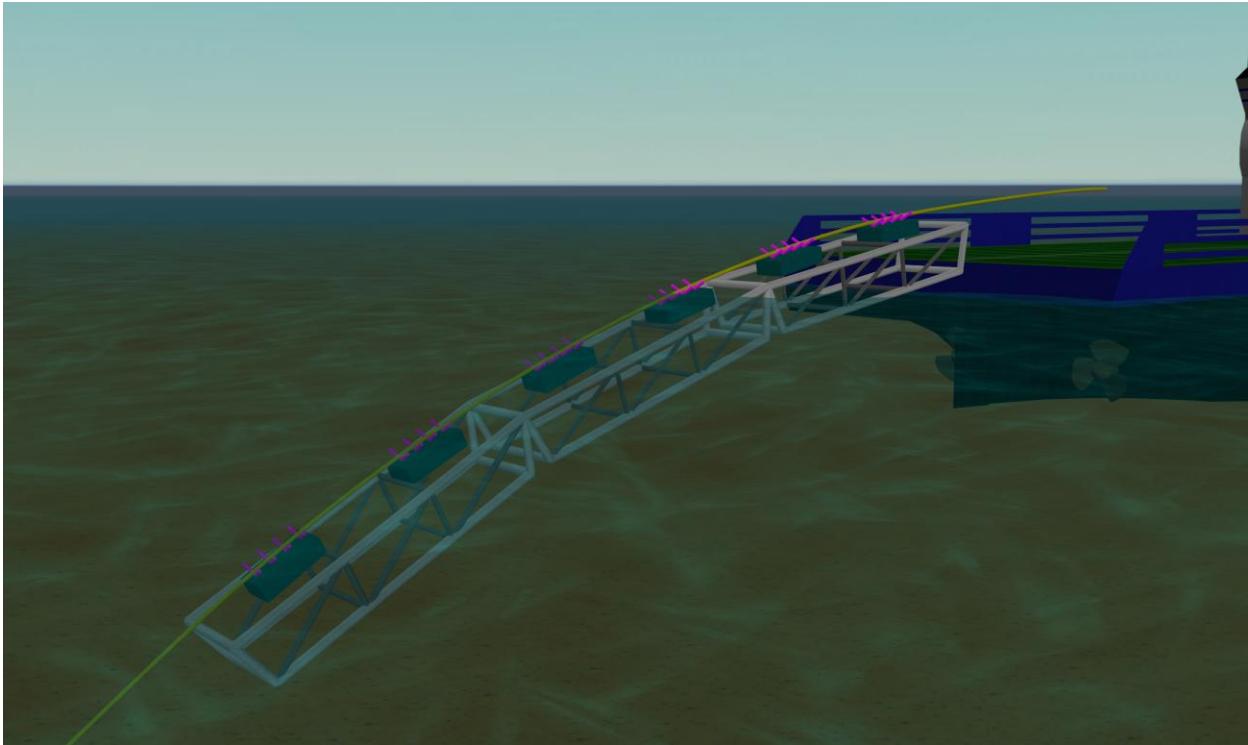


E04 Articulated stinger



This model represents a three-section articulated stinger with roller boxes, hinged off the back of a lay vessel. The stinger is detailed using an arrangement of single segment lines which provides an accurate representation of the true hydrodynamic properties of the welded steel framework. The stinger lines are connected to 6D buoys with negligible properties.

Previous examples in this set have treated each roller box on the stinger as a single support. This approach will be quite satisfactory for many applications, but it is not a precise representation of reality because each roller box typically consists of a set of rollers attached to a frame that is able to pivot slightly relative to the stinger. In this example, we model the roller boxes in detail.

Building the model

The active parts of the model consist of a lay vessel, the pipe being laid, and a stinger. The stinger is connected to the vessel using a constraint object, with one rotational degree of freedom (as described in previous pipelay examples) and the same arrangement is used to hinge adjacent sections of stinger.

