JCSS

Joint Committee
on Structural Safety

Workshop on Assessment of Existing Structures

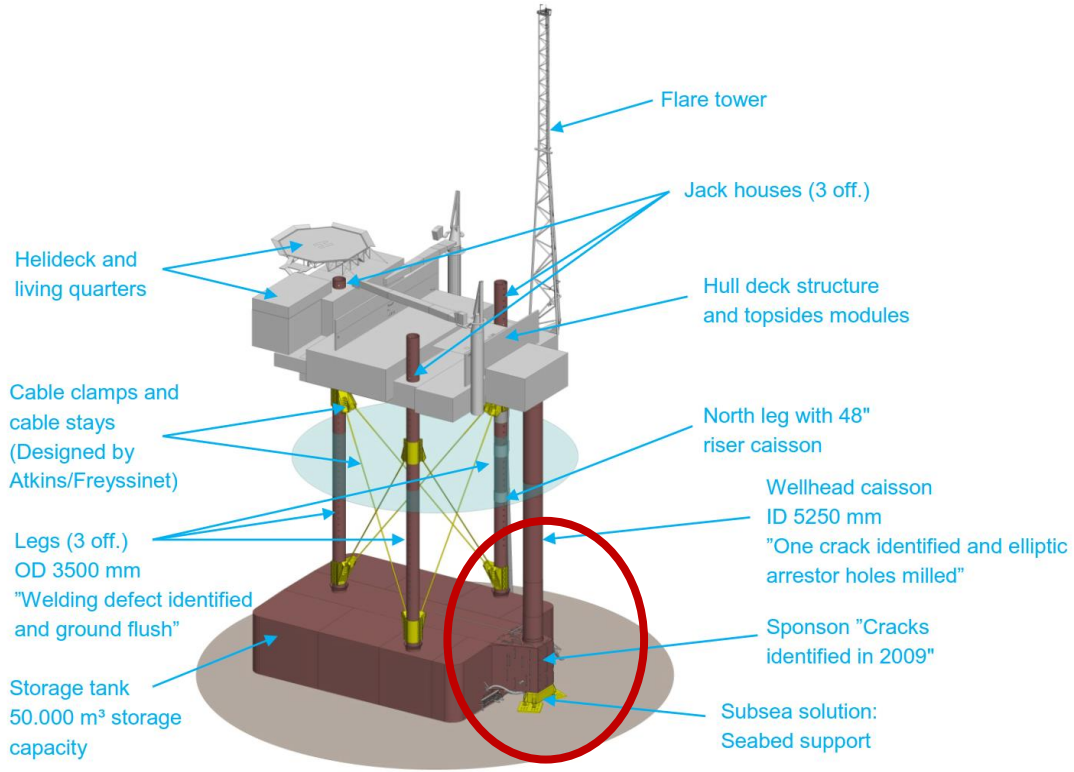
28th and 29th January 2021

Reliability-based approach to an existing offshore steel structure – a showcase

Matthias Schubert, Dr. sc. ETH

Introduction

- Danish sector of the North Sea.
- Platform was installed in 1998.
- Initial design life of 20 years (2018).

