Frequency-domain Roll Motion Analysis of a Transportation Barge Using Stochastic Linearization of Viscous Roll Damping

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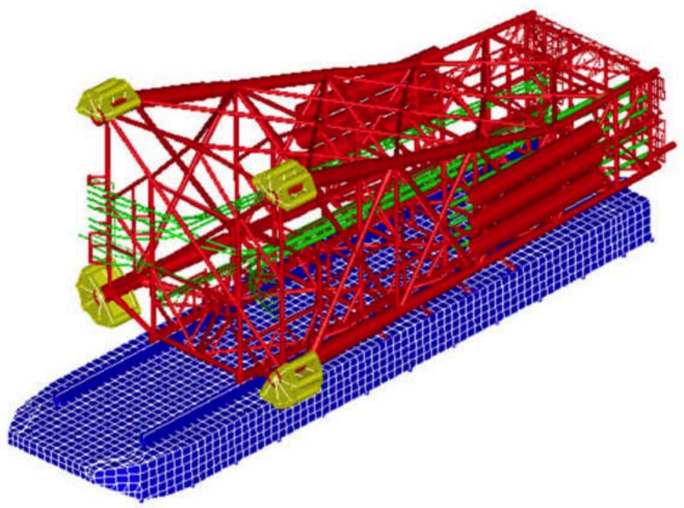
Introduction

Big offshore structures like jackets are commonly built in Asia, where they have big construction yards and cheap supply of labor. This requires a long transportation voyage when the the installation site is on the other side of the planet, e.g. Norway. The transportation of the structures are usually done by barges towed by tugboats where the structures will be subjected to fatigue damage. Inertia loads due to roll motion is one of the main contributions to the fatigue damage.

This is a comparative study between frequency domain and time domain. To be able to include non -linear damping in FD analysis we need to linearize the non-linear damping term. A stochastic linearization is performed in HydroD/WADAM and compared with results computed in time domain.



Objectives

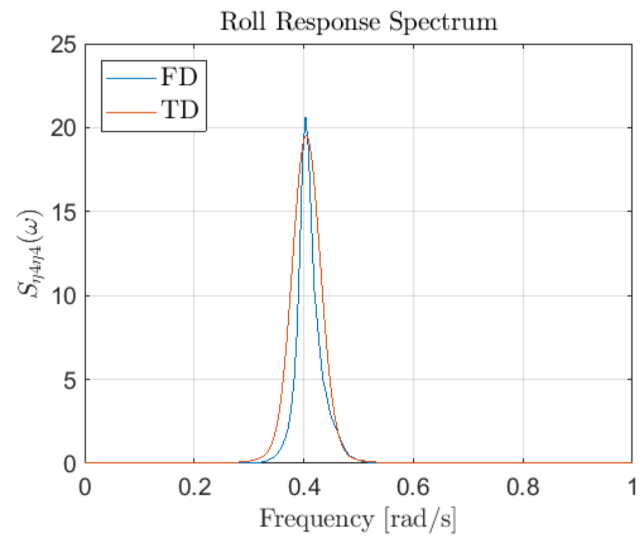
This thesis is a collaboration between Ingrid Mehn-Andersen and me, where Ingrid is using SIMA for the time domain (TD) analysis and I am using HydroDWADAM for the frequency domain (FD) analysis. The main objective is to compare the results in FD and TD. The scope of work is as follows:

Software

The model is created in GeniE and imported into the market leading software Hydro-D/WADAM, both part of the Sesam suite from DNV GL. HyrdoD/WADAM was used to analyze the barge-cargo system and computes responses in frequency domain, hence all input must be linearized. MATLAB is used for the final post processing.

Results

In the figure below a comparison of the response spectrum for roll motion in a wave heading of 45 degrees is presented:



1. Study how to use the software HydroD. Based on the input data from DNV-GL, establish a frequency-domain hydrodynamic model in HydroD and provide the hydrodynamic results for time-domain modelling in SIMA.
2. Perform the basic hydrodynamic analysis and compare the natural periods for heave, roll and pitch with the time-domain results.
3. Consider the wave direction of 45 degrees and 90 degrees, regular wave cases with wave amplitude of 1m, use the given quadratic damping and the stochastic linearization methods, perform frequency-domain motion analysis and obtain the roll motion RAO Compare these RAO results with the time-domain results.
4. Consider irregular wave cases using stochastic linearization methods, obtain roll motion spectra and compare them with the time-domain results.

