MECH 427 – AIRCRAFT DESIGN

WITH DR. GOUSHCHA

HOMEWORK #4

Date Due: 2020 November 6th at 11:00am

You will need to **s short report and attach your MATLAB code**. The word document should include comprehensive explanation of your calculation steps, including all formulas, constants, and conversion factors you used.

The objective of the homework is to calculate the true airspeed and Mach number of an aircraft based on the actual Flight Data Recorder (FDR a.k.a. "Black Box") information obtained from an approximately two-hour regional flight. The file contains data from the time avionics are powered on before the takeoff until the time they are turned off after landing.

Import Excel data into MATLAB using `xlsread` command. You must do some research on how to accomplish this. Here is the list of available data:

TAT – total air temperature (^oC)

SAT – static air temperature (^oC)

PT – total pressure ($mBar$)

PSA – average static pressure ($mBar$)

TAS – true airspeed ($knots$) (calculated onboard)

MACH – Mach number ($none$) (calculated onboard)

For each data set, you have the appropriate time vector in minutes. Note that data sets have different length. For example, TAT has 5656 elements and TAS has 22624. The sampling rate of each instrument varies. You need to extrapolate data as to have vectors of same size. This can be accomplished using MATLAB's `interp1` command. The command follows the following syntax:

```
Y_values_new = interp1(X_values_old, Y_values_old, X_values_new);
```

Since true airspeed vector has most elements, you want to reform all other data to have the same size. To extrapolate total pressure to have 22624 elements, you need to insert original time vector for PT, the original values for PT, and the vector which you want to match data to, in this case TAS time:

```
PT_long = interp1(PT_time, PT_values, TAS_time)
```

Repeat this procedure for all your data.

Now you can start the homework. Remember, this is a commercial airliner, which flies at high speeds in a compressible flow regime. Just like your grade, the density and air speed are not constant.

1) Plot TAT and SAT on the same graph. Convince yourself that when the airplane is stationary on the ground and there is no airflow TAT and SAT are same. Once in flight, due to compressibility, the TAT is always higher than SAT.
2) Using Pitot and static pressure measurements, PT, PSA, and isentropic flow relations calculate the Mach number of the airplane. Plot the calculated Mach number and the recorded Mach number, MACH on the same graph. They should be nearly equal.

   Note: In MATLAB, division of two vectors of same size `A/B` *will result in an error since you mathematically cannot divide matrices with dimensions (1,* 22624*) and (1,* 22624*). Recall inner dimensions must match. For example, you CAN multiply (2, 3) and (3, 2). If you want to find ratio* `PSA/PT`*, you are doing element-by-element division, which is different than mathematical matrix division. You need to include a "period" to show explicitly element-by-element operation in MATLAB:* `PSA./PT`
3) Based on SAT, calculate the speed of sound a.
4) Based on a and the calculated Mach number, calculate the true air speed. Make sure to be consistent with your units, convert meters per second to knots. Plot the calculated true air speed and the recorded airspeed TAS on the same plot. Again, they should be very similar.
5) Using temperature measurements, TAT, SAT and isentropic flow relations calculate the Mach number of the airplane. Plot the calculated Mach number and the recorded Mach number, MACH.
6) Format each plot. Add axis labels, appropriate titles e.t.c.