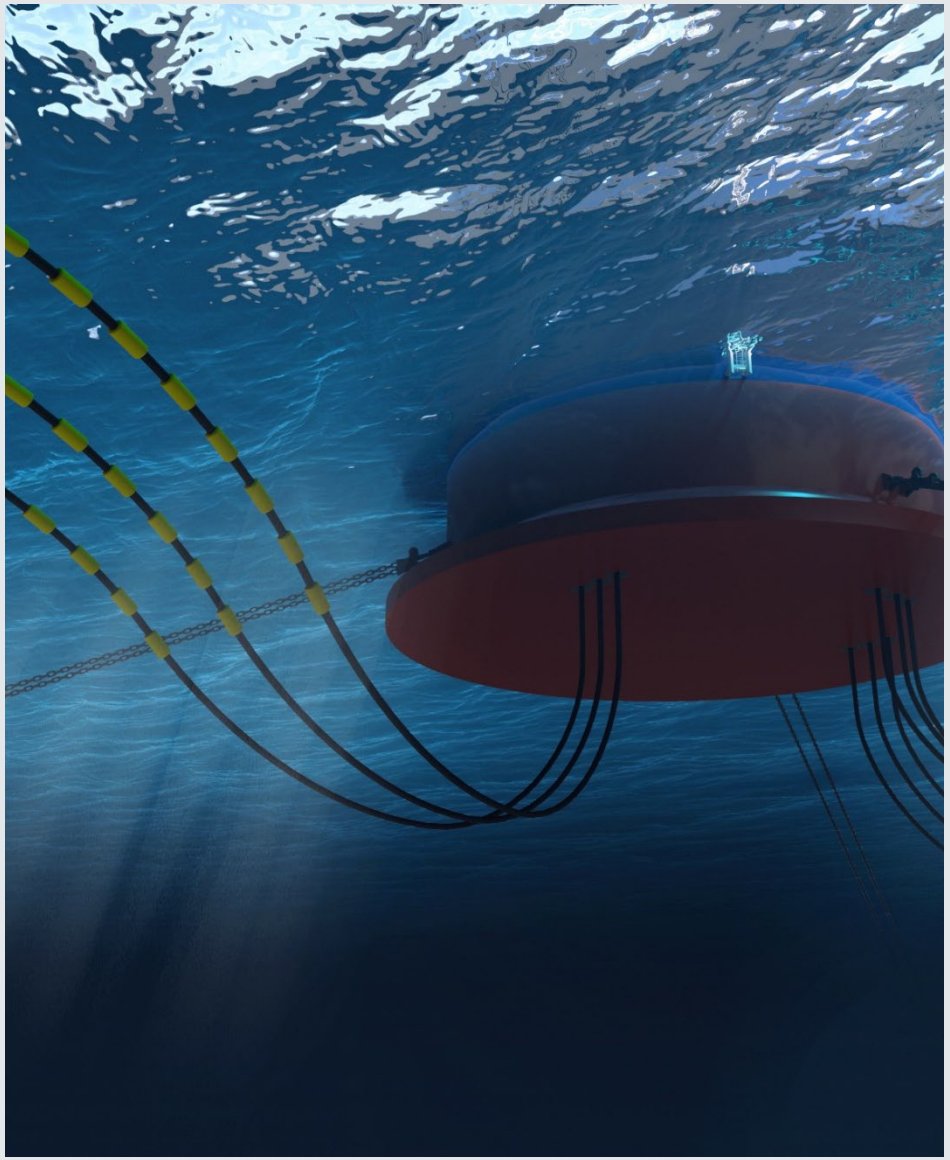
Experiences from mooring of Penguins FPSO

MOP 23- 24 April 2025



Experiences from mooring of Penguins FPSO

Agenda

1. Introduction to Sevan Deepwater Technology
2. Sevan standard mooring system design
3. Penguins mooring design
4. Winch design and FAT checks
5. Mobilisation chain loading issues
6. Corrective actions to mooring winches
7. Offshore Hook Up and lessons learned
8. Mooring integrity monitoring