The welded framework of the stinger has been modelled using the homogeneous pipes connected to 6D buoys (one 6D buoy per stinger section). The buoys have been set with negligible properties so that they don't influence the hydrodynamic behaviour of the stinger, which is defined only by the lines in this example. In each stinger section both ends of each line are connected to the buoy, and each line has been given only one segment, which means that each of the three sections of the stinger are modelled as a rigid body. For guidance on modelling a stinger structure in detail, see the example [E03 Detailed hinged stinger](#).

To view the construction of the stinger frame, 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 two main groups: *Stinger* and *Roller Boxes*.

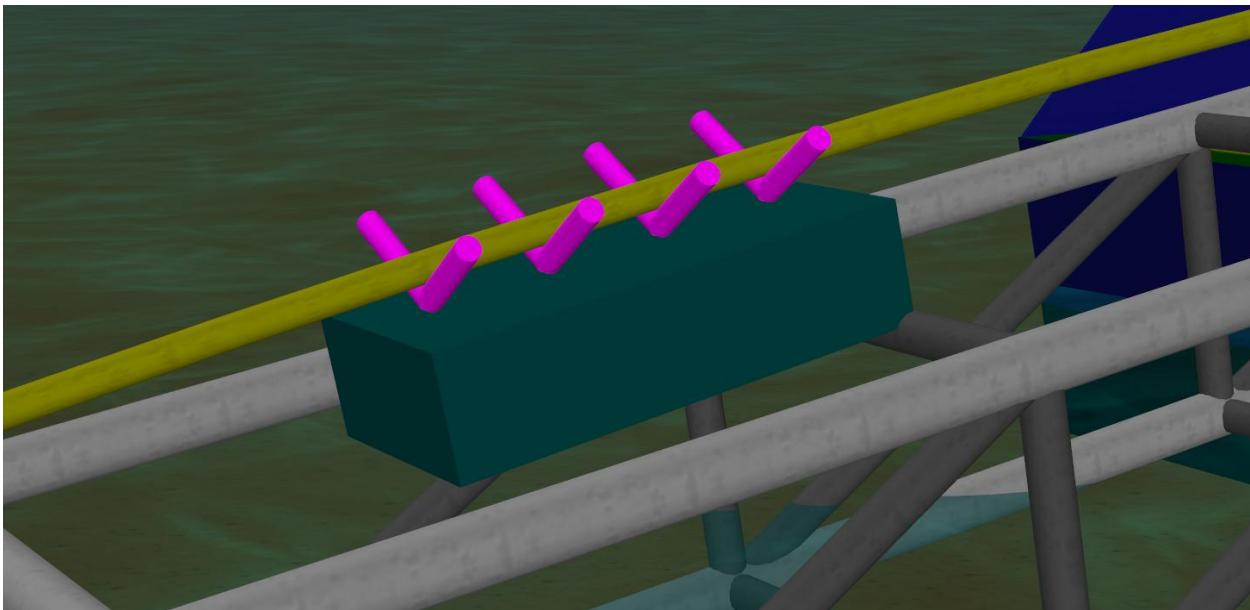
The *Stinger* group contains four sub-groups: one group for each of the sections, and then one group containing the connecting elements (hinges). Grouping the connecting elements together makes it easy to hide them, as has been done in this model: as with individual items, select the group in the *model browser* and either right-click and select *hide* or use the keyboard shortcut *Ctrl + H*. The stinger section sub-groups are called *Section1*, *Section2* and *Section3*. Each of these contain a 6D buoy, and sub-groups called *Stb Side*, *Port Side* and *Cross Braces*, which contain the groups of lines building up the frame.

Arranging sets of lines and buoys in groups like the stinger above is made straightforward by a combination of the *all objects data* form and the duplication facilities available in the *model browser*. By placing sets of lines and buoys in a group, the user has the option of duplicating and moving groups using standard [model browser facilities](#). Careful choice of object names at the start can make this process run much more smoothly.

