MAE 159 Midterm Aircraft Sizing Report

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1 Introduction

This report consists of a study on the cost and performance optimization for two subsoinc commercial transport aircraft, one non-stop aircraft and one one-stop aircraft. Herein, the reader will find a summary of the methods used and the data generated from an itterative python script which uses standard, well-defined aircraft deisgn methods to exactly meet the design specifications. Various parameters, including ... , were systematically varied to determine the optimum design parameters. In the conclusion of the report, the optimum design parameters will be given as well as an summary of why the design was chosen, and how the which of the two optimized aircraft may suit the customer's needs the best.

2 Design Specifications

As mentioned prior, two aircraft with distinct given design requirements, were considered in this design study. Both aircraft are requried to carry 225 passangers adn complete a 7400 nautical mile journey. The first larger aircraft must compelte the journey without any stops. The second smaller aircraft must complete the journey with one-stop, giving the airplane a required range of 3700 nautical miles. The complete set of given design specifications are listed in tables 1 and 2 below. For both aircraft, takeoff conditions were assumed to be at sea level on a hot day with an air temperature of $84°F$.

Non-stop Aircraft	
Design Specification:	**Parameter Value:**
Number of Passangers	225
Weight of Cargo	6,000 lbs
Still Air Range	7,400 nmi
Takeoff Field Length	10,500 ft
Landing Approach Speed	140 kts
Fuel Destination Payload	35%
Cruise Mach Number	0.85
Initial Cruise Altitude	35,000 ft

One-stop Aircraft	
Design Specification:	**Parameter Value:**
Number of Passangers	225
Weight of Cargo	3,000 lbs
Still Air Range	3,700 nmi
Takeoff Field Length	6,000 ft
Landing Approach Speed	130 kts
Fuel Destination Payload	0%
Cruise Mach Number	0.80
Initial Cruise Altitude	35,000 ft

3 Design Analysis

The object of this section is to perform an analysis for both aircraft and determine the optimized specifications for the design parameters such as aspect ratio, number of aisles, number of engines, number of seats abreast, and more. An itterative python script was written with allowable user input for user-selectable design parameters to make calculations of direct operating cost (DOC), weight, drag, and other airfact performance charactersitics easy, fast, and repeatable.

3.1 Aspect Ratio Variation

The aspect ratio describes the ratio of the airfact's wingspan to its mean aerodynamic chord length. A small aspect ratio describes a short and wide wing whereas a larger aspect ratio describes a long and narrow wing planform. The wing aspect ratio is an important factor in determing the available lift of the aircraft, the weight of the aircraft, and the induced drag during flight. For a typical jet transport aircraft, Schaufele gives an aspect ratio range of 7.0 to 9.5, as such, this formed the basis for design selection. Aspect ratios in steps of 0.5 were considered from 6.0 to 10.0 during this study. The method for comparison will be the resulting DOC per passanger, per mile. Figure **??** shows sweep angle versus the DOC with curves of fixed aspect ratio for both aircraft.