SEVAN DEEPWATER TECHNOLOGY

Chapter 1

Introduction to Sevan Deepwater Technology

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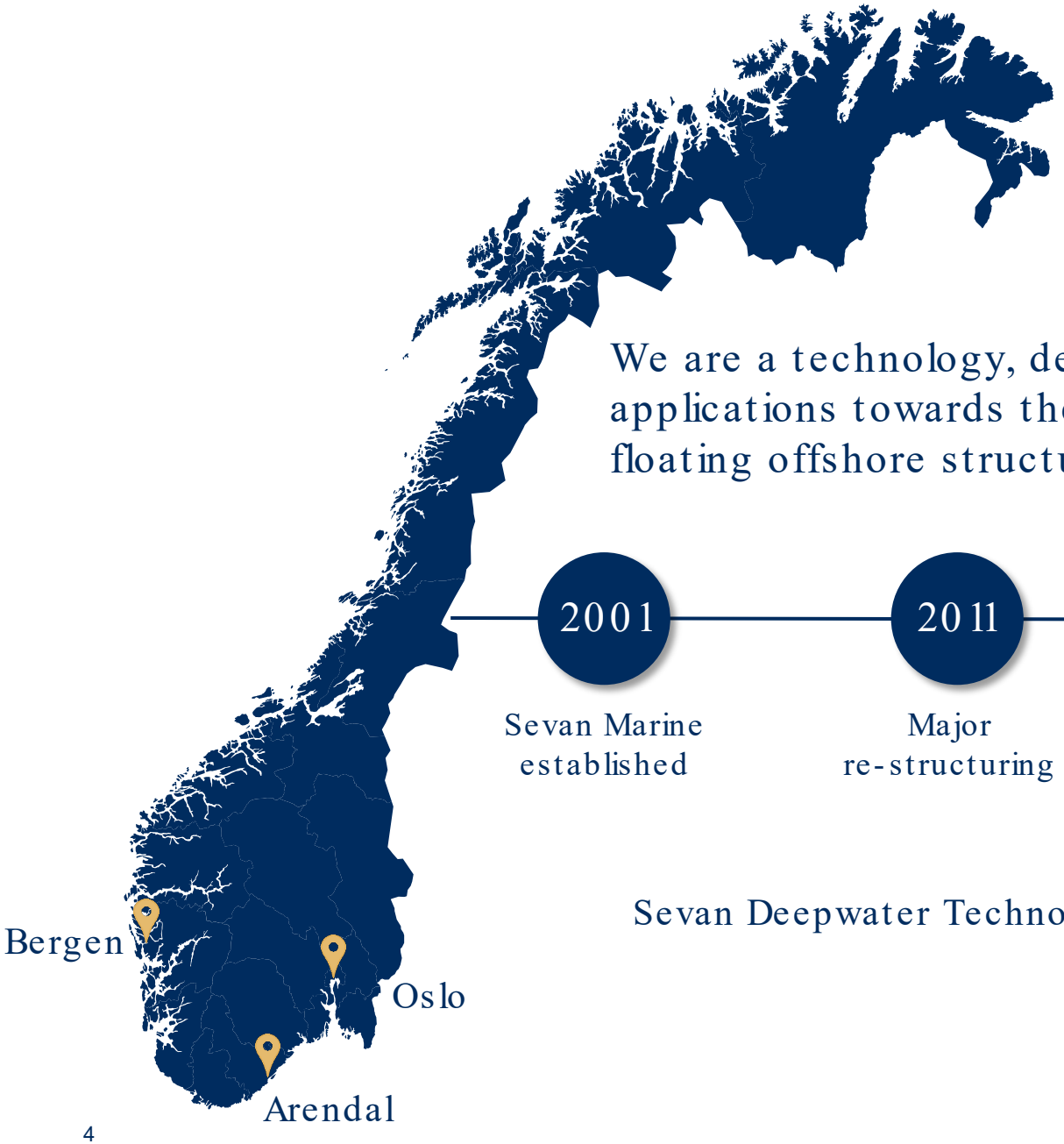
Sevan Deepwater Technology



We are a technology, design and engineering company with focus on floating applications towards the offshore market. Sevan has been an innovator within floating offshore structures for more than 20 years.

2001 – Sevan Marine established

2011 – Major re-structuring

2018 – Embedded in Sembcorp Marine Group

2023 – Merger of Sembcorp and Keppel → Seatrium

2024 – New name: Sevan Deepwater Technology, Centre of Excellence opened

Sevan Deepwater Technology is 100% owned by Seatrium - www.sevandwt.com

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Sevan History

2001 – 2018 Sevan Marine
Oil & Gas
Cylindrical units
Technology Development
Build, own, operate

2018 – 2024 Sevan SSP
Oil & Gas, Renewables
Cylindrical units
Technology development
Engineering

2024 - Sevan Deepwater Technology
Oil & Gas, Renewables
Floating units
Technology company
Early phase engineering

