**Introduction to Aerospace**

**Assessment of Aircraft Performance and**

**Stability through Wind-Tunnel and Flight testing**

|  |  |  |  |
| --- | --- | --- | --- |
| Group Number | 01 | Student CIDs | 02390378, 02376242, 02388707  02376386, 02380688, 02380343 |

**Answer the following questions within the space provided using 11pt Arial. Make sure tables and figures are properly formatted and readable. Marks will be deducted for bad formatting.**

**Q1.** Plot your results for aircraft Lift Coefficient vs Angle of Attack obtained from both the wind tunnel and flight tests. Concentrate on the lift curve slope , zero-lift angle of attack and max lift coef . Comment on the impact of the tailplane on the lift curve. How do the tunnel and flight test results compare? What might be the cause of any discrepancies?

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | | |  |  |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | --- | --- | |  | Units | Flight Sim Test | | | Wind Tunnel Test | | | |  | *n/a* |  |  |  | Tail off | Tail on | Tail on | | Lift curve slope, |  | 0.0908 | 0.0928 | 0.1011 | 0.0573 | 0.0671 | 0.0635 | | Zero-lift angle of attack, |  | 2.3502 | 2.4615 | 2.2226 | 2.5113 | 2.0775 | 1.5858 | | Max lift coefficient,( | *n/a* | 1.8041 | | | 0.86 | 1.00 | 1.04 |   As the CG offset increases the value of the lift curve slope increases for the flight sim test, this is because when the CG is forward of the neutral point the aircraft exhibits greater stability and this results in a higher lift curve slope of the aircraft. The opposite is true when the CG is behind the neutral point. The maximum lift coefficient was calculated as an average of the values from each of the three setups of CG. Moving the CG forward increases the zero-lift angle of attack as can be seen from the change of CG from -4 to 0, however there is a discrepancy when the CG goes from 0 to +4.  As the tailplane setting changes the value of the lift curve slope changes for the wind tunnel test, we can see that increasing the tailplane angle from -2 to +1 increases the lift curve slope, this is because when the tailplane angle is increased the trim angle of attack usually increases this gives a higher lift coefficient for any given angle of attack thus giving a higher lift curve slope. As the tailplane angle increases the zero-lift angle of attack increases and having a tail on increases the maximum lift coefficient by a lot but the tailplane angle doesn’t vary the maximum lift coefficient. | |

**(25% of marks)**

**Q2.** Plot graphs of the aircraft drag polar and the variation of aerodynamic efficiency with lift coef , as estimated through wind tunnel and flight testing. How do the results from the two sets of tests compare? What might the cause of any differences be?

|  |
| --- |
| In flight tests, initially, there was a high drag coefficient for lower lift coefficients. However, as the lift coefficient increased, wind tunnel tests displayed higher drag coefficients compared to the flight simulator results. This difference might be due to tufts on the wings of the wind tunnel model, potentially increasing the drag coefficient beyond that of the flight simulator. The data from each test followed parabolic curves. An issue occurred in the wind tunnel test without the tailplane, showing negative drag coefficients, which is not possible suggesting experimental errors. |

**(15% of marks)**

**Q3.** From your data presented in Q2, predict the aircraft zero-lift drag coef. ( and Oswald efficiency factor given for each test and configuration. How does your aircraft’s polar compare to the theoretical parabolic drag polar we have discussed in class? Why might differences arise.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  | | --- | --- | --- | | Test | Zero Lift Drag Coeff () | Oswald Efficiency () | | Flight Simulator | 0.0110 | 0.9006 | | Wind Tunnel Tailplane Off | 0.0612 | 0.5373 | | Wind Tunnel Tailplane | 0.0638 | 0.5822 | | Wind Tunnel Tailplane | 0.0664 | 0.5610 |   The difference between flight simulation and wind tunnel results mostly comes down to how well the pilots flew during the glide test, not because of model size or computer issues. They weren't consistent with altitudes, angles, or timing. In the sim, Cd0 was lower and Oswald efficiency higher than expected (0.06 and 0.7, respectively). In the wind tunnel, having a tailplane was shown to help improve Oswald efficiency as wingtip vortices were weakened and the tailplane created downwash, reducing drag. The experimental drag polars above showed minimum drag occurs at a non-zero lift coefficient, suggesting drag also depends on the interactions wings have with surfaces, and possibly lift from the fuselage, as well as lift generated by wings. However, the overall sim/tunnel polar curves and magnitude line up with theory. |

**(15% of marks)**

**Q4.** From your flight tests,plot the tailplane deflection required for trim vs lift coef for each of the different centre of gravity positions. Hence also plot the variation of the gradient with the centre of gravity position . What is the aircraft’s neutral point position , effective tailplane lift curve slope () and zero-lift pitching moment coef. (). Comment on the level of uncertainty in your estimates.

