Design of unmanned wellhead platform against accidental actions and fire

Anders Strand
Supervisor: Professor Jørgen Amdahl
Norwegian University of Science and Technology

Motivation

Subsea wells are cost intensive to maintain and operate.
In August 2014, Kværner was awarded a concept study related to a standardised, unmanned wellhead platform for the Oseberg Field (OffshoreEnergyToday 2014): “The concept is focused on minimisation of facilities, equipment and costs down to water depths of 150 meters and may be a cost effective solution compared to a conventional subsea tie-back solution.”. The concept was named Subsea On a Stick(SOS)

Kværner presenting early SOS concept (Skybakmoen 2015)

Picture from e24.no. (Lorentzen 2015)

All installations on the Norwegian Continental Shelf need to be designed against accidental actions such as fire. Incidents such as the disastrous explosion and subsequent fire on Piper Alpha(167 people killed), as well as the Deepwater Horizon accident(11 people killed) shows just how serious fires onboard offshore installations can be.

Piper Alpha fire, July 1988. (Exponent.com 2016)

Deepwater Horizon fire, April 2010. (Bryant 2011)

Passive Fire Potection(PFP) is a safety precaution often applied to primary and secondary structural elements in the offshore industry. The process of applying PFP is costly and poses a minor health risk to the operator. Should any fabrication errors be discovered after application, the PFP is stripped off in a large area around the repaired structure, before reapplying after repair. Thus, if the need for PFP can be shown not to be present, the saving potential is significant.

Specification

The aim of the thesis is to use publicly known information of the Kværner SOS platform, as well as any comparable structures, to design main structure of a similar unmanned wellhead platform.

- Main dimensions, loads and beam cross sections should be proven reasonable.
- Any necessary improvements to the structure are to be implemented and documented
- Suggested fire- and accidental loads to be applied are provided by Kværner, including loads from well intervention equipment or drilling cantilever collapse
- Investigate the need for PFP

Model

There are some existing unmanned installations operating offshore, though all of them have accommodation for maintenance crew. This will not be the case for this wellhead platform, as maintenance and installation jobs are to be performed with the use of a dynamically positioned service vessel. The closest comparable structure in the North Sea is BP’s Tambar platform.
Using data from Tambar (Terdre 2001), and assuming geometrical similarities to Kværner’s design from publications as input for dimensioning the platform:

- Three decks of $400\ m^2$, turned 45° in relation to the jacket(as seen in the first picture)
- Topside deadweight of 400 tonnes
- Total topside weigth of 800 tonnes

Simplified methods were used to estimate reasonable dimensions for the structural elements. Plate strip and beam theory as taught in Marin Teknikk 2 were essential for choosing the correct steel profiles quickly.

References

References

Bryant, B. (2011), ‘Deepwater horizon and the gulf oil spill - the key questions answered’.
URL: *http://www.theguardian.com/environment/2011/apr/20/deepwater-horizon-key-questions-answered*

Exponent.com (2016), ‘Piper alpha disaster’.
URL: *http://www.exponent.com/Piper$_{A}lpha_{D}isaster/$*

Lorentzen, M. (2015), ‘Ingen kjøpere har foreløpig meldt seg: Nå fokuserer kværner på "indremedisin"’.
URL: *http://e24.no/energi/kvaerner/ordreboken-kan-halveres-innen-nyttaar-ingen-kvaerner-kjoepere-har-meldt-seg/23449016*

