Thin Airfoil Theory


Consider (once again) three NACA 4-digit conventional airfoils: NACA 1412, 2412, and 4412. Using cambered thin airfoil theory, calculate the zero lift angle of attack ($\alpha_{L=0}$), lift coefficient at a given angle of attack, and quarter chord pitching moment coefficient ($c_{m,ct}$). This project is built on the project 2a, thus it is required to conduct this project with the same project group members of the project 2a.

Task 1) Using NACA 4-Digit Airfoil Profile Generator (http://airfoiltools.com/airfoil/naca4digit), generate airfoil coordinates (for NACA 1412/2412/4412). Then, generate mean camber line data from airfoil coordinates. Note that the mean camber line is the line connecting the intermediate points of upper and lower surfaces of airfoil. Plot both airfoil coordinates ($y/c$ v.s. $x/c$) and mean camber line data ($z/c$ v.s. $x/c$) for three airfoils: NACA 1412/2412/4412.

(Task 2) Using the method of curve-fit (similar to the example 01 of thin airfoil theory handout), mathematically integrate to calculate $\alpha_{L=0}$, $c_l$ at $-4$, $-2$, 0, 2, 4, and 8 degrees of $\alpha$, and $c_{m,ct/4}$ for three airfoils: NACA 1412/2412/4412. The mathematical integration may be done either by hand or MATLAB symbolic math toolbox, called MuPAD (or any symbolic math software). You must show all details of your mathematical integration (detailed handwritten work of math, MATLAB MuPAD worksheet, or detailed symbolic math output from software of your choice). There are numbers of symbolic math software (Maple, Mathcad, Mathematica, etc.), however, it is strongly recommended to use MATLAB Symbolic Math Toolbox (MuPAD) for this task (MuPAD is a standard toolbox available on campus PCs, bundled together with MATLAB).

(Task 3) Using the method of numerical integration (similar to the example 02 of thin airfoil theory handout), numerically integrate to calculate $\alpha_{L=0}$, $c_l$ at $-4$, $-2$, 0, 2, 4, and 8 degrees of $\alpha$, and $c_{m,ct/4}$ for three airfoils: NACA 1412/2412/4412. The numerical integration may be done either MS Excel or MATLAB. You must show all details of your numerical integration (spreadsheet or MATLAB code).

(Task 4) Compare results of (i) thin airfoil, mathematical integration results from Task 2, (ii) thin airfoil, numerical integration results from Task 3, (iii) Virginia Tech (Java) Vortex Panel results (from project 2a, Task 1), and (iv) XFLR5 simulation results (from project 2a, Task 2). Plot lift curve ($c_l$ v.s. $\alpha$) for these 4 different methods, compared against actual NACA data, in a single figure (in order to compare each other). Do this comparison for all three NACA airfoils (NACA 1412/2412/4412).

General Instructions for the Aerodynamics Group Assignment

1. This is a group assignment (minimum 2 / maximum 3 students: absolutely no exception).
2. Develop an original method/code of cambered thin airfoil theory.
3. Copying the method/code between groups is considered “cheating” (zero score).
4. Obtaining external help (students who took AE301 in the past, etc.) is “cheating” (zero score).
5. The instructor is happy to answer your questions, but will never de-bug your code (or perform math) for you.
**Required Submittals**

1. Short write-up (not a full-length report), including:
   - Cover Page (with group member’s names & signatures)
   - Result 1: plots of airfoil coordinates (\(y/c\) v.s. \(x/c\)) and mean camber line data (\(z/c\) v.s. \(x/c\)) for three airfoils: NACA 1412/2412/4412.
   - Result 2: the zero lift angle of attack (\(\alpha_{L=0}\)), lift coefficient at \(-4\), \(-2\), 0, 2, 4, and 8 degrees of angle of attack, and quarter chord pitching moment coefficient (\(c_{m,c/4}\)) by curve fit of mean camber line data & mathematical integration method (similar to the example 01 of thin airfoil theory handout) for three airfoils: NACA 1412/2412/4412.
   - Result 3: the zero lift angle of attack (\(\alpha_{L=0}\)), lift coefficient at \(-4\), \(-2\), 0, 2, 4, and 8 degrees of angle of attack, and quarter chord pitching moment coefficient (\(c_{m,c/4}\)) by numerical integration method (similar to the example 02 of thin airfoil theory handout) for three airfoils: NACA 1412/2412/4412.
   - Result 4: the lift curve (\(c_l\) v.s. \(\alpha\)) plot for 4 different methods (thin airfoil mathematical, thin airfoil numerical, vortex panel, and XFLR5), compared against original NACA data in a single figure, for all three NACA airfoils (NACA 1412/2412/4412).
   - **Conclusion:** based on the task 4 (comparison plot), **draw your own conclusion** (pros and cons) of different methods of aerodynamic potential flow analysis.

2. Your thin airfoil method/code sent via email (Excel spreadsheet, symbolic math software code, MATLAB code, etc.) to the instructor (on or before specified due date).
Due

Right after the completion of unit C-4. Actual date will be announced in class and posted on-line (course homepage).

- This is (half of) the second AE301 course project (project 2b). There are total two course projects planned (project 1a/1b & 2a/2b).
- All team members receive the exact same score.
- Forming and maintaining the project teams are 100% all your (student’s) responsibility: the instructor will not be responsible to form group(s) and take care of your group’s leadership, nor group’s time and work sharing, internal conflict resolution, etc.