Date: March 11, 2009
Location: MBARI
Present: MBARI: Hamilton, Sreeram
Airflow Sciences: Jim Paul, Andrew Banka, Jeffrey Franklin
MI&T: Dominque Roddier, Christian Cermelli
Ship Research Inc.: Bill Webster

Summary:
The purpose of this meeting was to gather the various groups that we're planning to have perform various analysis in the development of the wave-powered buoy platform. The intention is to have Dominique and Christian perform analysis and computations related to the floating buoy problem in waves and couple their code to a CFD solution of the submerged foil problem done by Airflow Sciences. Defining the mechanism of interaction between the groups was a main goal along with identifying the nature of the required computations needed by airflow sciences.

The meeting started with an overview of the origins of the DARPA project and grant, description of the project plans, and outline of the initial analysis to be performed. The group spent some time discussing the need for more specific requirements on the project. There was some discomfort at not having a defined sea-state for operation or power generation targets. I think this is a valid criticism but explained that we're very much in the concept development phase and are currently approaching things from the point of view of trying to determine what's possible. Nevertheless, good suggestions were made and I think that we'll have to make some specification regarding size and weight in the near future.

After everyone had a chance to explain why a rigorous engineering process was important we got around to discussing the options, assumptions and trade-offs related to analyzing the case of the submerged horizontal foil. Key points are summarized here:

1. In the coupled solution, MI&T will take care of advancing the equations of motion and will as such need to know details about the mass, added mass, and moment of inertial for the submerged foil. ASC will simply need to provide the forces generated by the foil at each timestep based upon a velocity supplied by the MI&T software.
2. The group felt that the "memory" effects due to the transient motion of the foil would be minimal and that the analysis could be performed in a quasi-static manner. If this is true, the CFD work by Airflow Sciences will be greatly simplified. They will be able to compute the forces on the foil at a range of angles of attack and velocities. Conceptually they can then provide a "look-up" table that the MI&T software consults to determine the forces on the foil at each time-step.
3. There was some discussion about how to validate this assumption. The "Theodorsen function" in airflow theory addresses this issue and may be a guide. Additionally, Airflow Sciences pointed out that they could do one transient run at a suspect motion profile and compare the results the quasi-static approximation. I personally and not as confident that the quasi-static assumption is OK, but I hope I'm wrong. Validation of this assumption is important.
4. Should the quasi-static assumption not be valid, we can still couple the solutions from the two pieces of software but they will have to be run together. Technical details of how to accomplish this were discussed and it was determined to be possible within the licensing agreements that Airflow Sciences must honor. This is really a second-class option since it will dramatically increase the amount of computations required to explore different options.
5. We discussed my concern about the wave-interaction theory only being theoretically valid at zero forward speed. The resounding opinion was that the forward speed effects to the wave

problem will be negligible. Drag due to the float moving through the water will be tackled using a "Morrison" formulation, (i.e. a drag coefficient). Wind loading and second-order mean wave drift forces can be incorporated in a similar manner.

6. There was some discussion about the capabilities of the MI&T software and what will be needed to accommodate our problem. Currently the software isn't quite as flexible as I thought. For instance, multiple submerged bodies aren't currently supported. It could be that our software becomes the preferred solution, but I think we should carry both possibilities forward to allow validation of our code and to keep options open. I did not mention to the group that we were developing a comparable capability.
7. We also discussed test-tank possibilities and the suggestions were in line with the discussions I had with Dominique previously. Two testing approaches seem possible, one in which the whole system is tested in a wave tank. The limitations here are that the available wave tanks can't make ocean sized waves so the scaling the entire system will be tricky (since wave effects scale with Froude number and viscous effects on the foil scale with Reynolds number, an age-old problem in ship model testing). Another approach would be to test the submerged foil behavior separately, driven by a "planar motion mechanism" mounted to a carriage above the water. This would decouple the buoy/foil interactions, but allow greater fidelity in determining the foil behavior, which is the bigger unknown. During the tour after the meeting Bill Webster was surprised to see our tank and felt we could do some significant testing right there by building a source of motion above the water (on the bridge or similar). I think we should keep this idea in mind, there can be enormous benefit in testing locally, but we shouldn't underestimate the effort in setting up our own test tank.

In conclusion, it is clear that we need to define the mechanism before we can make much progress in modeling. The nominal plan to move forward was discussed as follows, this is specific to the submerged foil concept :

1. We will roughly size the device, float size and submerged foil size.
2. MI&T will perform analysis to determine the forces and resulting motions on the device assuming the foil behaves as a submerged flat plate. (We have this capability here also).
3. We will determine the pitch control scheme and associated expected speeds and angles of attack the foil will see. This is a tricky item that will require quite a bit of thought and perhaps some experimentation.
4. Airflow Sciences will set up a model and run the expected range of velocities and create a "look-up" table that can be interpolated.
5. MI&T will create and run the coupled model, including forward speed drag, wind drag, and mean wave drag (2^{nd} order).

Of course before this can be done each company will need to quote on a statement of work. I told them they'd hear from me by March 20^{th}, but realistically it's going to take longer to define this to a point at which we can start computations.

Overall I think this was a very successful meeting and although we have some work to do before we can sensibly define the computations that are required by each group, I think we have the right people to do the work when we're ready. Additionally, everyone has now met and should be able to work together efficiently without much more person-to-person interaction.