# Determining the material properties of a thin walled cylinder using strain gauges

**(AS2100: Basic Aerospace Engineering Lab)**

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A thin walled cylinder made of an unknown metal is given. An experiment was designed to find the Young's modulus $E$ and Poisson ratio $\nu$ of the cylinder material. The cylinder is known to have uniform material thickness $'t'$. The experimental apparatus consist of two strain gauges attached perpendicular to each other on the surface of the cylinder. The strain gauges are connected to a strain indicator device which can directly give the strain values. There are also provisions to vary and measure the internal pressure in the cylinder. The experimental procedure is as follows. Once apparatus has been setup and verified to be working, the pressure $(p)$ inside the cylinder is set to a fixed value and noted down.The readings from the strain indicator can be fluctuating owing to random errors, so the readings are sampled for 2s with a sample frequency of 20 readings per second automatically by the device. After noting down the strain readings for both the strain gauges, the pressure inside the cylinder is increased by $\Delta P$ this is repeated several times. The same experiment was repeated by 5 different groups using the same instruments. The values of measured pressure $P$ and geometric parameters are known exactly unless specified. You can also neglect any the end effects of the cylinder.

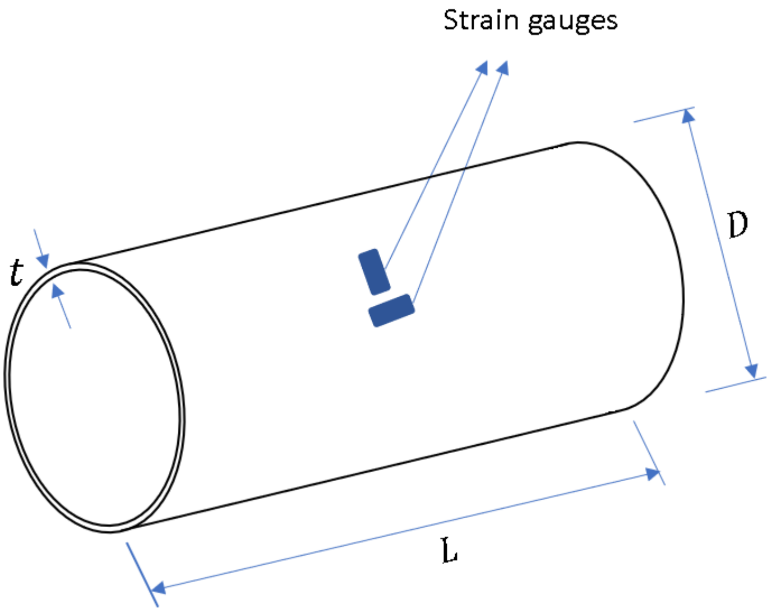


Figure 9: Thin Cylinder diagram

Use the following parameters wherever necessary:

- Length of the cylinder, L = 1m
- Diameter of the cylindrical tank, D = 0.15m
- Thickness of the walls,t = 0.0001m

The data set `P9_ThinCylinder.mat` contains,

- The gauge pressure inside the cylinder in pascal (each variable is an array of size 10 as there are 10 pressure values)

  $\Longrightarrow$ `"P_exp1","P_exp2","P_exp3","P_exp4","P_exp5"`

- Corresponding hoop and longitudinal strain readings (each variable is a $10 \times 40$ matrix, as the total number of readings taken over 2s is 40)

  - Hoop strain readings
    $\Longrightarrow$ `"eps_h_exp1","eps_h_exp2","eps_h_exp3","eps_h_exp4","eps_h_exp5"`

- Longitudinal strain readings
  $\Longrightarrow$ `"eps_l_exp1","eps_l_exp2","eps_l_exp3","eps_l_exp4","eps_l_exp5"`

1. Explain the theory behind the experiment and derive the governing equations
2. What are the possible sources of errors in the experiment and how to minimize them?
3. Using the dataset `P9_ThinCylinder.mat` plot normalised histograms of longitudinal and hoop strain readings for $P = 33333.33Pa$ for all the 5 experiments. Also plot the smoothened probability density function trends over the corresponding histogram plot.
4. Does the smoothened probability density curve obtained in the previous question resemble a normal probability density function? Determine the statistical quantities $\mu$ and $\sigma$ for each histogram and plot Gaussian probability density functions using these values. Compare it with corresponding smoothened plots obtained in question-3.
5. Derive analytical relations relating the pressure inside the cylinder to longitudinal strain ($\epsilon_l$) and hoop strain ($\epsilon_h$). Also Obtain the relationship for errors in $E$ and $\nu$ as a function of errors in pressure, strain and cylinder geometric parameters, if all these quantities have errors associated with them. (Hint:Refer to "function of errors/propagation of errors" in your textbooks.)
6. Find the mean value of $\epsilon_l$ and $\epsilon_h$ for each reading and make plots of $\epsilon_l$ vs $P$ and $\epsilon_h$ vs $P$ for each experiment.Fit the best linear curve over the data points for each case. What does the slope of each curve represent?
7. Find the best estimate for $E$ and $\nu$ from all the experimental results(express your final answer inclusive of the associated error in terms of $\pm 1\sigma$). Can you tell which metal the cylinder is made of ?
8. What are the short comings of the current experiment? Suggest better experiments to measure Young's modulus and Poisson ratio of a material.

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.