F07 Suction anchor lowering

In this example we show how to model a suction anchor lowering operation.

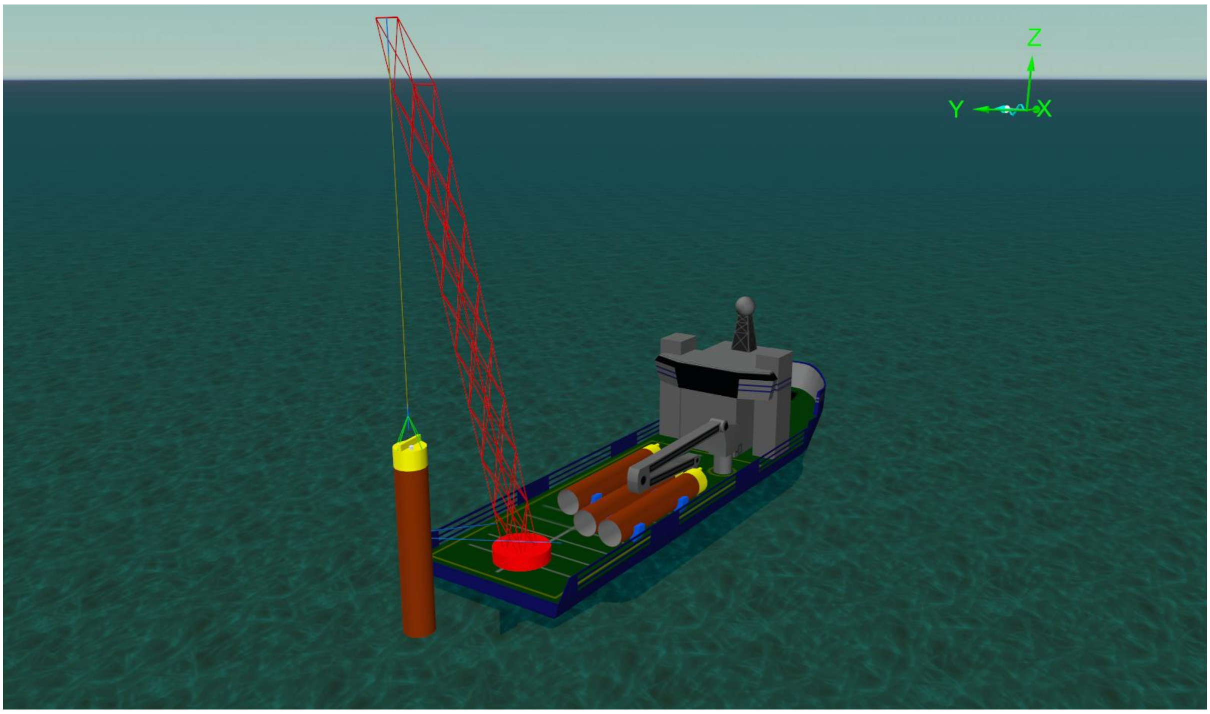
Lowering of a suction anchor vertically through the sea surface requires careful consideration of the change in axial added mass and inertial loads encountered as the suction anchor cap hits the sea surface, trapping a volume of water inside.

For most of the lowering operation, these effects will be small, because the water inside the bore of the suction pile can flow relatively easily in and out of the bottom of the suction anchor. In this case, a hollow 6D *spar buoy* works quite well because it will flood with sea water up to the instantaneous water level.

However, a hollow *spar buoy* will only allow the internal water to contribute to the buoy's inertia in the normal direction (perpendicular to the buoy's centreline) i.e. OrcaFlex assumes that the internal water will not contribute to the hollow buoy's inertia in the *axial* direction. Further details about this can be found on the Modelling, data and results | 6D buoys | Spar buoy and towed fish properties page of thew OrcaFlex help.

When the inside of the suction anchor cap hits the sea surface then, if any vent holes are small, the water within the suction anchor is effectively constrained in the axial direction. Thus, the added mass and fluid inertia loads must increase accordingly. Additionally, there will be a body of trapped water inside the anchor, which will act to increase the overall inertia of the suction anchor body.

This example considers how to account for these changes in added mass, inertia loads and trapped water loads for a typical suction anchor lowering analysis through the sea surface.



Building the model

Open the model *F07 Suction anchor lowering.sim*. The *Suction anchor* has been modelled using a *spar buoy* type 6D buoy, which is hollow (apart from the top section which represents the top cap). This spar buoy carries the majority of the physical and hydrodynamic properties of the suction anchor.

To accurately calculate the proportion wet, and buoyancy, for the spar buoy it has been discretised into many shorter cylinders (see the *cylinders* table on the *geometry* page of its data form). When the top cap is out of the water, it is likely that the suction pile will experience negligible hydrodynamic loads (drag, added mass and fluid inertia) in the axial direction.

Drag properties

Moving to the *drag & slam* page, the drag areas and coefficients have been estimated for the suction anchor's *normal* and *axial* directions. Note that, by default, both hydrodynamic and aerodynamic drag are applied to 6D buoys with drag areas and coefficients assigned to them.

If we look at the *axial* drag coefficients, we can see that cylinder number 1 – which represents the top cap – has a value of 0.85, and an area of 19.63m^2. So, the main axial drag has been apportioned here.

For the rest of the cylinders, the axial drag coefficient (0.008) has been set to account for some drag due to skin friction, with the drag area corresponding to the wetted area of the cylinder.

