ME 510
Laboratory #1
Due Friday 10/6 by 5:00 p.m.

Free Surface—Compressible Flow Analogy

1.0 Introduction

This lab utilizes the water tunnel located in CB 110 to demonstrate the analogy between compressible and free surface flows. In this experiment water flows through a horizontal channel of width 20.9 cm. A smooth bump is placed in the channel of maximum height 4.9 cm. The objectives of this experiment are to quantify frictionless open channel flow that can transition from subcritical to supercritical flow, to evaluate hydraulic jumps at different mass flow rates, and to relate the observations and measurements to compressible flow theory.

2.0 Methodology

This lab is a walk in lab conducted by you. Working as groups is encouraged for data collection and reduction. However, each person should submit an individually prepared laboratory summary report. See the example of a summary report in the undergraduate guide, pages A-33—A-42, for an example (http://www.byu.edu/me/UGuide.pdf). Neither a separate cover page, or abstract are required for this report.

2.1 Water Tunnel Operation

To turn the water tunnel on, plug the cable into the outlet located on the south wall in room 110. The pump is controlled by the variable frequency drive mounted on the water tunnel frame. Adjust the frequency to the desired value and start the pump by pressing run. To stop the pump simply press stop. Do not run the water tunnel at frequencies greater than 25 Hz. Three rulers for use in measuring the water depth at locations upstream from the bump, downstream from the bump, and at the apex of the bump are mounted on the outside of the test section. An additional ruler may be required.

2.2 Procedure

<u>Part 1</u>

1. Plug in the water tunnel
2. With no flow adjust the level of water in the test section to between 7.5 and 9.0 cm above the horizontal using the available tubing.
3. Start the water tunnel at 2.0 Hz and record the elevations at the three measurement locations. Also record your visual observations of the flow behavior.
4. Increase the speed by 0.5 Hz and repeat the measurements and observations from step 3.
5. Repeat step 4 until a speed of 14 Hz has been reached (after the hydraulic jump has moved out of the tunnel you may increase the speed by increments of 1.0 Hz).
6. At some critical speed a hydraulic jump will form downstream from the bump (4-8 Hz). Adjust the flow speed until the depths before and after the jump can be quantified accurately. Record both depths using a scale.

Notes: (1)Before the flow is supercritical at the downstream measurement location, it may be difficult to obtain a good measurement of the depth at this location. For the mass flow rates when this is the case, make the downstream depth measurement at a different downstream position.

(2) by placing an object just on the surface you can observe the difference between subcritical (upstream from bump) and supercritical flow (downstream from bump).

Part II (Hydraulic jump analysis)

1. Vary the water level in the tunnel and adjust the flow speed until you can quantify the hydraulic jump at this new mass flow rate. Record the depth at the critical height, upstream of the bump, before the hydraulic jump and after the hydraulic jump.
2. Repeat step 1 for 4-5 different water levels between 5.2 and 9.0 cm with no flow.

3.0 Analysis/Report

From your collected data and observations you should do the following.

1. Compute the volume flow rate for each motor speed at the water level used in part 1. (Graph this relationship)
2. Compute the Froude number at the three measurement locations and plot these vs. volume flow rate.
3. Plot the heights at the three locations vs the specific energy for each mass flow rate.
4. Concerning the hydraulic jump data, plot the ratio of depth after the jump to depth before the jump vs. the Froude number before the jump. On the same graph include the ratio of depths based on frictionless flow theory.

In your summary report include a very brief description of what you measured and the experimental setup, describe how you obtain volume flow rate from the depth measurements, present your results, and discuss your results with respect to your visual observations. A description of the different regimes of flow that occurred in the experiment is appropriate in this discussion. Use the graphs above in this discussion and give an analysis of these graphs, how the data compare with theory, and what physical insights are gained from each plot. A short section describing the experimental error for this lab is also appropriate and should appear before the discussion section. Lastly a discussion of how these data and observations relate to compressible flow theory should be included.