Time domain versus frequency domain VIV modelling with respect to fatigue of a deep water riser

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Introduction

As the search after oil and gas pushes operations further out into deeper water, several challenges emerge. One of them is vortex induced vibrations (VIV) of offshore structures, such as marine risers, due to ocean currents. VIV is a phenomenon important to include in dynamic analysis of marine risers and pipelines because it causes fatigue damage. As water depth increases the design and operation of risers gets more complex and VIV presents one of the biggest uncertainties facing riser engineers.

The methods for predicting VIV today is normally treated by frequency models like VIVANA. The problem with this is that the fatigue damage has contributions from both Morison forces and VIV effects. Morison forces are treated by time domain analysis like RIFLEX and SIMLA. Recently a new time domain model has been developed by PhD. Mats J. Thorsen that combines the Morison and VIV forces into one equation.

Thorsen's model is a new mathematical model of the hydrodynamic forces acting on a vibrating circular cylinder in a fluid flow. The basis of the model is that the total hydrodynamic force can be described as a sum of inertia, damping and vortex shedding forces. The hydrodynamic force model is formulated in time domain and implemented in RIFLEX and SIMLA.

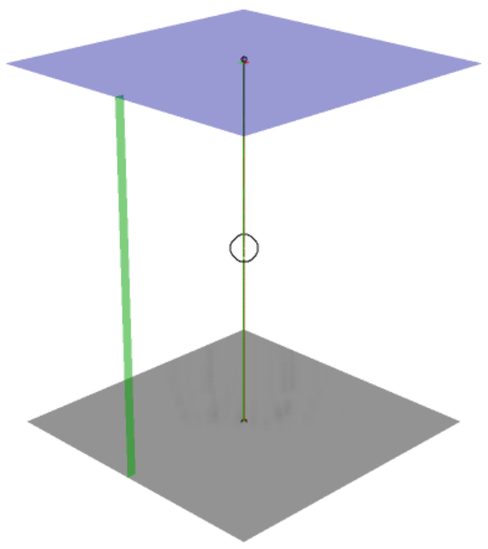
The purpose of this thesis is to compare the new model developed by PhD. Mats Thorsen with current practice with respect to fatigue of a drilling riser.

Scope of work

- Literature study into models for vortex induced vibrations (VIV), relevant standards for riser analysis and the computational tools RIFLEX and VIVANA.
- Establish VIVANA frequency domain model and RIFLEX time domain model for further studies.
- Investigate the simulation length needed for the selected sea states.
- Perform fatigue analysis for selected sea states and compare the results for the time domain model and Frequency domain model.

Model

The model that is studied consists of a drilling riser at a water depth of 1200 meters and 12 meters above sea surface. The riser is modelled by 606 elements, each of two meters length. The diameter of the riser is 0.3 meters and has a thickness of 0.001 meters. The model is shown in the figure below where the grey surface represent the sea bottom, the blue surface is the water surface, the black vertical line is the riser and the green line is the current.



Method

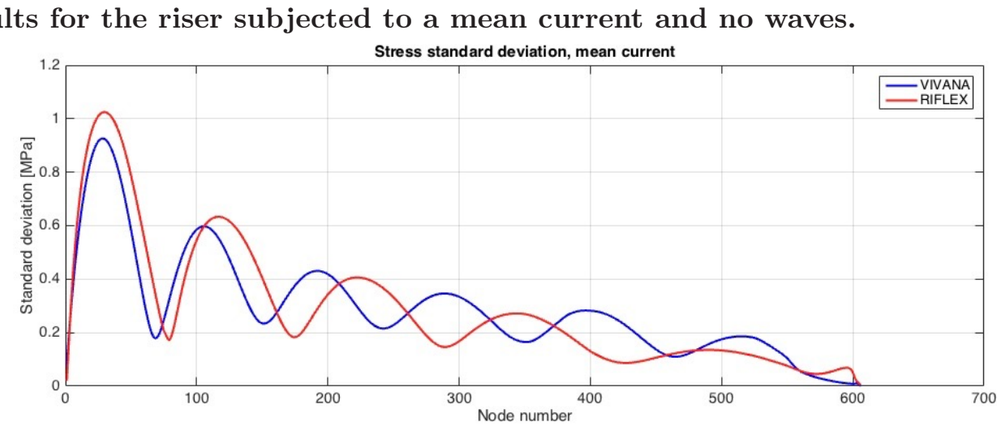
The model presented is analysed in the Sintef Ocean developed programs VIVANA and RIFLEX. VIVANA uses frequency domain to calculate the VIV response while RIFLEX uses time domain.