The individual rollers are built by assigning supports to 6D buoys. Multiple supports can be assigned to a vessel or 6D buoy, and in this case, four have been grouped into sections representing roller boxes (each roller box being a 6D buoy that can pivot relative to the stinger).

As part of each roller box sub-group there is a further constraint, which controls the motion of the 6D buoy. The constraints allow the roller box to pivot as they would in practice, they also have a non-linear rotational stiffness, which allows them to rotate, but only between a limited angle range, to represent physical stops.

From the *model browser*, open the variable data item *Roller Box Rotation Stops*. The variable data has been set up so that the constraints are free to rotate up to $\pm 5^\circ$ about the mean position. Beyond that, the moment increases significantly, which prevents further rotation. A second nonlinear rotational stiffness profile (*Stinger Rotation Stops*) exists to limit the main stinger hinges to $\pm 10^\circ$ rotation. Clicking the *profile* button displays a graph of the selected data.



Close the *variable data* form and reset the model (*F12*). Put the model into the default view (*Ctrl + T*) and then open the data form for the constraint *Roller box Hinge6*. This is the hinge on the left-most roller box in this view. On the *degrees of freedom* page the *Ry* DOF is ticked; meaning this constraint can rotate about its y-axis, but cannot for any other degree of freedom. Note that the *initial value* is set to zero. This is the orientation at which the constraint starts the static solution. The *declination* of the constraint is also zero – this is the position about which the rotational stiffness is applied – so the roller box in the view will be able to rotate $\pm 5^\circ$ about the rotation that you currently see (i.e. with the roller box in line with the section of stinger). With the data form moved slightly to one side, try different values in the *initial value* box to see the roller box rotating to new initial positions. Note, this only changes the position that the constraint starts the static calculation in. This does not change the position about which the $\pm 5^\circ$ limits apply, so the end result in this case will be the same. To change the position about which the limits apply you would have to alter the *declination* of the constraint.

Open the data form for the 6D buoy named *Roller Box1*, which is located in the group *Roller Boxes*. The two data form pages, named *supports* and *support coordinates*, are used to define the geometry of the supports, where they are positioned, and what line (or lines) they are supporting. For each roller box there are four V-shaped supports, positioned at different x intervals and a z offset of 0.6m. Multiple coordinate systems can be defined if necessary (for example if some supports are mounted on the vessel and some on the stinger) but, in this case, all the supports relate to the same coordinate system, at the centre of the 6D buoy. Hence, the z offset places the supports 0.6m above the centre of the buoy, and at x positions fore and aft of the centre of the buoy. The information on this data form is repeated for each roller box buoy (six in total). Note that the supports are all individually specified, even if they are all on a single buoy, so it is possible to specify different types if required (including customised profiles).

Open the *environment* data form. On the *waves* page, the environmental conditions in the example are set to consider JONSWAP waves, with 1.5m Hs, 8s Tz, 45° off the bow of the vessel. On the *current* page, a current is applied with a speed of 0.5 m/s, onto the port beam.

Results

Re-open the sim file and then load the workspace *E04 Articulated stinger results.wrk* to view a set of plots that summarise the behaviour of the system.

The range graph of *max von Mises stress* for Stage 1 of the simulation (top left-hand graph) shows the variation over the upper part of the line; the stresses are low elsewhere. Dynamic variations are large and, as expected, the highest stresses occur in the stinger region.

The upper right-hand graph shows the rotation of the last roller box from its initial rotation. The lower right-hand graph shows the same result but for the hinge between stinger sections 2 & 3. In this graph the effect of the nonlinear rotational stiffness modelling can be clearly seen for the limit stops at $\pm 10^\circ$ rotation.

Examination of the dynamic replay, where contact with the supports is shown by colouring the support white, shows that the pipe is lifting off some of the rollers along the stinger length. This is indicating that this particular set of environmental conditions is too severe for the current stinger arrangement, and further adjustments to the roller positions would be necessary.