Track Record – Cylindrical Units

6 Floating Production Units

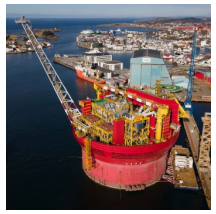

Piranema Spirit


Excalibur


Petrojarl Kong


Goliat


Western Isles


Penguins

4 Drilling Units


Sevan Driller


Sevan Brasil


Sevan Louisiana


Sevan Developer

2 Accommodation Units


Arendal Spirit


Stavanger Spirit

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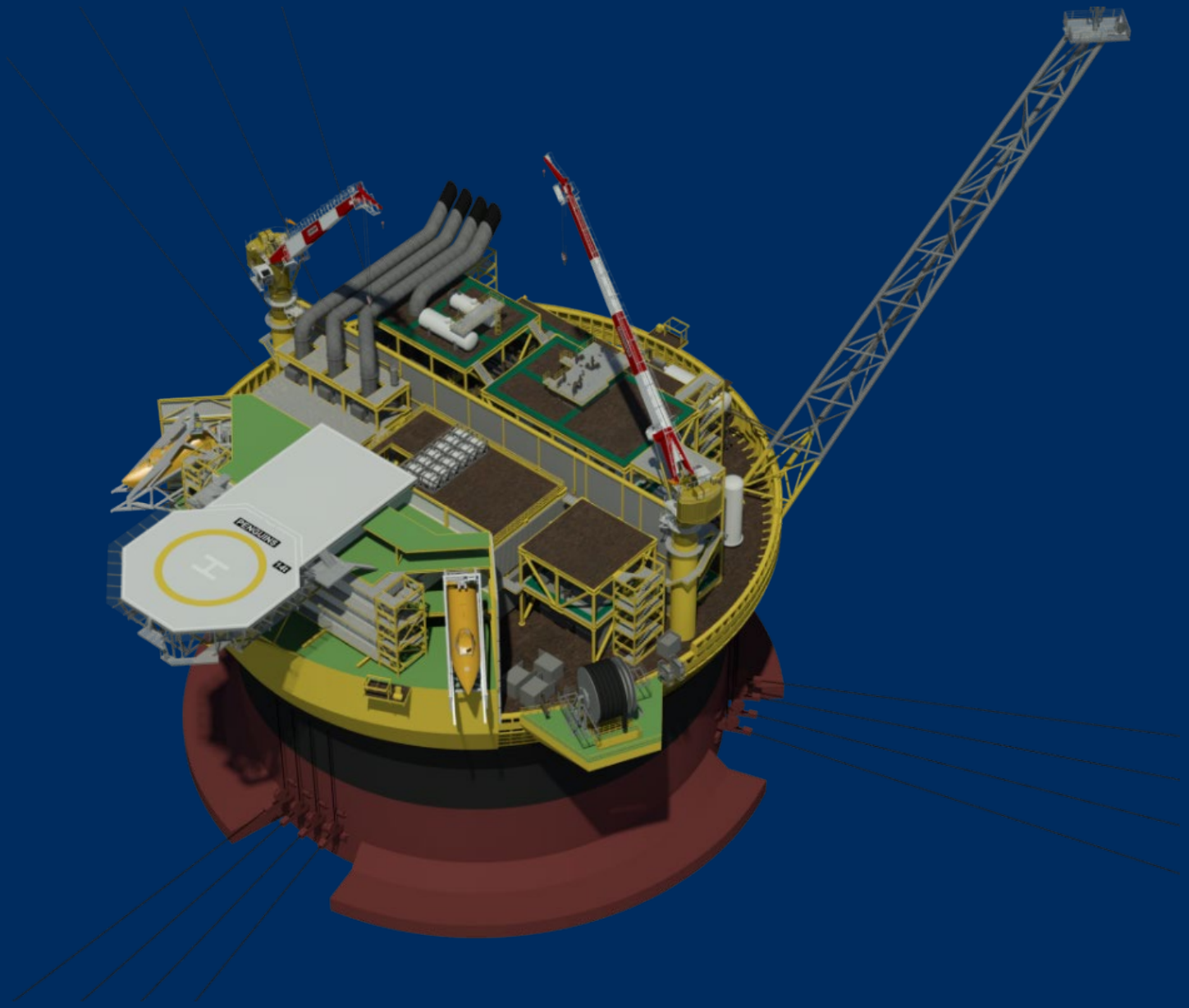

Chapter 2

Sevan standard mooring system design

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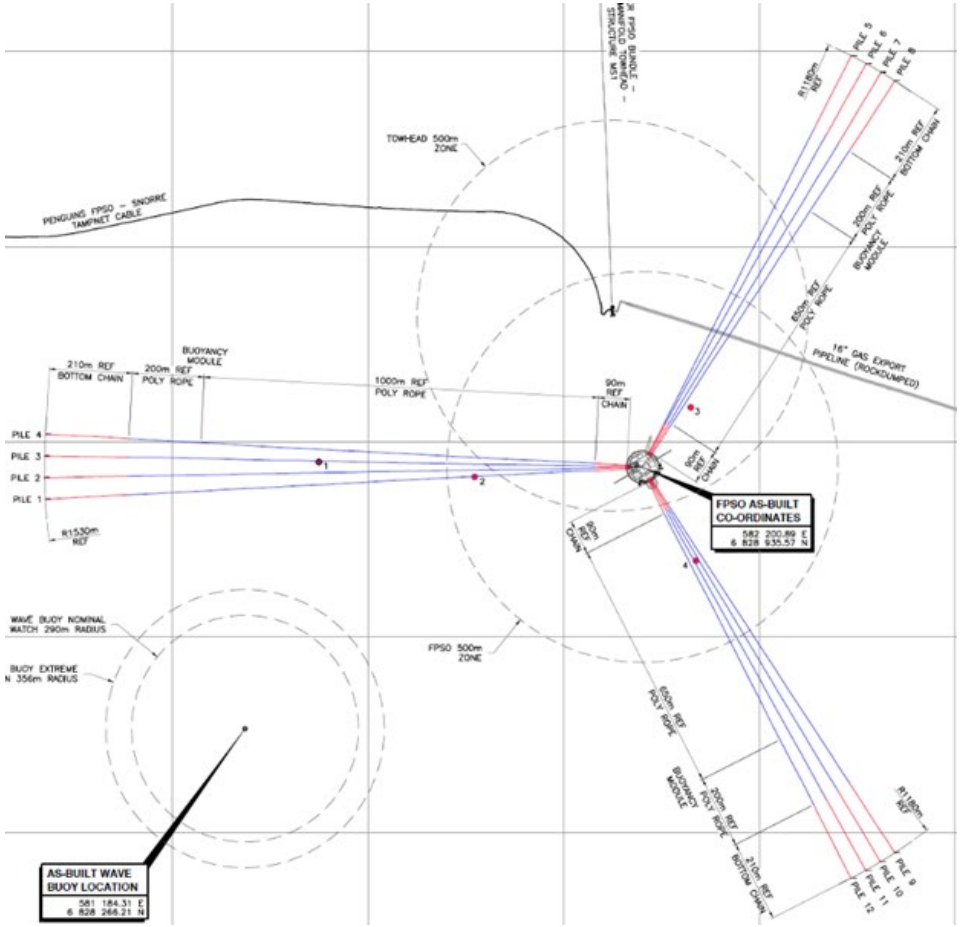
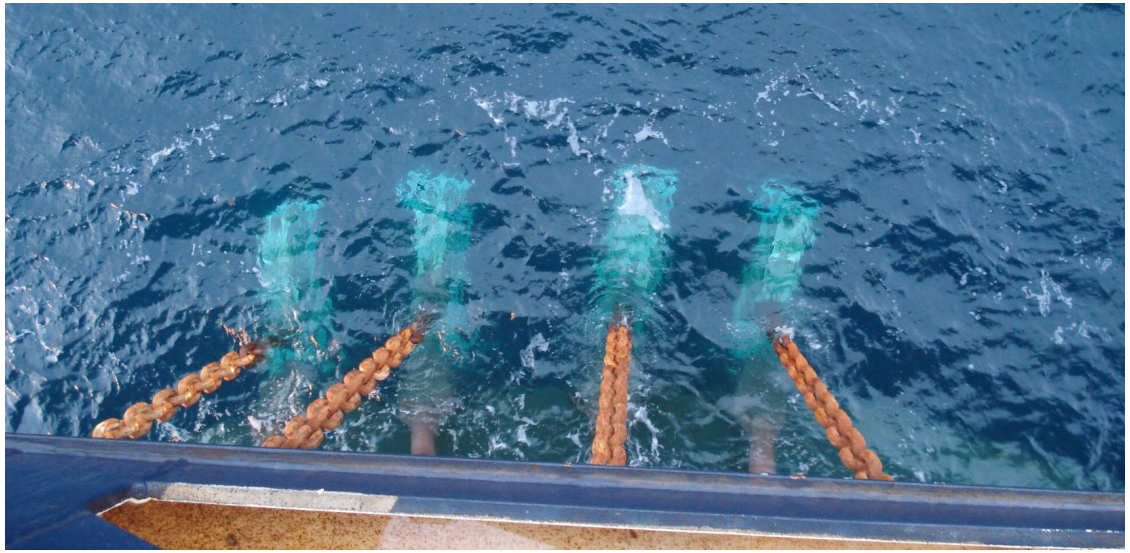
Sevan cylindrical floaters standard mooring design