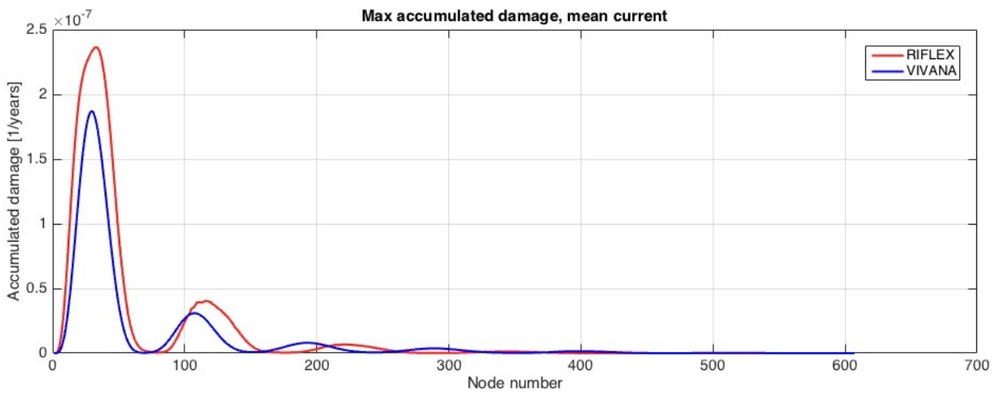
The riser is subjected to a current and waves and the response from this is calculated in the programs. The direction of the waves is 90 degrees on the current to obtain as great cross-flow VIV as possible. Current and wave effects are calculated in one analysis in RIFLEX while it is done in two separate analyses in VIVANA.

The fatigue damage from the current is calculated directly for the VIV contribution in VIVANA, while the fatigue damage from the waves in VIVANA and from RIFLEX is calculated in MATLAB. The calculations in MATLAB are based on the moments and axial forces in the riser as well as an given SN curve. The stress cycles are counted by rainflow counting and it is done in MATLAB by an extra tool package called WAFO.

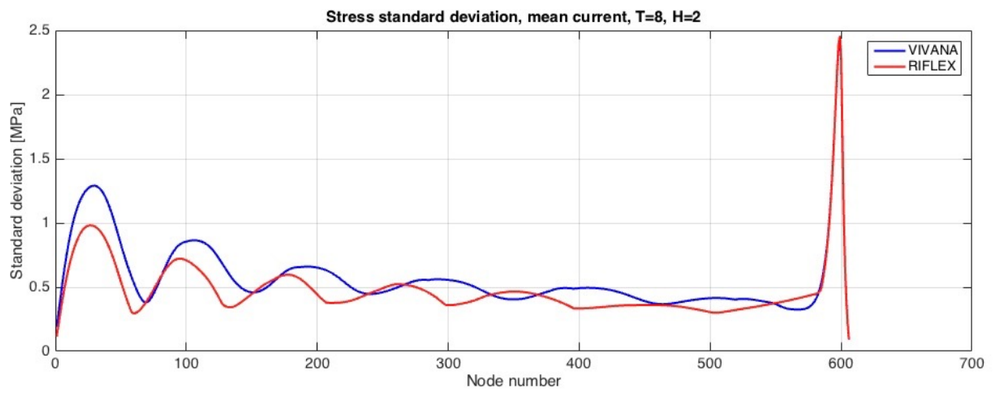
Results

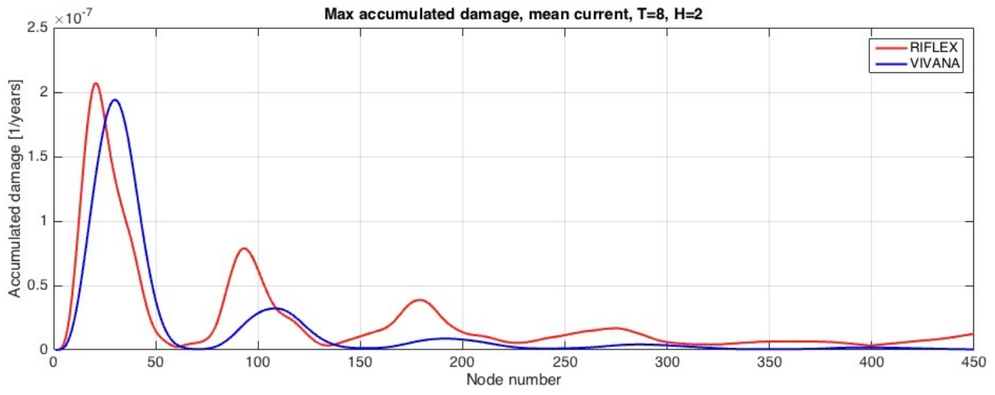
Results for the riser subjected to a mean current and no waves.



