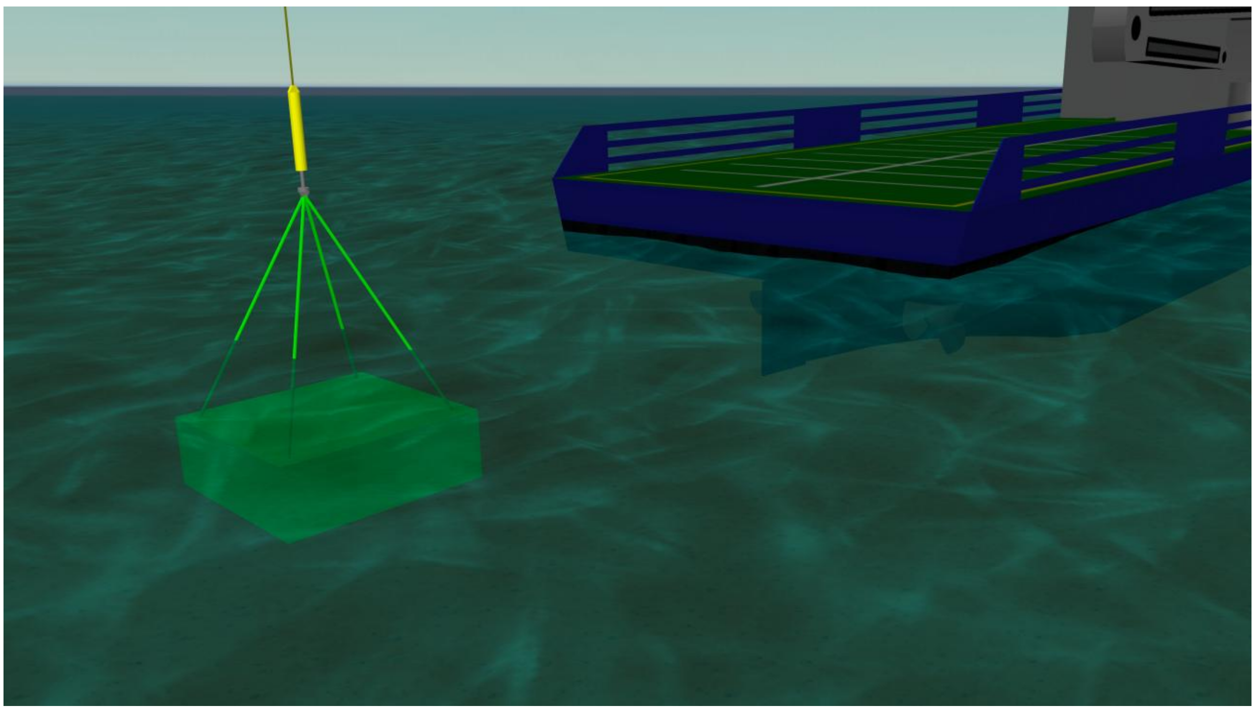
F02 Passive compensation

When lowering a structure into the water, from an offshore construction vessel, the heave of the vessel can result in severe motions of the payload and / or high loads on the crane.

To reduce these effects, heave compensation devices are often used. These can be active systems that adjust winch payout to keep the payload at a constant depth (see the example F03 PID controlled active winch), or passive systems where the payload is allowed to move but there is additional compliance, with damping, to reduce the loads on the crane when the vessel heaves upwards.

This example considers the passive system, using a generic passive heave compensation (PHC) device as an example.



Building the model

Make sure the *model browser* is in *view by groups* mode; this is set by right-mouse clicking in the *model browser* and checking that the *view by groups* option is ticked.

There are three systems present in the model to allow comparison between them: (i) no heave compensation, (ii) compensation with linear damping and (iii) compensation with nonlinear damping.

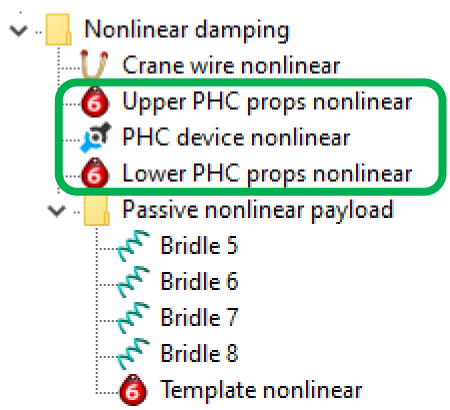
Modelling the PHC system

A typical PHC system consists of a sliding rod that has motion controlled and limited by combinations of hydraulic, pneumatic and spring mechanisms. OrcaFlex does not need to model each component in detail, just the net effect on stiffness and damping.

To better show the action of the compensator, the payload is very simple in this case. For clarity, the payload and bridles are drawn in different colour for each of the three compensation options.

The components that make up each of the three systems are placed into groups in the *model browser*: *No heave compensation*, *Linear damping* and *Nonlinear damping*. These groups can be shown or hidden (using the shortcut *Ctrl + H*) so that you can see how the behaviour differs between the systems.

