DNV·GL

OIL & GAS

Umbilical and Power Cable Assessments Validation JIP

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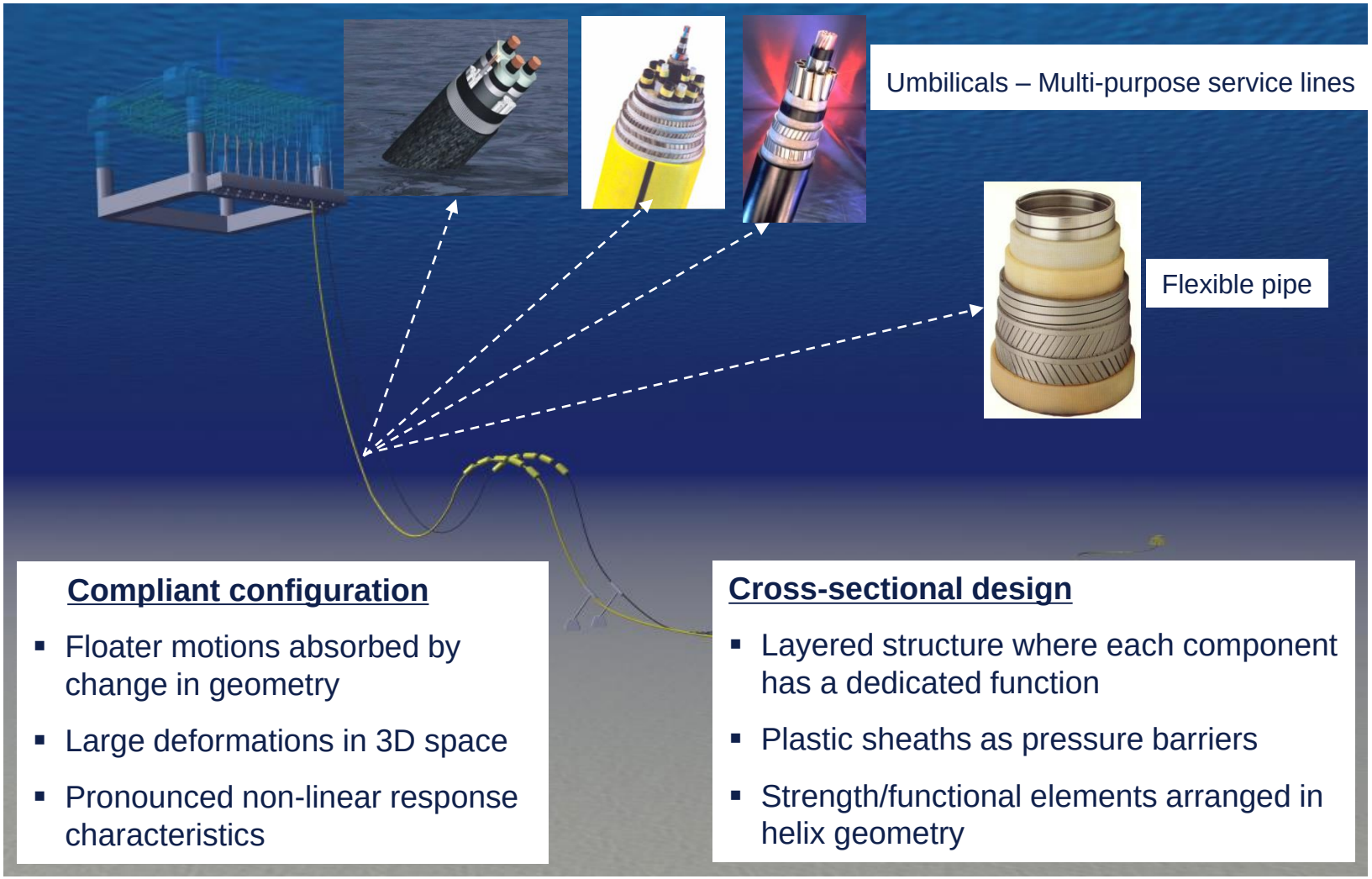
24 February 2020

DNV GL © 2013

Agenda

- Umbilical / Flexibles / Power Cables Design Overview
- DNV GL Tool for Strength and Fatigue Analysis – HELICA
- HELICA Validation – JIP
- Conclusion / Future Work
- Q & A

Flexible Pipes & Umbilicals



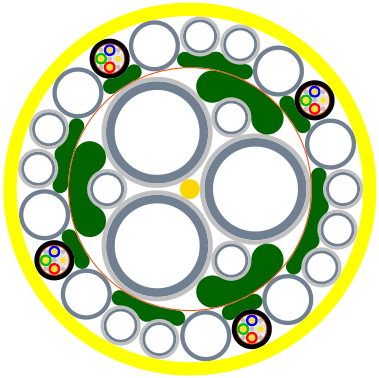
Compliant configuration

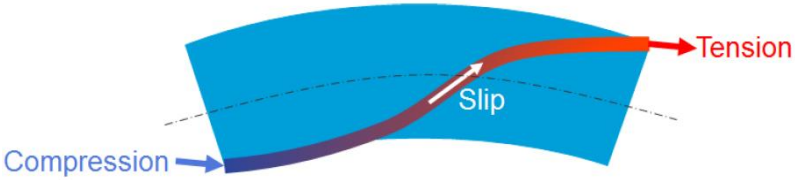
- Floater motions absorbed by change in geometry
- Large deformations in 3D space
- Pronounced non-linear response characteristics

