TORSION INSTABILITY OF DYNAMIC FLEXIBLE RISERS AT THE TDP

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PROBLEM

The safe operating window for the installation of flexible risers is limited by whether induced motions giving rise to dynamic tension and curvature at the touch-down-zone (TDZ). With the addition of torsion moment, possibly either from manufacturing or yaw movement of the installation vessel etc., a looping condition known as "hocking" may occur. Today's methods are quite conservative and an expansion of the operating/installation window will have direct economical benefits for the industry.

SCOPE OF WORK

This project work includes a literature study, as well as establishments of realistic installation scenarios and cross-section parameters for both dry and wet annulus conditions. There are done predictions of the critical curvature associated with kink formation for these cases and for torque. Further, a dynamic analysis with built-in torque level based on non-linear models for moment-curvature and torque-torsion have been preformed, along with a number of cycles to try prove that kink formations is not developed due to accumulated plastic deformations.

MODELLING

The analysis have been preformed using the computer program BFLEX2010, while the post possessing have been done by BFLEX2010Post, Matlab, Excel and X-post. Two different geometries have been analysed: one 6" pipe and one 14" pipe. Except the prestudy, all the analysis follows the same procedure:

Step 1: The model is defined on the seabed and then lifted up at one end in static domain. Gravitation and external sea pressure is added, while the pipe material is held elastic. No seabed friction.

Step 2: Plasticity in pipe material is turned on, along with seabed friction (μ_x=1, μ_y=0.4). A prescribed rotation θ about the global z-axis at the top end of the pipe is added in dynamic domain, while the other end is held fixed.

Step 3: A sinusoidal heave motion with period T=10s, is prescribed to the top end of the pipe in dynamic domain.

REFERENCES

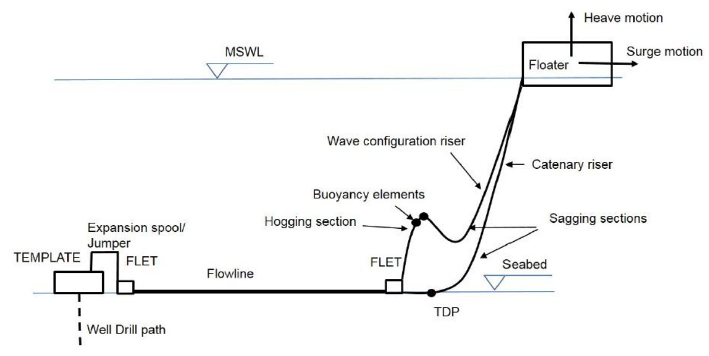
[1] S. Sævik, BFLEX2010 - Teori Manual 20.06.2013.

[2] A. G. Neto and C. Martins, Structural srability of flexible lines in catenary configuration under torsion. In *Marine Structures 34 (2013) 16-40.*

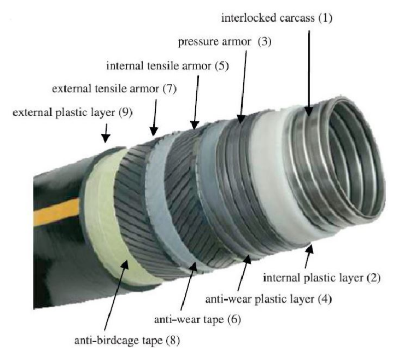
[3] S. Sævik, Lecture notes in offshore pipeline technology (2015).

INTRO AND PRESTUDY

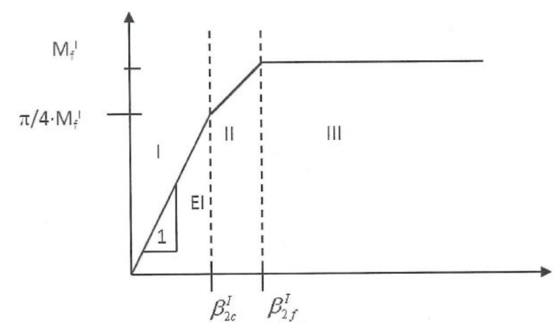
Typical Lay-out



Pipe Configuration



Bending Moment - Curvature

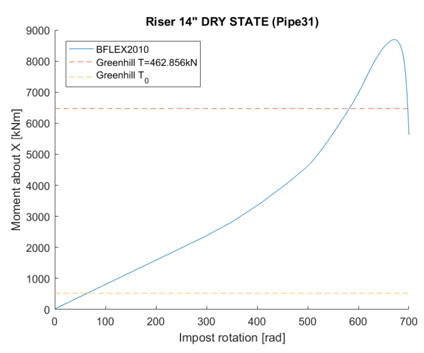


Dynamic flexible risers are a common term for cables, umbilicals and flexible pipes, that are freely or semi-freely suspended between two points (offshore). Flexible pipes are made up of several layers. The different layers contribute with different qualities, therefore to find the global stiffness parameters a prestudy of a small pipe section is done.

