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Design & analyses on SCR configurations for deep water

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Objective

The marine riser is an important part in the oil and gas industry. Integrity and reliability of such structure is very important. Failure will lead to major loss and severe consequences. This will be of particular concern in relation to future exploration and development of oil and gas resources, which to a large extent will face the challenge of water-depths exceeding 1000m. This implies that design of the systems connecting the subsea-installation to the surface floater in general must focus on other types of loading and load effects than for more traditional water-depths.

A variety of different riser concepts are proposed, both with respect to geometric shape and selection of materials. Accordingly, methods for calculation of loads and load effects for the different configurations need to be both advanced and accurate, and generally numerical solution methods are required.

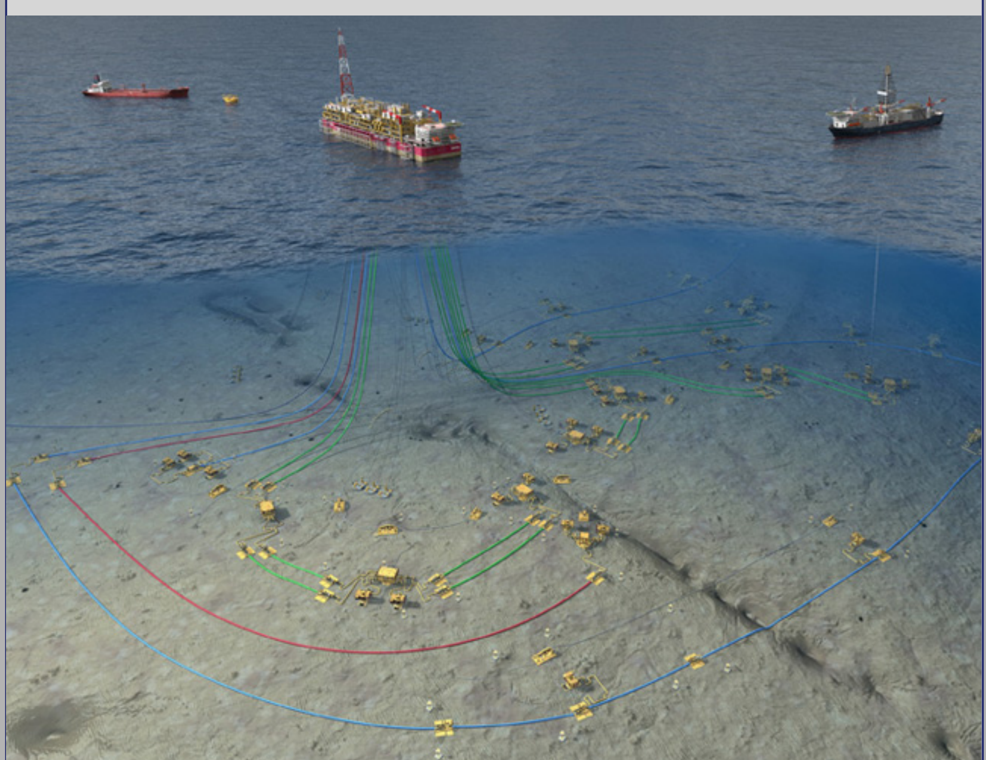
The candidate shall address the following topics:
1. Possible geometric shapes of the riser system shall be described (Vertical, simple and multiple catenary solutions). Various types of relevant materials for such applications are to be discussed (Steel, titanium, fiber-composites, flexible pipes). Different installation methods shall be briefly described.
2. The loads acting on the riser system shall be described, and methods for computation of load-effects along the riser shall be summarized. A summary of relevant guidelines for design of such systems shall be given.
3. Response analyses are to be performed for a conventional free hanging steel catenary riser system. These analyses shall also be performed on a weight-distributed steel catenary riser system. The results of the analyses are to be compared and discussed. For the analyses, the computer program SIMA/RIFLEX can be employed.

Introduction

The petroleum industry is constantly evolving and adapting into new environments involving deeper water depths.
In recent years, the water depth of exploration and production activities has increased drastically, and new fields are discovered in deeper and deeper waters. As the water depth increases, both technological and economic challenges also increase. A key to success when moving into these new environments, and the development of new fields, is advanced riser technology.

The riser is a major factor for success in all the operational phases subsea. While drilling, the drill string is carried in and out through the riser, and the riser also serves as the return path for the drilling fluid. In addition to assist the drilling phase, the riser system is also included in workover-, production- and export phases. A riser can, similar to flow- and pipelines, transport production materials (e.g. injection fluids) and produced hydrocarbons.