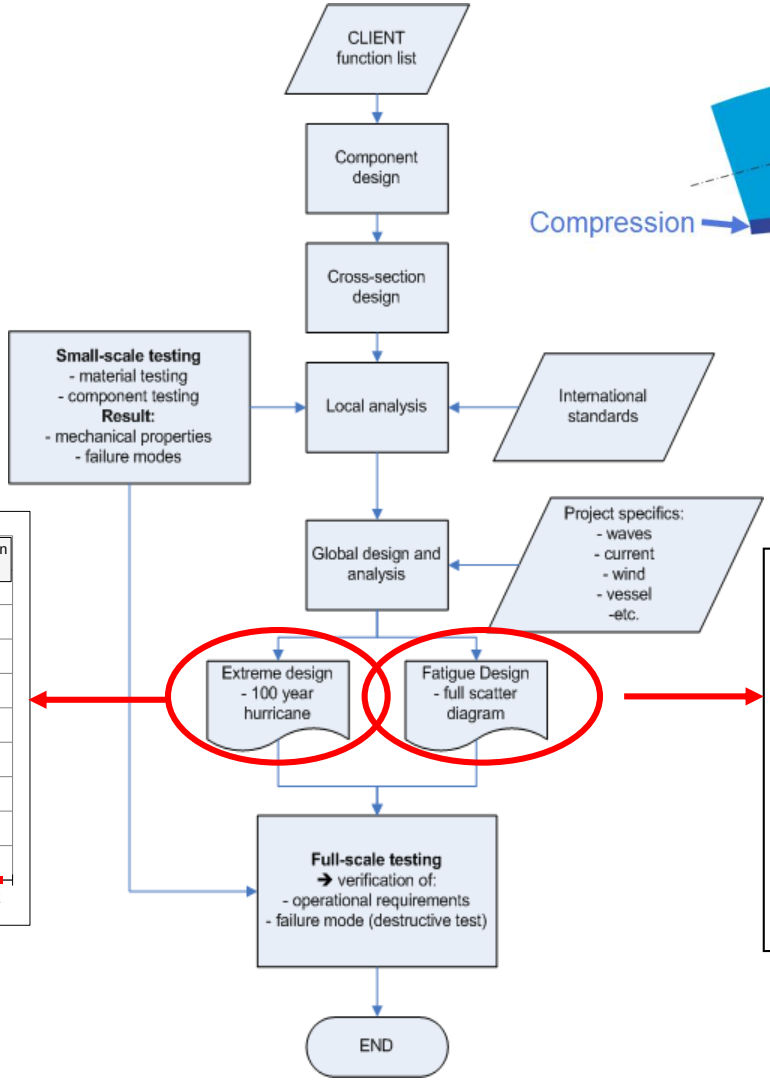
Cross-sectional design

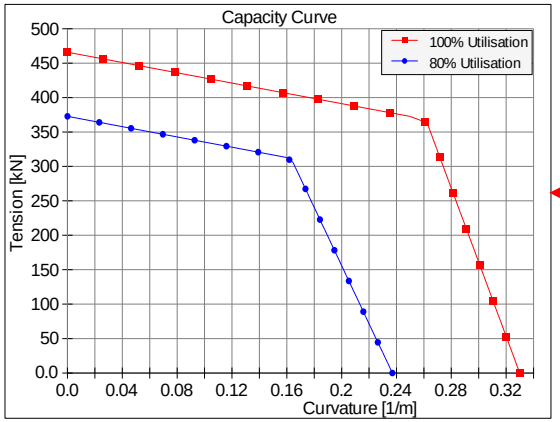
- Layered structure where each component has a dedicated function
- Plastic sheaths as pressure barriers
- Strength/functional elements arranged in helix geometry

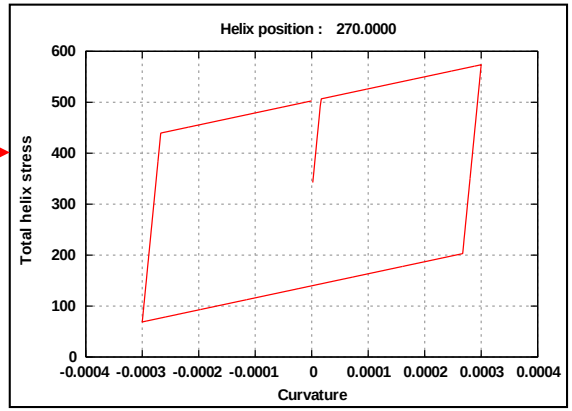
ISO 13628-5 Dynamic Umbilical Design Process