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Variable | Unit | Offset | | | For plots of the tailplane deflection vs Lift coefficient the data points all show a strong linear trend with high values. The trendline passes through most error bars for all 3 settings, showing the linear fit is consistent with our measured uncertainty range.  The plot of the gradients from figure 7 vs the centre of gravity positions shows a strong linear trend with between all centre of gravity positions. Due to the testing of only 3 settings we tested it is difficult to deduce the trendline for this graph. | |  |  | +4 | 0 | -4 | |  |  | 10.21817195 | 10.11657195 | 10.01497195 | |  |  | 0.136835 | 0.136835 | 0.136835 | |  |  | 0.080339906 | 0.113775921 | 0.113814572 | |  |  | -3.115069 | -5.025434 | -5.470337 | |  |  | 10.74761126 | 10.97069824 | 10.94471426 | | Constant Fig 7 |  | 0.931213 | 1.318767 | 1.319215 | | Fig 7 |  | 0.9972 | 0.9873 | 0.9851 | | Gradient Fig 8 |  | 11.590885 | 11.590885 | 11.590885 | | Constant Fig 8 |  | -121.796969 | -121.796969 | -121.796969 | | Fig 8 |  | 0.8857 | 0.8857 | 0.8857 | |

**(15% of marks)**

**Q5.** Comment on the appropriateness of any assumptions made in deriving the equation

which your prior analysis of flight tests data has relied upon. To what extent do these assumptions reflect the behaviour of the aircraft based on your measurements and how might they have impacted your estimates in Q4?

|  |
| --- |
| The equation only considers the lift produced by the Horizontal stabiliser and the wing; however, a small amount of lift is produced by the aircraft’s fuselage. Therefore, the plots will underestimate  Additionally, the creation of large vortex shedding, and induced pressure drag is not accounted for in our theoretical model which would become prominent at turbulent flow regimes. The trailing edge vortices would disrupt flow around the tailplane and reduce lift on the tailplane, causing a variation in pitching moment and the overall lift coefficient. |

**(10% of marks)**

**Q6.** Using your wind tunnel test data, plot a graph of pitching moment coef. () vs lift coef. ( for the three cases tested. Hence, using the methods detailed in the laboratory handout determine the aircraft’s neutral point position , effective tailplane lift curve slope (), the downwash angle derivative , and the zero-lift pitching moment coef. (). Comment on the level of uncertainty in your estimates. Why might the values of estimated through flight testing and wind tunnel testing differ?

|  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| |  |  |  |  |  |  | | --- | --- | --- | --- | --- | --- | | Variable | Unit | Tailplane setting | | | Drawing faired curves increased However, due to various assumptions in our calculations, the uncertainty in our calculations was increased. The values of may differ between flight testing and wind tunnel testing as the wind tunnel testing was carried out at low speeds and angles of attack, whereas the flight testing involved a wider range of flight conditions. Furthermore, in the wind tunnel, certain corrections were required for solid blockage, drag due to support and the wall effects, which alters the accuracy of the calculations for , in the flight sim, these are modelled more accurately. | | Tail setting |  | Tail off | iH = +1 | iH = -2 | |  |  | N/A | 0.0985 | | |  |  | -0.0504 | | | | CL at,CM,cor = 0 |  | 0.324 | 0.083 | 0.629 | |  |  | 0.164 | | | |  |  | 0.469 | 0.456 | 0.495 | | Kn |  | N/A | 0.192 | 0.212 | |  |  | 0.1863 | -0.1922 | -0.2180 | | Fig 9 |  | 0.9740 | 0.9988 | 0.9863 | |

**(15% of marks)**

**Q7.** Based on your plot in Q6 and your observations of the wool tufts, comment on the stalling behaviour of the aircraft. Does the aircraft exhibit a stable pitch break at stall? Is that consistent with your experience flight testing the aircraft’s stalling behaviour?

|  |
| --- |
| First of all, the gradient of two lines (tails on) is negative so it is stable, and the gradient of tail off is positive so it is unstable. Therefore, the negative value shows that flight sim is more stable than the tail-off. Secondly, during a stall in an aircraft with a tail, the lift coefficient (Cl) goes down, indicating a loss of lift. Also, the pitching moment coefficient () shifts from positive to negative, causing the aircraft’s nose to pitch downward. Then we find pitch break stall when the gradient change from negative to positive. So, it changes from stable to unstable. In our flight simulations, when the flight sim reached a certain angle of attack in the flight sim, we did experience a nose-down tendency in the plane. This is consistent with our experimental results. Compare the results pf the simulation fly test and wind tunnel test. The flight Cl figures are double of the wind tunnel. Thirdly, when the stall happened, the edge of the rope had frequent vibrations. It seems to generate a vortex in the trailing edge. |

**(5% of marks)**