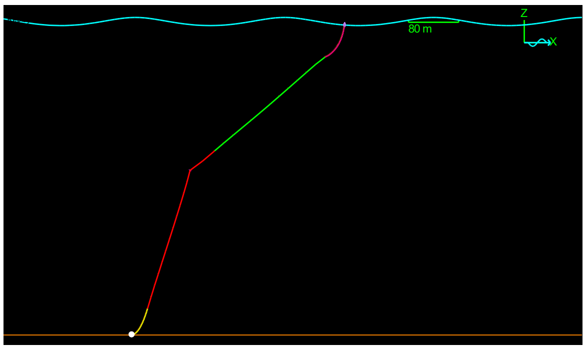
C07 Metocean buoy in deep water

Introduction

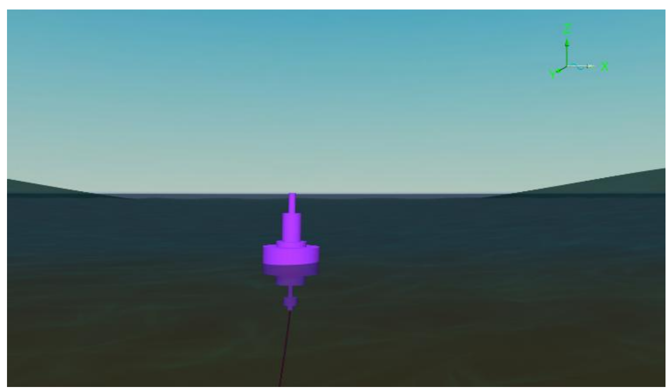
The example shows a metocean buoy moored in deep water. It is held in place by a long mooring line anchored at the seabed. A regular wave train has been applied.

Building the model



The metocean buoy is modelled as a 6D spar buoy so as to capture the interaction with the sea surface. See the help topic [Modelling, data and results | 6D buoys | Modelling a surface-piercing buoy] for further details. A smaller buoy at mid-depth is represented by a *clump* attached to the line. The mooring line itself is made up of several line types with different properties.

The metocean buoy geometry is defined in terms of a stack of cylinders of given diameter and length. The stack base and the centre of mass are positioned relative to a user-defined origin. In this case, the origin lies on the buoy axis 2m above the stack base. The centre of mass is placed at the origin but with a very small (1mm) offset in the x-direction. This offset is needed to assist with the static calculation. We have modelled a system that is rotationally indeterminate i.e. the buoy could solve in any orientation about its vertical axis and still be in equilibrium. OrcaFlex doesn't know which of these rotations is the 'correct' one and therefore fails to solve. By offsetting the centre of mass slightly, we bias the buoy towards a specific orientation, and hence a static solution can be found.



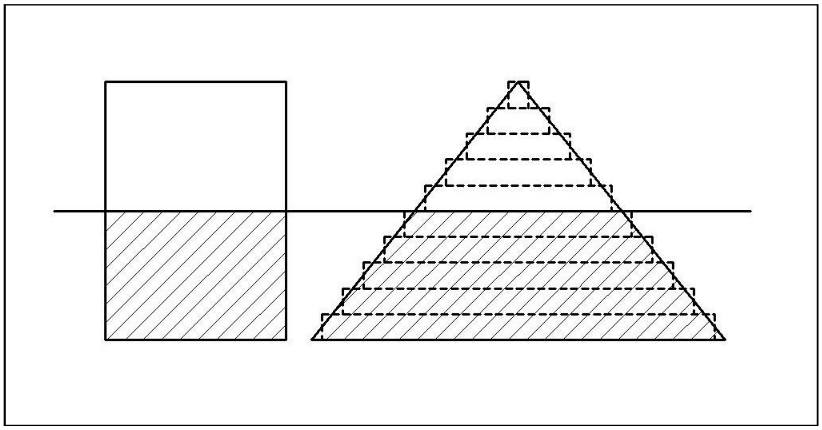
The cylinder geometry is used to determine the buoyancy forces acting on the buoy, taking account of the instantaneous position of the water surface and its slope, relative to the buoy. Therefore the centre of buoyancy position is a product of the cylinder geometry and the buoy position.