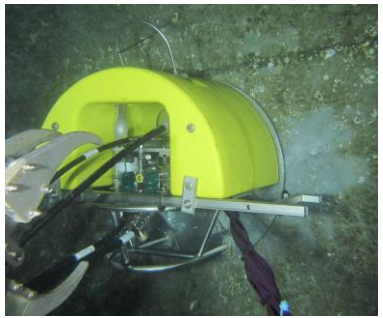


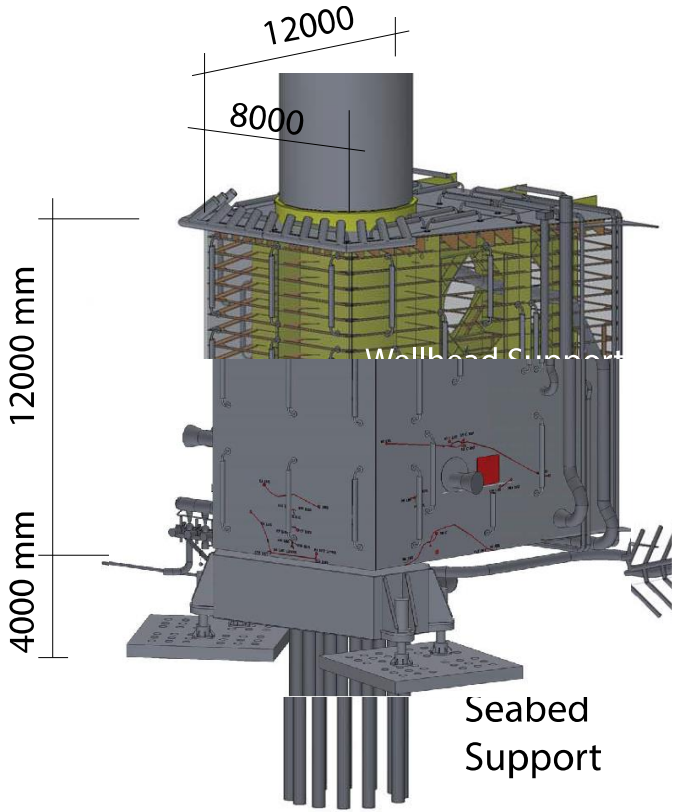
Introduction

In 2009, fatigue cracks were discovered in the Sponson part of the subsea structure.

In 2010, the seabed support was installed.

In 2012, the degraded concrete between caisson and sponson was fixed with steel wedges.

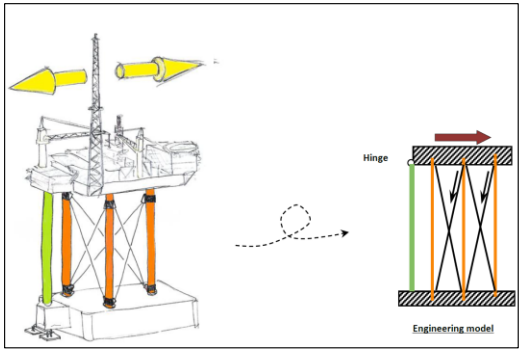


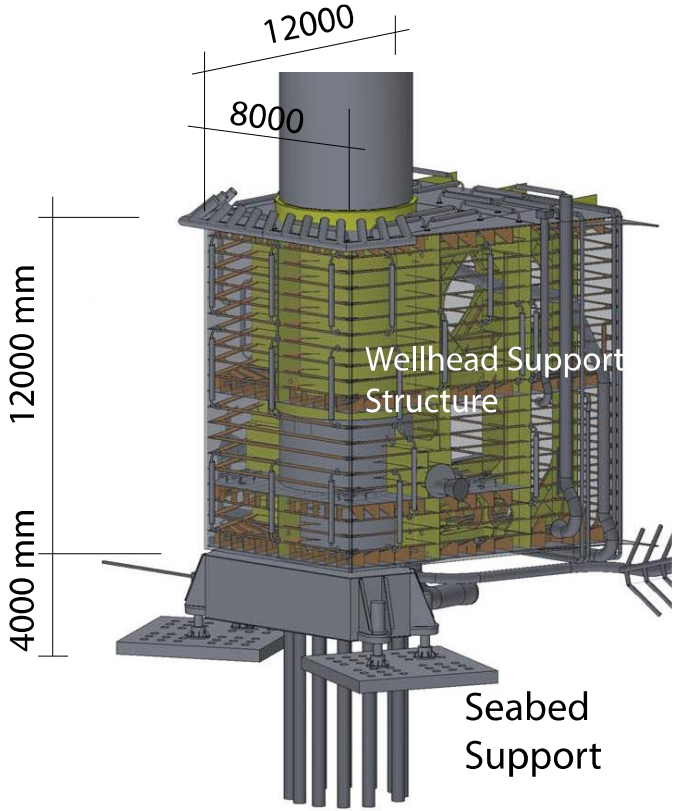


Introduction

Additionally, **6 cable stays** between the platform legs were installed in 2014.