The PHC mechanism is modelled using a combination of a constraint object (to provide the stiffness and damping of the PHC) and two 6D buoys (to provide the mass, inertia and hydrodynamic properties of the PHC). The image below highlights the objects in the *Nonlinear damping* group that make up the PHC.



The body of the PHC is modelled using the *Upper*… and *Lower*… 6D buoys. The default workspace that opens, when you first open the simulation file, shows a close-up view on the PHC (see the lower left-hand view).

In this instance we have used the ability to read panel mesh files to create a visual representation of the PHC cylinders. The required mesh files were first created in the WAMIT gdf format – using a 3rd party software – before being imported through the *drawing* page of the respective buoys.

Further details about this can be found on the [User interface | 3D views | Importing wire frame drawing data] page of the OrcaFlex help.

The mass, inertia and hydrodynamic properties of the PHC device are distributed between the two buoys (see the *properties* page of each buoy's data form). These properties are arbitrary but, in this example, 80% of the weight is on the upper buoy and the crane wire will take that load directly. The remaining 20% is at the bottom, so will be affected by the compensator mechanism.

The three parts of the PHC are connected as follows: the constraint is connected to the *Upper*… 6D buoy, and the *Lower*… 6D buoy is connected to the constraint. The constraint between the two buoys then allows the sliding motion of one part of the PHC device relative to the other.

PHC stiffness and damping

The sliding motion, and the stiffness and damping properties that control it, are all part of the constraint object.

Open the data form for the *PHC device nonlinear* constraint and look at the *degrees of freedom* page. The constraint has *calculated DOFs* and it is only free to move in translation in the z direction. The same setup has been considered for the *PHC device linear* constraint.

The sliding needs to be controlled to some extent. This is achieved by applying stiffness and damping properties: see the *stiffness & damping* page for each constraint.

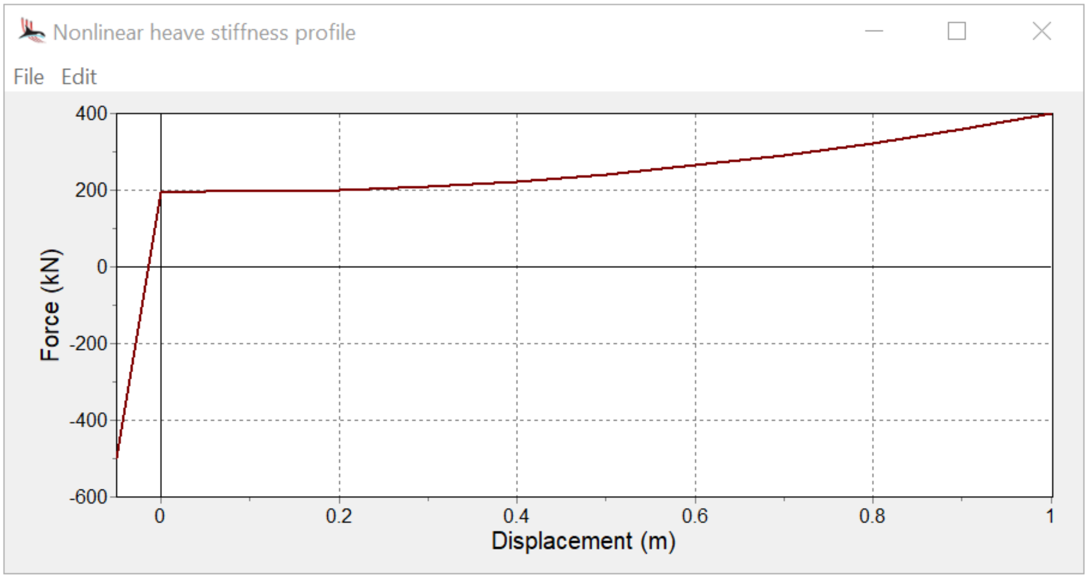
The first step is to identify the *static* load that the device is required to support, and what stroke position the device needs to be in when experiencing that load. The payload has a submerged weight of 193.68kN, and the lower part of the PHC device (which is above the sea surface) has a dry weight of 1.96kN. Both properties can be found by right mouse clicking on the object in the *model browser* and selecting *properties* from the pop-up menu. The combined weight of these two components, in the position considered, is 195.64kN (payload submerged, PHC dry).

The mechanism being modelled has the stroke just offset from the compressive limit when supporting this load. In this case, the stroke is set to 0.05m.

On either one of the constraint's data forms, on the *stiffness & damping* page, note that the *translational stiffness* data item has been set to a variable data item called *nonlinear heave stiffness.* Right-click on the data item and select *edit variable data* from the pop-up menu. Click the *profile* button to see the force vs displacement curve applied to the constraint.

