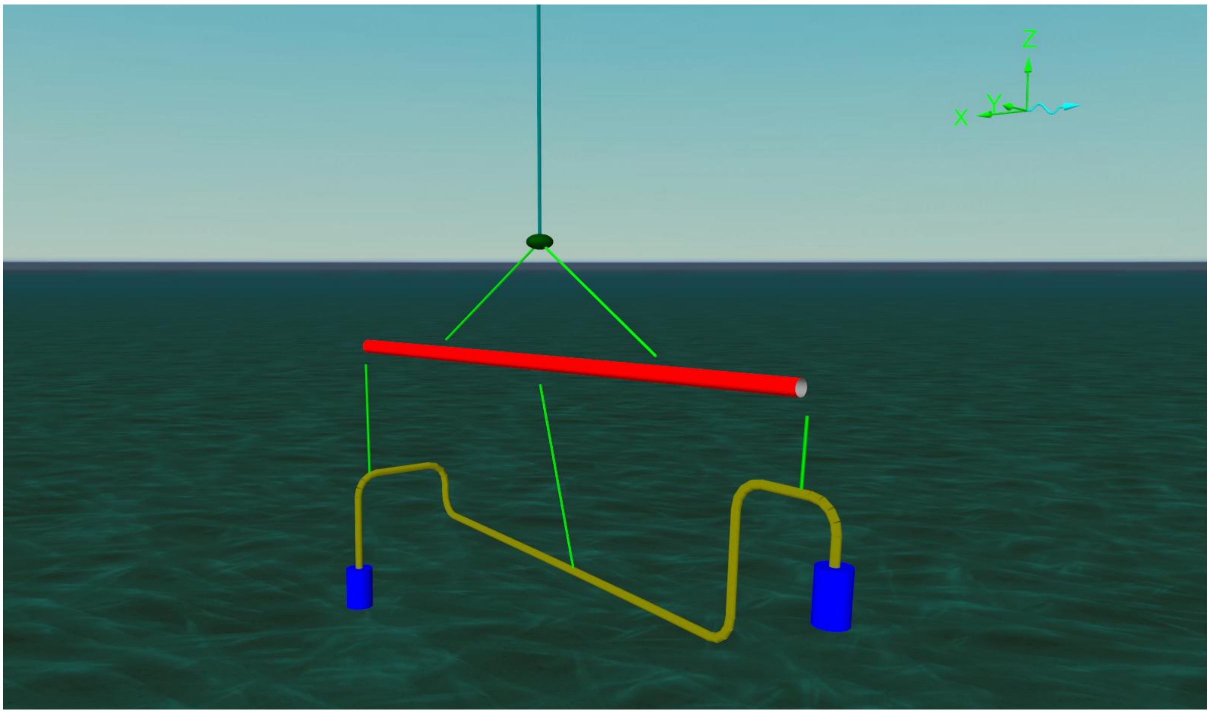
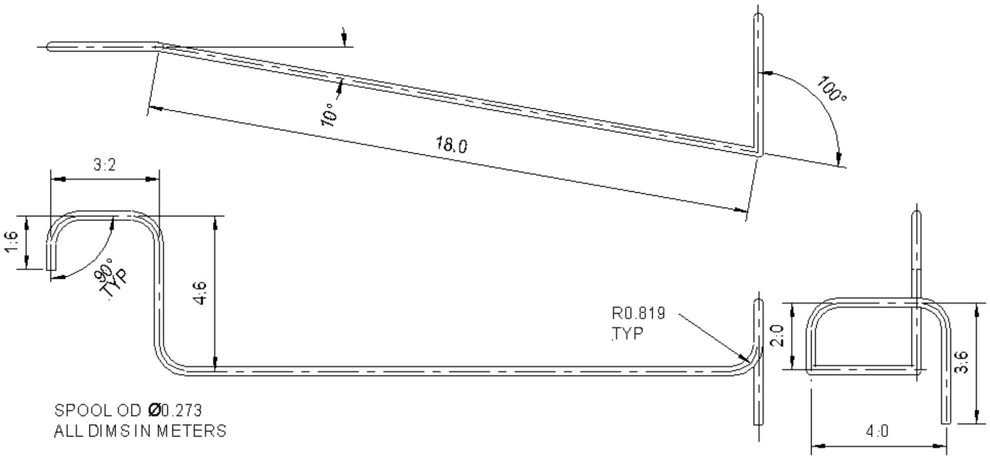
F06 Spool piece manoeuvring

