Power producing buoy for strategic applications: Design Trade Study – Q2 Report

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Report Period:	5/9/2009-8/8/2009

Summary

In the second quarter of this project, we have completed and tested a computer modeling framework for wave-body interaction problems typical of wave-energy extraction problems. This computer model will allow us to investigate the effectiveness of a variety of wave-energy extraction and station keeping concepts without building hardware. In order to have confidence in the effectiveness and accuracy of the model before proceeding with a lot of analysis, it is important to validate the model against a physical result. To do this we constructed an instrumented test buoy that incorporates the key components of the computer model such as wave-body interactions and floating body interactions with a submerged reaction mass. Two tests were performed to validate that the computer model matches the experimental results; the first of these tests is a simplified "step-response" test in which the motion of the system is measured after an initial displacement. The second test is an at-sea test in which the behavior of the system is measured in ocean wave conditions. By comparing the results of these validation experiments with the models predictions, the effectiveness of the model can be validated. The step response test was performed within the period this report applies to and preliminary results from that test are presented. The at-sea test was performed on August 10th and 11th, 2009, results from that test will be included in the project final report.

Activities

1. Completed development of a general purpose computer code for modeling wave-body interaction problems.
2. Designed and built a test buoy system for validating the computer model.
3. Performed a "step-response" test with test buoy in the MBARI test tank.

Technical Status and Results

The validation test buoy is shown in Figure 1 and consists of a surface buoy that is 96 inches in diameter and weighs 2600lbs. Submerged below this buoy is a flat, circular steel plate that is 48 inches in diameter and weighs 1300lbs. These two elements are connected by a 20 meter long tether and a 6 foot long hydraulic ram that operates as a spring/damper. One side of the hydraulic ram is plumbed to a system of accumulators that compress a gas as the ram is extended by the tension of the tether. These accumulators approximate a linear spring as shown in Figure 2. The flow of hydraulic oil through the hoses and fittings introduces some damping also. These spring and damping characteristics have been estimated and are incorporated into the numerical model of the system. With this information, all important characteristics of the system are modeled, the buoy and plate mass, the buoy and plate hydrodynamic behavior, and the spring/damper characteristics.

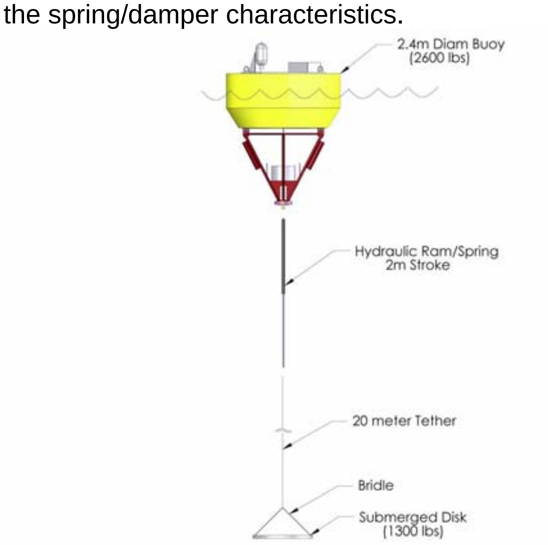

Figure 1: Diagram of test buoy system.

A step-response test has been performed in which the buoy was lifted 12 inches above its static waterline and dropped. Because the buoy drops faster than the submerged plate, the ram is initially drawn in by the spring force provided by the accumulators. However, when the buoy reaches the bottom of its travel and starts back upward due to its buoyancy, the plate is still moving downward and the ram extends. The elongation and force history on the ram is the primary measurement made during the experiment and by comparing these to the motions predicted by the model, a validation of the model is accomplished. Figure 3 shows a photograph of the buoy in the MBARI test tank, the submerged steel disk is shown in the background of Figure 3 before deployment and submerged below the buoy in Figure 4. The top of figure 4 also shows the hydraulic cylinder between the buoy and the submerged plate in its static condition, extended about half-way due to the weight of the submerged plate.

Figure 5 shows the model prediction plotted on the same axis as the measured results. To achieve the close agreement shown here, the damping in the ram system had to be increased above that which was estimated a priori. This defect is currently being investigated by carefully measuring the actual damping in the test system. Also evident in the results is a “stiction” effect that is present in the ram. In other words it takes a certain amount of force to start the ram moving, at which point it takes a smaller amount of force to maintain its motion. This is currently not modeled and this omission creates the discrepancy evident late in the motion where the ram stops moving abruptly and the modeled results show a slow decay in speed.

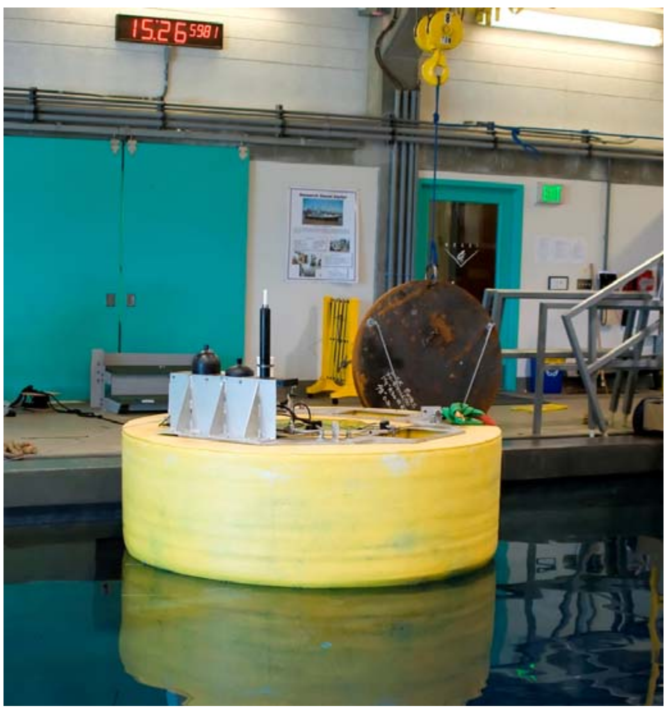

Figure 3: Test buoy in MBARI test tank.

