General Information on the Examples

Each example is stored in its own folder in the "Examples" folder. Within each example folder there is an "in" folder and an "out" folder. The "in" folder contains all the WAMIT input files and the "out" folder contains all the WAMIT output files. To run an example just copy all the programs from the "Program_Files" folder into the "out" folder. You create the hydrodynamic time-domain array model by running the "create_td_WEC_array_model.m" code and you test the correctness of the resultant time-domain model by running the "td_v_WAMIT_fd_comparison.m" code.

Example 1

This is a linear (i.e. all in a line) array of six identical vertical cylindrical buoys and each buoy is constrained to move in heave only. That is, this is a six degree-of-freedom problem. The modes of the first buoy are numbered 1 to 6 (i.e. 1 surge, 2 sway, 3 heave, 4 roll, 5 pitch and 6 yaw). The modes of the second buoy are numbered 7 to 12 etc. Thus the free modes for the present problem are modes 3, 9, 15, 21, 27 and 33. Each buoy has a radius of 1.65m and a draft of 3.1m. The water depth is 24.75m and the centre-to-centre spacing of the buoys is 42.0375m. The dimensions of these vertical cylindrical buoys correspond to that of the buoy in Figure 5.7 on page 135 of [1].

Let us start with the "in" folder and tips for modelling arrays in WAMIT. We set up this problem to look at a multi-directional (spread) irregular sea interacting with the array. That is, we need to analyse multiple wave directions (beta angles) coming into the array. The predominant (0 degrees) wave direction is along the line of the array. We analyse 37 wave directions from -90 degrees to +90 degrees in steps of 5 degrees (this can be seen in any of the ".frc" files – note, in this case, the main ".frc" file is called "example_1.frc"). We also analyse 101 wave frequencies, including the infinite wave frequency and the 100 frequencies 0.02, 0.04, ..., 2.00 rad/s (see the ".pot" file and note that IPERIN=2 in the ".cfg" file). A fast way to do this in WAMIT is to use the lines "0 -1 IRAD IDIFF" and "0 NBETA" in the ".pot" file. This only solves for the radiation potentials and does not solve for the diffraction potentials. This is good because the radiation potentials only depend on the wave frequencies, they do not also depend on the incident wave headings, as do the diffraction potentials. All the diffraction/excitation forces for all the buoys, wave frequencies and wave headings are then solved for much more quickly by using the Haskind relations and setting the 37 BETAHs in the ".frc" files. Now look at any of the "#.frc" files, where # stands for a number. Since all the buoys are constrained to move in heave only, the only important entry in the 6x6 mass matrix is the displaced mass of 27310kg in the 3,3 position. If the buoys were also free to move in roll and pitch, care must be taken in the time-domain with the mass matrices to ensure that the buoys are statically stable (i.e. they don't want to capsize). More information on static stability and metacentric heights etc can be found on, say, page 294 (and in section 6.16) of [2]. Furthermore, if you allow buoys to move freely in surge or sway in the time-domain, you will find that it is necessary to apply some external stiffness to stop the buoys "numerically" drifting away. Finally, for this part, you will notice from the "#.frc" files that each buoy has an external heave damping of 50200kg/s applied to it. This could crudely simulate a PTO damping.

Now let us turn to the "out" folder. The first thing to do is run the "create_td_WEC_array_model.m" file to obtain a mat file like "example_1_MassDampStiffMatsRadSS_291118.mat" which contains data necessary to run the Simulink time-domain array model "time_domain_array_sinusoidal_input.slx". The thing to look out for when running "create_td_WEC_array_model.m" is the few lines of code starting with the comment:

% **** TRANSFER FUNCTIONS ARE ONLY FITTED UP TO THIS OMEGA (FREQUENCY) ****

When fitting transfer functions to all of the radiation impedance functions, it doesn't always work. Actually, the higher frequencies are not really that important. The largest frequency analysed is determined by last_omega_index. With line 924 uncommented, this largest frequency is the last one (last_omega_index = num_freqs i.e. the number of frequencies and in this case this is 100). What I have done is commented out line 924, uncommented line 928 and manually reduced last_omega_index until all the transfer functions for all the radiation impedance functions have been obtained. However, even that may not be enough and you need to check that a single state-space system "sys" has been obtained and the condition number of the state (or system) matrix is less than the order of 1000 (i.e. < O(1000)). To do this, just keep manually reducing last_omega_index and rerunning that section until cond_num in the Workspace is <O(1000). This will ensure that a stable radiation state-space model has been produced. In this case, setting last_omega_index = 66 will ensure that all of the approximating transfer functions are obtained and then, when these are transformed to a single, equivalent state-space system, the condition number of the state matrix is approximately 160 which is a lot less than O(1000). Finally, run "create_td_WEC_array_model.m" until its end.

The last thing to do is to run "td_v_WAMIT_fd_comparison.m". This code checks that the time-domain model is working correctly (by comparing against the frequency-domain results) for all the incident wave frequencies (in this case 100) and all the incident wave directions (in this case 37). That is, in this case, the time-domain model of this 6 buoy array will be run for 37x100 = 3700 different incident sinusoidal waves (i.e. of different frequencies and incident wave directions) and the results compared against the frequency-domain results. Note the time-domain models will need to be run for long enough for the initial transients to die away and for steady-state oscillatory behaviour to be reached.

Start running the code and do as follows. When asked whether the excitation forces and body motions were calculated using the Haskind relations or the diffraction potential, you need to type "1" for the Haskind relations. The incident wave amplitude is not important, I just usually type 1 (for 1m). The "Examination of Body Motions" section is important. You need to find out when steady state conditions have been reached for all frequencies and wave directions. I usually use the smallest omega (in this case 0.02) and beta = 0 and then the largest omega (in this case 2) and beta = 0. In the present case, a good finishing time for the simulation is 100 (seconds). You can examine the response for any one of the six modes and it looks like the transients have died down and steady-state oscillatory conditions have been reached for both extremes of omega at 10 (seconds). You can then go on to the next sections and input that "you think steady state will have definitely been reached for all the wave frequencies (omega) and wave headings (beta)" at 10 and give a sufficiently large end time of 50. Then you can run the "Main Loop". This will take a bit of time (an hour or so on a standard desktop) because it needs to run 3700 time-domain models. However, I've done it for you and saved the entire Workspace in the .mat file "error_surf_data.mat". The last section plots the RAOs and error surfaces. An example output of this is shown in "mode_3_plot.jpg". Mode 3 is the heave of buoy 1. The top plot is the magnitude of the RAO over all frequencies and wave directions. The natural frequency of one of the buoys in heave is around 1.6 rads/s but the resonance peak in the RAO surface at that frequency has been completely removed by the large heave damping (50200kg/s) mentioned above. If you like, you can go through the whole process above and reduce that damping? The middle surface is the relative error in amplitude between the frequency-domain amplitude and the time-domain amplitude over all frequencies and wave directions. The maximum of this is 2.5% but this occurs for a relatively small RAO magnitude. The bottom surface shows the error in phase between the frequency-domain response and the time-domain response over all frequencies and wave directions.

The maximum of this is 1.4 degrees. This shows that the time-domain model is working well over all of the wave frequencies and wave directions.

References

[1] Falnes, J. (2002) "Ocean Waves and Oscillating Systems", Cambridge University Press.

[2] Newman, J. N. (1977) "Marine Hydrodynamics", MIT Press.