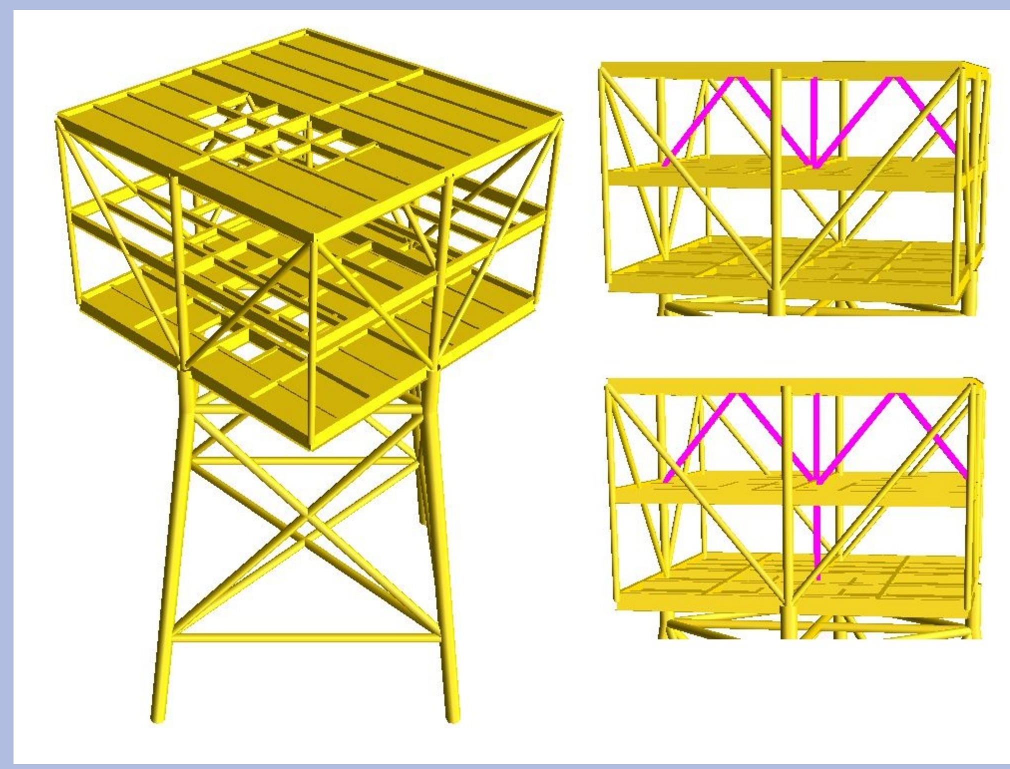
OffshoreEnergyToday (2014), ‘Kvaerner selected for oseberg platform concept study’.
URL: *https://www.offshoreenergytoday.com/about-2/*

Skybakmoen, J. (2015), ‘- oljeprisen har gjort bransjen fartsblinde’. The website is not free.
URL: *http://www.adressa.no/pluss/article11480990.ece*

Terdre, N. (2001), ‘Norway: Tambar first oil set for july, gas will maximize ula output’.
URL: *http://www.offshore-mag.com/articles/print/volume-61/issue-4/news/norway-tambar-first-oil-set-for-july-gas-will-maximize-ula-output.html*

USFOS structure

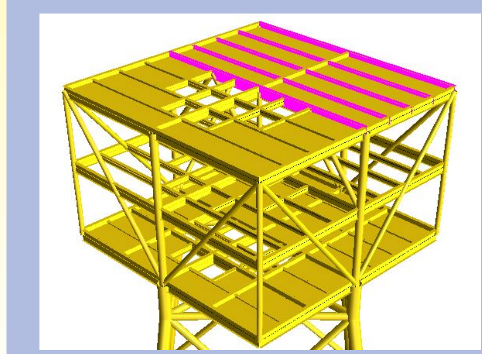
An USFOS model was established based on chosen geometry and steel profiles.



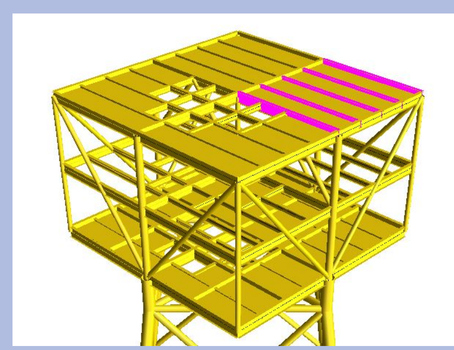
First model file in USFOS

An internal truss was proposed to deal with the accidental action of drilling cantilever collapse. This also helps with operating load condition. By extending the middle column down to the cellar deck and thereby halving the deck span, a capacity increase before first yield of almost **60** % was obtained as the failure mode changed from deck beam bending to truss member buckling.

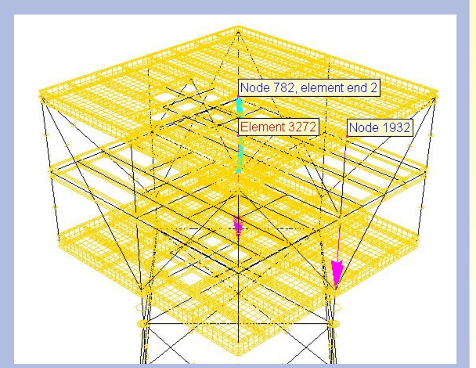
The well intervention equipment was modelled as 150 tonnes distributed over transverse deck beams in various configurations, examples shown below. The extreme case of cantilever collapse is modelled as point loads through vertical columns in different configurations, by the assumption that though the cantilever corner will most likely miss the "most favourable spot", the weight will ultimately have to be carried through them anyway. One configuration shown below, total weight 1000 tonnes.



