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5. Irradiation Sample Transfer Line Snubbing Section Behavior

The M.I.T. reactor is used to irradiate various isotope samples so that they can be used for medical treatment and research. These samples are packaged in a small cylinder and then inserted into a curved transfer line and lowered to the core of the reactor. (The curved line is to prevent personnel from radiation exposure at the point of insertion.) The sample is retrieved after a suitable interval. If the retrieval system fails, the sample drops to the bottom. To prevent such an accident from damaging the transfer line or the materials in the cylinder, a snug-fitting sleeve section has been installed in the bottom of the transfer line. The clearance between the cylinder and the tube in this section is small enough that air is trapped below the cylinder and is released slowly; this results in reduction in the speed of the cylinder.

This investigation has been commissioned to develop a methodology for designing the snubbing section. To verify the methodology, the experimental values of interest are:

a) The cylinder impact velocity at the bottom of the transfer line, as a function of the cylinder mass.

b) An estimate of the distance the cylinder has traveled before it bounces back as a function of the cylinder mass. (How would you estimate it from the data?)

c) The pressure of the air trapped in the line, both the peak value and the value when the cylinder has reached terminal velocity.

Note that results (a) and (b) are important to verify that your line design model is correct; (c) is just data for checking your theory. (The pressure is negligible compared to the materials yield strength.)

In the actual case, the air at the bottom of the tube is not at room temperature, but at a temperature of about 300°C. Also, the actual drop is one meter taller than the one in the lab. Thus, after confirming the validity of the model with the lab apparatus, the model must be used to predict results for the actual situation.

A simulated transfer line has been set up in the lab. The velocity of the cylinder before entering the snubbing section can be measured by determining the transit time of the cylinder as it passes a light sensor. Similarly, the velocity at impact may be obtained from the light sensor signal at the bottom of the tube. The pressure versus time behavior can be measured with the pressure transducer installed in the snubbing section. The mass of the cylinder can be altered by unscrewing the top and changing the mass of pellets inside.

A model for the motion of the sample in the snubbing section should be developed compared to the experiment. You have to formulate and solve the set of differential equations describing the dynamics of the system. (The terminal velocity is the steady state solution.) You may use MATLAB or write a simple program to simulate the dynamic behavior.

The critical questions to be answered with the model are:

(i)   What is the impact velocity?
(ii)   How long should the snubbing section be?

To answer (ii), you have to get your model to reproduce the experimental results (especially item (b) in the above) with reasonable confidence. Then the model is applied to snubbing sections of different lengths to see whether the cylinder reaches the terminal velocity before hitting the bottom.