Power producing buoy for strategic applications: Prototype and Testing – Q9 Report

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Summary

The main activity in the ninth quarter of the project has been the in-lab testing of the MBARI designed power take-off device. This system largely met the performance targets and is capable of converting mechanical power to electrical power at greater than 60% efficiency. The tested system is not suitable for use at sea and work began to construct a sea-going version. Additionally, the homing sonar (USBL) has been integrated into the AUV and commissioning tests were performed at sea. The data from the at-sea testing performed in January/February has also been analyzed and used to further validate the numerical performance predictions of the system. The effort to test the flapping foil propulsion system came to an end in this quarter and further testing will be restricted to a drifting mode unless an ongoing analysis indicates that a thruster design could provide useful station keeping behaviors.

Activities

1. Analysis of January/February sea tests and comparison to modeled results.
2. Development and lab test of MBARI designed power take-off system.
3. USBL homing sonar integration into AUV and at-sea commissioning of USBL.
4. Design and fabrication of sea-going power buoy system for Fall 2011 sea-tests.

Technical Status and Results

The lab tests of the MBARI designed power take-off (PTO) device were very successful and demonstrated an efficiency of greater than 60% for mechanical to electrical conversion as shown in Figure 1. This efficiency represents the amount of mechanical power input (force times speed) that is converted to electrical output (voltage times current) and so includes friction losses in the system. The output power at this point is not converted to a voltage level suitable for battery charging at this point so an additional loss will be incurred at that step. Design work is underway to engineer the appropriate power converter. The design requirements of this device are relatively sophisticated and is therefore not commercially available. Not only does the converter need to convert a wide range of input voltages to a nominal 24V battery bus, but it needs to maintain a prescribed voltage to current ratio on the generator output. This is required to keep the system dynamics in a regime that optimally harvests wave energy.

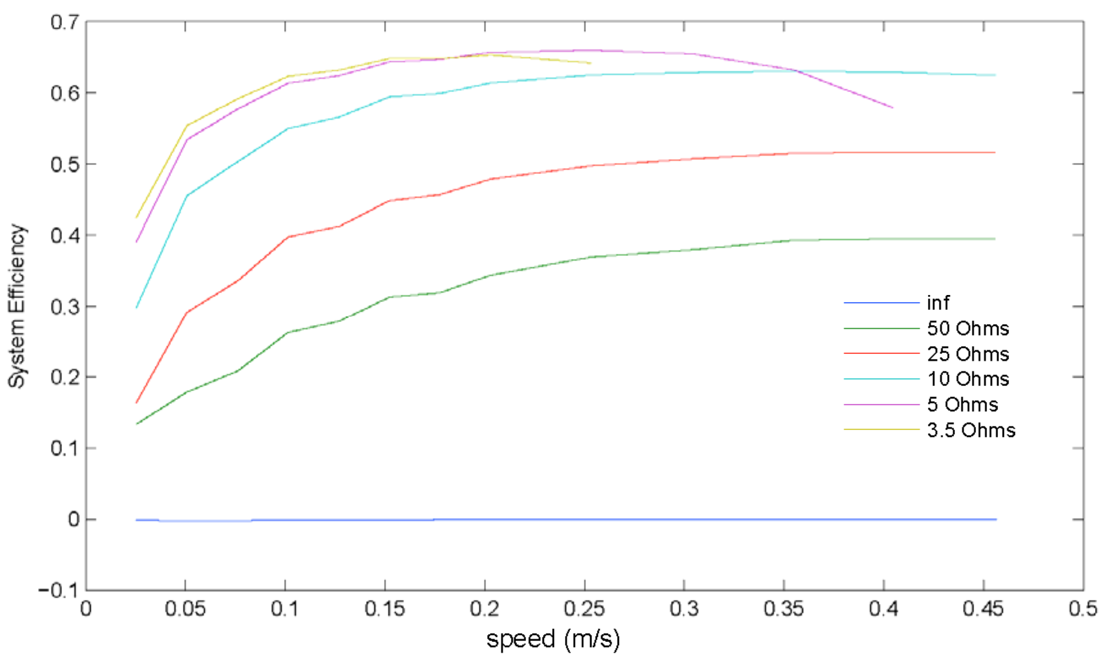

Figure 1: Conversion efficiencies of power take-off system at different speeds and electrical loadings.