Figure 4: Plate submerged below buoy in test tank, supported by hydraulic ram visible in the top of the photo.

The equations of motion for rigid bodies such as these are well understood and are not in question; the aspects of the model that need validation are primarily the hydrodynamic forces that act on the floating and submerged bodies. The theory that is used for the wave-structure interactions is based upon an assumption that the viscosity of the water is zero. For very large structures such as oil platforms, this is a fine assumption. For smaller systems such as this one, the zero viscosity assumption is more questionable, this is one reason this validation test for applying this computational code to these problems is important. It is possible to apply corrections to adjust for the potential invalidity of this approach and this validation test will determine if this is necessary.

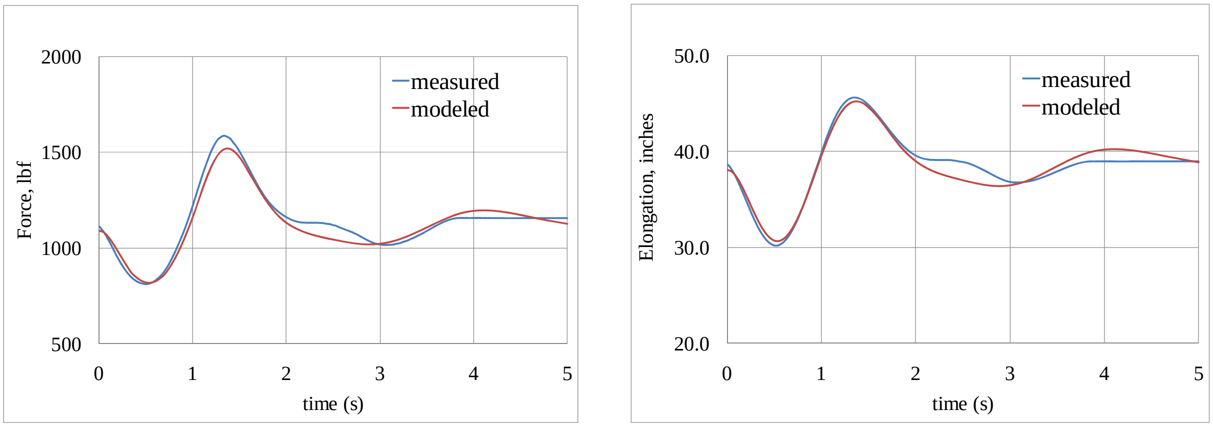

Figure 3: Ram force and elongation comparison for modeled and measured results.

The step-response test is a simplified test of the model in that it does not include any wave exciting forces, that is, the buoy and plate motion is entirely a result of its initial displacement as there are no incoming waves to cause the system to move. This is in contrast to the at-sea tests in which all the motion of the system is due to the incoming waves. The two tests are complementary in that the step-response test includes all frequencies of motion (in theory), but doesn't exercise the models ability to represent forces on the system due to incoming waves. The at-sea test includes the wave-exciting forces, but only subjects the model to frequencies that are present in the incoming wave-field. Those tests have been completed and the result comparison will be included in the project final report.

Budget and Spending

As of 8/8/2009, the entire budge of this project has been nearly spent. The goals of the effort have been met and a final report will follow this quarterly report shortly. The attached budget status report shows the spending categories as of 8/19/2009.

Attachments

1. MBARI Grant Status Report

Projection Groups: Reports

Project List | Select Projection | Report Groups | Commitments | Logout

Export to Excel

707956

Projection Name	Project
707956	707956.00 - EP Buoy:DesignTrade Study

Time (in Hours)

Individual	Line Label	Rate	Actual	Total
ENG-Institute Mech Tech		$37.13	27.00	**27.00**
ENG-Institute Mech Tech		$37.13	58.00	**58.00**
ENG-Machinist		$36.74	6.00	**6.00**
ENG-Mechanical (TERM)		$36.06	927.00	**927.00**
ENG-Systems Engineer		$66.07	827.00	**827.00**
SCI-Research Tech		$32.44	320.00	**320.00**
Total Time			**2,165.00**	**2,165.00**

Cost

Line Item	Budget	Actual	Committed	Total	Remaining
5120-000 | OS - External Ship Time	-	$4,100	-	**$4,100**	**($4,100)**
5130-000 | OS - General	$20,500	$17,676	-	**$17,676**	**$2,824**
5200-000 | Postage/Shipping	-	$130	-	**$130**	**($130)**
5300-000 | Supplies - Cmptr/Hdwr	-	$914	-	**$914**	**($914)**
5310-000 | Supplies - Cmptr/Sftwr	-	$2,102	-	**$2,102**	**($2,102)**
5330-000 | Non-Capitalized Equipment	-	$6,530	-	**$6,530**	**($6,530)**
5360-000 | Supplies - General	-	$3,628	-	**$3,628**	**($3,628)**
5500-000 | Travel - Domestic	$6,600	$738	-	**$738**	**$5,862**
Labor	$106,873	$103,042	-	**$103,042**	**$3,831**
Fringe	$56,643	$54,612	-	**$54,612**	**$2,031**
Overhead	$97,213	$93,803	-	**$93,803**	**$3,410**
Total	**$287,829**	**$287,275**	**$0**	**$287,275**	**$554**