the VLM_Camber program, the Main Window opens as shown in Fig. 1. A default wing similar to the one in the figure is already present but no results are shown initially. The user is then free to vary whatever parameters are desired before calculating the performance. The main window consists of a 3D graphic of the wing and several boxes, called frames, containing various controls and parameters. The remainder of this section will describe each of the frames and their parameters.

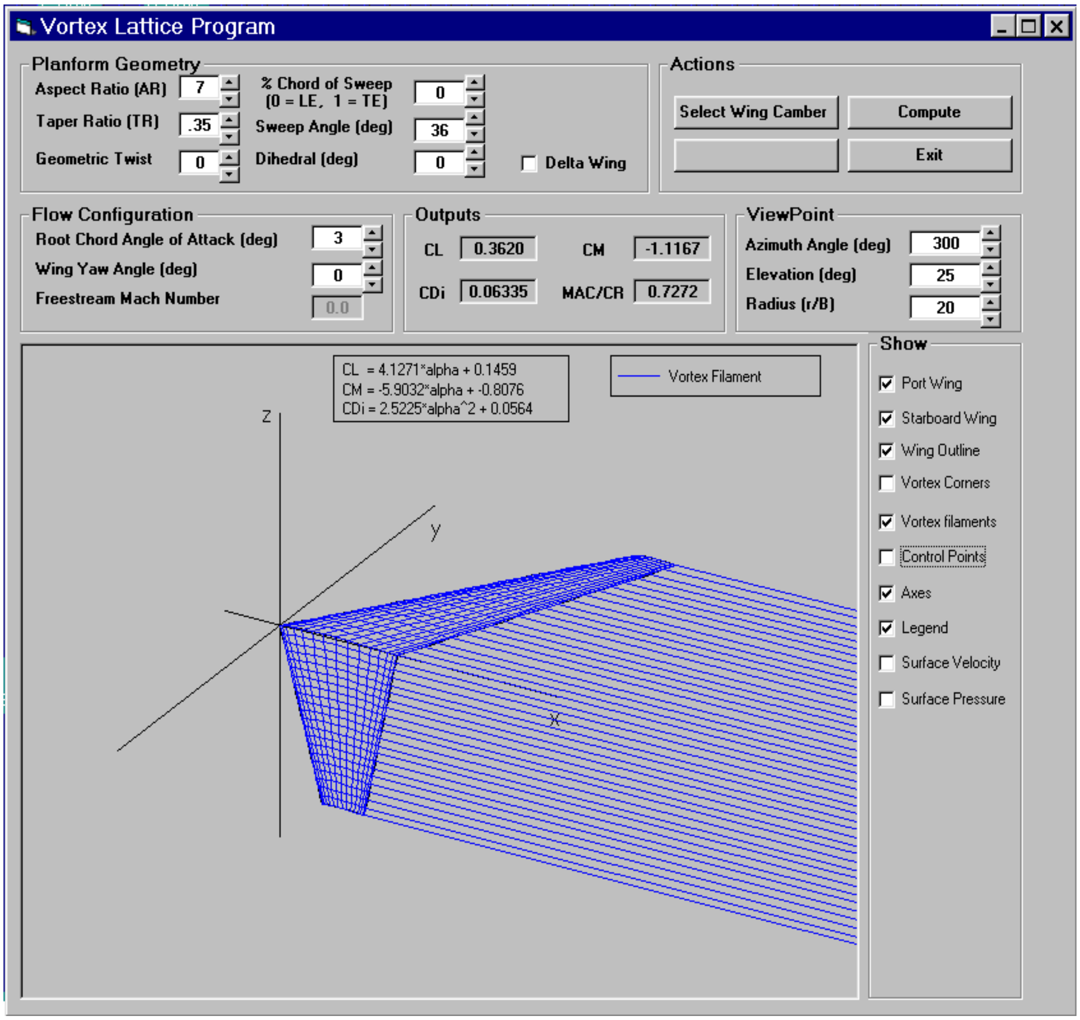

Figure 1. Main Window

Planform Geometry Frame

This frame contains the main planform parameters which determine the overall shape of the wing. These are:

Aspect Ratio (AR) – The aspect ratio of a wing is defined as b^2/S where b is the wing span length and S is the wing planform area (area of the wing projected to the x-y plane). Generally, higher aspect ratios mean a longer wing.

