INPUT TO DOE MKH GRANT

By David B. Coakley

For Ken Gluck and Henry Swales

January 30, 2015

Early work on the Aquantis MKH turbine centered around a moored structure with two rotors and a single mooring line. A basin test at NSWCCD in 2002 demonstrated that a 1/30th scale model of such a turbine could be stable, with or without a dynamic control system including three movable flaps located on a wing connecting and extending beyond two laterally symmetric nacelles, and could feasibly extract significant power from faster ocean currents. It was also found that the existing wing design was not large enough to lift the Cplane high enough in the water column.

NSWC became involved in the design of the next generation of Cplane in 2010. Early work centered on developing a hydrostatic simulation of the Cplane, and in reducing the complexity of the earlier dynamically controlled design. Findings by NSWCCD early in 2011 resulted in guidance by A. Fleming at Ecomerit to determine if a passive design was feasible with no moving control surfaces that could, by virtue of its passive design, seek a proper depth to avoid damaging high currents. By May 2011 a passive design had been found at NSWCCD by Coakley and Banko that would seek the proper depth in a water column based on hydrostatic analysis. A lifting wing was found not to be needed; that a ratio of net buoyancy to rotor drag of between 0.15 and 0.25 was enough to ensure that the Cplane could to a large degree, find the right depth in a water column with faster moving current at shallower depths. Key to this was the 2-point mooring, where in addition to a forward line resisting rotor drag, a vertical line is added to prevent the Cplane from rising to the surface during periods of low current. This two point mooring became the basis of the 3-point mooring used now, which has a redundant forward line, and which in the vertical plan behaves exactly like a 2-point mooring.

Technical findings from this period found that:

1. Stability derivatives of several rotor designs showed they have static stability when held at their mass center;
2. Forces and moments calculated from Flightlab compared well with those computed from an accurate Reynolds Averaged Navier Stokes solver run by an expert at ARL Penn State, and that these forces and moments could be captured to a large degree by the standard coefficients used in U.S. Navy coefficient simulations of ships and towed systems;
3. Cplane buoyancy , weight and rotor forces dominate the hydrostatics and hydrodynamics;
4. In normal operation subjected to ambient turbulence, gyroscopic forces contribute little to Cplane hydrodynamic response;
5. and that considering a)-d) above, that stability is expected from analysis of a wide variety of Cplane designs using first principles.

The hydrostatic stability findings were presented at a Concept Design Review in May 2011; all of the above findings were known by this time.

In October 2011 a Preliminary Design Review was held that included simulation results from DCABIM, a dynamic simulation developed from a proprietary Navy code called DCAB. DCAB itself was developed in the 1990s to analyze dynamic stability of typical navy towed systems.

DCABIM has several additions and improvements beyond DCAB, including:

1. ability to handle multiple bodies such as nacelles, rotors and wings;
2. inclusion of rotor gyroscopic forces and moments;
3. estimates of current reduction over the structure due to the rotor induced drag;
4. a second cable that is used to model the vertical line.

Work presented at the Preliminary Design Review (PDR) in October 2011 showed that the Cplane design consisting of 4 rotors and nacelles connected by a large truss structure located forward of the moderately raked rotors showed hydrodynamically stable responses to lateral and vertical plane current perturbations. An assumption made for this analysis was that the rotor tip speed ratio remained constant during a dynamically evolving run. Work not published showed that a rotors forward design should also show dynamic stability.

DCABIM results matched the hydrostatic calculations done early in 2011. Beyond this it showed that at a depth of 70 m, the 4-rotor design would not be seriously affected by 7 m significant wave height (SWH) waves, possibly expected in large storms, but would be affected by 12 m (SWH) waves, as might possibly occur during a hurricane.

Work at NSWCCD on the hydrodynamic aspects of the Cplane design essentially ceased shortly after the 2011 PDR, and began again in January 2013. Major results here are in the GMEC paper.

Note to Ken and Henry. I met you in December 2012, so I think you started around this time. I did not do much work on Aquantis until January 2013: you were aware of the work.