Here, the PHC has a compressive stroke limit applied by a stiff spring rather than hard 'stops'. Activation of the spring is modelled as a rapid linear increase in stiffness if the stroke reduces below 0m. For the extension, a limit has not been applied because it should not be reached (provided the device is designed correctly). Instead, the stiffness rises in a nonlinear manner to provide increased resistance to motion. Note that the slope is steep and linear from -0.05m to 0m, representing the compression limiter spring, then increases in a gentle, nonlinear curve to represent the net hydraulics / pneumatics.

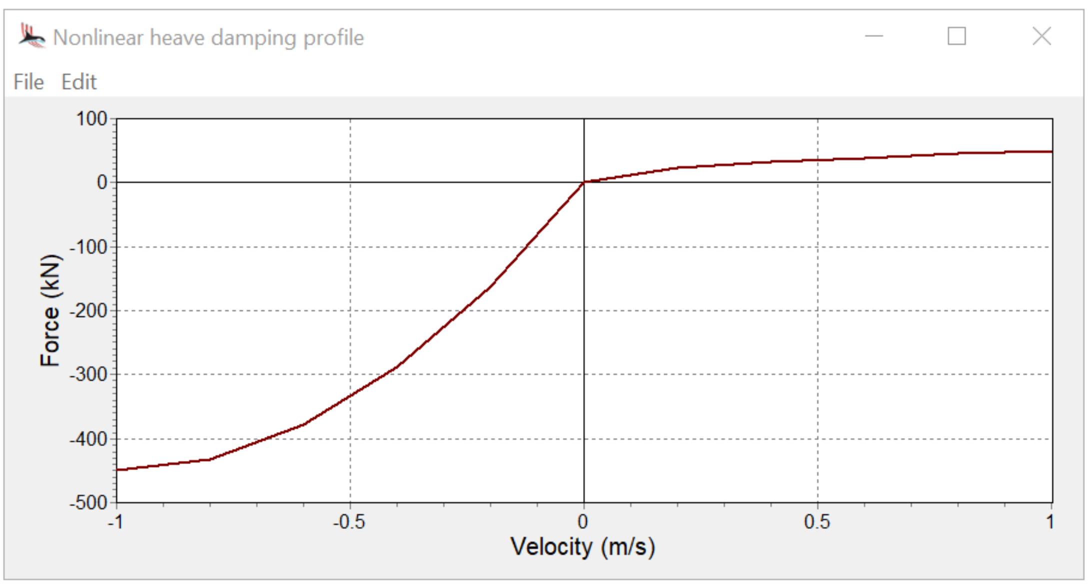
If you look closely at the variable data table, you will see that a value of 195.64kN is assigned to a displacement of 0.05m, thereby ensuring that the desired deflection is achieved under the static load. Again, the resistance profile applied here is arbitrary.



The other part of the control mechanism is the damping of the motion. The mechanism modelled here provides more damping on the return, than it does on the extension. This has been reproduced by applying nonlinear damping to the *PHC device nonlinear* constraint.

The figure below shows the damping characteristics applied here. Both extension (+ve velocity) and compression (–ve velocity) show a nonlinear curve. However, the compressive one is much steeper.

This example model also includes a linear damping value of 250kN.s/m for comparison. This has been set for the *PHC device linear* constraint.



Results

Close the data forms and open the workspace file *F02 Passive compensation device detail.wrk.* The upper left-hand results window shows the *displacement* and *in-frame connection force* results for the constraints, in the static state.

The right-hand plots show time histories of the constraint's *z* results, which represent the vertical position of the constraints out-frame, relative to the axes of its in-frame. Checking these results helps to ensure the PHC remains within its operational range.

The same plots show the difference that the linear vs nonlinear damping makes to the PHC device displacement. The …*linear* device hits the compressive stroke limit (i.e. the displacement goes to, and slightly beyond, zero), but the …*nonlinear* device does not. The magnitude of the motion cycles is also reduced with the nonlinear damping applied.

Re-open the default workspace (*workspace* menu, then select *use file default*). The three graphs here show the crane wire top tension with no compensation, with compensation & linear damping, and with compensation & nonlinear damping.

The PHC devices have had little impact on the magnitude of the loads in the environmental conditions considered here, but it's clear that there is much more noise in the crane wire without any compensation (top right-hand graph).

The middle graph shows the response with linear damping. Here the effect of the compression limit being reached can be seen; the higher frequency responses coincide with the points where the PHC displacement reaches zero. The bottom left-hand graph shows the response with nonlinear damping.

Note that the results graphs all use the same axis ranges, to help with comparison between them. The axis range used in any results graph can be adjusted by double clicking on the graph and setting the *minimum* and *maximum* range values on the *axes* page. If you then save the arrangement as a workspace, you can choose whether the graph axis ranges are preserved by ticking the *preserve axes ranges* option on the *workspace* menu before saving the workspace.

Lastly, for the lower left-hand view on the model, the edit view parameters option has been used to set the view *relative to* the *PHC device nonlinear* constraint. This gives a view from a camera that moves with the chosen object, which allows for better visualisation of the stroking action of the PHC device when viewing the simulation replay.