The phase between 2010 and 2014 is called the pre-cable installation phase.





DONG energy

news.cision.com / Dong Energy / Temporary stop of production on t...

Temporary stop of production on the Siri-platform

MON, AUG 31, 2009 19:45 CET

During a routine inspection on Monday 31 August, cracks were observed in a construction attached to the subsea oil tank at DONG Energy's production platform Siri, which is situated in the Danish part of the North Sea.

During a routine inspection on Monday 31 August, cracks were observed in a construction attached to the subsea oil tank at DONG Energy's production platform Siri, which is situated in the Danish part of the North Sea. The cracks were observed by a remote operated vehicle equipped with a camera. DONG Energy has chosen to stop production on Siri temporarily, while examining the cause and the nature of the cracks. For further information, contact: Media Relations Ulrik Frøhlke +45 9955 9560

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Siri platform repair cost soars

DONG Energy says the cost of implementing a permanent repair to the North Sea has risen.

Apr 18th, 2012

Offshore staff

COPENHAGEN, Denmark – DONG Energy says the cost of implementing a permanent repair to the Siri platform in the Danish North Sea has risen.

During a routine inspection in August 2009, the company discovered cracks in the nose of the platform's subsea oil tank. No pollution occurred, but the production was shut down for five months as a safety measure and re-started in January 2010 after implementation of a temporary solution.

DONG originally budgeted $352 million for a longer-term solution, but has now revised its estimate upwards to $617 million, of which $105 million was incurred in 2011. Work should be completed in 2013.

Flemming Horn Nielsen, VP responsible for DONG Energy's Danish oil and gas activities, maintains that the chosen repair solution and continued operation of the platform Siri are both valid, despite the cost increase.

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Siri: Resumed use of the oil storage tank

01.10.2014 08:30

DONG Energy has resumed production under normal conditions in the Siri area after having used a temporary solution for more than six months.

With repair work at full speed during spring, the clamps intended to hold the cables between the platform legs in place, were installed.

North Sea platform temporarily demanned

15-09-2011 12:00:00

OFFSHORE: D
in the Danish N
employees was d

The gale hit the p
employees on the
evening 12 Septe

Supplementary sa
discovered in 200
cracks have led t

Source: DONG

Nachricht vom 04.01.2010 | 07:58

The Siri-field expected back in production in January

DONG Energy A/S / Miscellaneous

04.01.2010

Dissemination of a UK Regulatory Announcement, transmitted by
DGAP - a company of EquityStory AG.
The issuer is solely responsible for the content of this announcement.

Due to rough weather conditions in the North Sea, production from the Siri-field in the Danish part of the North Sea is not expected to be resumed until sometime in January 2010.

On 31 August 2009, the operator of the Siri field, DONG Energy, decided to stop production from the field following a routine inspec
subsea structure connected to the oil storage tank u
platform.

A temporary solution involving a metal frame that su
will ensure the stability of the construction so it
production until a permanent solution is in place. T
temporary solution is progressing, but rough weather
Sea in December have delayed the installation of the
bed. DONG Energy expects to complete the installatio
production during January 2010 depending on favourab

The Nini East-field, also operated by DONG Energy, i
three new wells and is expected to commence initial
the Siri-platform resumes production. The Nini East
the total production from the area significantly. Th
satellite to the Siri-field with a new un-manned pla
Siri.

DONG Energy's partners in the area are Noreco and Rh

The production stoppage at Siri will adversely affec
production from the area in 2009. However, as produc
fields have exceeded expectations, the overall effec
previous guidance for DONG Energy's financial result
expected investment level.

