Compressive Waves

This document describes the behaviour observed in the touchdown region when high compressive loads are generated.

1. What is the problem?

On occasions an unacceptable behaviour is observed in the region of the touchdown point. This consists of high compressions coupled with high curvatures. These curvatures usually consist of multiple, short duration waves in the line.

The result is snatch loading as the waves pull out, over bending, unacceptable compression over an extensive length of line and increased fatigue damage.

Most at risk are the simple catenary arrangements in deep and shallow water, though it can also be observed in other systems.

As the top of the catenary is moved up and down, the suspended length attempts to move with it. The line takes the easiest route to do this which is usually axial motion. In some configurations this can result in it moving down the water column until it meets resistance from the seabed. Compression builds until the line relieves by local bending. The figure below shows a typical response.

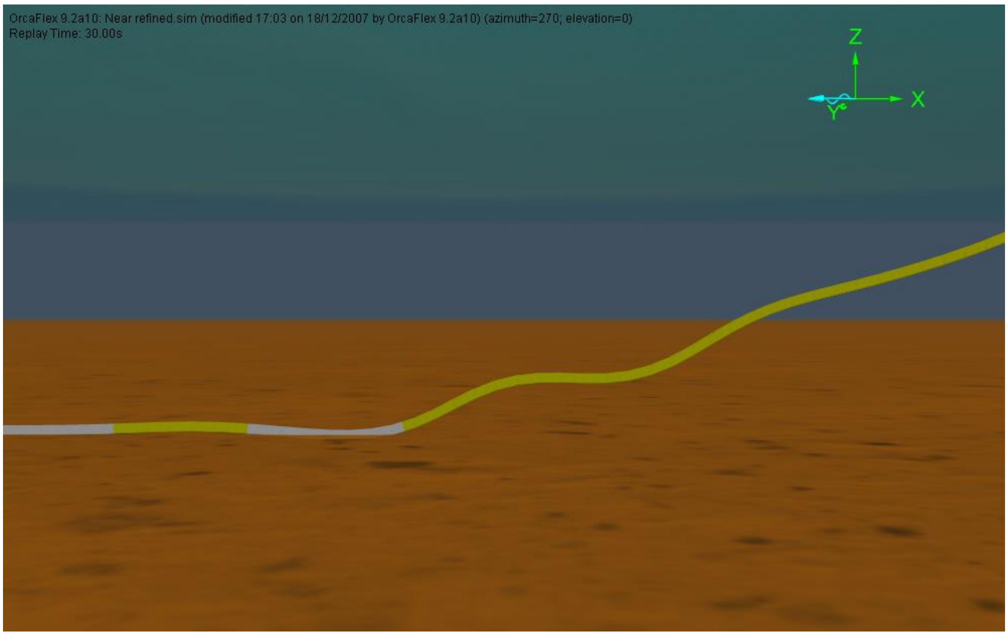

Figure 1-1: Typical Touchdown Response

The trigger for relieving compression can be very small mathematically so this is a chaotic response. Therefore the results reported for the behaviour can be considered as qualitative only. We cannot be sure what the extreme result will be because when and how the trigger will take place in the actual installation cannot be identified.

Therefore this behaviour is considered unacceptable and the analyst aims to design it out.

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2. Identifying the Behaviour Correctly

This behaviour can exhibit in a number of ways, depending on the refinement of the model. Things to look out for are:

2.1. High Compression

The simplest way of spotting this behaviour is high compression, especially if this compression extends along a significant length of the line. A lot of line can be affected because of the build-up above touchdown or because of travelling axial waves.

The plot below shows a typical tension range plot. The hangoff is at 0m and the seabed anchor is at 1100m. Note that 350m of the length is in compression. Also the maximum compression is 110kN.