Added mass properties

When the top cap has submerged, and the water inside effectively becomes trapped in the axial direction, the buoy can no longer be considered as having an annular geometry; instead, it will have hydrodynamic behaviour closer to that of a solid cylinder.

In this example we have assumed that the ventilation hole is less than 5% of the top cap's area, so the buoy has been assumed to be solid (as per DNVGL-RP-N103, *Modelling and analysis of marine operations*, July 2017). We have also assumed that the axial added mass contribution from the steel annulus of the anchor will be small in comparison to the top cap; meaning this contribution has been ignored.

Looking at the *added mass & damping* page of the *Suction anchor*'s data form, note that the *added mass force coefficients (Ca)* in the *axial* direction have all been set to zero. Instead, these coefficients will be accounted for on a separate *lumped buoy* type 6D buoy (named *Axial added mass when top cap hits sea surface*) which is attached to the spar buoy at the top cap position. If you open the data form for that buoy, you will see that it has negligible properties; except for its *height* & *hydrodynamic mass* in the z-direction, and corresponding *Ca* & *Cm* coefficients.

Note, this setup will result in the forces being applied at the top of the anchor, rather than at the geometric centre. However, this is unlikely to significantly affect the system response.

The *height* of this buoy has been set to a small value (0.05m), as it represents the top cap, and we only want the additional added mass forces to come into effect when this top cap touches the sea surface.

The added mass for the solid cylinder has been calculated in accordance with a simplified approximation, for the added mass in heave for a three-dimensional body with vertical sides, as per DNVGL-RP-N103 (*Modelling and analysis of marine operations, July 2017*).

This added mass value has been accounted for by simply setting the *hydrodynamic mass* (*Hydromass*) and *Ca* according to the formula below. In the model, *Ca* has simply been set to 1, meaning the *hydrodynamic mass* is equal to the added mass in heave for the solid cylinder.

$$Added\ Mass_{heave} = Proportion\ wet * Hydromass * C_a$$

The fluid inertia force (otherwise known as the Froude-Krylov component) has been accounted for by means of the following equation:

$$Inertia\ Force_{heave} = Proportion\ wet * Cm * Hydromass * A$$

where *A* is the component, in that direction, of the local water particle acceleration relative to the earth.

The hydrodynamic inertia coefficient (*Cm*) has been calculated, based on the displacement of the entire suction anchor, using the following equation:

$$Cm = \frac{\Delta_{Suction\ Anchor}}{Added\ Mass_{heave}} + 1$$

where $\Delta_{Suction\ Anchor}$ is the displacement of the suction anchor assuming the body is a solid cylinder. Note, an alternative approach that has been put forward is to just consider the displacement of the steel annulus when calculating this value, this will result in a smaller *Cm* value.

Trapped water effects

As discussed previously, the trapped water under the cap of the buoy will also increase the overall inertia of the structure (due to the increased contents mass in the axial direction).

To capture this effect, another *lumped buoy* type 6D buoy (named *Extra Mass from trapped water*) has been attached to the *Suction anchor*. Again, this additional buoy has been given negligible properties, except for its *hydrodynamic mass* and *Ca*.

For this buoy, the *hydrodynamic mass* has been set equal to the mass of the trapped water in the suction anchor, with *Ca* set to a value of 1. In this way, the inertia of the buoy will be increased by the expected mass of the trapped water, but only in the axial direction. For this reason, it is important to set the *hydrodynamic mass* and *Ca* values to zero for the other buoy directions. It is also important to set the hydrodynamic inertia coefficient (*Cm*) to zero, for all directions, to avoid generating unwanted fluid inertia contributions through this buoy.

The advantage of using the added mass properties of a lumped buoy, to introduce the additional body inertia, is that hydrodynamic loads (including added mass) are scaled by proportion wet in OrcaFlex. This means these loads will not be introduced until the buoy has submerged. If we place this buoy at the top cap location and set its height to a reasonably small value, then we will ensure that the additional body inertia is only introduced once the top cap has submerged.

The disadvantage of this method is that the additional body inertia is then applied at the top cap location, rather than at the geometric centre of the trapped water volume. However, this is unlikely to significantly affect the system response.

Further details about how OrcaFlex calculates added mass for *lumped buoy* type 6D buoys can be found on the Theory | 6D buoy theory | Lumped buoy added mass, damping and drag page of the OrcaFlex help.

Crane and rigging

The model includes a simple rigging arrangement of 4 x slings (represented by link objects) connected between the *Suction pile* and a 3D buoy named *Master link*. Two constant tension winches have been used to represent tugger lines; required to aid lateral control of the suction anchor during the lowering process.

The crane wire has been modelled using a combination of a winch object (*Main crane*), which has a pay-out rate of 0.1m/s, and a line object (*Crane wire*) so that any hydrodynamic loads acting on the crane wire can be accounted for). An alternative approach is to simply lower the structure using a line with *line feeding*, which would remove the requirement for a winch. This approach has been considered as part of the F01 Lowering hydrodynamics, F04 Payload transfer and F06 Spool piece manoeuvring examples in this topic.

Results

Opening the simulation file opens up the default workspace file, which displays a shaded graphics view of the lift, along with some important results of interest.

A time history of the *Main crane* winch *tension* is shown (bottom right) which exhibits an increased tension variation when the top cap meets the sea surface. Also shown is a time history of *slam GZ force* for the *Suction anchor*. Here we can see the short duration slam loads which act on the structure as the anchor cap crosses the sea surface.