For additional information, please contact

Media Relations
Ulrik Frohlke

PRESS RELEASE - 31 AUGUST 2009 18:45

Temporary stop of production on the Siri-platform

Press release from DONG Energy sent at 07:45 PM on Monday 31.08.2009

Temporary stop of production on the Siri-platform

n on Monday 31 August, cracks were observed in a
he subsea oil tank at DONG Energy's production platform
e Danish part of the North Sea.

by a remote operated vehicle equipped with a camera.

Home > Fossil Energy

Siri Area Fields Back In Production

February 5, 2014

Thursday the 28th of January, the oil tanker Siri Knutsen was connected via pipelines to three of the Siri area's four oil fields, offshore Denmark. Thus, E&P is again able to produce from the Siri area, and yesterday Nini East delivered the first oil drops.

Siri Area Field Back In Production after

The fields in the Siri area have not been in operation since July 2013. This is due to a crack found in a new area of the sponson – the tank nose – on the Siri platform's oil tank. However, thanks to the hard work of many employees, the fields Cecilie, Nini and Nini East are now little by little back in operation. The only difference being that the oil will not, as is otherwise the case, be sent to the oil tank below the Siri platform, but directly to a tanker.

"We have been working determined to get Siri's satellite fields back in production in order to create value, while repairing the Siri platform at the same time. On the platform we still have a huge work in front of us before we can produce from the Siri field itself," says Flemming Horn Nielsen, country responsible for DONG Energy's Danish oil and gas business.

The work of reinforcing the Siri platform itself will continue in parallel with the satellite fields producing oil and will be completed this summer according to plan. The Siri license is 100% owned by DONG Energy.

siri facts

The Cecilie license is owned by DONG Energy (22%), Noreco (61%) and RWE (17%).

The Nini license, which comprises the Nini as well as the Nini east fields is owned by DONG

2009 to 2014 …. Phase of uncertainty

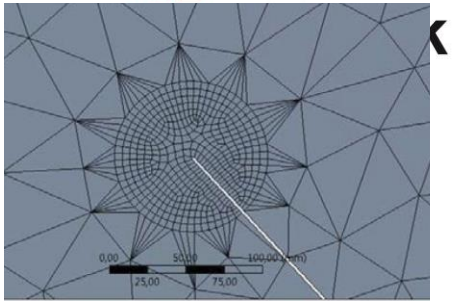
- Can we produce or do we have to de-man an shut down?
- Is the structure presently save and how can we demonstrate this?
- Will the structure be save enough until all measures are implemented?
- Will the damaged structure be save enough after implementation of measures?
- How often do we have to inspect – during the pre-cable installation phase and afterwards?
- How can we demonstrate the fitness for purpose and get operation permissions?

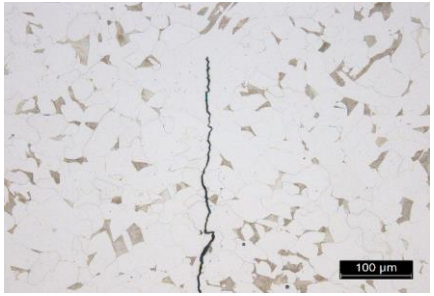
Actions initiated by the owner (DONG):
Planning of engineering measures, measurement and test campaign, inspection campaign, FE-Modelling campaign, recalculations (ULS & FLS), back calculations of storm events (Bodil 2013), **reliability based approach**

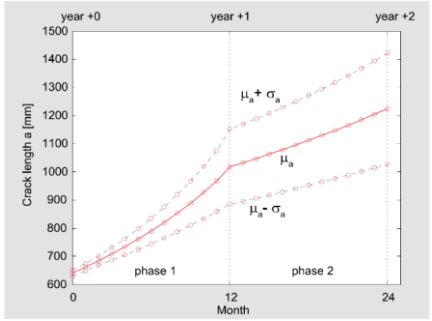
Reliability based approach – crack growth

Each crack has been probabilistically modelled and the crack growth has been predicted.