For deep water fields, steel catenary risers (SCRs) have been the preferred solution due to its flexibility in choice of host platform, simple engineering concept and the fact that it is a cost effective solution compared to other riser systems. The system is composed from a simple steel pipe, and may therefore be applied to deeper waters without a severe increase in cost. The figure below illustrates a riser system with catenary risers shown in the red, blue and green lines hanging from the floater vessel.



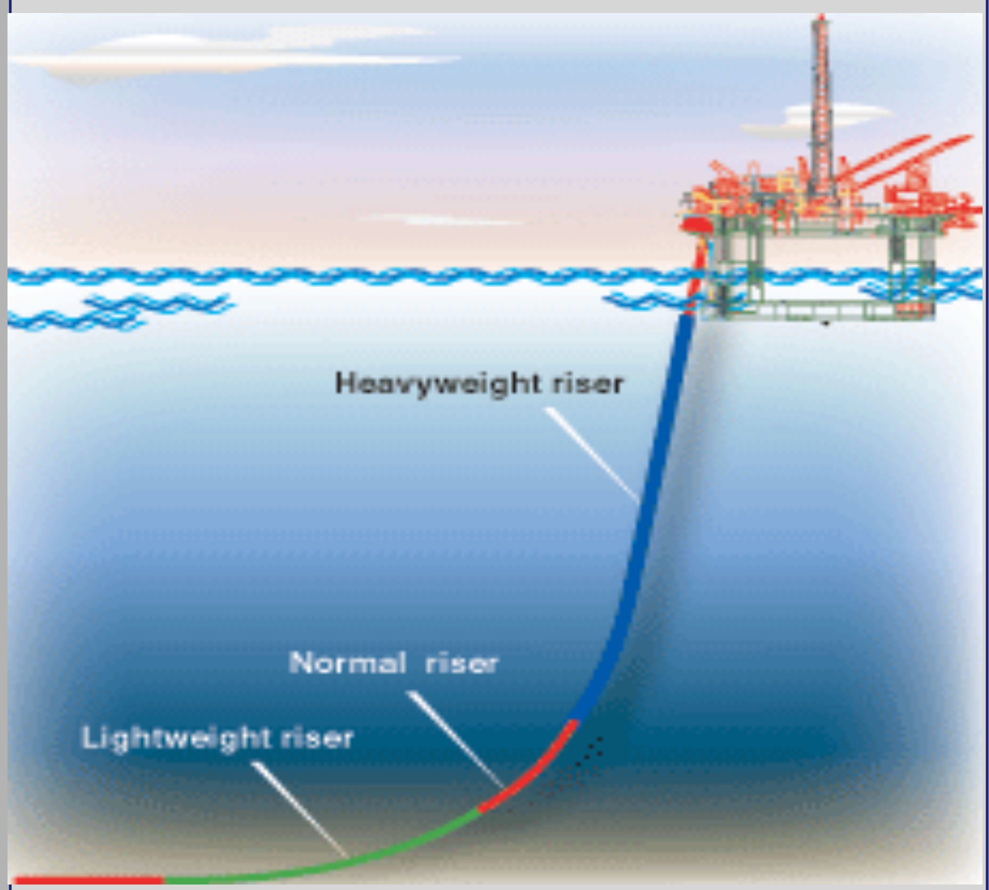
In recent years, a number of SCRs have been installed around the world with great success. However, in deep water and harsh environments there are challenges also to this system. The main challenge is the large motions from the host platform. Significant heave and surge motions from the host platform creates an excessive bending stress at the touchdown point (TDP), while the suspended riser length creates challenges considering the tension due to its weight.

Weight-distributed SCR

To cope with the challenges SCRs are facing in deep waters and harsh environments, different configurations are being proposed, researched and developed. One of these is the weight-distributed SCR.

This configuration is based on varying the weight along the riser. This can be done either by applying coating with different weight, or by using clump weights along the riser, as well as different wall thickness.

The idea is to have heavyweight on the straight areas of the riser to help keep it steady and withstand current forces etc., and to have a more lighter weight around the TDP to decrease the excessive bending moment (as shown in the figure below).



Host platform

Traditionally, TLP has been used in combination with SCRs for water depths ranging from "mid" to deep waters. The low slow drift motion of the TLP has been the major reason for why it has been used for SCRs.