Well intervention equipment over $20\ m \cdot 10\ m$



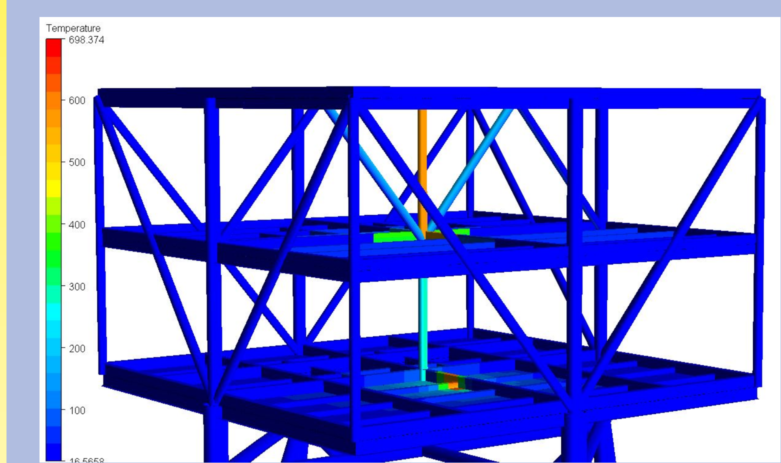
$10\ m \cdot 10\ m$



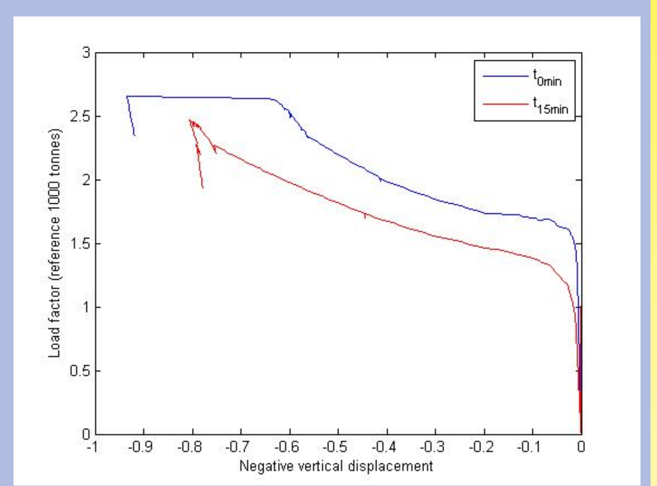
Cantilever collapse as point loads.

FAHTS analysis

FAHTS was used to produce USFOS input in order to take elevated temperatures into account. The given fire scenarios were combined with relevant loads from well intervention equipment, and accidental loads from cantilever collapse.
The survivability of the unmanned platform will mainly be to maintain structural integrity long enough to evacuate and shut down production. This is simulated by defining a set of fire scenarios and a minimum time interval before failure. These cases will not be presented here, but the degradation of structural integrity due to elevated temperatures should be clear in the example below.



FAHTS simulation, temperatures up to 600 K are reached in 15 minutes



Vertical displacement of topside center node, result from USFOS "pushdown" analysis

Here, a jet fire has sprung out from a manifold on the cellar deck. It flares almost vertically along the center column for 15 minutes, reducing it’s capacity. The point loads from cantilever collapse are applied. Not the most likely case, but illustrative for temperature induced capacity reduction.

As the thesis’ analyses are not finished, more detailed results are still not ready. The aim is to simulate multiple fire scenarios in combination with the different load cases described above. Comparison of the three different fire analysis methods is also of interest:

- Temperature-load domain
- Temperature domain
- Load domain(Pushdown)

Acknowledgements

Special thanks goes to Professor Jørgen Amdahl, for excellent guidance and superivision.

Though this thesis is not an official collaboration with Kværner, a lot of info, help and guidance has been provided by Trond Granli at Kværner Jacket Technology Trondheim.
Great care has been taken to ensure that no copyrighted material belonging to Kværner has been used. All Likeness to Kværner’s concept is gathered from published newspapers.