Method

To be able to do computations in FD we need to linearize the non-linear damping term. Thus we introduce a new linear damping term where the energy loss for the linear equation shall be the same as the real energy loss per cycle. We call this term the equivalent damping shown in the equation below for regular waves:

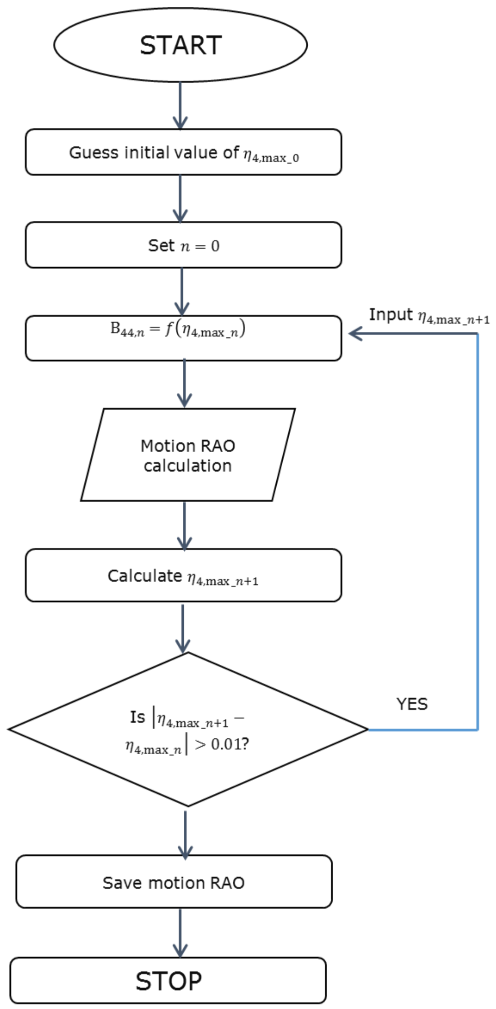
$$B_{eq} = B_1 + \frac{8}{3\pi}\omega\eta_{4A}B_2$$

Where B_1 is the linear damping, ω is the eigen frequency, η_{4A} maksimum roll angle and B_2 is the non-linear damping.

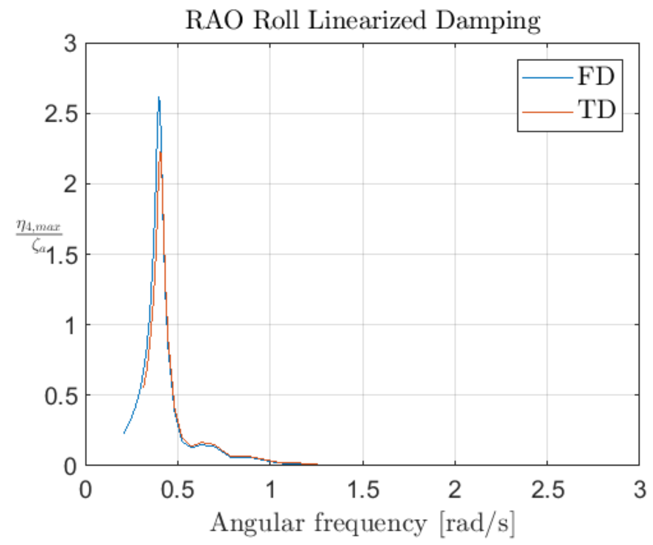
For irregular waves we define the roll motion by the standard deviation of the response due to its irregular response expressed in the equation below:

$$B_{eq} = B_1 + 2\sqrt{\frac{2}{\pi}}\sigma_{\dot{\eta}_4}B_2$$

Both of this methods needs to be done iteratively, and the procedure is presented in the figure to the right.



In the figure below a comparison of the response in roll motion in a wave heading of 45 degrees in regular waves is presented:



Conclusions and Discussion

The roll response results obtained from the TD and FD analysis should be close, especially for regular waves where they are expected to be equal. But the results are slightly different around the eigen frequency. This is probably caused by the coupling effects from Yaw and Sway since they are defined a bit differently in SIMA and HydroD/WADAM

References

The most important references used in the master thesis are listed below:

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