- ✓Passive mooring system
- ✓3 clusters with 4-6 mooring lines each
- ✓Anchor – bottom chain – polyester – top chain
- ✓Midline buoyancy in shallow water depths



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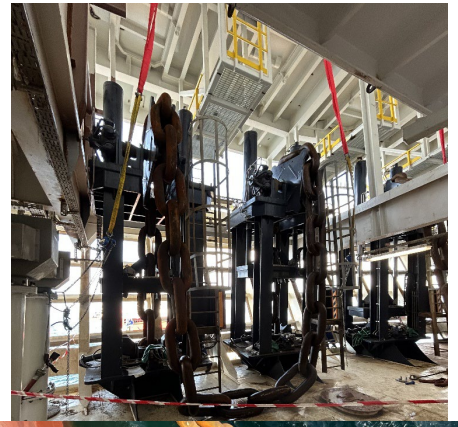
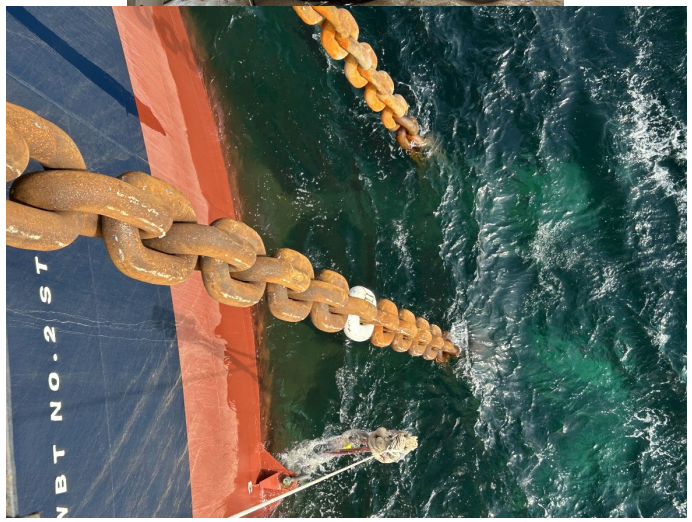
Three variations of mooring equipment

Voyageur





Goliat

Western Isles

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Chapter 3

Penguins mooring design

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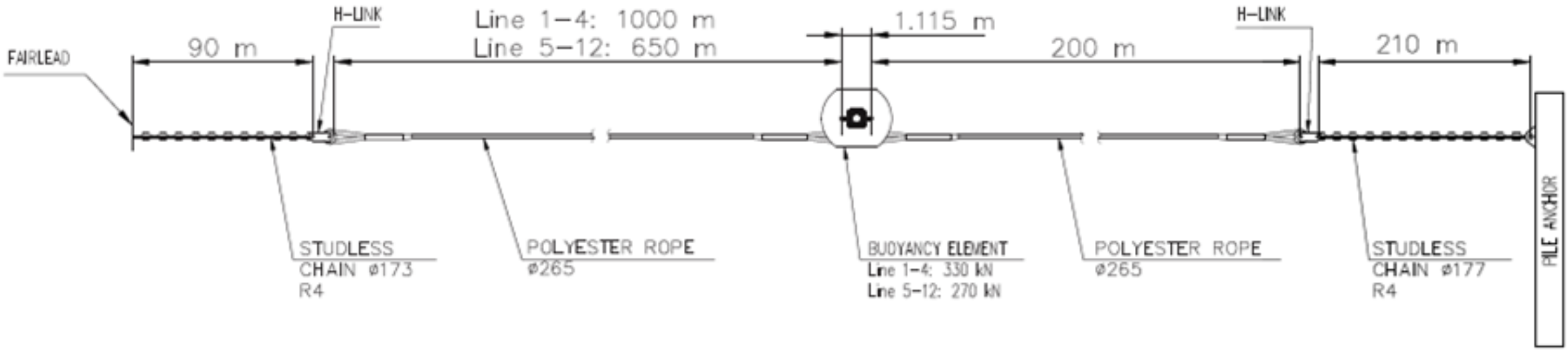
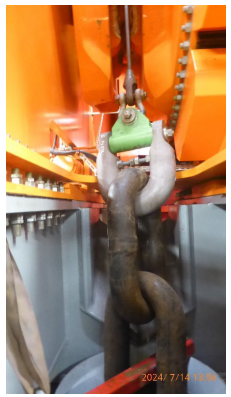
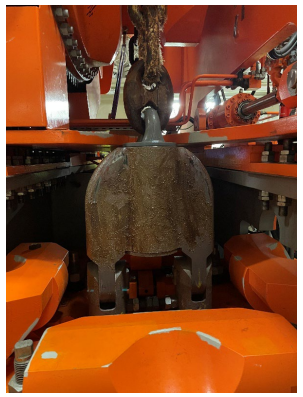
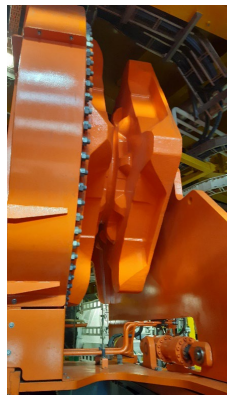
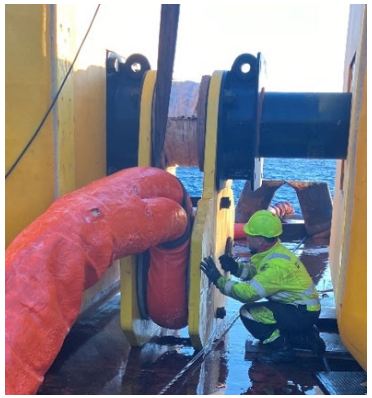
Penguins mooring design

