AE6343 Aircraft Design Project #1 – 2015

Aircraft Constraint Analysis

This document provides the project description for Project 1 of the Aircraft Design I (Fixed Wing Design I) course listed as AE 6343. Please read this information carefully and refer any questions to the class assistants.

Objective

This project is an exercise where students can apply the sizing and synthesis theory presented during lecture and pertaining to Chapter 2 of the course material. Students must integrate the different methods and approaches taught and provide an initial mission sizing and constraint analysis assessment in the context of conceptual design. This exercise should furthermore provide a deeper understanding of the mathematical models used for these tasks and associate them to the underlying physical principles and relationships.

Project Description

General

Using all the class material provided relevant to sizing & synthesis, each student must study the energy-based constraint analysis method as well as the weight fraction approach to the mission sizing analysis. An analysis tool capable of fully implementing sizing & synthesis calculations must be created and validated against existing data. You must benchmark your tool against the known performance of a reference aircraft, provided in this project description. This project will be conducted individually. <u>Distance Learning students will also conduct this project individually.</u>

Deliverables

Report

A project report must be submitted no later than **3:05 pm on Friday October 16th**. No late submissions will be accepted. This report must be written in Microsoft Word ® using the template provided in the class website, or similar, and the formatting guidelines specified therein. The contents of the report must address all of the requirements, questions and issues described in the sections below. Your report quality should adhere to "best commercial practices," which will be expected for all assignments from this point on. It must be concise, written with a professional tone and avoiding wordiness and grammatical / spelling mistakes. **All sources must be adequately cited**. **See honor code statement**. Images must be in color and all plots must be legible (labels, axes, units, etc). A heavy-duty stapler is provided for your convenience in the copier room (Weber 314). The report should not exceed 20 pages of content including images (does NOT include cover page, list of figures, references, or extra credit). The report section names do NOT need to follow the names given to each of the requirements as shown in the section below. Items in appendices will not be graded unless specifically noted in these guidelines.

Cover Page and Honor Code Statement

Each report should have a cover page with the title of the assignment, “Instructor: Prof. Dimitri N. Mavris”, name of the student, date the assignment is due, and the following signed statement: "I certify that I have abided by the honor code of the Georgia Institute of Technology and followed the collaboration guidelines as specified in the project description for this assignment."

<u>Distance Learning Students</u>: You can just type your name on the signature line, or use an electronic image of your signature if available.

Sizing & Synthesis Tool

The tool that you create must be submitted electronically no later than **3:05 pm on Friday October 16th**. To do so label your files as follows: "**`FirstName_LastName_FWD_P1`**". Label an electronic version of your report in a similar manner. These files can be submitted as an attachment using T-Square. Look under the "Assignments" tab on the T-Square site for AE 6343. Alternatively, and only if this first option does NOT work, you can email your file to the class assistants.

It is ***STRONGLY*** recommended that this tool be generated as a spreadsheet in Microsoft Excel ®. If you wish to use an alternative program you must check with the teaching assistants ***before*** you proceed to generate the tool.

Requirements

Report Introduction

You must provide a ***brief*** introduction to your report explaining what the purpose of your efforts is, what information is contained in the report and what final results or conclusions you are attempting to get across to the reader. This section should also introduce the concept under study and ***briefly*** summarize the mission and requirements.

Formulation of Sizing and Synthesis Approach

After describing the requirements you must explain how you will proceed with the sizing & synthesis assessment. Explain what theory you will use for this purpose and particularly what elements of that theory you will implement for the problem at hand. For example, if you are going to use historical data for the calculation of the wing element explain why and how that data applies to the sizing tasks of your vehicle; or if the vehicle you are modeling has a sustained turn requirement explain how the theory you are implementing provides a way to model that. Do ***NOT*** give extensive and in-depth description of all the sizing & theory provided in class. Remember to reference your sources appropriately

Creating Your Sizing and Synthesis Tool

Create an analysis tool for sizing and synthesis. This tool must provide as a final result a *constraint analysis plot* and should enable the user to directly identify a *design point in terms of thrust to weight ratio and wing loading*. It must also provide a *mission analysis* for the sizing of the system indicating the converged *estimated weight and weight contributions from the different weight groups*. All inputs and outputs of the tool must be clearly labeled and visible to the user. Any values that are input as a result of assumptions must also be clearly labeled, and the correct assumption values for the system you are modeling must be indicated. Your tool should focus on *ease-of-use* and *reusability*; the tool that is deemed the best will be released to the entire class. Users should have the option of inputting a number or adjusting a slider bar. Colors and visuals will make your tool easier to understand.

Documenting the Sizing & Synthesis Tool

Your report must include a complete but concise description of the sizing & synthesis tool created. Use of data-flow diagrams, screenshots of the tool, and descriptive images is encouraged. The reader must be able to understand the architecture of the tool, what the control inputs are and how they can be changed, what the resulting outputs are and where they are shown. It must also show how the assumptions' values are controlled.

Benchmarking Exercise

You will benchmark your aircraft design tool against a known aircraft design (the F-86L Sabre aircraft). Design mission and performance constraint data will be provided in the appendix of this project description. The following information from the benchmarking exercise must be clearly and concisely reported.

Mission Analysis

- Clearly indicate ***ALL*** assumptions and design decisions made, and most importantly the reasoning behind them. Justifying your choice for parameter values is a critical part of this assignment as it reveals your competence and understanding of sizing and synthesis. Remember to reference all sources appropriately.
- Indicate the converged value of weight and weight breakdown.
- Provide a mission analysis specifying instantaneous weight, aerodynamic and propulsive characteristics, and instantaneous T/W and W/S values for *key points* in the mission (e.g. start, begin of cruise, end of cruise, end of loiter, etc.)

