CEE 5614: Analysis of Air Transportation Systems Spring 2024

Assignment 2: Basic Performance Calculations

Date Due: February 5, 2024 Instructor: Trani

Problem 1

Use the Eurocontrol interactive BADA database (https://contentzone.eurocontrol.int/aircraftperformance/default.aspx?) to answer the following questions.

a) Examine the performance characteristics of the Boeing 787-8 (see Figure 1). Find the **typical cruise Mach number** for the aircraft according to the BADA database. The aircraft code name in BADA is B788.

b) According to the graphical flight profile (called details) of the BADA database, the Boeing 787-8 climbs at an indicated airspeed of 290 knots between flight levels 150 and 240. for the to estimate the **True Airspeed (TAS)** of the aircraft during the climb procedure at 15,000 feet (Flight Level 150). Estimate the true airspeed at FL150 and FL240. Assume ISA conditions.

c) Find the Mach number for the Boeing 787-8 at FL 150 and FL240 using the values of true airspeed estimated in part (c).

d) Use Flightaware to examine the flight track and altitude profile for Japan Airlines flight 65 from San Diego (SAN) to Tokyo Narita airport (NRT) on Sunday January 28, 2024.

e) Use the NOAA re-analysis wind data demonstrated in class to explain the differences in travel time for JAL 65 and JAL 66. Using the NOAA web tool, plot the wind vector data at 250 mBar level (35,000 feet) and estimate the maximum winds encountered by both flights (read off the bar section in the NOAA plot).

Figure 1. Boeing 787-8 Landing at San Diego International Airport (A. Trani).

Note: For this problem, you can use the Matlab scripts provided in class. However, for one of the problems, I would like you to show me a sample calculation using the equation to convert IAS to true Mach and then True Airspeed (TAS).

Problem 2

Use the Matlab computer programs such as **ISAM.m** (available in the Matlab files section of our web site - http://128.173.204.63/courses/cee5614/matlab_files_cee5614.html) to answer the following questions:

a) A Boeing 747-8 (see Figure 2) flies at Mach 0.85 and at 36,000 feet. Assuming ISA atmospheric conditions, find the true airspeed (in knots) of the aircraft, the typical outside atmospheric temperature, and the density of air at Flight Level 360.

b) In another flight, the atmospheric temperature at FL 360 is 15 degrees Celsius above ISA, estimate the value of air density at FL 360 (you are allowed to use the **densityAltitudeOffISA Matlab** script supplied). Compare the air density value obtained with part (a) of the problem.

c) An aircraft crosses Mesa (AZ) with an indicated airspeed of 300 knots at 21,000 feet. Estimate the value of true airspeed (TAS) assuming ISA conditions.

Figure 2. Boeing 747-8 at Chicago ORD Airport (A. Trani).

Problem 3

The minimum flight speed in steady-flight (called stalling speed V_{stall}) can be estimated using the fundamental lift equation (assuming Lift is equal to aircraft weight, mg):

$$V_{stall} = \sqrt{\frac{2mg}{\rho S C_{l\max}}}$$

where: m is the aircraft mass (in kilograms), g is the gravity constant (9.81 m/s-s), S is the aircraft wing area (square meters), ρ is the air density (kg/cubic meter) and C_{lmax} (dimensionless) is the maximum lift coefficient (a parameter determined during flight testing).

According to Federal Aviation Regulations (FAR Part 25), the approach speed (over the runway threshold) of a commercial aircraft should be 1.3 times the stalling speed (30% safety margin to protect against wind upsets on final approach) in the landing flap configuration. Similarly, the safe climb speed (after takeoff) is 1.2 times the stalling speed in the takeoff flap configuration.

a) Estimate both, the stalling and the approach speeds for a four-engine transport aircraft similar to the Airbus A380-800 - see Figure 3) with the following parameters: S= 850 square meters, C_{lmax} = 2.85 (with flaps down 30 degrees in the **landing configuration**), landing mass of 394,000 kg (the maximum allowable landing mass) and landing at sea level ISA atmospheric conditions.

b) Find the **approach speed** for the twin-engine aircraft when the aircraft lands at Bogota El Dorado Airport (Colombia) located at 8,360 feet above sea level conditions) at 394,000 kgs. Comment on the difference in the approach speeds at sea level and in Bogota.

c) The four-engine aircraft has a maximum lift coefficient of 1.90 (with f**laps down 10 degrees** in the **takeoff configuration**. Find the **initial safe climb speed** (1.2 times the stall speed in the takeoff flap configuration) with a takeoff mass of 520,000 kilograms.

d) Find the **initial safe climb speed** (1.2 times the stall speed in the takeoff flap configuration) with a takeoff mass of 520,000 kilograms in Denver , Colorado. Assume ISA conditions. Comment on the differences observed.

Figure 3. Airbus A380-800 Landing at Dulles International Airport (A. Trani).

Problem 4

A low-fidelity Simulink-based aircraft runway simulator has been developed and it was demonstrated in class. The simulator for this analysis has been modified to approximate the runway performance characteristics of a Boeing 737-8 Max (see Figure 4). You can pick up the Boeing 737-8Max runway simulator at the website. Before using the runway simulator download the Aerospace Blockset from the Mathworks website and install it.

The simulator estimates the the takeoff safe speed using the block labeled "Takeoff Speed at Altitude (knots)" shown below. The takeoff speed of 150 knots if the takeoff speed at sea level conditions. The Takeoff Speed at Altitude is adjusted according to the density ratio if the airport elevation is other than sea level conditions.

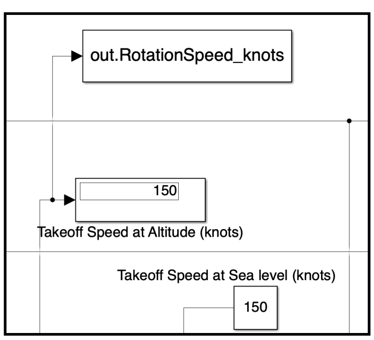

Figure 4. Boeing 737-8 Max (A. Trani).

a) Study the effect of aircraft mass on the runway length required to reach the takeoff safe speed. Start with a mass of 70,000 kilograms. Create a table and find the runway length needed (to reach the takeoff safe speed) for mass values of 70,000, 72,500, 75,000, and 80,000 kilograms. For each simulation, you estimate the runway length required by inspecting the distance traveled versus speed plot. The runway length needed is the distance required to reach the takeoff safe speed labeled “Takeoff Speed at Altitude (knots)”. For example, if the “Takeoff Speed at Altitude (knots)” is calculated to be 160 knots, the runway length is the distance traveled by the aircraft to reach the 160 knots.

b) Plot the runway length versus mass and comment on the results obtained.

c) Study the effect of airport elevation on the runway length required to reach the takeoff safe speed. Start with sea level conditions and estimate the runway length required for airport altitudes 1000, 1500, and 2000 meters. In the calculations use 75,000 kgs. as the aircraft takeoff mass.