Experimental determination of thrust of a gas turbine engine

(AS2100: Basic Aerospace Engineering Lab)

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In this experimental setup a Gas turbine engine is mounted on a test bed strongly attached to the ground as shown in the figure. The cross sectional area of the intake A_{intake} is already given. Intake and exhaust velocities $\boldsymbol{v_{in}}$, $\boldsymbol{v_e}$ are also measured accurately and it is assumed that there are no errors in their measurement. The thrust T is measured directly from the strain gauge attached to the test bed. For each exhaust velocity $\boldsymbol{v_e}^j$ with $j = 1 \cdots 5$, 100 observations are recorded to quantify the error.

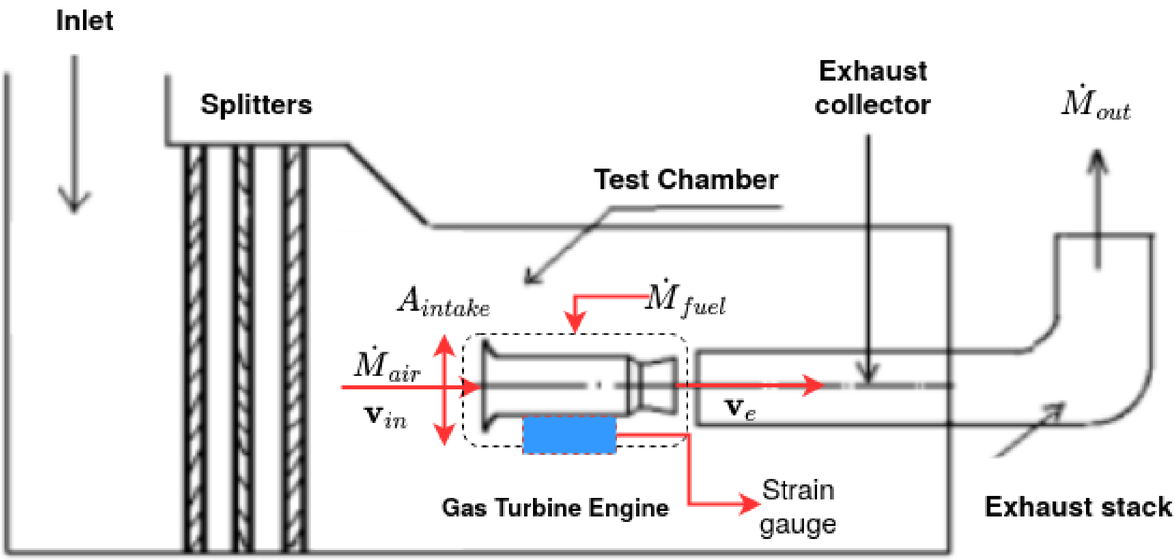

Figure 6: Schematics of the experimental setup.

Parameters used in the experiment are as follows:

- Area of intake cross section $A = 0.7854m^2$
- Stoichiometric air-fuel ratio: 14.7 : 1
- Inlet velocity $V_{in} = 50m/s$

The data set `P6_GasTurbine.mat` contains the following:

- Area of Intake (`"Area_intake"`)
- Exhaust velocities (`"Vexhaust"`):

$$\boldsymbol{v_e} = \{v_{e1}, v_{e2}, v_{e3}, v_{e4}, v_{e5}\}$$

- True thrust values(`"Thrust_True"`) calculated using Stoichiometric air-fuel ratio:

$$\boldsymbol{T^{True}} = \{T_1, T_2, T_3, T_4, T_5\}$$

- Experimental thrust measurements(`"Thrust_Exp"`) from the strain gauges:

$$\boldsymbol{T^{Exp}} = \{T_1^i, T_2^i, T_3^i, T_4^i, T_5^i\}_{i=1}^{N=100}$$

Using the given data set, do the following:

1. Explain the theory behind the experiment of thrust determination using a test bed with strain gauge attached to it. Outline the assumptions involved. At higher exhaust velocities, if the temperature of the outer casing of the turbine increases and is of the order $O(10^3)K$, how would this affect the strain gauge measurements? What are the alternatives to using strain gauges in measuring the thrust of a gas turbine engine?

2. What are the possible sources of errors in this experiment? How can we minimise them?

3. From the given measurement data of thrust($\boldsymbol{T^{Exp}}$), obtain the mean value of air-fuel ratio and compare with the stoichiometric air-fuel ratio. Obtain the mass flow rates of air($\dot{m}_{air}$) and fuel($\dot{m}_{fuel}$) respectively.

4. Using the true thrust values(T^{True}) given in the data set, plot the normalised histograms of the errors in measurements of thrust ($e_{ij} = T_j^{True} - T_{ij}^{Exp}$ for $i = 1 \cdots 100$ and $j = 1 \cdots 5$). Determine the mean and standard deviations of the errors in each case. Also plot the smoothened probability density function trends over the histogram plots.

5. Determine if the probability distributions obtained above for the errors are Gaussian, if so, then using the mean and standard deviations of the errors, e_j for $j = 1 \cdots 5$, plot smooth Gaussian density function over the corresponding histograms and smoothened probability density function plots obtained previously in question 4.

6. Determine the accuracy(given by mean absolute error $|T_j^{True} - \bar{T}_j^{Exp}|$ for $j = 1 \cdots 5$ where $\bar{T}_j^{Exp}$ is the mean experimental thrust) and precision in the measurements(given by $\pm 1\sigma_{T_j}$ for $j = 1 \cdots 5$).

7. Obtain a linear fit for thrust(T) vs exhaust velocity($\boldsymbol{v_e}$).

   Note: Obtain fits for both, mean experimental thrust data $\bar{T}_j^{Exp}$ and true thrust values T_j^{True} for $j = 1 \cdots 5$. Compare the slopes and intercepts obtained for both the cases.

In addition to answers to the above questions each report should also include introduction about the experiment , schematics of the experimental setup, a results and discussion section and a conclusion section.