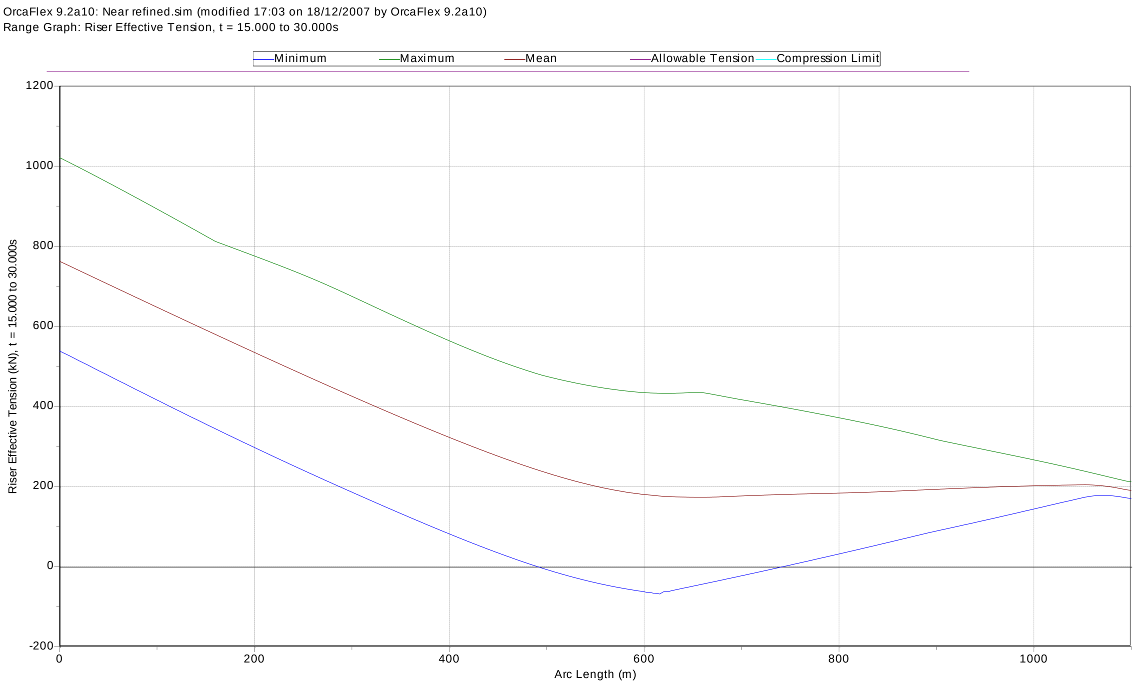

Figure 2-1: Typical High Compression Result

2.2. High Curvature

The curvature range graph will typically show a mean low curvature in the region of the touchdown point with shorter wavelength curvature superimposed on top of it. Or, in extreme conditions, just a lot of high curvature waves. An example is shown below.

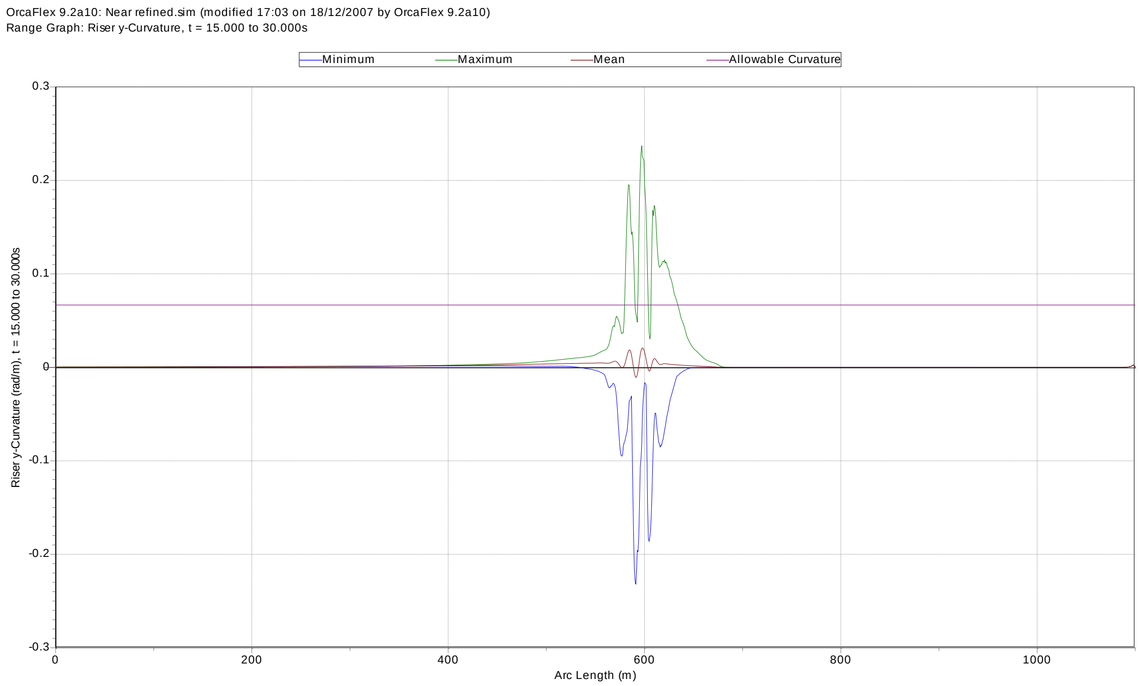

Figure 2-2: Typical Curvature plot in the riser plane

The instantaneous range graph will frequently show the small waves propagating at the touchdown then moving up and down the line length.