For maximum wave-energy extraction performance, the power take-off system must operate along a particular force-speed operating curve (determined from numerical modeling of the entire system). For the power take-off device tested, the electrical loadings that produced the peak efficiencies resulted in a speed-force relationship that was close to the optimum desired for at-sea use, but not exactly at the target. Small adjustments are being made in the design of the sea-going device to bring the peak efficiencies that can be realized in line with the desired force-speed operating points.

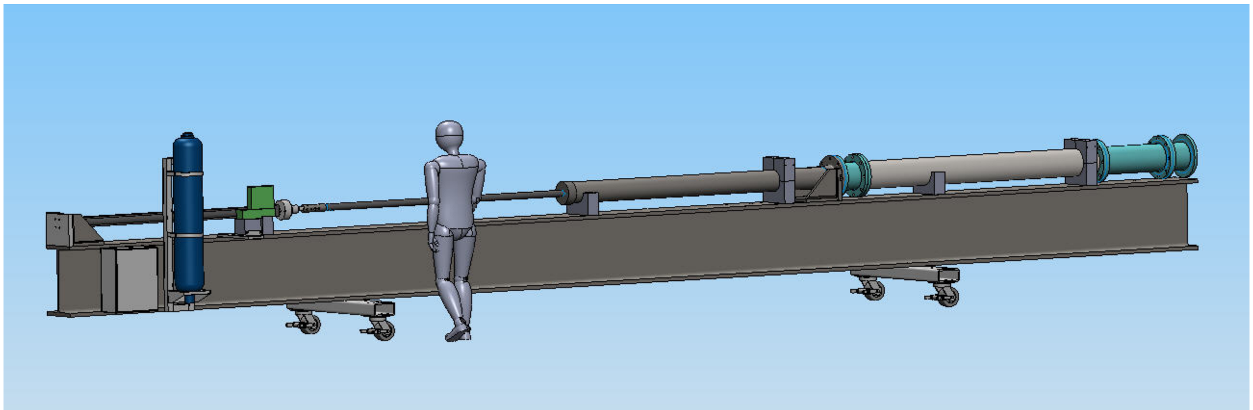

Figure 2: Illustration of lab test equipment, the buoy power take-off system is shown on the right and the driving hydraulic components are shown on the left.

With the fundamentals of the PTO system proven in the lab, work has begun to design and fabricate a sea-going version. A significant issue that needs to be addressed is the presence of side-loading on the PTO device that exists in the ocean but isn't present in the lab. In fact, the February 2011 deployment demonstrated this problem, the large waves on that day introduced side loading that significantly scored the hydraulic rods in the system. In addition to a longevity issue, this problem can be a source of significant power loss. There are two approaches that have been considered, the first is to make the hydraulic rods and seals large enough to withstand the side loading without becoming permanently bent or damaged. Engineering analysis has indicated that while possible, the needed 3 inch rod size introduces significant seal drag as well as size, weight, and cost issues.

The second approach involves adding a guide tube to the end of the PTO that will guide the tether and isolate the side loading from the hydraulic rods, see Figure 3. This approach concentrates the wear and drag issues at the tether guide entrance and allows more modestly sized hydraulic components to be used. In order to explore this approach, lab testing of a tether guide prototype was performed. Figure 4 illustrates the test set-up. The test was relatively aggressive and exerted the maximum expected side loading on the system for about 150,000 cycles (two weeks of test time). The cable and guide wear was minimal during this time and force versus speed measurements during the test indicate that the friction added to the system will contribute only a few percent to the total power loss. Although the drag does represent loss, this arrangement does allow smaller hydraulic rods and seals so there will be a drag reduction in those components. This design is will be tested at sea in October, 2011.