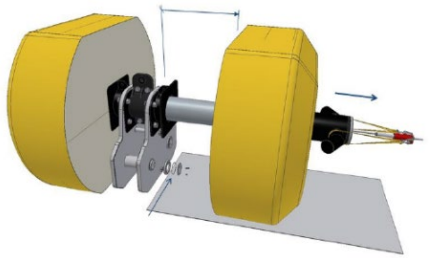












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Chapter 4

Winch design and FAT checks

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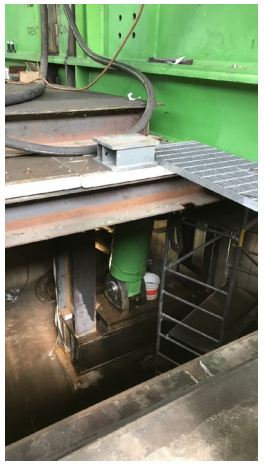
Mooring winches

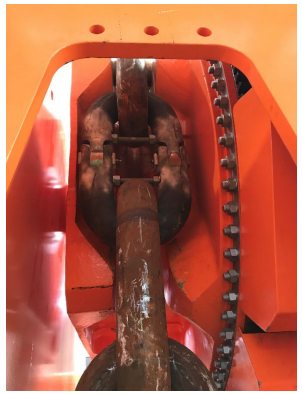
173mmtop chain

- ✓ Outer 5 pockets
- ✓ Stalling capacity : 4000kN
- ✓ Nominal pull capacity : 3500kN

52mm installation chain

- ✓ Inner 10 pockets
- ✓ Stalling capacity : 2281kN
- ✓ Nominal pull capacity : 2000kN





Standard DNV test program:

- ✓ Wrap test
- ✓ Stalling test
- ✓ Brake test

Project additional test:

- ✓ 200Te dynamic pull test on the 52mm installation chain.
- ✓ Test was performed with only 0.8m travel available on the cylinder

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Chapter 5

Mobilisation chain loading issues

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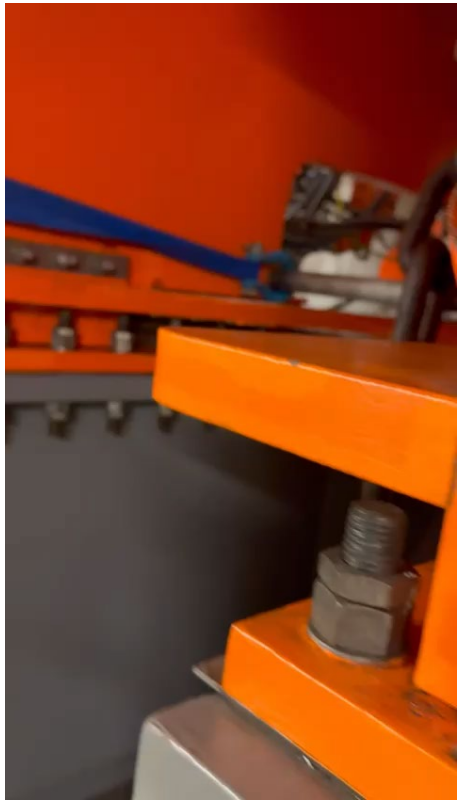
FPSO mobilisation

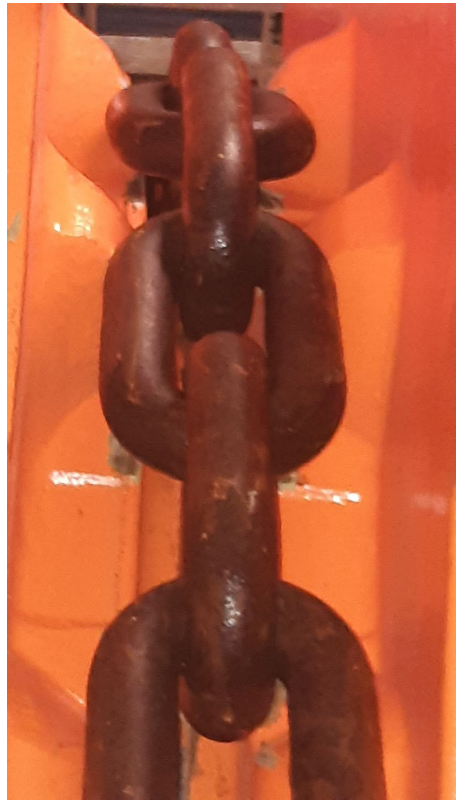
Original mobilisation planning

- ✓ Original plan: Load chains and run winch tests at building yard → had to be abandoned due to COVID travel restrictions
- ✓ Delay in commissioning priorities → winch testing on critical path