Constraint Analysis

- Clearly indicate ***ALL*** assumptions and design decisions made, and most importantly the reasoning behind them. Justifying your choice for parameter values is a critical part of this assignment as it reveals your competence and understanding of sizing and synthesis. Remember to reference all sources appropriately.
- Provide a constraints diagram corresponding to the segments of the design mission. Identify what are the limiting or critical constraints. Analyze and explain why the constraint curves look the way they do and if they make sense with respect to the physics they model and the conditions you have assumed.
  NOTE: Your comments should focus on the performance and physics of the problem, NOT on the mathematical structure of the curves.
- Repeat the above requirement for the minimum performance requirements
- Provide a plot with *all* constraints (mission segments and performance requirements) and outline the feasible design space.

Conceptual Design Point

Having obtained a predicted takeoff gross weight, T/W, and W/S, calculate the predicted maximum required thrust at sea level and the predicted wing area. Compare these predicted values to the known values within the Standard Aircraft Characteristics. Extend this comparison to other characteristics that you have assumed, such as aspect ratio or lift to drag ratio. Keeping in mind that your efforts are at the conceptual phase of design, comment on the similarities and differences between your predicted design and the actual F-86L. Indicate the source of these differences, i.e. why these differences exist.

Appendix A: Benchmark Aircraft Design

This appendix describes the performance requirements, design mission, and known design data of the F-86L Sabre aircraft. This data is to be used for the benchmarking exercise, as described in the project description.

Design Mission and Performance Constraints

- Vehicle Mission
  - Take-off and clear a 50ft obstacle in less than 4400 ft (sea level, 90 degree day) at maximum power (with afterburners). A maximum rate of climb of 90 ft/sec should be assumed.
  - Achieve 1200 ft/sec air speed at sea level using maximum power (with afterburners)
  - Climb to a cruise altitude of 35,400 ft. under full military power (without afterburners)
  - Perform a cruise climb from 35,400 ft to 38,700 ft for 550 nautical miles. Use a cruising speed of 458 knots and normal power. Integrate the fuel burn from first principles (do not use the Breguet range equation).

- Search (Loiter) at 38,700 ft at normal power for 10 minutes.
    - Climb to 47,550 ft
    - Combat at 47,550 ft at maximum power (with afterburners) for 5 minutes. A combat speed of 536 knots should be achievable at this altitude.
    - Cruise at 37,000 ft for 550 nautical miles at a speed of 458 knots under normal power.
    - Loiter at 35,000 ft for 10 minutes under maximum endurance conditions.
    - Land in less than 5,000ft (sea level, 90 degree day) without high lift devices.
- Other Requirements
    - Land with a 10% fuel reserve
    - Carry 1 crew member (pilot) with gear, totaling 210 lbs
    - Carry 432 lbs of payload

Propulsion System Assumptions

Your engine model should approximate the performance of the J47-GE-33 engine. Thrust available at sea level for the three relevant power settings can be seen in Table 1 below. You should apply a reasonable thrust lapse model to account for changes in thrust with altitude. You should refer to other sources (lecture notes, Raymer, Roskam, or other) for a model of engine fuel consumption. Remember to document all assumptions and sources.

Table 1: Sea Level Thrust of the J47-GE-33 Engine[1]

Power Setting	S.L. Static Thrust (Lbf)
Maximum (with Afterburner)	7650
Military (without afterburner)	5550
Normal	5100

Structural Weight Assumptions

You should use an empirical based empty weight fraction approximation. Refer to other sources (lecture notes, Raymer, Roskam, or other) for a model of empty weight fraction as a function of gross takeoff weight. Remember to document all assumptions and sources.

Aerodynamic Assumptions

You should construct a drag polar from assumed values of zero lift drag, Oswald efficiency factor, and wing aspect ratio. Refer to other sources (lecture notes, Raymer, Roskam, or other) for these parameters. Remember to document all assumptions and sources.

Benchmark Results

You should be able to predict the design point (thrust to weight versus wing loading), weights breakdown (fuel, empty, payload, and crew weight components), and wing planform area of the F-86L aircraft after applying your design tool to the interception mission described above. Research the actual values of these design parameters from the unclassified 1958 Standard Aircraft Characteristics document for the F-86L. You should be able to find this document using the internet. Your result will be similar, but not exactly equal to, the true performance of this aircraft. Answer all questions and report all results outlined in the project description

Bonus

When creating your sizing and synthesis tool, it would be nice to think that you can use it in situations that are not only AE 6343. Try to increase the usability of your tool by making it as flexible as possible. Ideally, you should be able to create a tool that can handle military and commercial aircraft. The hardest part of this will involve the

[1] Standard Aircraft Characterisitics for North American F-86L Sabre, 5th Edition Addendum Nr 9, 22 September 1958, United States Air Force

engine-specific parameters. If you can successfully make your tool more versatile AND write up an additional appendix (no more than 2 pages) about how you increased the versatility of your tool and what challenges you had to overcome, then you will receive **up to 10 bonus points**. Important note: in order to receive the full 10 points, you need to make sure you adequately demonstrate the versatility of your tool (e.g., talk about the games you have played and can play) and document your method in that additional write up; the tool should also be VERY obvious about how different aircraft can be analyzed. This should not be your primary focus; you should wait until everything else is done before working on this. Remember, if your tool/report is unfinished, 10 bonus points will not do anything worthwhile.

Note: this should be an extra appendix in your report – if this is not specifically mentioned as the title of an appendix (e.g., "Appendix A: Tool Versatility"), **you will receive no bonus points**.