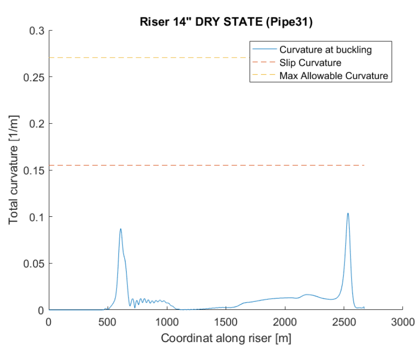
During bending the pipe will first start to behave like a rigid beam due to friction, but at a certain point the layers will start to slide relative to each other [3]. This point is referred to as the slip point. For the condition of wet annulus the slip point will be significantly lower than in dry condition.

ANALYSIS

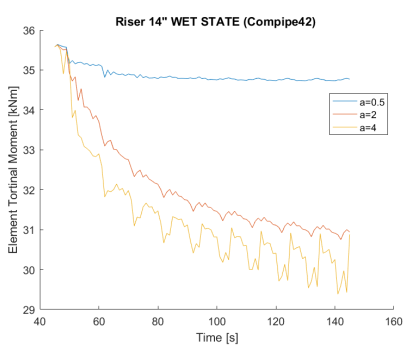
Critical Torque



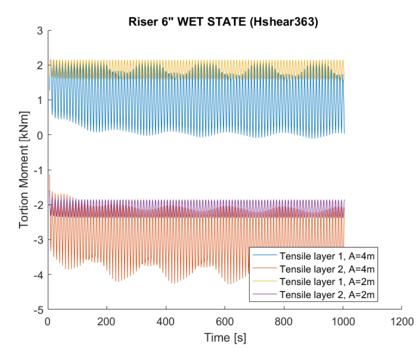
Critical Curvature



Heave Scenario



w/ Local Buckling



To start of the analysis the critical torsion moment and curvature was established for a 2000m water depth, using the methodology presented by [2] (Modelling step 1 and 2). This was done using an elastic model and then a non-linear model. The elastic model i unable to describe slip, therefore in the case of dry annulus the initial bending stiffness was used, while for wet annulus the post-slip stiffness was used. The elastic model and the non-linear model gave the same results for dry state as the slip curvature was higher than both critical curvature and maximum allowable design curvature. However, for the wet state, the elastic model clearly underestimated the strength of the pipe.

The next analysis centres around proving that the found critical curvature was a true indication for kink under dynamic heave oscillations. By subjecting the pipes to different utilisation of critical torsion θ_{crit}, and different wave amplitudes, it was found that the established critical curvature indeed was a good indication for kink. On the other hand, critical torsion seemed to be dependent on the application speed. In regard to solution stability, an increase in curvature was spotted in all cases. Although, in the cases were critical curvature was not exceeded, the increase was gradually reduced.

For the last set of analysis, there was made an attempt to connect global and local effects. This was done by dividing the cross-section into several elements. To mimic lateral buckling in the tensile armour, the inner tensile layer axial stiffness was set to near zero for stresses exceeding critical buckling stress. Analysis were then preformed at, and just above, critical water depth, with and with out built in torsion. In none of the cases were there seen any kink formation after 100 oscillations. For the 6" pipe the solution seemed to have stabilised, but not for the 14" pipe.

CONCLUSION

For establishing critical torsion moment and curvature for flexible pipes, the elastic model is seen sufficient in most cases of dry annulus. However, for the case of wet condition, a non-linear analysis describing slip is recommended.

The methodology presented in this project appears to give good indications of pipe behaviour in relation to global torsion instability, concluding that today's methods are too conservative. However, the solution is not stable in all cases.

For future work a testing of other geometries and oscillations are suggested.