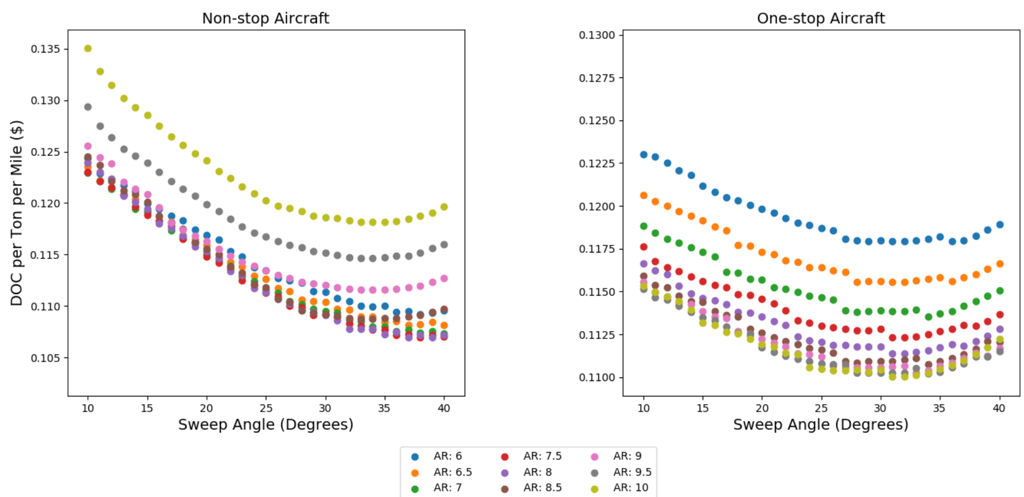

Figure 1: Direct operating cost, per ton, per mile plotted against sweep angle for the non-stop and one-stop aircraft at different aspect ratios.

From figure **??**, it is evident that for the non-stop aircraft, the optimized aspect ratio is between 7.5 and 8. For the one-stop aircraft, the optimized aspect ratio is between 9.5 and 10.

3.2 Wing Sweep Angle Variation

Starting with the best two values of aspect ratio determine from the aspect ratio variation plots, the optimized wing sweep angle can be determined by plotting the DOC against the wing sweep angle. For easier interpertation of the data, only the best two aspect ratios obtained in the previous subsection were utilized in this determination. These results are plotted in figure **??**.

From figure **??**, it is determined that the minimum DOC per ton, per mile is $0.1069204 and $0.11001131 for the non-stop and one-stop aircraft respectively. These lowest DOC values correspond to an asepct ratio of 8 with a sweep angle of 39 degrees for the non-stop aircraft and an aspect ratio of 10 with a sweep angle of 31 degrees. Interestingly, in this configuration, the optimized non-stop aircraft has a lower DOC than the optimized one-stop aircraft.

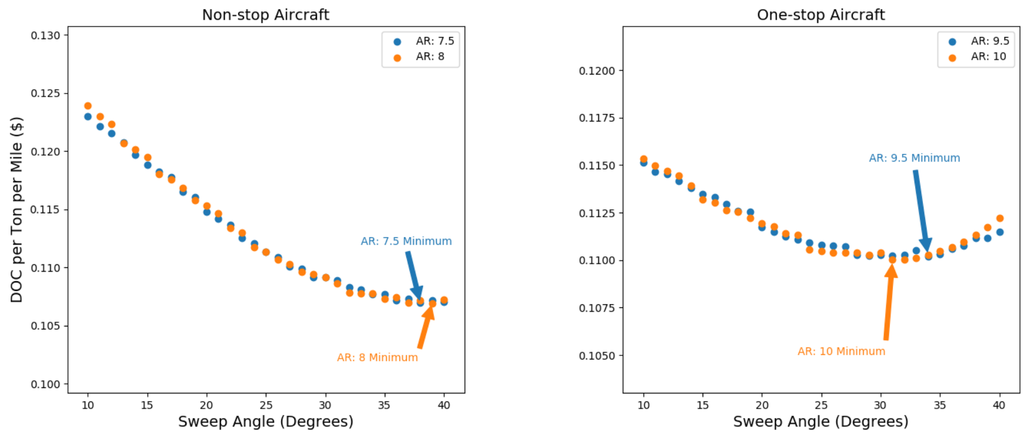

Figure 2: Direct operating cost, per ton, per mile plotted against sweep angle for the non-stop and one-stop aircraft at the optimized aspect ratios.