Taper Ratio (TR) – The ratio of the tip chord length to the root chord length. If the ratio is one, then the tip and root chords have the same length. If zero, the program will ask if the user wishes the wing to be a delta wing as these are the most common wings with a zero taper ratio.

Geometric Twist – The difference in angle of attack between the tip and root chords. If positive, the tip chord sees a smaller angle of attack than the root chord. This is called outwash and is the usual practice.

% Chord of Sweep and Sweep Angle– These are the chordwise location of the user-defined wing sweep and the sweep at that chordwise location. If the chord of the sweep is set to zero (the default), the wing is swept about the leading edge. If the value is set to 0.25, then the wing is swept about the quarter chord. Clipped delta wings may be quickly made by specifying a zero sweep of the trailing edge % chord of sweep = 1).

Dihedral – This is the angle in the y-z plane defined by the angle through which the untwisted wing tip has been rotated upward. A small amount of dihedral is used on low wing vehicles to improve roll stability.

Each of these controls has up/down arrow boxes for simple incrementing of the values with a mouse.

Delta Wing check box – If the user selects the Delta Wing check box, the program assumes that the wing will be a delta wing and will set the taper ratio to zero, set the trailing edge sweep to zero and calculate the leading edge sweep.

Flow Configuration Frame

This is where the user sets the flight conditions encountered by the wing. These are:

Root Chord Angle of Attack – This is simply the geometric angle of attack. Use of the term root chord considers that the wing may be twisted so that only the root chord will see the full angle of attack.

Wing Yaw Angle – If the user wishes a nonzero yaw angle may be specified. This is the angle of the oncoming flow in the x-y plane.

Mach Number – (not yet implemented) This is the ratio of the freestream velocity to the sound speed. Specifying a nonzero Mach number allows for compressibility corrections to be added to the computation of the wing performance.

Outputs Frame

This frame shows the results of the VLM_Camber theory applied to the wing and flow configuration the user has specified. Presented are:

CL – This is the total inviscid wing lift coefficient predicted by VLM theory. If there is vortex lift present, the inviscid CL has been replaced by the sum of the potential lift and vortex lift described by Polhamus. A small vortex lift box appears in the 3D graphic to show these quantities. An example is shown in Figure 2.