As the industry evolves and moves into deeper waters in search for new fields, Semi-Submersible platforms are more and more preferred. As the water depth increase, so does the length of the legs on the TLPs, which may cause design problems, and fixed structures are therefore not practical. By using Semi-Submersibles this problem is solved and hence preferred, even though the slow drift motion for Semi-Subs are around 10-15% of the water depth compared to TLPs who have up to 9% of the water depth.

In this thesis, a semisubmersible is being used and hence the offset of the platform is a challenge. Therefore, analyses are done for far, near and mean positions of the semisubmersible. To understand what the offset of the semisubmersible does with the riser and the forces affecting it, both 40 meter offset and 100 meter offset will be investigated in the static analysis.

Mean position: Defined as starting position.

Far position: Defined as offset in the negative x-direction, away from the TDP. Challenges in far position is increased top tension, as the weight of the suspended riser length becomes significant.

Near position: Defined as offset in the positive x-direction, towards the TDP. Challenges in near position is increased bending stress, as the bend on the riser in the touchdown zone (TDZ) is sharper.

Software for simulations/analysis

SIMA/RIFLEX is used as the analysis software, and this program is developed by MARINTEK and SINTEF in cooperation with NTNU as a joint industry project. Large companies including Statoil, BP, Conoco Norway, Esso Norge, Norsk Hydro and Saga Petroleum have all participated in developing the program.

The program does static and dynamic analysis on the riser system based on a configuration set by the user including environment data, riser data, fluid data, etc.

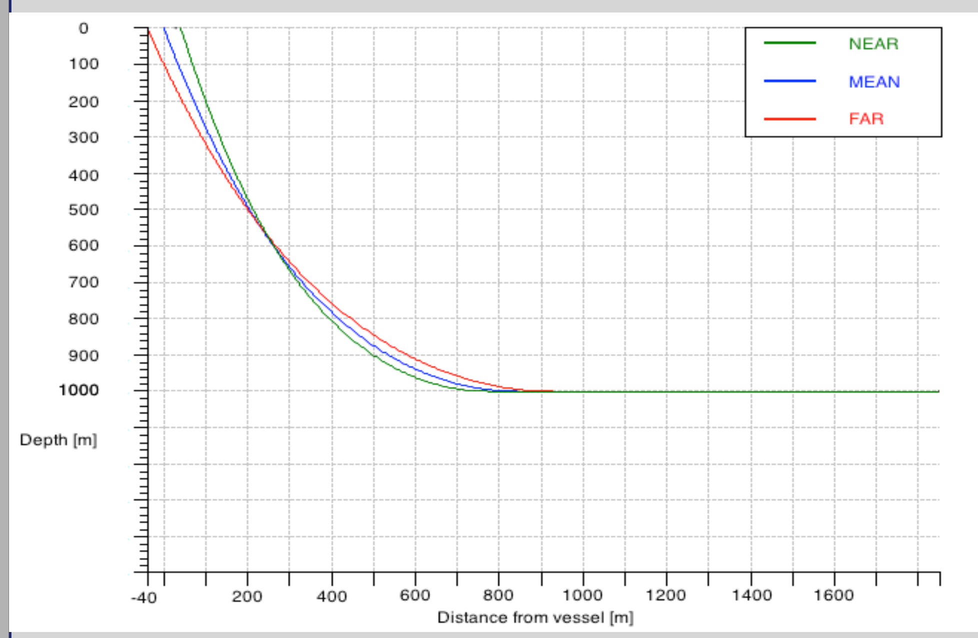
Static analysis comprises:
- Equilibrium configuration
- Parameter variations of tension or position parameters, current velocity and direction

Dynamic analyses comprises:
- Eigenvalue analysis, natural frequencies and mode shapes
- Response to harmonic motion and wave excitation
- Response to irregular wave- and motion excitation

