University of Victoria | Graduate Studies

Notice of the Final Oral Examination for the Degree of Master of Applied Science

of

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"A Wave Energy Converter for ODAS Buoys (WECO)"

Department of Mechanical Engineering

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Engineering Office Wing
Room 230

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Dr. Peter Wild, Department of Mechanical Engineering, University of Victoria (Supervisor)
Dr. Brad Buckham, Department of Mechanical Engineering, UVic (Member)

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Abstract

Ocean Data Acquisition System (ODAS) buoys are deployed in many seas around the world, a subset of these are wave monitoring buoys. Most are powered by solar panels. Many of these buoys are subjected to movement from waves, and could benefit from a wave energy converter specifically designed for ODAS buoys (WECO). A particular buoy that could benefit from this technology is the TriAXYS wave buoy[1]. This thesis discusses the development of a self-contained WECO that would replace one of the buoys four on board batteries, and harvest energy from the buoy motion to charge the remaining three batteries. A major constraint on the WECO is that it can not affect buoy motion and jeopardize wave data that is derived from the motion.

Rather than follow a traditional approach to simulating the motion of the buoy / WECO system, using hydrodynamic modelling and theoretical wave profiles, existing motion data from a buoy installation was analyzed to find the loads that were applied to the buoy to cause the motion. The complete set of mass properties of the TriAXYS buoy were derived from the 3D model, provided by AXYS Technologies. These mass properties were compared to the linear and rotational accelerations to find the loads that were applied at the buoy center of gravity (CG) to cause the recorded motion.

An installation off the coast of Ucluelet, BC was selected for this investigation because it is subjected to open ocean swells, and data from the winter months of November to March of 2014 to 2016 is available. Winter data was used since there is more wave action to power the WECO during the winter months, and there is sufficient solar irradiation to power the buoy in summer months. Accurate buoy motion data at a 4 Hz sampling rate was available from three rotational rate gyros, and three linear accelerometers installed in the buoy. Each dataset of samples represented a 20 minute window that was recorded once every hour.

Five conceptual WECO designs were developed, each of which focused on the extraction of power from a different degree of freedom (DOF) of buoy motion (surge, sway, heave, roll, and pitch). Three designs used a sliding (linear) oscillating mass, and one was aligned with each of the surge, sway, and heave axis of the buoy. Two designs used a rotating oscillating mass, and the axis of rotation of each device was aligned with either the roll or pitch axis of the buoy.

All proposed WECO configurations, were modeled as articulated mass, spring, and damper systems in MATLAB using the Lagrange method. Each WECO/buoy assembly formed an articulated body. Mass properties for each configuration were derived from the 3D models. The equations of motion for the original buoy no longer applied, but the environmental forces applied to the hull would still be valid as long as the WECO didn't alter motion significantly.

The power take off (PTO) was modeled following standard convention as a viscous dashpot. The damping effect of the dashpot was included in the models using Rayleigh's dissipation function that estimated the energy dissipated by the PTO.

The resulting motion of the articulated TriAXYS-WECO system was directly integrated. The results of these open-loop simulations were validated by comparing them to the original buoy motion in the frequency domain, and to the results of applying the same load datasets to a model of the original rigid buoy with the same method. The buoy motions from all models were almost identical to the original motions, and all WECO designs that were analyzed were considered acceptable with regards to their affect on the buoy motion.

A subset of load datasets was selected for evaluating the maximum power potential of each WECO. Each WECO was tuned to each dataset of loads using the spring rate, and the damping coefficient was optimized to find the maximum power while avoiding end stop collisions. A second subset of data was selected to evaluate the average power that would be generated throughout the winter months for the two most promising designs. This evaluation was performed for static spring and damping coefficients, and the coefficients that resulted in the highest power output were discovered.

The motion of the WECO oscillating mass with respect to the buoy was used in conjunction with the damping ratio to form an estimate of the ideal (i.e. with no mechanical or electrical losses) power generation potential of each WECO configuration during the winter months. The two leading WECO designs both had sliding (linear) oscillating masses, one was aligned with the surge axis and produced theoretical average of just over 0.5 W, the other was aligned with the heave axis and produced theoretical average of just under 0.5 W.