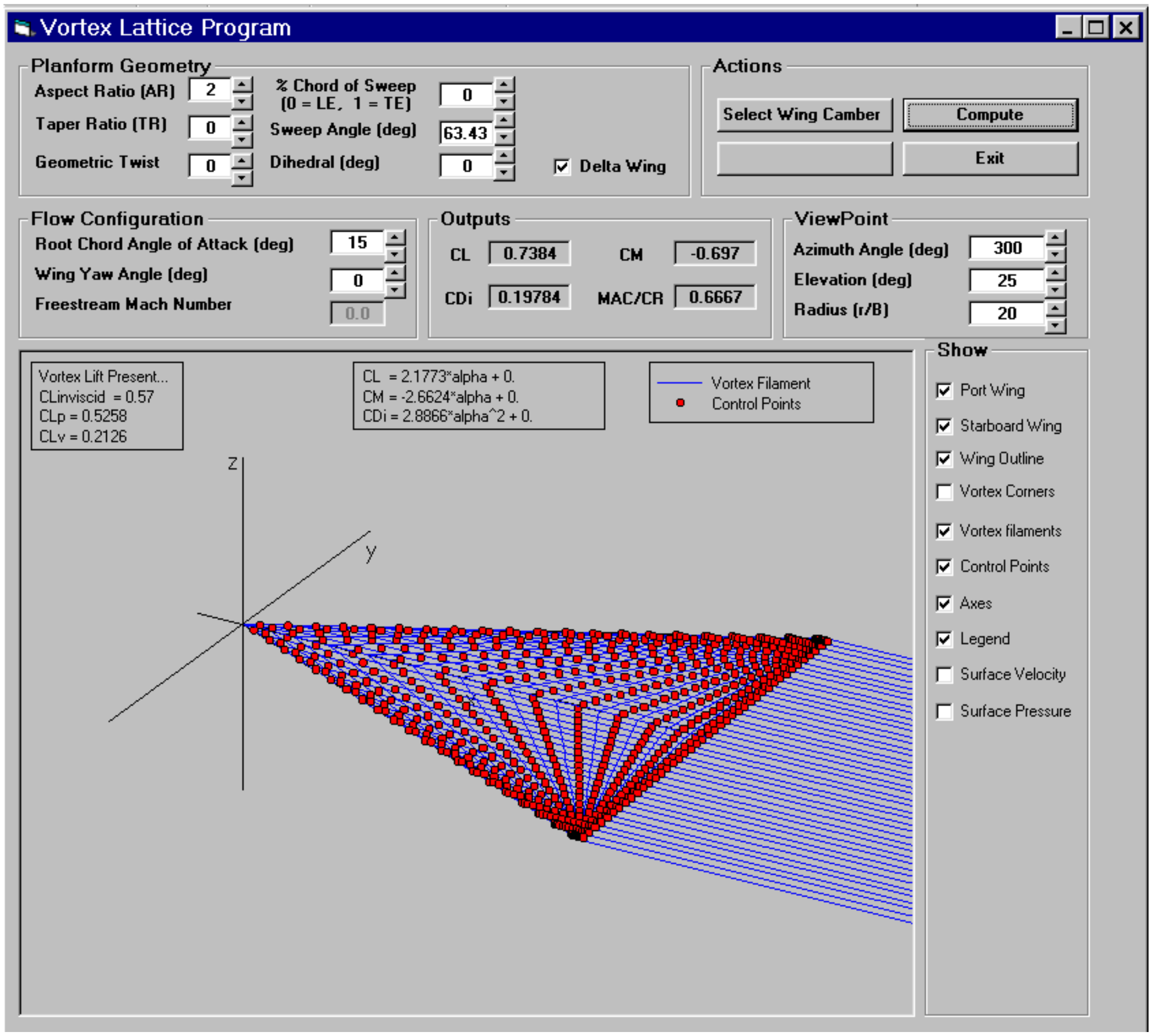

Figure 2. Example of Delta Wing and Vortex Lift. Also shown are the control points as red circles.

CDi – This is the total wing induced drag coefficient and represents only that drag arising from the lift and no other source.

CM – This is the wing pitching moment coefficient about the root chord LE.

MAC/CR – This is the Mean Aerodynamic Chord divided by the root chord. For straight-tapered wings, the integral expression simplifies to:

$$C mac = \frac{2(C_{root}^2 + C_{root}C_{tip} + C_{tip}^2)}{3(C_{root} + C_{tip})}$$

Actions Frame

Select Wing Camber Button – This button opens the Select Camber Window shown in Figure 3.

