Generating Spectral RAOs

This document discusses how to generate Spectral RAOs and why you might use them.

1 Why use Spectral RAOs

Dynamic analysis of a line attached to a vessel can be carried out in two ways.

With irregular Waves you apply a wavetrain with a spectrum matching that of the storm. Typically 1hr-3hr wavetrains would be applied. This long duration result in longer runs. The results are harder to interpret and the maximum expected response needs to be predicted by statistical prediction from results.

With regular waves you apply a series of identical waves with the maximum expected height and the associated period range for the storm. Typically you run it for about 5 cycles to allow transients to settle out. This method is fast and interpretation of results is easier.

However allowing the system to settle into a cyclic response can produce greater loads than would occur in a real storm where each wave would be different. In extreme cases, if the wave is at the resonant period of the system, then a resonant response can build up. The resulting loads would be far greater than expected.

If the main cause of this excitation is the response of the vessel to the passing wave then Spectral RAOs may assist.

The maximum expected wave does not necessarily produce the maximum expected vessel response at the line attachment point. Sometime the motion produced by coupling of the maximum wave and associated period is more severe than the maximum expected vessel motion. This is because the vessel response depends on the wave height, period and heading and also what location on the vessel you are considering.

The peak and distribution of the vessel response spectrum can therefore differ from the storm spectrum that generated it. The period and magnitude of predicted maxima will differ as a result.

Spectral RAOs are therefore generally used to give the speed and clarity of the regular wave analysis without the possible over conservatism.

2 What are Spectral RAOs

Spectral RAOs are vessel RAOs where the amplitude has been factored. The factoring is done so the resulting vessel response in the maximum expected wave will be the maximum expected vessel response.

A Spectral RAO is for a specific storm, heading and line end location. It cannot be used for other conditions and locations.

3 Method within OrcaFlex

The method described below uses facilities in OrcaFlex to assist in deriving the spectral RAOs. It is easiest to explain by setting up an example using the default vessel settings. We therefore will consider the following:

- Vessel heading 0º. Origin at midship sealevel Draught Loaded
- Line attached Point A at X 50m, Y 10m, Z -5m.
- Wave heading 30º with Jonswap storm Hs 7m x Tz 8sec so Hmax 13m x Tass 9.8s

3.1 Identification of Maximum 3hr Vessel Response.

The first stage is to identify the maximum expected response of the vessel at Point A. OrcaFlex can report the maximum expected response in a specified 3hr storm.

We set up an OrcaFlex model with the default vessel and the storm.

Select the button called "Report Vessel Response" on the vessel page. Then tell it the headings you want considered for the storm. These are heading RELATIVE to the ship. If you only want the headings you input on the vessel and environment page then leave it as "~" and OrcaFlex will work it out.

Next input the points on the vessel you want responses for, Point A in this case. Remember that coupling for translational and rotational motions means the response will vary around the ship. So we input a 30º heading and the coordinates of Point A.

Finally we input the duration we want to consider, typically this is 3hr but could be less for an installation analysis. Then we select "Report Spectral Response". The result is the significant and maximum amplitude and the mean period for the displacement, velocity and acceleration. This set of results can now be exported to an excel sheet.

The resulting displacements for this case are shown below. Also shown are the motions at End A that would have been produced by the maximum expected wave above. In all six motions the maximum expected motion is less severe than the motion associated with the maximum expected wave.

Item	Surge	Sway	Heave	Roll	Pitch	Yaw
Max.Amp in 3hr Storm (7m–8.0s)	3.363m	3.905m	10.728m	9.766º	10.436º	3.580º
Associated Period	9.9s	9.5s	9.4s	9.5s	9.2s	9.4s
Amp from Max Wave (13m–9.8s)	3.755m	4.294m	11.839m	11.454	10.998	3.924

Table 3-1: Motions at Point A

3.2 Adjustment of Vessel RAO set.

The motions of a point depends on where it is on the vessel. For example the heave motions at the bow of the vessel are a superposition of the heave at the RAO origin and the pitch. Therefore it can be difficult to adjusting the RAO amplitudes at the vessel origin to get the required resulting motions at Point A.

An easier option is to obtain the RAOs at Point A. OrcaFlex can do this for you.

Generating Spectral RAOs

Change to a regular wave with height, period and heading for the wave you intend to apply. Then return to "Report Vessel Response" on the vessel page. The location of Point A and the wave direction should still be there.

Now make sure the Phase origin is "at each point". It is optional to produce the RAOs in OrcaFlex standard conventions. If you choose this then make sure you make the conventions settings in vessel types consistent.

Select "Report RAOs" and you will be given the RAOs at Point A. Look to the bottom of the Position RAO table and it will give the RAOs for your regular wave. The RAOs at Point A for this case are shown below.

Period	Surge		Sway		Heave	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
9.8sec	0.577m/m	333.9°	0.664m/m	40.7°	1.834m/m	322.7°

Table 3-2: Translations at Point A

Period	Roll		Pitch		Yaw	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
9.8sec	1.763°/m	10.6°	1.693°/m	157.3°	0.604°/m	74.2°

Table 3-3: Rotations at Point A

The RAOs need to be adjusted so that when you apply the regular wave, the response has the amplitudes identified by the spectral study. To do this we have to make two assumptions.

- The responses will be at the same period as the applied wave. In this case we know the applied wave is 9.8sec and response periods vary from 9.2s to 9.9s so this is not too bad an assumption.
- The phases will be unchanged.

Now we must adjust the amplitudes in **Table 3-2** and **Table 3-3** so when they are multiplied by 6.5m (½Hmax) they give the maximum amplitudes in **Table 3-1**. The resulting Spectral RAO is therefore given below. These have the RAO origin at End A. It is important to set this on the Vessel Type page and then apply the new RAOs on the vessel page.

Period	Surge		Sway		Heave	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
9.8sec	0.517m/m	333.9°	0.601m/m	40.7°	1.650m/m	322.7°

Table 3-4: Spectral Translations at Point A

Period	Roll		Pitch		Yaw	
	Amplitude	Phase	Amplitude	Phase	Amplitude	Phase
9.8sec	1.502°/m	10.6°	1.606°/m	157.3°	0.551°/m	74.2°

Table 3-5: Spectral Rotations at Point A

Generating Spectral RAOs

Note that these spectral RAOs are only appropriate for the following:-

- Regular Wave 13m x 9.8sec from a Storm Hs 7m by Tz 8sec
- Wave heading 30º relative to vessel
- Loaded Draught
- Motions at Point A.

3.3 Checking of Adjustment.

Because this process has many stages where an error could occur, it is wise to run a model with just the vessel in and the regular waves. Check the motions at Point A to see if they match those in **Table 3-1**. Remember to be sure you are looking at amplitudes, not maximum ranges. Also there may be slight variations due to rounding.

We hope that the information in this article is useful, but do contact us if you have any comments or questions.

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