In this example, we have considered the tail (bottom three cylinders) as free-flooding. This is sometimes used to increase buoy stability. Therefore the bottom cylinders have been given a non-zero *inner diameter*. The water inside is considered trapped for horizontal motions (the walls will prevent flow) but free for vertical motions (open ended). OrcaFlex automatically includes this trapped water as part of the buoy properties. In cases where the vertical inertia of the trapped water is important, it can be represented by a dummy line object – with appropriate properties – attached to the buoy instead.

The *bulk modulus* can be assumed to be infinite (this data is only required for submerged systems where the buoy compressibility has a significant effect on its buoyancy).

For complex shapes the geometry is best represented by something like a strip model. For example, we subdivide the tail tube into a number of cylindrical sections and may use a number of thin slices to represent the tapered sections of the top and bottom of the hull. When we consider the forces acting on these slices we must use values which are appropriate for the whole shape, not the individual slice.

This strip method is important when modelling surface piercing objects. For example compare a cylinder and a cone of identical volume and height (pictured below). Both are immersed to half their height, yet the displacement for the cone is significantly greater than for the cylinder. The spar buoy discretises the cone into a series of cylinders as shown by the dotted image below.



OrcaFlex calculates the hydrodynamic forces on each component cylinder independently. However it does not calculate shielding of one cylinder by another. This must be accounted for when setting drag and added mass values.

Drag areas in the normal direction are simply diameter x length for each cylinder. However remember the diameter must be set to give the correct displacement. With more complex structures this may be different from the actual diameter. Use the actual diameter when calculating drag area.

Drag in the axial direction needs to be considered carefully because only the part of the cross-sectional area exposed to the fluid is relevant. This may differ on the upper and lower parts of a cylinder, in which case some judgement is required. In this case the exposed areas have been considered from the base up, however OrcaFlex does not differentiate between exposed areas up and down so will apply for both directions. It is important to consider both options.

When determining the coefficients to apply, it can help to split the cylinders into groups. In this example there is a hull group (cylinders 4 and 5) and three short cylinders, the counterweight (cylinder 7) and the tail (cylinders 6 and 8). Apply the resulting coefficient to all the cylinders in the group.

Apply the similar methodology for added mass shielding and coefficients.

Damping forces and moments are applied on the *added mass & damping* page. OrcaFlex does not include radiation damping (wave-making at the water surface), although this is an effective way of extracting energy from a surface-piercing buoy, particularly for small amplitude motions where the quadratic drag terms become extremely small. Radiation damping forces vary linearly with velocity and are represented in OrcaFlex by the unit damping force and unit damping moment terms. It often proves impossible to obtain theoretical values for these and they are normally set by adjusting the values until the OrcaFlex motions match the results of still water heave and rock tests. The values used in this model are arbitrary.

You can choose whether the buoy velocity used with the damping data is the buoy velocity relative to earth, or the buoy velocity relative to the fluid. To model wave radiation damping the velocity relative to earth should be used, whereas to model skin friction damping the velocity relative to the fluid should be used. In this case, we have indicated that it is relative to the fluid because the buoy is small and viscous damping (skin friction) is significant.

An attachment is used to model the mid-line buoy. Look at the *Mooring* line's data form, *attachments* page, to see where this is attached. Click on the *attachment types* button at the bottom of the form to view the details of the buoy. In this instance, we have opted to have the attachment aligned with the *line axes* rather than the *global axes*. This is appropriate for a buoy that wraps around the line, and therefore has its own axis aligned with the line to which it is attached.

Results

Look at the close up view of the buoy while running the latest wave animation. The buoy follows the local water surface variations well in terms of its vertical motion (heave) but less well in terms of its inclination (pitch). This means that the buoy's heave is a good measure of wave height but the buoy's pitch is not a good measure of wave slope.

Look at upper graph of buoy *X* and *Z* motions. The *X* motion has a mean drift: if the simulation had been run for a longer duration this would have settled.

Now look at the lower graph of buoy *Z* against *sea surface Z* at the buoy. The graph very quickly settles to a straight line at 45°, with *Z* amplitude equal to wave amplitude. This confirms the visual observation that the buoy heave motion is a good measure of wave height.

Also be aware of the short wave issue where the wavelength is less than 3x the buoy diameter. This is discussed in detail in the example C06 CALM buoy.