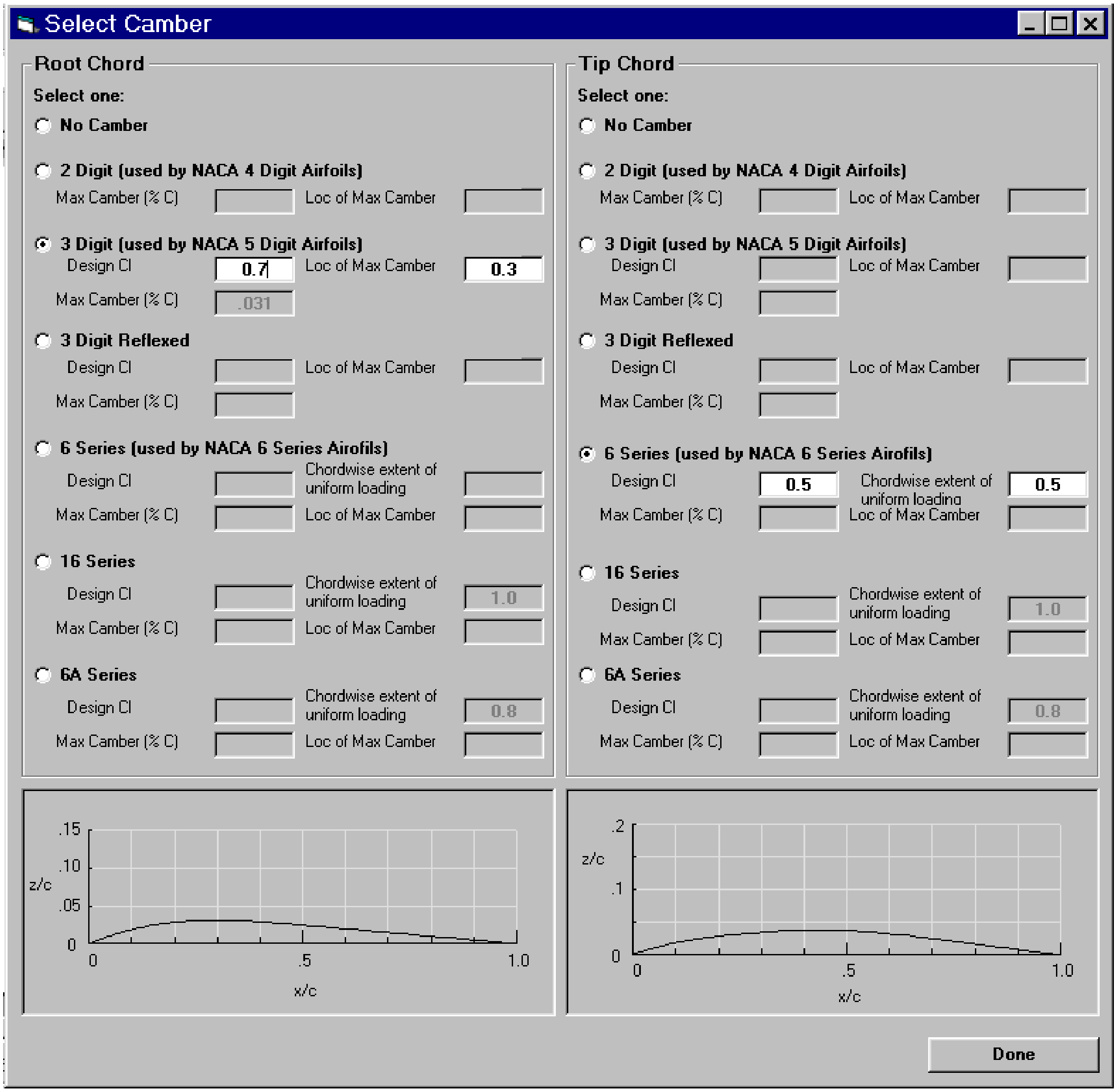

Figure 3. Select Camber Window.

In the Select Camber window there are two main frames, one for the root chord and one for the tip chord. In each frame is a series of choices for the camber based on the defined camber line functions from NACA. When the user selects one of the choices, the parameter windows activate, as indicated by the background color changing to white from grey. Suggested values appear in the boxes when they activate and the graphic window below the frame displays the camber function. The graphic changes with each camber selection change and with each change or entry of a camber function parameter.

When the user has finished selecting the camber functions for the root and tip chords, the Done button at the lower right is pressed. This returns the user to the Main Window. The wing in the 3D graphic in the main window should now show the camber chosen by the user.

Compute Button – Pressing this button causes the program to compute the performance of the user's wing using VLM theory. The mouse cursor temporarily changes to an hourglass while the program does this computation. When finished, the boxes in the Outputs frame are filled in and a formula box appears on the 3D graphic. The formula box contains formulas for CL vs. alpha, CM vs. alpha, and Cdi vs. alpha squared.

Exit Button – When finished, the user closes the application by pressing the Exit button.

ViewPoint Frame

The quantities in the ViewPoint frame control the direction and perspective of the view the user has of the wing and horseshoe vortex system. The viewpoint parameters are:

Azimuth Angle – This is the angle around the z-axis from the x-axis.

Elevation Angle – This is the angle up from the x-y plane toward the z-axis.

Radius – This is the distance of the viewer to the origin of the system. The further away the viewer is from the system, the less perspective there is in the image of the wing.

For the convenience of the user, up/down buttons can be used to increment these parameters. Holding either angle button down will cause a continuous motion of the wing.

Show Frame

Here the user selects what is to be shown in the 3D graphic window by clicking in the appropriate check boxes. Defaults are shown in Figure 2. A legend in the 3D graphic picture gives a key to identifying the items related to the vortices.