Introduction

This example demonstrates how to use the *pre-bend* facility in OrcaFlex to model a spool piece. This feature facilitates the modelling of lines which are not straight when in the unstressed state.

In this example, the spool piece shown below has been modelled. The analysis considers the scenario where the spool piece is lowered through the splash zone, capturing slamming effects. Constant and variable slam data is applied to both the spool piece (modelled as a line object) and the spreader bar (modelled as a 6D buoy). *Line feeding* is utilised to lower the spool into the water.





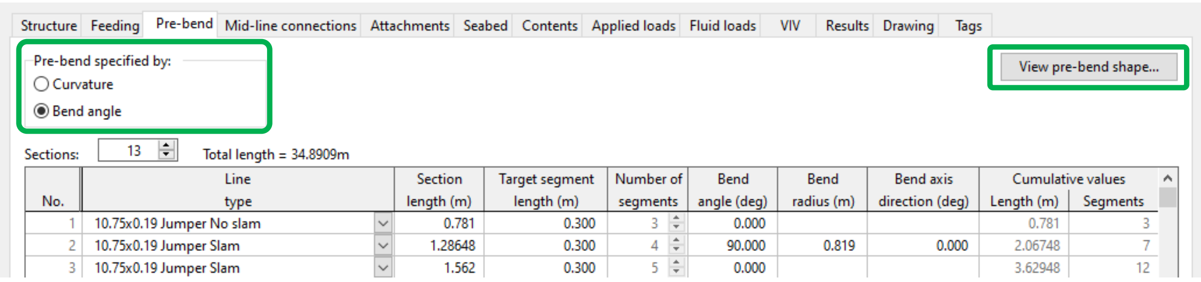
Building the model

Open the model *F06 Spool piece manoeuvring.sim* and run the replay to see the spool being lowered into the water. Note the shape that the yellow line takes i.e. its 'pre-bent' shape.

Specifying the pre-bend

Pre-bend is specified on a section-by-section basis so, to be able to distinguish the pre-bent sections from the straight ones, it is important to split the line up into multiple sections. Each section has a constant curvature and plane of bending.

OrcaFlex gives a choice of how the pre-bent shape is specified; this can be either by *curvature* or by *bend angle*:



To specify the shape by *curvature*, you enter the curvature values (in radians per unit length) for each section of the line. The *curvature* is specified in the local x- and y-axis directions of the first node of that section.

However, it is generally more common for the analyst to have the spool's bend radius and bend angle information available, directly from an engineering drawing. So, specifying the shape by *bend angle* is usually the most convenient method.

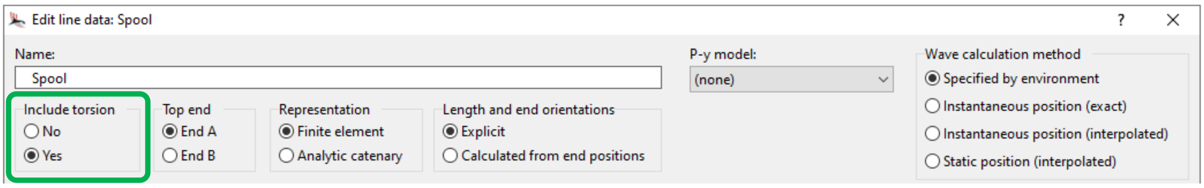
Here, we have populated the data tables for both types of input data. So, you can select either method and the resulting spool shape will remain the same. Normally you would simply use the method that is most convenient, based on whichever format the data is available in.