- Stresses are calculated by FE-Analysis. Wave loads have been modelled by using in situ accelerator measurements.
- Steel parameters have been modelled based on material tests from drilled coupons.
- Crack growth predictions are compared with in situ measurements



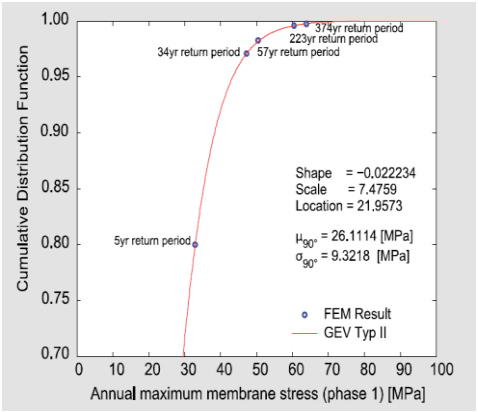


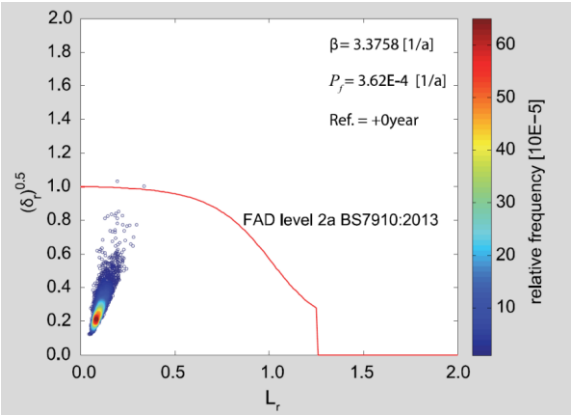


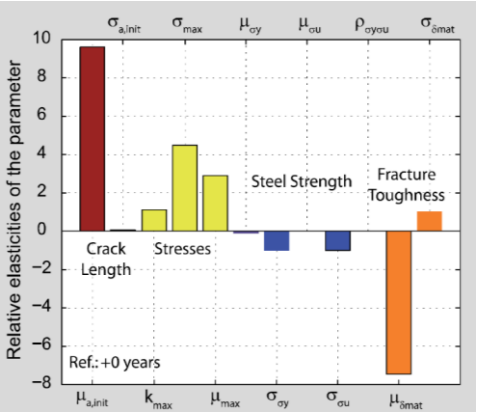
Reliability based approach – crack failure

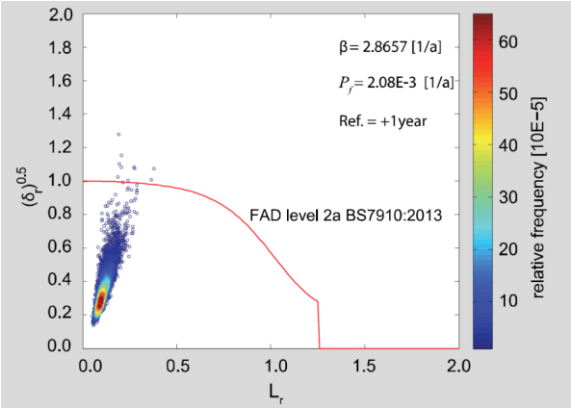
For each crack length (time step) the failure probability of the crack is calculated (sudden rupture).

- Probability distribution of extreme stresses is modelled
- The assessment of failure is based on the FAD diagram (limit state function).
- Material parameter and load characteristics are formulated probabilistically









Reliability based approach

For each crack acceptable failure probabilities have been defined.

Cracks not fulfilling the acceptance criteria, repair actions have been defined (e.g. drilling).

Cracks fulfilling the acceptance criteria have to be observed.