3.3 Advanced Technology (aluminum v composite, conventional v supercritical)

Modern technology and manufacturing advancements has allowed for the use of more exotic airfoil shapes that previous heritage aircraft could not take advantage of. Supercritical airfoils have been cited to improve aircraft fuel efficiency and thus lower the direct operating cost of the aircraft. The Boeing 757 and 767, developed during the 1980s were some of the first commerical aircraft to use this technology. However, these airfoils types are comprised of more complciated compund curves which presents added complexity in the manufacturing process, driving up initial cost of the aircraft however, the decrease in operational costs of the aircraft exceeds the initial procurement cost increase of the aircraft. Figure **??** plots the direct operating cost of the aircraft versus the sweep angle for the optimized aspect ratios obtained in the previous sections, and with the implementation of the supercritical airfoil versus the wing sweep angle. It is evident that for all vlaues of the sweep, the DOC was lower when implementing the supercritical airfoil technology to the aircrafts' wings. However, the optimal sweep angle shifted for both aircraft when the aspect ratio was held constant, from the optimized value gathered from the previous section, section 3.1.

Using the supercritical airfoil technology with an aspect ratio of 8 and 10 for the nonstop and onstop aircraft respectively, the minimum direct operating cost per ton, per mile were $0.08639182 and $0.09680141, with wing sweep values of 40 degrees and 36 degrees, for the nonstop and onstop aircraft respectively. Again, the nonstop aircraft had a lower direct operating cost than the onestop aircraft.

3.4 Aircraft Seat Configuration

The aircraft seat configuration can also be varied. In this case, the main metric of comparison will be the direct operating cost. Both the supercritical and conventional airfoil types were considered in this section of the study as well. It stands to reason that the supercritical airfoil will be the optimal choice regardless of the seat configuration however for sake of robustness. Above, the standard configuration of two aisles and eight passangers abreast were considered. However, there are other options for seat layout of the passanger seating area. For sake of brevity, only one other common seating layout was considered, the single aisle, six passangers abreast configration. These results are plotted in figure **??**

From this study, it is evident that the optimal sweep angle did not change for either the supercritical or

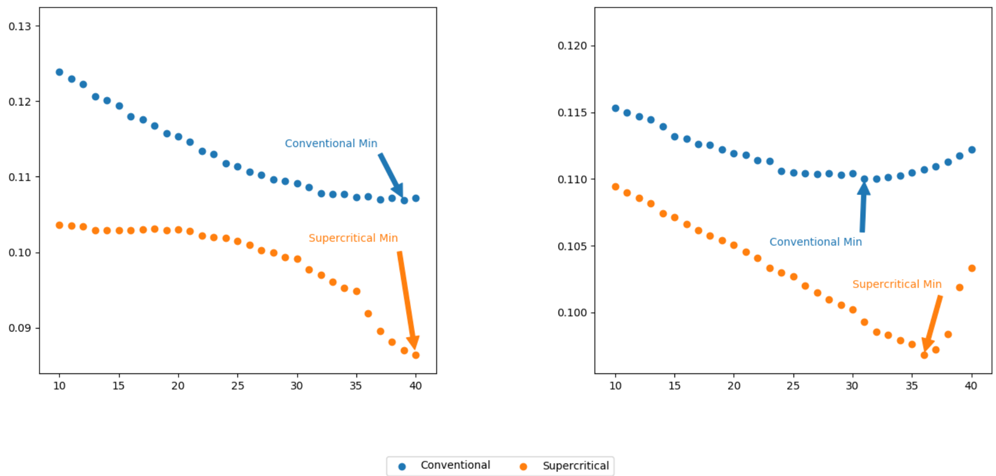

Figure 3: Direct operating cost, per ton, per mile plotted against sweep angle for the non-stop and one-stop aircraft at the optimized aspect ratios, while comparing the effects of a supercritcal wing airfoil.

Figure 4: Direct operating cost, per ton, per mile plotted against sweep angle for the non-stop and one-stop aircraft at the optimized aspect ratios. Both the conventional and supercritical airfoil types were considered in this analysis. The number of seats and aisles were varied.

convnetional airfoil configuration, when the seating configuration was changed. However, it is clear