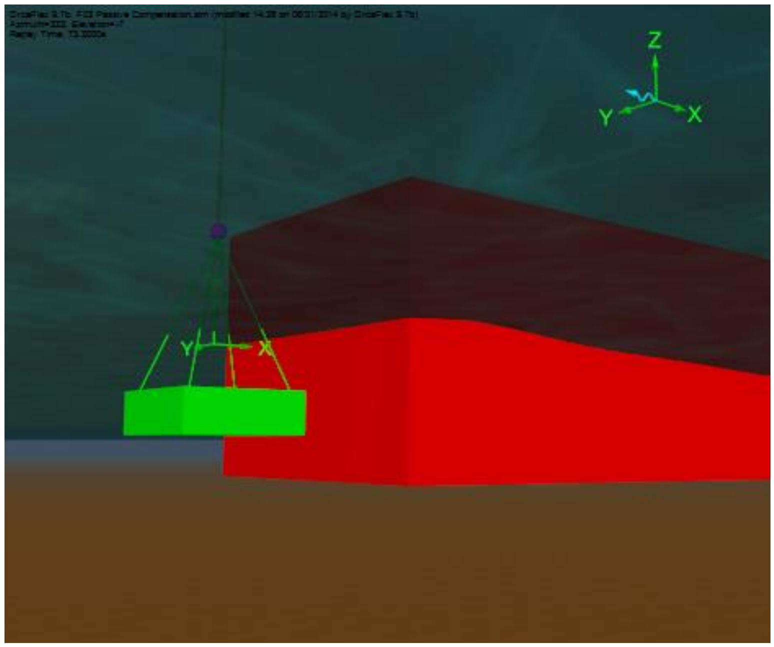
F02 Passive compensation



Introduction

During the lowering process, 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, 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 it heaves upwards.

This example considers the passive system, using a CRANEMASTER device as an example. The principles can also be applied to other devices. You need to view the model browser in the *view by groups* mode. There are three systems present in the model to allow comparison between them. The three systems shown are: - no heave compensation, compensation with linear damping and compensation with non-linear damping.

Building the model

A typical 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.

Note the payload is very simple in this case to better show the action of the compensator. For clarity, the payload and bridles are modelled in a 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 named *No Heave Compensation*, *Linear Damping* and *Non-Linear Damping*. These groups can be shown or hidden (using the shortcut *Ctrl+H*) so that you can see the differing behaviour of the systems.

The passive heave compensation mechanism is modelled using the combination of a single segment line section and a spring/damper link. The single segment line helps the statics to solve more robustly.

The line section represents the structure of the compensator (in this case 1m long) and is positioned in the cranewire length at the location of the device. Look at the *structure* page of either *Crane Wire Linear* or *Crane Wire Non Linear* to see how this is modelled.

Because it is a single segment, it cannot bend. We then give this segment negligible mass and displacement, default bend stiffness (because this property is not used) and a low axial stiffness (to allow it to act as a slider).

The actual mass and stiffness of the *Compensator Rod* are added as clump weights at the top and bottom of the segment (see the *attachments* page of the *line* data form). In this example, 80% of the weight is at the top so the cranewire will take that load directly. The remaining 20% is at the bottom, so will be affected by the compensator mechanism.

The result is a segment that is correct for mass and displacement and will slide freely axially while not bending. See the drilling riser examples for more applications of sliding slip joints.

The sliding now needs to be controlled; this is done with a link. We position the link parallel to the segment, each link end attached to each end of the segment (see either the *Passive Heave Linear* or *Passive Heave Non Linear* link data form).

The first step is to identify the static load that the device is required to support, and what stroke position you want it to be in when experiencing that load.