Initial chain loading for sail away

- Loaded 2x chains through hawse pipes over winch into chain lockers
- Chains were "sticky" when heaving in with some outboard back tension
- Chain started climbing the gypsy on pay out with no possibility to engage the links in the pockets
- Chain loading abandoned after 2 chains. Vendor called in to initiate rectification program



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Chapter 6

Corrective actions to mooring winches

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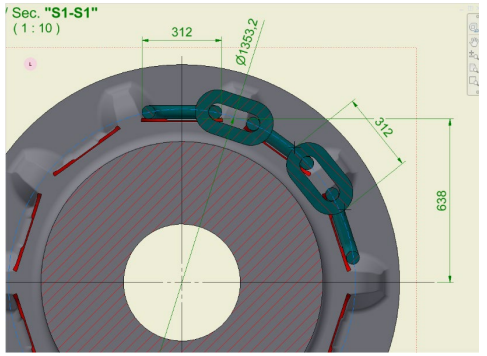
Baseline Checks

- ✓ Detailed dimension verification of test chain and comparison with loaded chain by Norwegian Mooring
- ✓ Analysis of detailed DNV manufacturing measurement reports for deriving exact tolerance band of loaded chains (and all other installation chain)
- ✓ Checked gypsy drawings and design tolerances
- ✓ Measurements of as built pocket radius and calculate the effect on chain engagement with actual dimensions of delivered chain



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Max. 5+5 links	**31**	**54.2%**
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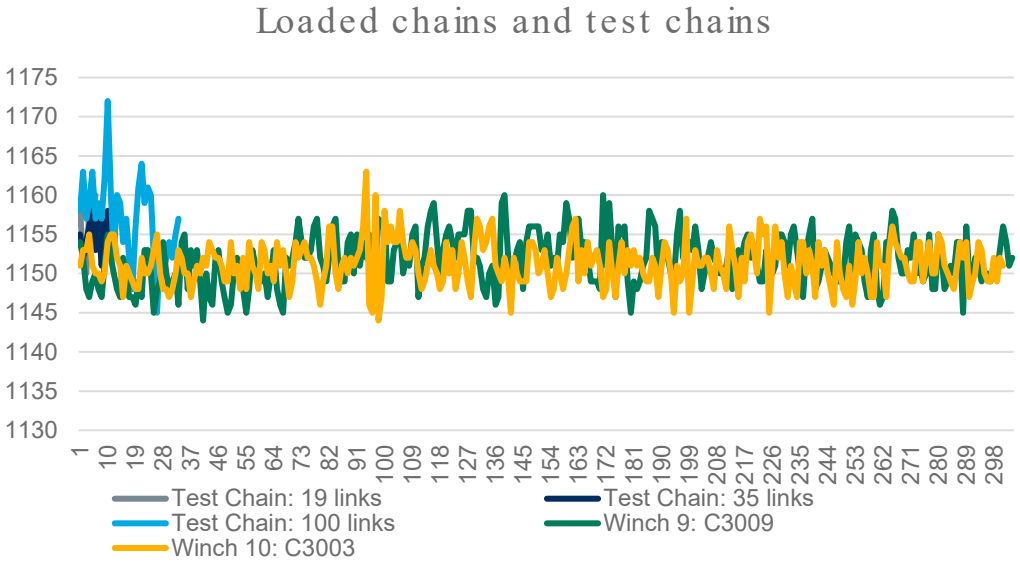

