Department of Mechanical Engineering

Massachusetts Institute of Technology

2.20 Marine Hydrodynamics, Sample Laboratory Assignment

Laboratory Assignment A

High-Speed Free-Surface Impact Hydrodynamics

To be performed at the Water Impact Lab (WIL) at the Ocean Engineering Propeller Tunnel.

Introduction In this lab you will estimate the added mass of an accelerating sphere at various depths of submergence using:

- an oscillating, vertical spring-mass system, and
- a high-speed camera to observe at least one free-surface impact.

At least one member of each group should bring a calculator. You will need need a notebook to record the results of your work. At the (WIL), you will receive instructions on how to use the experimental equipment.

Pre-Lab Preparations You **must** submit a "pre-lab" report of the following pre-lab preparations at the beginning of the lab. Although you are encouraged to work the preparation as a lab group, your submitted "pre-lab" **must** be individually.

In your final lab report you should include a copy of your "pre-lab" (in addition to the one turned in the day of the lab) along with a short paragraph that discusses the lab preparation.

(Time spent here will certainly save you many times the effort during and after the lab!)

1. Read through the entire lab *carefully* so that you have a clear idea of what has to be accomplished. Be familiar with the expected results and calculations so that you can repeat suspicious measurements (*during the lab*).
2. Derive the equations of motion for a spring-mass system in air and in water. You need to assume small motions,(vertical displacement << radius) but keep all other terms until your measurements show which, if any, can be neglected.
3. From your equations determine the natural frequency and period of oscillation in each case.
4. Which configuration (air/water) should exhibit a longer period?

5. Discuss (qualitative arguments) of how you expect the added mass coefficient to vary for different submergence depths.

6. Derive an expression for the added mass of the body as a function of the ratio of the natural frequency of oscillation (of the spring-mass system) in air over the natural frequency of oscillation in water, and the mass of the body. Do you need information for the spring used?

7. Can viscous drag be ignored in this experiment?

8. Derive the equation of motion (EoM) for the water-sphere during impact. Integrate with respect to time and obtain the integral form of the EoM. State clearly which terms that appear in the integral form of the EoM can be determined analytically, which require experimental measurements, which terms you expect to be negligible and which terms you expect to be of dominant importance.

9. Suggest how you can estimate the added mass of an accelerating sphere at various depths of submergence using a high-speed camera and the integral form of the EoM.

   Be prepared to discuss with the lab staff your action plan when you enter the lab.

Laboratory Assignment

Equipment

A transparent tank, two springs, at least two spheres of different diameter/weight, a strain gauger and a high speed camera.

Objectives

To compare the added mass of an oscillating sphere in heave with the added mass of a sphere during free-surface impact. In both cases the added mass should be given as a function of the submergence depth.

Measurements

WIL personnel will provide instructions for the operation of the gauger and the high speed camera. Please follow their instructions.

1. Calibrate the strain gauger using prototype weights.

2. A spherical weight has been prepared for you. Weigh the body using the strain gauger and determine its mass. Evaluate the dimensions of the body and determine the buoyant force acting on it in fresh water.

3. Suspend the body from a fixed pivot above the floor and time the period of small oscillations in air using the gauger. Then re-suspend the body in the tank. Time the period of small oscillations in water, for various depths of submergence. Use the calculator, your measurements, and a provided chart to check your results as you go. You are welcome to repeat the trials if you wish.

4. Release the sphere for the pitching machine in the WIL (instructions will be given by the WIL lab) and tape the impact, using the hight speed camera.

Post-Lab Analysis (To Be Done Individually)

In your lab report, the final results you present must be in non-dimensional form. The gravitational acceleration is $g = 9.80665 m/s^2 = 32.174 ft/s^2$).

The lab report should include copies of your pre-lab preparation, the specific procedure of your group's experiment, data analysis, and a discussion of your results.

Besides the issues required to discuss/explain the above measurement steps, the following results are required to be analyzed and discussed in your lab report. In addition to these, you are encouraged to discuss other hydrodynamic issues you have learned from the experiments. You are also encouraged to design/perform new measurements in addition to those outlined above, with the permission of laboratory staff. Any novel ideas and insightful discussions will be given extra credit in the lab grade.

1. Justify your assumption that viscous drag was ignored in this experiment. Hint: You may argue from information contained in your class notes or the textbook, but the most powerful argument can be simply constructed from your own careful observations.
2. What is the accuracy in your estimations for the velocity of the sphere during the impact? Give an estimate in meters per second.
3. How does the added mass coefficient change with submergence depth in the case of the spring-mass system?
4. How does the added mass coefficient change with submergence depth during the impact?
5. Compare in a graph the added mass coefficient for the sphere as a function of the submergence depth, for both the spring-mass system and during the impact. Are the two coefficients equal? Explain, using physical arguments.

The lab report should be written in a professional way. It should be type-written and should have been edited for grammatical and spelling errors. Although it needs to be complete, **conciseness** is also emphasized.