MAE 5510 : Exercise Set 2

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For the following problems, we will consider a version of the British Spitfire with the following geometric and aerodynamic characteristics:

$$S_w = 244\text{ft}^2, \qquad b_w = 36.83\text{ft}, \qquad C_{L_w,\alpha} = 4.62, \qquad \alpha_{L0_w} = -2.2^\circ, \qquad C_{m_w} = -0.053,$$
$$S_h = 31\text{ft}^2, \qquad b_h = 10.64\text{ft}, \qquad C_{L_h,\alpha} = 4.06, \qquad \varepsilon_e = 0.60, \qquad C_{m_h,\delta_e} = -0.55,$$
$$W = 8,375\text{lbf}, \qquad l_h - l_w = 18.16\text{ft}$$

Assume that the center of gravity lies at the quarter-chord of the main wing, the horizontal stabilizer has a symmetric airfoil, and that the main wing and horizontal stabilizer have zero twist.

2.1 The main wing of the British Spitfire has an elliptic planform. From lifting-line theory, the lift coefficient produced on an elliptic wing with zero twist can be computed from

$$C_L = C_{L,\alpha}(\alpha - \alpha_{L0})_{\text{root}} \tag{1}$$

where

$$C_{L,\alpha} = \frac{\tilde{C}_{L,\alpha}}{[1 + \tilde{C}_{L,\alpha}/(\pi R_A)]} \tag{2}$$

Assuming the main wing has a thin airfoil, compute the lift on the main wing at 5 deg angle of attack and a velocity of 200 mph at sea level.

2.2 The horizontal stabilizer on the British Spitfire has an elliptic planform. Assuming is uses a thin airfoil, compute the lift on the horizontal stabilizer at 5 deg angle of attack and a velocity of 200 mph at sea level without any influence from the main wing.

2.3 Using MachUp 4, compute the lift produced on the main wing at 5 deg angle of attack and a velocity of 200 mph at sea level. Assume that the airfoil used on the main wing is thin and has a zero-lift angle of attack of $-2.2°$. The root chord of an elliptic wing can be computed from

$$c_{\text{root}} = \frac{4b}{\pi R_A}$$

Compare this result to that in problem 2.1.

2.4 Using MachUp 4, compute the lift produced on the horizontal stabilizer at 5 deg angle of attack and a velocity of 200 mph at sea level. Compare this result to that in problem 2.3.

2.5 Using MachUp 4, compute the lift produced on the main wing and horizontal stabilizer at 5 deg angle of attack and a velocity of 200 mph at sea level when the horizontal stabilizer is placed a distance of $l_h - l_w = 18.16$ft aft of the main wing. Compare this result to that in problems 2.1 - 2.4. Discuss your results.

2.6 Using the simplified analysis for estimating the downwash, estimate the downwash on the horizontal as a function of the lift coefficient on the main wing.

2.7 Using the results of 2.6, find the mounting angle of the main wing and horizontal stabilizer required for the aircraft to be trim in steady-level flight at sea level at a velocity of 200 mph with zero elevator deflection and zero angle of attack. Compare your results to those from problem 1.13. Discuss your results.

2.8 Compute the aircraft static margin. Compare your results to those from problem 1.14. Discuss your results.

2.9 If the main wing and horizontal stabilizer both have zero mounting angles, compute the angle of attack and elevator deflection required to trim the aircraft in a steady climb at an altitude of 5,000 ft and a climb angle of 20 deg at a speed of 200 mph. Include the effects of downwash and compare your results to those from problem 1.15. Discuss your results.

2.10 Using MachUp 4, compute the global inviscid lift, drag, and pitching-moment coefficients about the origin for the aircraft at angles of attack of 4, 5, and 6 deg.

Angle of Attack [deg]	C_L	C_{D_i}	C_m
4.0			
5.0			
6.0			

2.11 Using the results of problem 2.10, find the location of the aerodynamic center (x_{ac}, y_{ac}) using the general relations for the aerodynamic center. Compare your results to that which would be obtained from the simplified analysis in problem 2.8. Discuss your findings.