

UNIVERSITY OF NOTRE DAME  
Department of Aerospace and Mechanical Engineering  
AE 440: Flight Mechanics and Introduction to Design  
Fall 1998

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Project #9

Due: Friday, October 16, 1998

Airfoil design is a complex and challenging discipline and it represents one of the many contributing disciplines in the flight vehicle design process. Developments in numerical methods and the ever-increasing computing capabilities for numerical simulation have introduced many valuable tools to the designer. This project involves using a computational fluid dynamics (CFD) method and it has two primary purposes. The first is to "benchmark" this new "tool" and the second is to use the method to develop a candidate airfoil for a new aircraft concept. This will require you to evaluate the performance of a given airfoil and to conduct a simple parametric trade study related to the airfoil performance. The prediction method you will be using involves an iterative solution to the potential flow problem based upon the airfoil geometry and an approximation to the boundary layer. This software was initially developed by NASA and was called the MCARFA code. Details on the software are included in a number of NASA references. Instructions for using the UND version of this software, "airfoil", are in the handout provided.

We will begin the development of an atmospheric sampling UAV concept which will provide the primary aircraft design application for the remainder of this course. In this phase of the project you will be required to select a candidate airfoil for the wing. We will limit our candidate airfoils to the NACA 4-digit series and will use "airfoil" as the primary tool for concept selection. As you will see the number of design parameters will grow rather quickly in this project. The selection of a reasonable number of candidate designs for analysis is an important issue. The following tasks are suggested as a guideline for your study.

1. Select the nominal chord for your aircraft (or at least the range considered for the root and tip chords of the main wing) and determine the flight Reynolds number for the stall and cruise conditions. Using the wing area you have selected for your design and assuming a "uniformly distributed load" estimate the wing and thus section lift coefficients necessary for these two conditions.
2. For the one "benchmark" data point provided (NACA 2412 data), evaluate the "performance" of the code "airfoil" and comment on its suitability and limitations for the proposed study.
3. Based upon input from your "structures group" assume that the airfoil will be at least 12% thick, perform a trade study in which the amount of camber and the location of maximum camber are varied and the following state variables determined:
  - L/D max and the angle of attack (and associated lift coefficient) at which it occurs
  - the maximum lift coefficient that can be achieved without turbulent boundary layer separation occurring on the airfoil as predicted by "airfoil".
4. Select a candidate airfoil for your aircraft and provide a justification for your selection.

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The following provides "requirements" and an initial gross takeoff weight estimate for your UAV aircraft concept. This concept will be an electric powered vehicle with stored battery energy. This particular energy storage and propulsion system presents some additional opportunities and challenges for this design project.

W payload = 5.0 lb

Volume payload = 6" x 6" x 12"

W avionics = 0.9 lb

V maximum > 60 ft/sec

V min < 28 ft/sec

ROC max at S.L. = 5.5 ft/sec

Takeoff ground roll distance < 85 ft

Range max > 6.5 miles

Static margin between 15% and 25%

V rotation < 26 ft/sec

based upon a current data base:

Gross takeoff weight = 12 lb

$C_{Lmax} = 1.2$