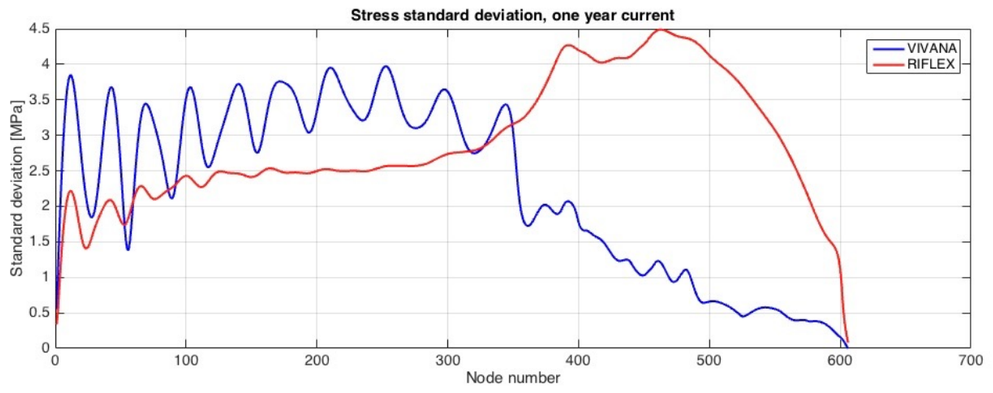


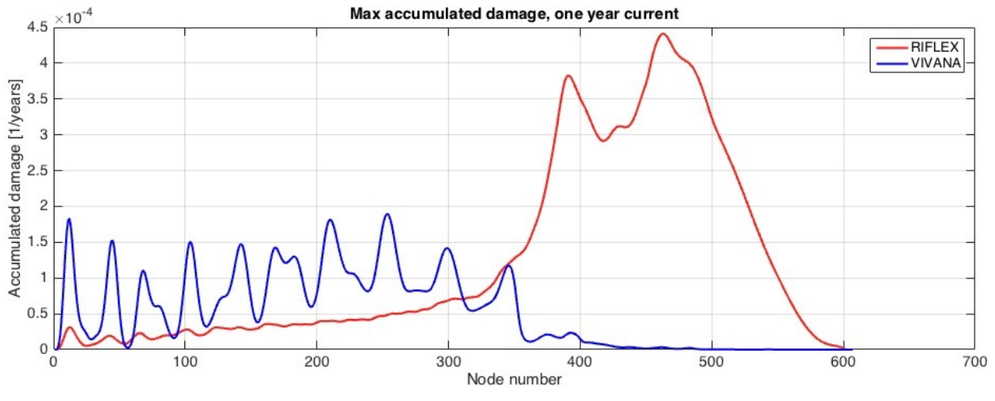
Results for the riser subjected to a mean current and waves with Hs = 2m and a period of 8s.





Results for the riser subjected to a one year current and no waves.





Discussion

The stress standard deviation in the upper figure in the results gives a good agreement for VIVANA and RIFLEX. It seems like they have the same mode and the shapes are quite similar as well as the magnitude. The maximum accumulated damage for the same sea state is given in figure two under results. The damage is a function of the stress in the power of four, and will therefore have the same shape as the stress. From the second figure the result from RIFLEX lies above the results from VIVANA as for the stress standard deviation as expected.

The stress standard deviation in figure three shows a good agreement for VIVANA and RIFLEX as for the first figure. The accumulated damage is also quite similar for the two programs, but not as good as for figure two. Reasons for deviations for the two programs might be differences in frequencies and/or different modes. An other factor that might cause differences is the way rainflow cycles are calculated and counted.

For the last sea state taken into account on this poster there are huge differences in the two programs. VIVANA gives highest response in the bottom of the riser, from 600 meters below sea surface and down, while RIFLEX gives highest response on the top of the riser. One reason for this might be that VIVANA uses frequency domain and each frequency will be associated to an excitation zone and the frequencies excited in the top of the riser gives small displacement amplitudes compared to the once further down. By changing the way VIVANA dedicates excitation zones from simultaneously acting frequencies to time sharing the result might be different.

Several sea states that are not presented here were also investigated for the agreement of the two programs. The majority of them showed good agreement between VIVANA and RIFLEX as for the examples presented on this poster. In addition to environmental loads are RAOs for a semi-submersible added to see how this influences the accumulated damage in the two programs. The difference between the two programs was not affected by the RAOs, but the maximum accumulated damage increased slightly for all cases.

It would be beneficial to compare the results to experimental methods and full scale experiments to see which of the methods that gives the most appropriate results.

Conclusion

After investigating the drilling riser exposed to different values for currents and waves the two programs have shown good agreement for some of the sea states and not that good for others. When deciding which of the programs that have the best result, when the results are deviating, experimental methods have to be considered. The program that have results which best fits experimental methods have the best result.

The new model developed by PhD. Mats Thorsen shows good similarity with the current practice for some of the sea states.