Reset the model (*F12*) and open the *Spool* line data form. On the *pre-bend* page, toggle between the *curvature* and *bend angle* options to see the difference in how the data is specified.

The *view pre-bend shape…* button enables you to see the results of the bends that you are specifying, while you are creating them. This is a useful feature because it allows you to see the spool in its unstressed state i.e. without the effects of the spool's self-weight, or end connections, which can cause the spool to deform out of shape.

You have the option to click this button multiple times, to open multiple preview windows at the same time. So, for example, you can view the plan and elevation views simultaneously. Any changes you make to the pre-bend data will instantly be reflected in the previews.

Note that, when modelling pre-bend, torsion must be enabled for the line; by setting the *include torsion* option to *yes* at the top of a line's data form.



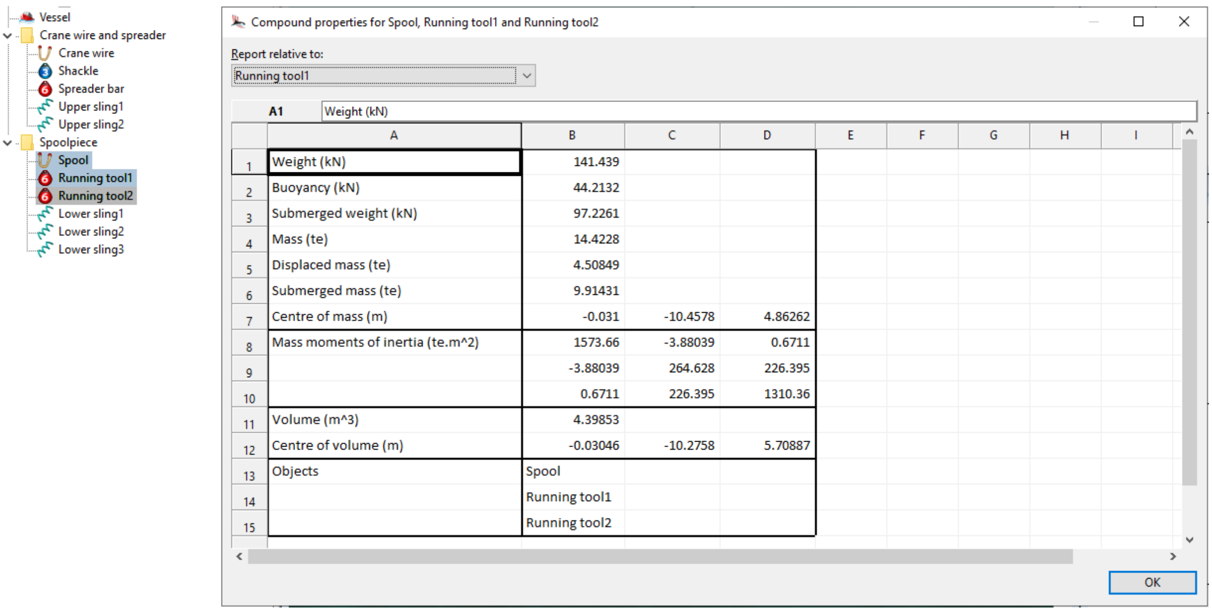
Once the pre-bend data has been specified, note that the line remains in the reset state in the GUI *until* you run statics (*F9*). The *Spool* then forms into shape, accounting for any loads imposed on it, such as end connections, buoyancy forces, sling connections and self-weight.

Compound properties

The spool has typical properties for a steel pipe applied to it. You can check the properties of the spool by right mouse clicking on the *Spool* in the *model browser* and selecting *properties*, or by left clicking on the *Spool* and using the keyboard shortcut, *Alt + Enter*.