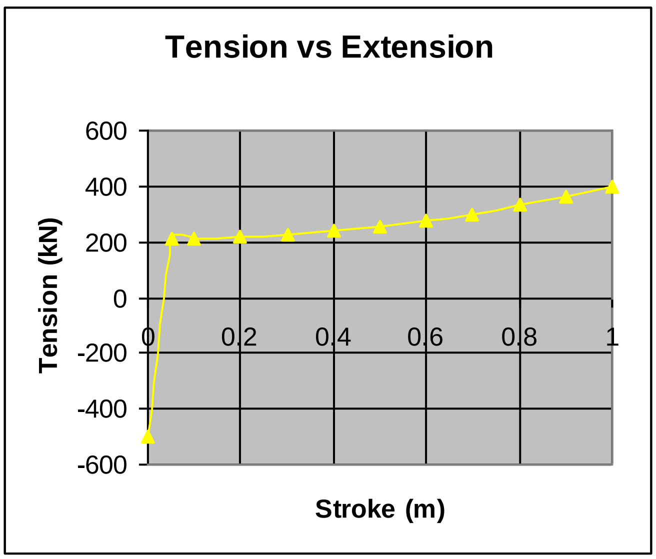
Reset the model (press F12) and then run statics only (F9). Open the workspace file *F02 Passive compensation static result.wrk*. This shows the static state *effective tension* result in the uncompensated crane wire in the top right-hand view window. In this instance, the payload produces 195.7kN tension at the bottom of the *Compensator Rod* (i.e. the end B static tension result from *Crane Wire*).

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 for this load. The heave compensated devices actually settle at 0.0865m with a tension of 196.1kN (this can be seen in the summary results shown in the bottom right-hand window), indicating that the load distribution is a bit more complex, but this is a small difference so the method is considered to be a reasonable estimate.

Because the mechanism being modelled is a CRANEMASTER device, the compressive stroke limit is 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 0.05m.

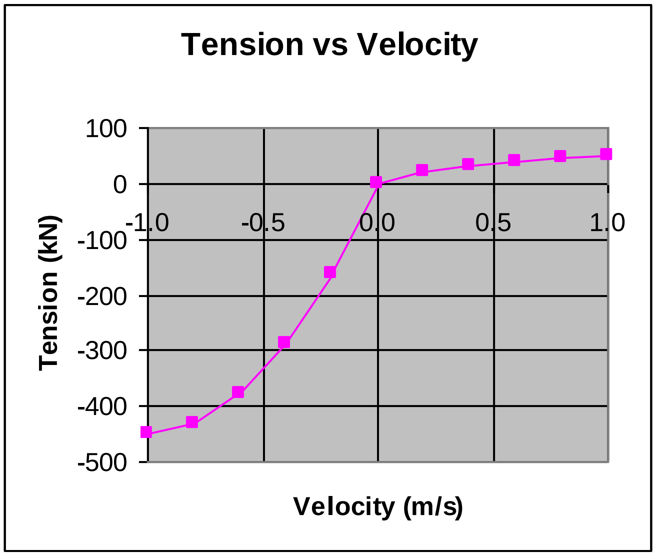
For the extension, a limit has not been applied because it should not be reached if the device is applied correctly (however you should always check the link length to make sure operation is within range). Instead, the stiffness rises in a nonlinear manner to provide increased resistance to motion. This change is chosen to match the characteristics of the CRANEMASTER device.

The figure below shows the stiffness characteristics for this example. The slope is a steep and linear from 0m to 0.05m, representing the compression limiter spring, then a gentle rise to represent the net hydraulics/pneumatics. The table can be seen applied as a non-linear stiffness profile in the *Passive Heave Linear* and *Passive Heave Non Linear* links.



The other part of the control mechanism is the damping of the motion. The CRANEMASTER mechanism provides more damping on the return than on the extension. This has been reproduced by applying non-linear damping to the *Passive Heave Non Linear* link.

The figure below shows the damping characteristics for this example. Both extension (+ve velocity) and compression (-ve velocity) show a nonlinear curve. However the compressive one is much steeper.



The example also includes a linear damping value of 250kN/(m/s) for comparison. This is in the *passive heave linear* link.

Results

Re-open the sim file to open the completed simulation and load up the default workspace. The three graphs presented show the crane wire top tension with no compensation, with linear damping and with non-linear damping.

The top left-hand plot shows the crane loading with no compensation. The loads are large and there is a lot of noise. The top right shows the response with linear damping. Amplitudes are reduced (although the magnitude has increased slightly) and the noise has also reduced. The bottom left graph shows the response with non-linear damping. In this example, the damping relationship can be simplified to linear with little change in response.

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. If you then save the arrangement as a workspace, you can choose whether or not the graph axis ranges are preserved by ticking the *preserve axes ranges* option on the Workspace menu before saving the workspace.