A key issue related to AUV docking is the ability to maneuver the vehicle to hit a dock that is moving due to wave motion. Analysis of the AUV maneuverability and the expected dock motions when connected to the power buoy system indicates that this will only be possible in calmer sea states. In order to further refine this estimate, testing is planned to exercise AUV homing behaviors to a dock-like structure attached to the wave-generation system. Additionally, techniques to stabilize the dock during the short periods of AUV approach and capture are being explored.

The preferred homing sensor is an ultra short baseline sonar system (USBL), previous docking efforts at MBARI have successfly utilized systems from Benthos and that is the equipment of choice for this application. To date the USBL itself has been integrated into the vehicle and commissioning tests have been performed. These tests consisted of swimming the AUV by the USBL sound source and logging the range and direction of the fixes on board the vehicle. The USBL system being used also has the ability to transfer data while ranging, this will allow the USBL modem on the dock itself to transmit the docks depth and orientation to the vehicle during the homing approach. Additionally, the standard behavior has a range and angle update rate that is limited to less than once a second. Benthos has been contracted to create a custom firmware solution that will increase this rate to the 2-3 Hertz necessary for successful homing and docking to a moving target.

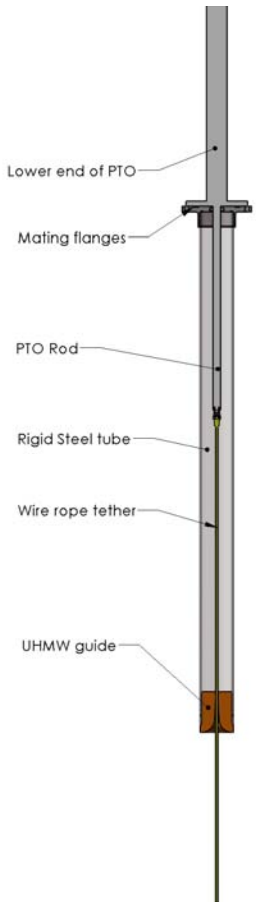

Figure 3: Tether guide concept

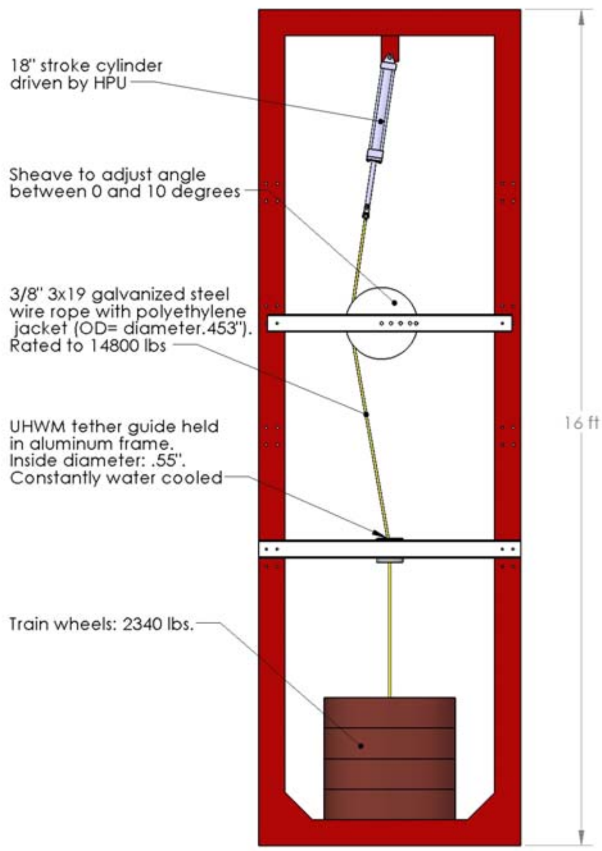

Figure 4: Tether guide test set-up.

Budget and Spending

As shown in the attached budget report, there is 44% of the original budget remaining to be spent and there is 33% of the performance period remaining. As such the spending rate is a little behind on average but the project is spending money at a faster rate now than in the first year of the effort due to expanded staff and activities (addition of AUV docking). Considering the project plans, the funding should last through the planned project end date of September 25th, 2012.

Attachments

1. MBARI Grant Status Report