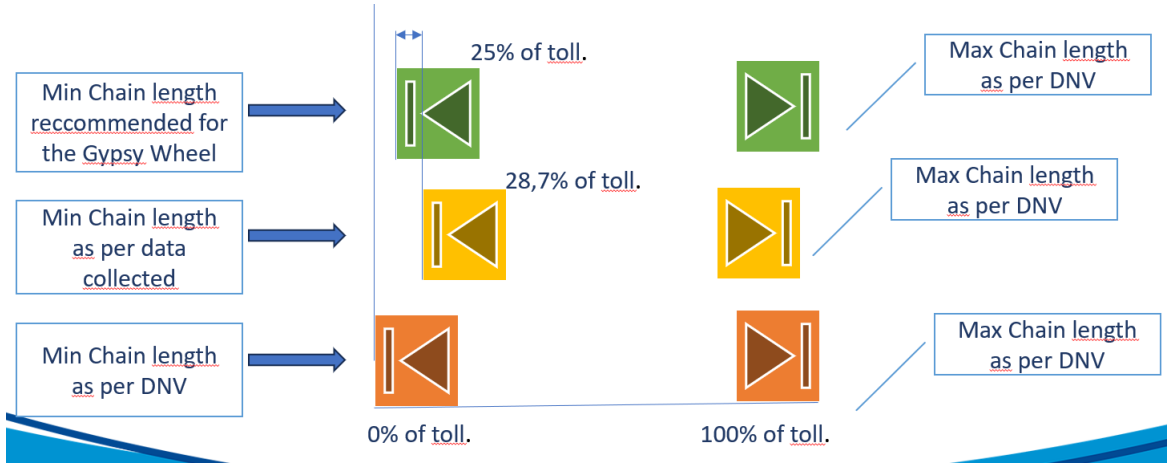

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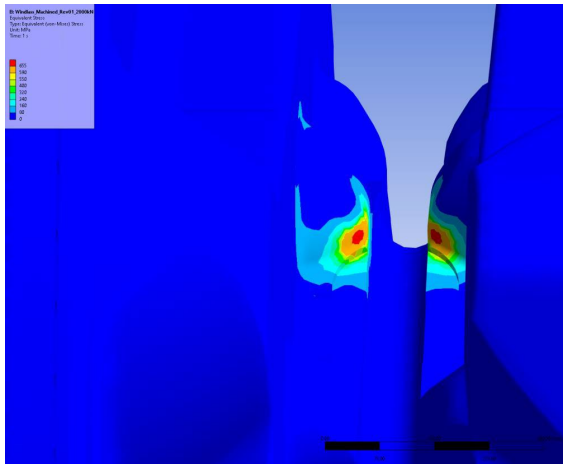
Engineering of corrective actions

A. Stretch installation chain to meet the required length to fit the gypsy pitch

B. Reduce the gypsy pitch to meet the chain tolerances ASTM F765-93 rule chapter 9

9.3 The dimensions of the wildcat may be reduced by chipping, grinding, or air-arc cutting for an acceptable chain fit. If air-arc cutting is used, not less than the last ⅛ in. (3 mm) of material shall be removed to a smooth contour by grinding. Do not use flame cutting.



- ✓ Develop a method for dimensional control of the winch by establishing a reference frame for gypsy pockets radius and the milling machine's exact alignment
- ✓ Design the ideal tolerance band for the delivered chains and document tolerances for future operations
- ✓ Check for hot spots and structural integrity when removing materials of the gypsy
- ✓ Get precise control over milling depth and angle on a rotating surface to maintain exact diameter

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Chapter 7

Offshore hook-up and lessons learned

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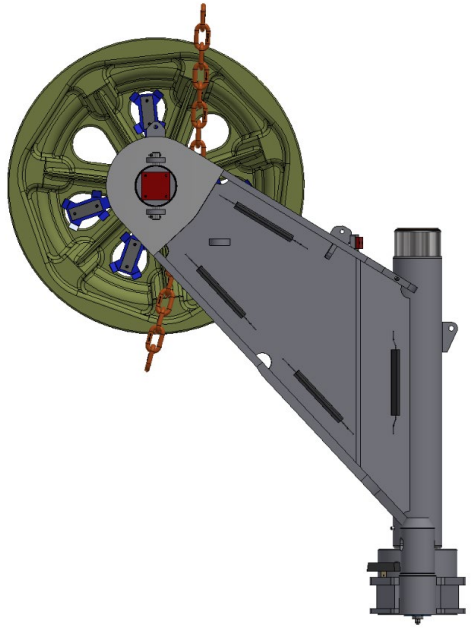
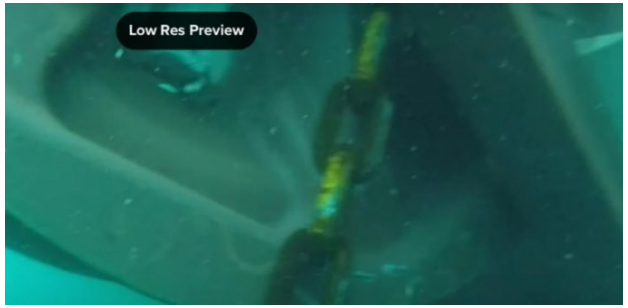
Installation chain issues

- ✓ Chain still slightly sticking and climbing gypsy under higher tensions (>150Te) due to high friction
- ✓ Fairleads won't swing out by a 'gentle' pull from the AHV with installation chain due to high fairlead weight, and the lever arm being near the turning axis
- ✓ Fairlead gypsy edges are 'square' which makes the 52mm chain to naturally climb out of the groove and ride on the edge → Concern for stressing the chain on the edges and shock loads when the connection link passes
- ✓ Gap between gypsy and fairlead frame just large enough to let pass the 52mm chain in between and getting jammed
- ✓ 173mm chains started to not engage in the gypsy pocket on pay out due to friction and little back tension