The *compound* page of the *properties* report is particularly useful in this instance because, in addition to reporting the weight in air, weight in water, etc. it also reports the centre of mass for the spool when formed into its pre-bent shape.

Note that to get the combined properties of the spool *plus* the two attached running tool objects used in this model, you need to multi-select all three objects, then open the *properties* report as previously described.



	A	B	C	D
1	Weight (kN)	141.439		
2	Buoyancy (kN)	44.2132		
3	Submerged weight (kN)	97.2261		
4	Mass (te)	14.4228		
5	Displaced mass (te)	4.50849		
6	Submerged mass (te)	9.91431		
7	Centre of mass (m)	-0.031	-10.4578	4.86262
8	Mass moments of inertia (te.m^2)	1573.66	-3.88039	0.6711
9		-3.88039	264.628	226.395
10		0.6711	226.395	1310.36
11	Volume (m^3)	4.39853		
12	Centre of volume (m)	-0.03046	-10.2758	5.70887
13	Objects	Spool		
14		Running tool1		
15		Running tool2		

Modelling slam forces

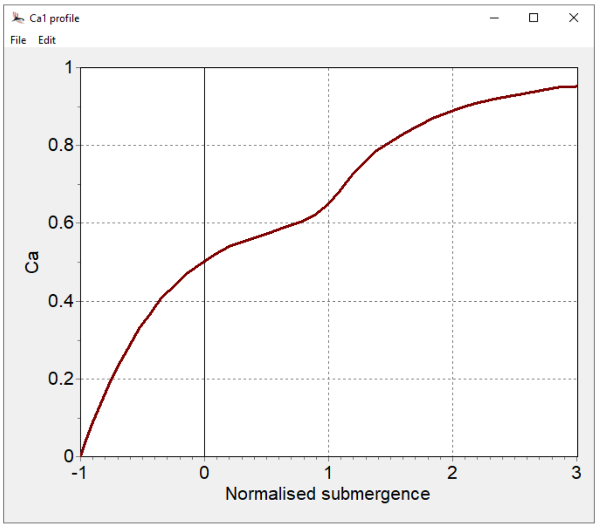
Two different line types are used to model the spool. This allows us to differentiate between the sections we want to include slam loads on, and the sections we don't.

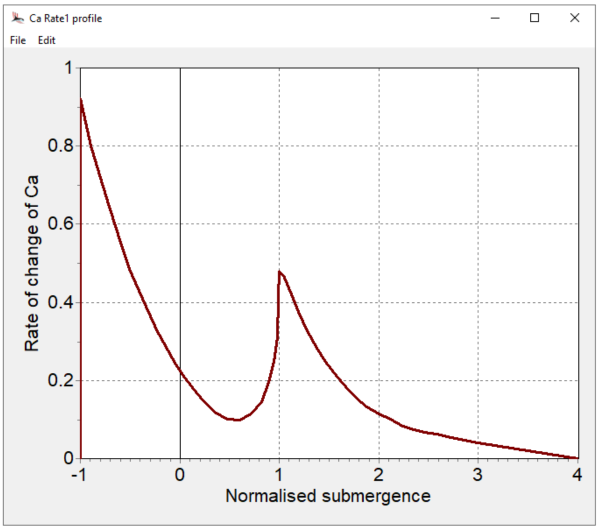
Open the *line type* data form and look at the *added mass, inertia, slam* page. Both the …*No Slam* and the …*Slam* line types have a variable added mass coefficient (*Ca1*). This data set represents the high frequency limit of vertical added mass coefficient as a function of normalised submergence, for a circular cylinder, as per DNVGL-RP-N103 (*Modelling and analysis of marine operations, July 2017*), Figure 3-5.

In addition, the …*Slam* line type has a variable slam coefficient in the entry direction (*Entry (Cs)*). This variable data set is the rate of change of added mass with normalised submergence, again as per the above-mentioned figure of the DNV recommended practice.

