Response to IDMEC Data Request

Andrew Hamilton
2/15/2013

Averaged sea-spectra at the deployment site

We have good data for this at different times of year. What is the best way to present this data? Shall I follow the lead of your paper and create 8-10 spectra and assign a percentage of time each is expect to be present? This will take a little time to assemble so that will follow this package on Monday. Let me know if you would like this data in any particular format or if a different approach makes sense.

Added Mass and damping for the buoy as computed by WAMIT

I have included the WAMIT output files we have used for this buoy. At the moment they are not evaluated at the frequencies you specify. I'll need to run these again at the appropriate frequencies, or possibly interpolate the existing data. My WAMIT installation is giving me trouble at the moment after being installed on a new computer, so I'm not certain if re-running the cases is quick for me to do right now. Also, I'm struggling to locate the original input files, we haven't changed the buoy geometry in a long time so have just been using the results I've attached in our modeling. In the worst case I will have to re-create the input files.

Added Mass and drag for the submerged plate

I have previously given added mass and drag estimates for the submerged plate but the added mass numbers are still a little in question. We have recently performed a WAMIT run for the submerged plate which is where my best added mass estimate is from. Unfortunately there was an error in the input file and the depth of submergence for that run wasn't as deep as it should have been, I'm working now to re-run that case. I think the current estimates aren't terrible, but there is probably room for improvement.

EOS strategy

There is nothing sophisticated here, there is a "hydraulic stop" at the end of the hydraulic cylinder that causes a hydraulic compression to slow the piston/rod before it hits the end. This takes effect for the last 2 inches or so of the travel and is not well characterized. Generally in the deployments the piston doesn't travel so far to hit the ends. We did leave the system out through a storm last fall and the piston was reaching the end 10 times per hour or so in 4-5m significant wave heights. This prototype was never designed for severe conditions and we were operating outside of our design envelope at that time. Due to the prevailing weather it is extremely unlikely that we will see waves that large.

Pneumatic Spring Volumes

Attached are our graphs of our estimates of the spring response versus piston position based upon adiabatic and isothermal gas compressions. The actual response witnessed during sea tests is somewhere between these two but closer to the adiabatic case. The initial gas pressures and volumes have been chosen to provide a nearly linear spring behavior. A decision should be made if modeling the pneumatic spring details is necessary or simply modeling it as a linear spring is sufficient.

The piston diameter is 5 inches and the rod diameter is 1.5 inches, the rod is only attached on one side of the piston so the areas are different for the upper chamber and lower chamber, see system diagram. The absolute gas pressures and volumes when the piston is at mid stroke are as follows (sorry about the English units…):

	Upper Chamber	Lower Chamber
Gas Pressure	75 psia	184 psia
Volume	2212 in^3	3834 in^3

The matlab script used to compute the attached plots is included also (ForceProfile.m).

Hydraulic Cylinder/Motor/Generator

The hydraulic PTO consists of a hydraulic system (bore diameter = 2.5 inches, rod diam = inches), a hydraulic fixed angle bent-axis piston motor (Parker F11-5), and an brushless servo motor running as a generator (Kollmorgan m). The resulting three-phase power is rectified and the resulting bus current is controlled by a system that converts some of the resulting power to a 28V battery bus to charge batteries, and dumps the excess to a load dump. The rectified current is controllable at a 10Hz rate by the system and is currently controlled to implement a linear damper of variable damping coefficient.

The decision at this point is if it makes sense to model the details of the hydraulics, motor and generator, or if it's sufficient to characterize the entire PTO system as a system with a controllable force to speed ratio, we have measured data on the system for force and electrical power versus speed as a function of loading. Before we built the system I constructed such a mathematical model of the expected performance based upon the published torque/speed as a function of pressure and flow characteristics for the motor, and the voltage and torque constants for the generator. The result matched the measured results only to first order, largely because the manufactures data on the hydraulic motor was low resolution, especially at low speeds, and the magnetic losses in the generator were difficult to capture.

System Geometry

The system topology in figure 1 of your data request is close to how the system is configured, but the orientation of the pistons and the bore tubes isn't quite right. In fact there is a single outer housing that is connected directly to the buoy, the connection is a big shackle so it articulates but there isn't any mechanical cable at that location. The two pistons (pneumatic and hydraulic) are connected together by a rod and then there is a second rod that penetrates out the bottom of the housing and the tethers connect there. I've attached a drawing and also a cross-section of the PTO that shows the arrangement of pistons and rods. The tether from the bottom of the PTO to the submerged plate is a piece of spectra that is about ½" in diameter. This material is very stiff and I doubt the stretch in this element is significant at all relative to the motions of the PTO. Similarly the bridle above the plate consists of sizeable wire-rope elements that have negligible stretch. I could estimate the axial stiffness of these elements if you feel their needed.