Aerodynamics 3 Coursework

T. Rendall

Submission only by BlackBoard through the Turnitin submission point. Feedback/comments will also be through the Turnitin feature on BlackBoard. You will likely have reports returned 2-4 weeks after submission; I will do my best to mark as promptly as feasible.

Please structure your report according to the sections and numbered items below. Spellcheck, reference where necessary and ensure all figures are captioned and numbered. There is a 1500 word limit excluding captions and code. Do not exceed this, and do not aim specifically for it. A good explanation is not a long explanation. Please don't ask for the word limit to be raised, as I will refuse. Concise writing is an important skill.

Comments in boldface are intended to help you avoid errors. Not all marks are of the same difficulty; please take time to think about each point before answering.

1 3D flow: Lifting Line/AVL

1. The *LLM.m* code outputs the total lift coefficient and sectional lift coefficients. Add calculations to output the total pitching moment (about the root quarter chord point) and total induced drag coefficient, and include the new lines of code in your report, **with comment lines to explain what you are doing.** The lines to modify can be found between the comments *START MODS—–* and *END MODS—–*. **If you are in doubt, please refer to the equations in the course notes**.

   [2 marks]

2. Download the spreadsheet avl_results.xls, which contains the precomputed AVL results you require. Run a comparison between your LLM code and AVL using two wings (note that you can alter the variable *tipposy* in *LLM.m* to change the wingspan):

   (a) Straight untapered swept wing of $A_R = 5$ with quarter-chord sweep of 20^o

   (b) Straight untapered swept wing of $A_R = 20$ with quarter-chord sweep of 20^o

In your report present values of C_L, C_D and C_M at $\alpha = 5^o$ for each wing in tabular form. For this incidence, also plot graphs of local lift coefficient C_l against spanwise position from this code and from AVL (which was also set to use 1 chordwise vortex for the results in the spreadsheet) for each wing. Make sure that you plot the results from LLM and AVL on the same graph for each case. Suggest reasons for any discrepancy between the results.

[5 marks]

2 2D Compressible Flow: $\frac{\partial C_L}{\partial \alpha}$ and Wave Drag

Note: do not use VGK downloaded from the ESDU website. Make sure to use the VGK version downloaded from the course BlackBoard page; the ESDU version may not run on 64b systems correctly.

Note: VGK can be temperamental. Before starting go through *Define→VGK Calculation Parameters* and set the number of coarse and fine iterations to 1000 and 3000. You should also set the subsonic relaxation parameter to 1.7 (this enables convergence at higher Mach/incidence combinations). Run in inviscid mode unless otherwise stated. When looking at drag values, use C_{D_p} in the VGK output window (drag from integration of surface pressures) for total inviscid drag, and $C_{D_p} + C_{D_f}$ for total viscous drag.

Lock proposed the relation

$$C_D = K(M - M_{crit})^4 \tag{1}$$

Note that in experimental results Lock observed an apparent offset in M_{crit}, whereby better experimental agreement is given if

$$C_D = K(M - [M_{crit} - 0.1])^4 \tag{2}$$

1. Run VGK inviscid at M from 0.05 (lowest that VGK allows) through to 0.9 (or highest M you can reach) (choose your own increment of M) to determine $\frac{\partial C_L}{\partial \alpha}$ for 65(1)A012 for each Mach number. To do this, you will need to use a finite difference to find this gradient. Check that the increment $\Delta\alpha$ that you use is neither too small (where numerical rounding would corrupt the results) nor too big (where nonlinearities would change the result) by plotting $\frac{\partial C_L}{\partial \alpha}$ against $\Delta\alpha$ for Mach 0.8 (**NOTE: this graph is not the same as a plot of C_L versus α**).

   For the VGK results and for the Prandtl-Glauert compressibility correction, plot $\frac{\frac{\partial C_L}{\partial \alpha}_M}{\frac{\partial C_L}{\partial \alpha}_{M=0.05}}$ against M (we plot it normalised, because there is a slight incompressible influence of thickness, which is not of interest here - refer to your 2^{nd} year notes if necessary. Note that VGK refuses a Mach number below 0.05; this is a common trait of compressible CFD codes). Why does the lift gradient deviate from the Prandtl-Glauert correction? **Note: do not divide the VGK data by $\sqrt{1 - M_\infty^2}$ when plotting the data - this is incorrect because the VGK data is intrinsically compressible**.

   [3 marks]

2. From an incompressible computation, $C_{p_{min}} = -0.3352$ for 65(1)A012 at zero incidence. Using the method from 2^{nd} year notes calculate M_{crit} and include the bisection iteration table in your report. Also use VGK to find M_{crit} and explain the difference compared to the method from 2^{nd} year.

   [3 marks]

3. Perform a sweep in Mach number (for $C_L = 0$) and compare C_D to Lock's 4^{th} power law (at zero incidence) with and without the offset of 0.1 in Mach number. You will need to perform a least square fit to determine K. Do this for both zero offset and assuming the offset is 0.1.

   In paragraph 2 of page 9 of the report (available on BB), Lock suggests explanations for this offset. Discuss which you consider more plausible.

   [5 marks]

4. Determine using VGK the value of M_{DD} (drag divergence Mach number) at zero incidence, which is the Mach number when $\frac{\partial C_D}{\partial M} = 0.1$. From the Korn equation, calculate the value of the aerofoil technology parameter for 65(1)A012.

   [2 marks]

5. Now switch to viscous mode, setting $Re = 10^7$ and $xtu = xtl = 0.01$, with $C_L = 0.5$ (note that VGK has an internal trimming routine that will keep lift coefficient fixed, so tick the box for 'specify lift coefficient', and set it to 0.5).

   By sweeping through from $M = 0.7$ to $M = 0.75$ in increments of 0.01, determine the Mach number that gives the greatest value of $\frac{MC_L}{C_D}$, and produce a plot of C_p against $\frac{x}{c}$ for the optimal condition. On the same graph, also plot C_p against $\frac{x}{c}$ for the inviscid flow at the same angle of attack. Comment on why the two C_p curves are different. Why are the differences greater on the upper surface?

   [4 marks]