3. Model Health Checks

If your model shows the behaviour above then it needs further investigation. It could be that your model is insufficiently refined so giving under or over conservative results. The following checks are advised.

3.1. Coarse Model

The high compression may be due to having too coarse a line segmentation.

Look at the effective tension range graph. If the “Compression Limit” curve on the graph is exceeded then this is indicating the segmentation is insufficient to model the curvature. This means the compression cannot be relieved effectively and so will probably be higher than in actuality. Refine the model and run again.

The compression should reduce and the curvature increase. You then need to check the model by further refinement of the segmentation. If the compression was simply due to a coarse model then further refinement will make little difference to the result.

However if it is a compressive wave behaviour then the results will continue to change with further refinement. This is due to the chaotic nature of the response.

It is always advisable to spot check your model with more refined line segmentation to be sure you have the optimum.

3.2. Large Timestep

Because the compressive waves are a high frequency response, a large timestep can filter this and so underestimate the risk. This is more of an issue with implicit algorithms. With explicit the timestep is generally relatively small compared to the period of the response.

Because of the risk of filtering, halving the timestep might appear to give consistent results. However this might be because filtering is still significant.

The best check is to run with explicit and see if the results are consistent.

3.3. 2-Dimensional Problem

The behaviour is a balancing act between compression and its relief by curvature. The line wants to relieve by curvature.

However if you have built a perfectly 2-dimensional model then the line can only relieve in that 2-dimensional plane. This is because it is a mathematical model and so without any loading out of the plane it cannot relieve in that direction.

For example if you had set up a model with the waves and current exactly in the same plane as the line then the line can only relieve the compression by curving vertically up and down.

Because of gravity and the seabed there is more resistance to curvature in this direction. Therefore compression will build to a higher level before relieving.

In reality the seabed is not perfectly flat, currents rotate and wave energy spreads. Also there will be imperfections in lay routes and the physical properties of the line itself. So a perfectly 2-dimensional situation does not exist.

Your model needs to remain a 3-dimensional problem. There are a number of ways to do this but a common practice so to have the wave and current heading diverge a small amount. This is not unreasonable due to the nature of the waves and current themselves. A typical divergence is about 5°.

3.4. Constant Normal Drag

While normal drag is high and axial drag is low, the easiest route is to move axially. Assuming a constant normal drag coefficient could results in results that are over or under conservative.

Setting a drag coefficient that varies with Reynolds number will allow OrcaFlex to select the appropriate value and remove this risk. It will also allow consideration of the transition zone where normal drag drops to a low value.

3.5. Vessel Peak Response

The vessel heave is the usual excitation for this behaviour. If the case being considered has a regular wave at the period of the vessel peak heave response then it could be overly conservative. A series of waves passing, all at the vessel resonance, has a low probability.

One way to resolve this is to consider a spectral RAO analysis. This adjusts the RAO set to give the maximum response expected in a 3hr storm. This is not straight forward to set up but we have another knowledge base article to give guidance, called “Spectral RAOs”.

If the system is inertia driven then it is the peak heave acceleration that is important. Spectral RAOs would therefore be set for acceleration rather than displacement.

3.6. Omni-directional Parameters

Switching from omni-directional weather and offsets to directional may resolve the issue for selected cases.

3.7. Layback Distance

The layback distance is the horizontal distance for touchdown back to a reference point on the vessel. The compressive behaviour is generally observed if the distance is too short (line nearing vertical) or too long (line is straighter).

It is suspected that in both cases the line configuration finds axial motion the easiest option. In most cases there is a point between the two extremes where compressive waves do not

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occur and a solution can be found. But in some cases the zones overlap so adjusting layback on its own will not solve the problem.

3.8. Local Buoyancy and Weight

Because the line wants to bend to relieve the compression, one option is to let it bend but control where and how.

For in-place lines, application of local weight or buoyancy in the region of the touchdown can have a beneficial effect. For line-laying operations it is not so easy an option. However moving weight and buoyancy methods have been investigated.

We hope that the information is this Orcina Knowledge Base Article is useful. Please do not hesitate to contact us if you have any comments or questions.

The Orcina Team