Note, these data sets are provided in this model for demonstration purposes only; meaning the user <u>must</u> check the suitability and accuracy of these data before using them for other purposes.

Further details about the slamming theory used by OrcaFlex can be found on the [Theory | Slamming theory] page of the OrcaFlex help.





In this instance we have applied a constant slam coefficient (*Ce*) in the exit direction.

For this example, the spreader bar is assumed to be rigid, so it is modelled using a *spar buoy* type 6D buoy. Alternatively, this could be modelled using a line object if, for example, modelling its flexibility was a requirement.

Crane wire payout

The spool piece is lowered into the water by means of *line feeding* applied to *end A* of the *Crane wire*. The full length of wire required must be included in the line's structural properties, therefore on the *structure* page of the *Crane wire* data form, the length of the wire is defined as 30m. On the *feeding* page, the *initial arc length* at *end A* is set to 22m, which means that only 8m of wire is present in the model initially, with the remaining 22m being inactive but available to be paid out during the simulation.

The crane wire's *payout rate* is specified using a variable data source (*Payout rate1*), which ramps up the payout rate from zero to 0.5m/s between times of 15s and 20s, then continues to pay out at a constant rate of 0.5m/s for the rest of the simulation.

You will see the result of this if you make *node axes* visible from the *View | Axes and labels* menu at the top of the OrcaFlex window (or using the keyboard shortcut, *Ctrl + Alt + Y*). The node axes show the local x- and y-directions of each node using short red and green lines respectively.

Run the replay (*Ctrl + R*) and you will see the nodes appear from the crane tip as the line pays out.

Flooding of the spool and spreader bar

Note that the inner volumes of both the spool and the spreader bar will free flood with water as they submerge, however OrcaFlex assumes that the bores will fill as if the water can pass through the spool or spreader bar walls, rather than from the ends only.

This is probably a reasonable assumption for the spreader bar, but less so for the spool in its complex shape. A more accurate flooding process could be modelled by setting the *contents method* for the *Spool* line to the *slug flow* option (available on the *contents* page of its data form).

Time step selection

Open the *general* data form, *dynamics* page. In this model we have used a fixed *time step* of 0.02s. In models that include slamming it is often necessary to use a shorter *time step* than the default (0.1s) because the slam event can be very short in duration i.e. there is a risk that any slam events could be missed completely if the *time step* is too long.

In addition, with a shorter *time step*, the *sample interval* should also be reduced to match, because slam results are not spike logged. Therefore, maxima or minima that occur between the logged times will not be recorded. However, logging results at more frequent intervals will increase the size of the simulation file, so in this case, to keep the downloadable file small, we have left the model with the default logging interval of 0.1s.

For details of which results are spike logged, please see the User interface | Results | Producing results page of the OrcaFlex help.

As always, we recommend that appropriate sensitivity studies be performed to check that the *time step* and *sample interval* suitably capture any discrete / isolated events to a sufficient level of accuracy.

Results

If you have reset the model, then re-open the simulation file so that the default workspace is re-loaded. Replay the simulation (*Ctrl + R*) and watch the slam loads acting on the *Spool* and *Spreader bar* in the left-hand view, as they pass through the sea surface.

Note that when using line *pre-bend*, the curvature, moments and stresses are reported relative to the pre-bent position. You will therefore *not* see a curvature of 1.22rad/m (0.819m bend radius) on the *curvature* range graph for the *Spool* (upper right-hand graph).

Note also that using *pre-bend* breaks some of the assumptions used in calculating stress results, and therefore in fatigue analysis calculations, because OrcaFlex assumes a straight cylinder and standard beam theory.

This simulation models the response of the spool to one specific crossing of a regular wave. However, for a typical deployment analysis, many realisations of any given sea state would be required to provide confidence that the possible variations in the environmental conditions have been modelled adequately.