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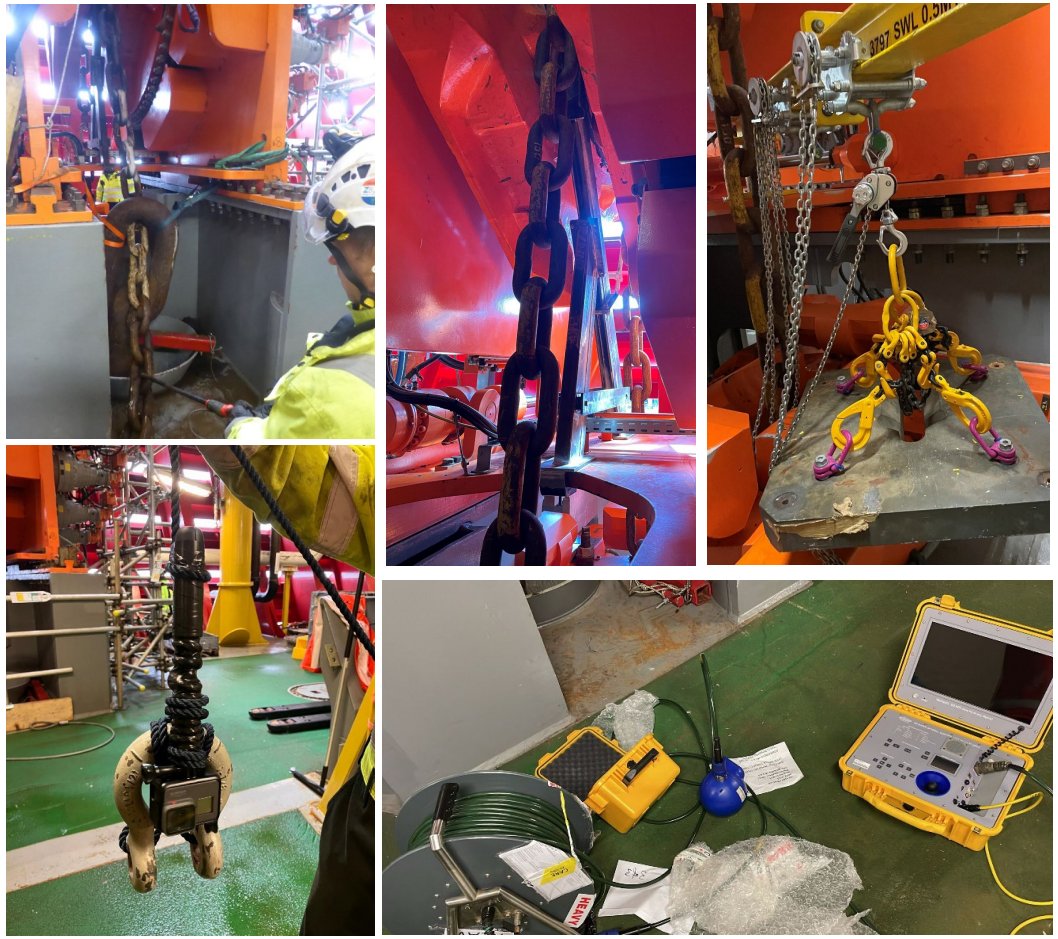
Immediate actions to proceed with hook up

- ✓ Sevan engineering (24/7) duty team started work on analysing causes and assist offshore team
- ✓ Pull sticky chains out with chain blocks
- ✓ Fabricate and install chain stripper
- ✓ Use temporary chain stopper to offload chain and re-engage in pockets
- ✓ Use an improvised friction set-up for getting chain engaged in pockets
- ✓ Pulled chain back into FL groove with AHV
- ✓ Heeling of the FPSO to swing out the fairleads on gravity
- ✓ Monitor the chain angle and engagement with inspection camera, adjust AHV position/tension to keep chain aligned and stop to adjust if climbing is starting
- ✓ Keep 173mm wet to reduce friction. When climbing is observed, close main chain stopper, take off tension and let the chain engage again



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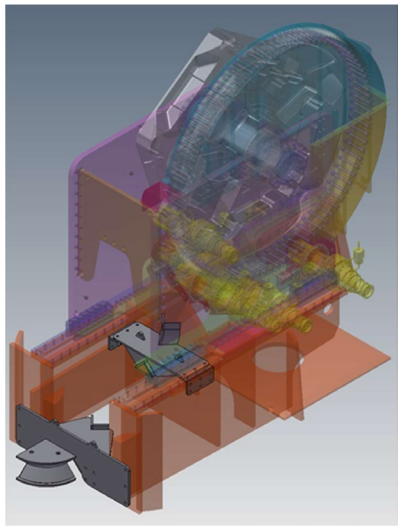
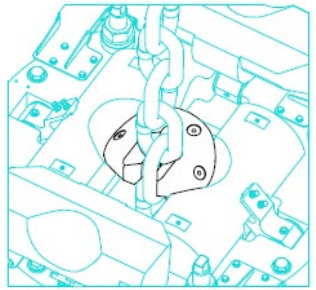
Long term solutions and lessons learned for future projects

- ✓ Improve temporary chain stopper design
- ✓ Design friction device for paying out on chain
- ✓ Design back-up chain pushing system to force chain into pockets
- ✓ Subsea inspection cameras to be mobilised to continuously monitor 52mm chain behaviour in fairlead





- ✓ **Fairlead** gypsy design to be checked for centering small chain into groove at all times
- ✓ **Fairlead** structure design to be checked for possibility of small chain passing gaps between frame and gypsy and add barriers before such gaps
- ✓ **Winch** gypsy's inner not - standard pockets to be manufactured to "exact" tolerances (machined)
- ✓ **Winch** for growing large - size chain pocket design to be re - visited to solve friction issues
- ✓ **Chain** manufacturing to exact defined tolerances according to gypsy design
- ✓ **Winch** rigorous dynamic testing program for small chain running in inner gypsy
- ✓ **General design** all non - standard solutions for chain handling to be carefully reviewed for possible consequences (f.ex. 10 pocket winches have 50% less tolerance for chain from normalDNV standards)

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Chapter 8

Mooring Integrity Monitoring

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At a Glance

inquire provides mooring integrity monitoring services incorporating numerical models and new or existing sensors to evaluate mooring system status versus operating limits and recommendations.

The system is built from the ground up with focus on performance for the specific parameters we, as mooring designers, find most important for integrity management of your mooring system.

Purpose of Mooring Integrity Monitoring

- Prevent mooring line failure
  - Manage potential causes: wear, corrosion, fatigue, design errors, manufacturing errors, installation errors, accidental damage, operational errors or any combination thereof
- Prevent excessive offset
  - Manage potential causes: design errors, manufacturing errors, installation errors, operational errors or any combination thereof
- Reduce need for and increase efficiency of inspections
  - Provide necessary input to risk-based inspection approach to inspect the correct component at the correct time

Underlined causes may be monitored using inquire.

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Main Features

- Present data
- Fatigue monitoring
- Virtual target
- Mooring model on demand

- Optimized database structure
- Responsiveness
- Full interface flexibility (no hardware to push)
  - We can team up with 3rd party, if required

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