Project Design Assignment
Re-Design of BWB

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Due Dates

- Design Strategy Proposal: Due Wednesday, November 23 at the end of lab

- Design Report: Due Friday, December 2 at 9am

1   Objective

The objective of this Project Assignment is to re-design the BWB such that the approach and cruise design constraints can be met while minimizing the impact on the estimated induced and friction drag at cruise conditions.

2   Operating Condition Specifications and Requirements

2.1   Cruise

1. Cruise altitude is 39,000 feet

2. Mach number, $M_\infty = 0.85$

3. Assume cruise weight is Maximum take-off weight (MTOW), and MTOW = 800,000 lbs.

4. 5% static stability margin for more on static stability).

5. Flaperons are not to be deflected in cruise.

2.2   Approach & Stall

1. Approach speed = 150 knots (set by air traffic safety)

2. If the sectional $c_{l\max} < 1.2$, then slats will not be needed in the design. With slats, then $c_{l\max} = 1.6$. Note: these limits will set the maximum lift and, therefore, determine the stall speed. In either case with or without slats, the winglet c_l's are not required to be below $c_{l\max}$.

3. Approach speed = 1.3 × stall speed (for safety)

4. Aircraft is carrying full payload with 25% fuel remaining. Assume aircraft empty weight is 400,000 lbs, payload is 200,000 lbs, and fuel weight is 200,000 lbs.

5. 5% static stability margin at approach and stall speeds.

6. Flaperons can be deflected in approach and stall conditions, but, the same flaperon deflections must be used for both.

3   Geometric Design Constraints

To meet the operating condition requirements, a wide range of geometry modifications can be pursued. However, a few geometric design constraints must be met by the redesigned BWB. Specifically:

1. The number of flaperons can be decreased and the location and size of the flaperons can be changed. However, the size of the flaperons should be less than the minimum of either 15 feet or 30% of the local chord.

2. The wing span can be not be increased beyond the current length of 280 feet.

3. Tails are not allowed (i.e. the plane must still be a blended-wing body).

4. Any geometry modification must result in a smooth geometry at the design condition. For example, if the airfoil sections are redesigned, the airfoils must not have discontinuous slope changes. Also, the spanwise distribution of the chord, sweep angle, geometric twist, etc. must be smooth (no sudden changes).

5. The size (chord and thickness) of the center of the BWB, specifically the first 50 feet from the wing root, cannot be modified. This is to ensure the passenger compartment does not change size.

4   Required Tasks

Note: the points for each of the tasks is given with each item.

4.1   Design Strategy Proposal (20 points)

Decribe the design strategy that you will pursue to meet the operating requirements. Provide an aerodynamic justification for why you have chosen this strategy. Note: you do not have to provide quantitative numbers in the proposal, rather just a general strategy. For example, you might say something like: "To achieve the required static margin at cruise we plan on increasing the thickness of the outer portion of the wing since we know thickness has a significant impact on pitching moment through the Bernoulli effect." By comparison, you do not need to say something as detailed as "To achieve the required static margin at cruise we plan on increasing the thickness by 10% for all airfoils that are beyond 100 feet of span. We expect this change will increase the static margin to 10%." Admittedly, the above strategy is not very good regardless of the amount of detail provided and would lead to swift punishment by the Board of Aerodynamic Authorities. To help provide some ideas for how to design a tailless aircraft for static stability, some links have been provided in the Related Resources section.

   Note: the Design Strategy Proposal (type-written) is due Wednesday, November 23 at the end of lab. The strategy should be concisely stated and well-reasoned. The proposal must fit on **no more than a single page of text using reasonable font sizes.**

4.2 Final Re-Designed BWB Geometry

- **(10 pts)** Describe the final modifications made to the geometry including a comparison of the geometry parameters that changed from the original to the re-designed BWB. When appropriate, plots should be made to demonstrate these changes.

- Tabulate the location and size of the flaperons for the redesigned BWB. Also, include the deflection angles of the flaperons at the approach condition. **Note: this data must be provided in order for your report to be graded, however no points are awarded.**

- An AVL input file for the redesigned BWB must be emailed to Course TA by the final report deadline.Also, if you modified the airfoil sections, input files for the modified airfoils must also be emailed. **Note: this data must be provided in order for your report to be graded, however no points are awarded.**

4.3 Cruise Analysis

Note: in the following analyses, use the original reference areas and lengths for non-dimensionalization. In otherwords, for the reference area, use $S_{ref} = 7840$ sq. ft. and for the reference length use $c_{ref} = c_{\mathrm{mac}} = 30.75$ ft.

- **(10 pts)** Estimate and compare the ratio of the induced and friction drag coefficients to the lift coefficient (i.e. $(C_{Di} + C_{Df})/C_L$) for both the original and redesigned BWB.

- **(5 pts)** Using AVL, estimate x_{ac}/c_{mac}, x_{cp}/c_{mac}, and the stability margin at cruise. Note: this is only required for the redesigned BWB.

- **(10 pts)** Plot x_{ac}/c_{mac} and x_{cp}/c_{mac} versus C_L from $C_L = 0$ to twice the cruise C_L. Note: this is only required for the redesigned BWB.

4.4 Approach Analysis

- **(5 pts)** For approach and stall conditions, use AVL to estimate x_{ac}, x_{cp}, and the static margin for the redesigned BWB.

- **(5 pts)** Plot $c_l(y)$, $c_l(y)c(y)/c_{\mathrm{mac}}$, and the induced angle of attack (i.e. using the Trefftz plane plot) at the approach conditions for the redesigned BWB.

- **(5 pts)** Plot $c_l(y)$, $c_l(y)c(y)/c_{\mathrm{mac}}$, and the induced angle of attack (i.e. using the Trefftz plane plot) at the stall conditions for the redesigned BWB. Also include a zoomed in version of this plot which highlights the c_l range around the $c_{l_{\max}}$ constraint. For example, if you are using slats, zoom in the plot from approximately, $1.4 < c_l < 1.8$. Reminder: the winglet is not required to have c_l's below the maximum limit.

- **(10 pts)** Plot x_{ac}/c_{mac} and x_{cp}/c_{mac} versus C_L from $C_L = 0$ to the stall C_L. For this plot, fix the Mach number at the approach conditions.

4.5 Review of Proposed Design Strategy (20 points)

If your proposed design strategy worked, you do not need to do anything for this section (i.e. you will automatically receive full credit). If your design strategy did not work, you must explain why your initial reasoning proved to be incorrect to receive full credit. Furthermore, you should propose

an alternative design strategy and provide aerodynamic justification for this alternative strategy. **Note: you are not required nor in anyway expected to implement this alternative strategy to receive full credit.**

5   Report Conventions

- Only one report is required for a team.

- Include a breakdown of how the work was accomplished between you and your partner.

- Both partners must sign the report.