Reliability index β [1/a]	Target reliability index β [1/a]	Requirement
>5.1	4.10	Fulfilled
4.15	4.10	Fulfilled
>5.1	4.10	Fulfilled
>5.1	4.10	Fulfilled
4.13	3.10	Fulfilled
4.11	3.10	Fulfilled
>5.1	3.10	Fulfilled
>5.1	3.10	Fulfilled
>5.1	4.10	Fulfilled
4.89	4.10	Fulfilled
4.61	3.69	Fulfilled
>5.1	4.10	Fulfilled
>5.1	4.10	Fulfilled

Results 2014

Managing Technical Risks
Matrisk

For the pre-cable installation phase it was demonstrated

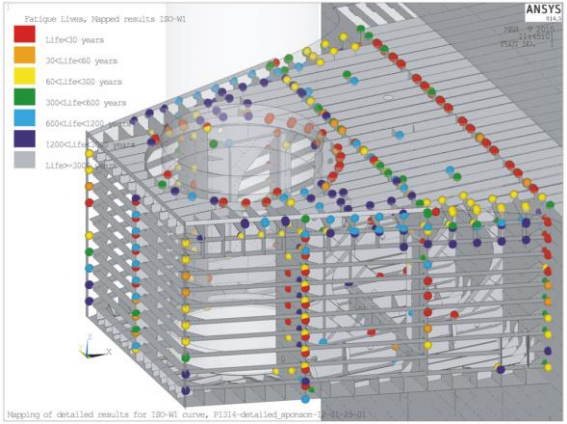
- Some cracks need immediate **repair measures**.
- Some cracks need observation but are **save enough** until the cables are installed.
- The platform is save for production (under some conditions) until the cables are installed.

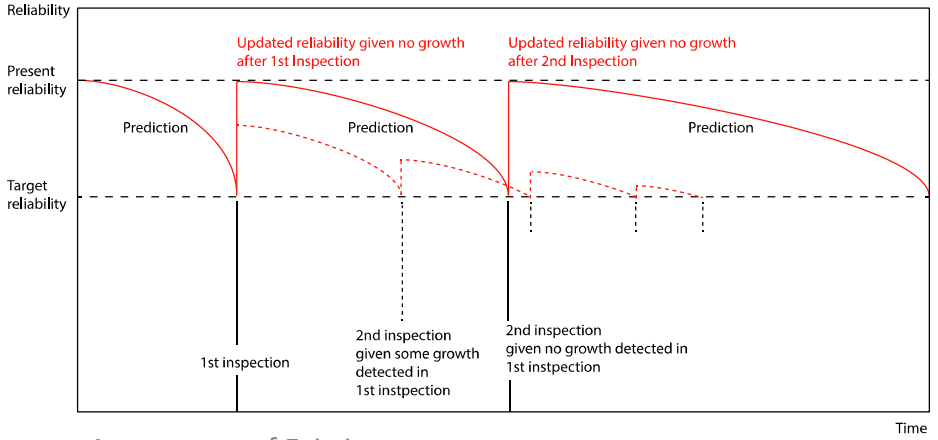
For the post-cable installation phase it was demonstrated that

- the **crack growth is stopped**.
- the existing cracks have a sufficient **small failure probabilities**.
- The platform is save for production.

Observations 2021

- Presently (2021), no further crack growth is observed which is in agreement with the reliability assessment.
- No indication of cracks in non-observable structural parts (oil storage).
- Based on the predictions, the time between inspections has been increased.
- The methodology is also used for identified hot spots and based on this, a RBI strategy was developed.





Conclusions

- The methodology **provides more information** on the structure and the structural behaviour at each time and can be compared to observations.

- The reliability (and also a risk based) based approach has a large potential to demonstrate **fitness of purpose** for existing (and damaged) structures.

- Putting **more engineering efforts** in the analysis has a large **potential for savings** – saving of costs and natural resources without impairing safety.

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