Static Analysis example

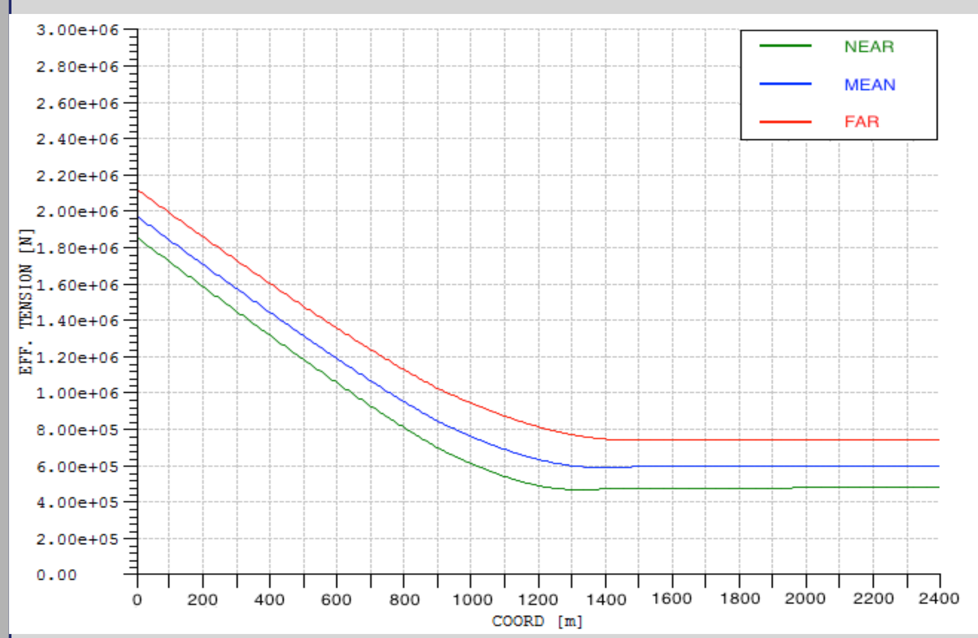
The static analyses performed are the riser XZ-configuration, static effective tension and static bending moment. The full thesis covers both 100m and 40m offset, but in this example only 40m offset is considered.

First off, the static xz configuration is calculated.



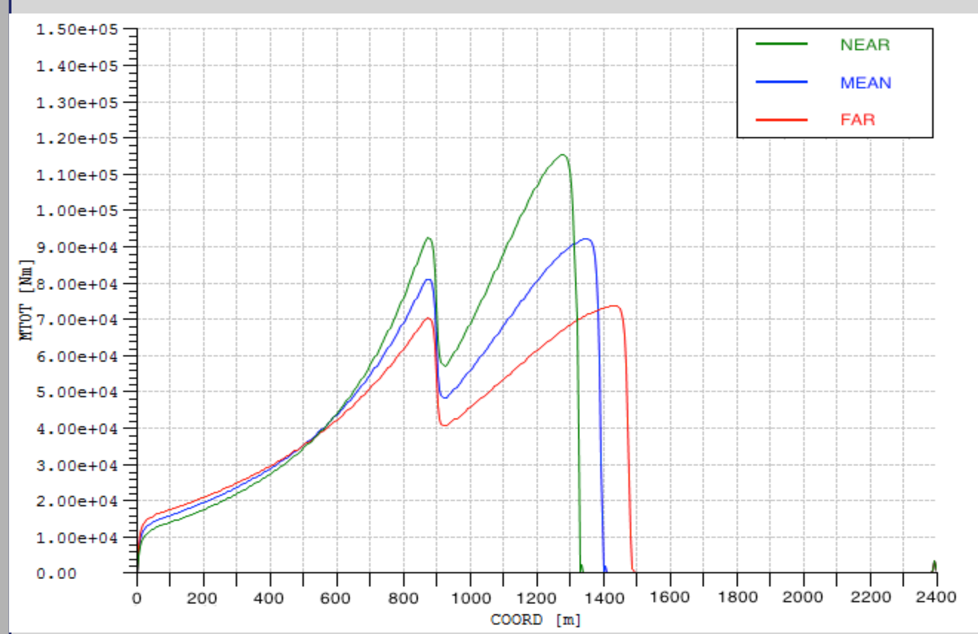
Already with an offset of 40 meter, we notice that it has significant impact on the configuration. The TDP changes drastically, which cause different dynamic behavior for the three different cases. For the near case, the bending moment becomes higher. For the far case the bending moment becomes lower, however, the top tension increase because the weight and free span of the riser is higher.

The next analysis performed is the effective tension on the riser.



As we can see from this figure, the configuration with the longest suspended riser length is the one with the highest effective tension, and that the tension is highest at the top end. The reason for this is because the riser hangs freely in the water, and thus the forces are concentrated highest at the top.

Lastly, we have the bending moment in the figure below:



In contrast to the effective tension, the bending moment is highest for the near case, and lowest for the far case. Because the distance from the semisub to the TDP is shortest for the near case, the bend is sharper, and the bending moment is highest. The bending moment is increasing steadily until the wall thickness is reduced, then it drops before it steadily increase until it reaches its max at the TDP, and then drops to zero when interacting with the soil.

Results

Only a small part of the analyses are being shown in this poster. As the thesis is not fully finished, final results and conclusion are not ready for publishing, hence it will not be discussed here.

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