Typical Umbilical Analysis Tools:

Cross Section Design Tool

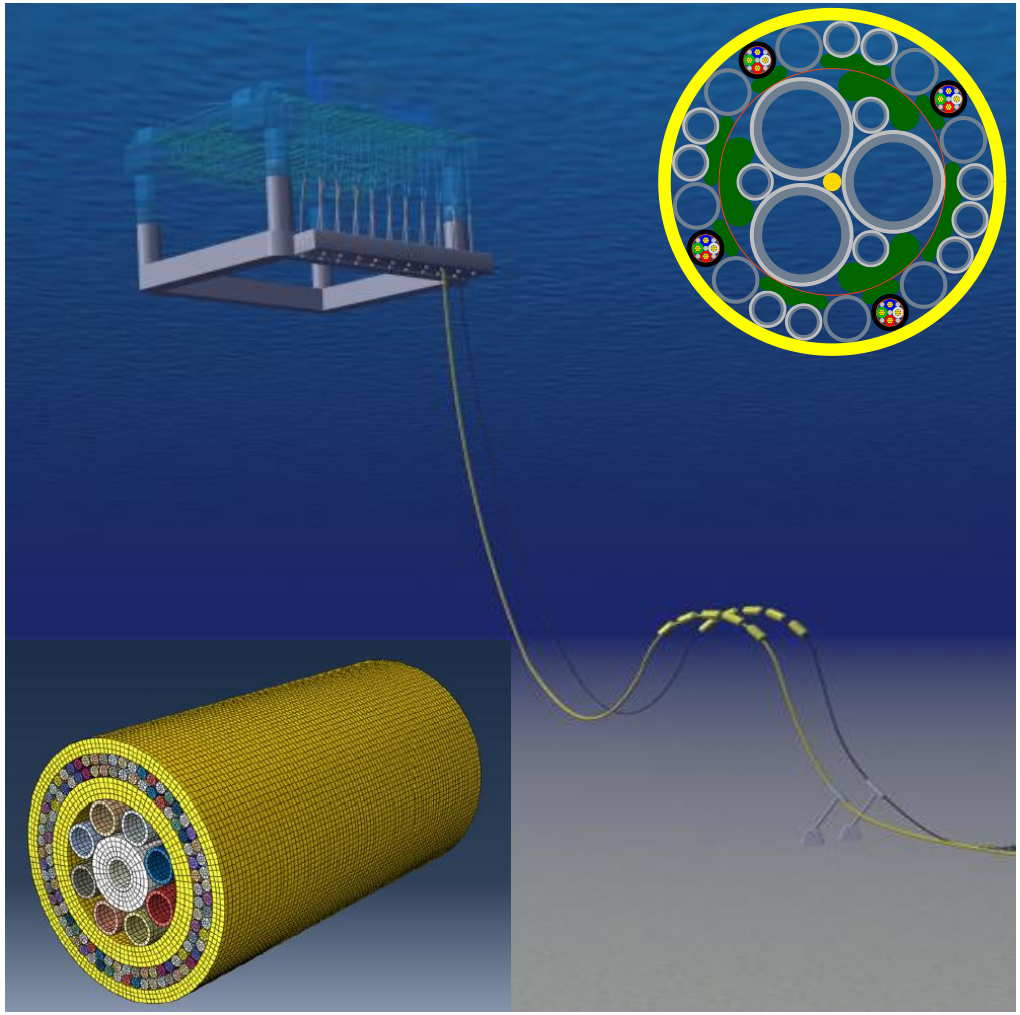
- CAD: UmbiliCAD
- HELICA
- Customized / Proprietary tools

Global Analysis Tools

- Orcaflex
- Flexcom
- DeepC (Riflex & Simo)
- Abaqus
- Other tools

Local Analysis Tools

- HELICA
- Abaqus
- Customized / Proprietary tools



Strength Design – ISO 13628-5

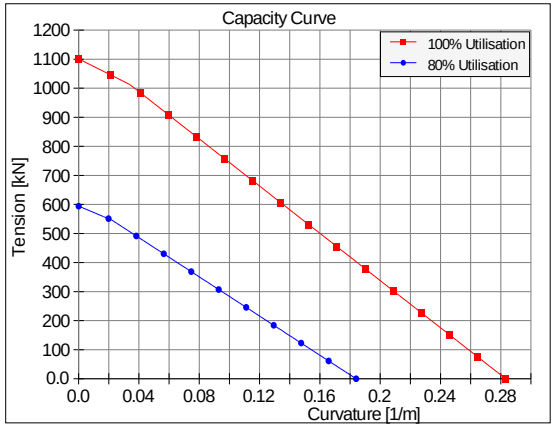
- ISO 13628-5: Umbilicals to be designed in accordance with the von Mises stress norm:

$$\sigma_e = \frac{1}{\sqrt{2}} \cdot \sqrt{(\sigma_h - \sigma_a)^2 + (\sigma_a - \sigma_r)^2 + (\sigma_r - \sigma_h)^2 + 6\tau^2}$$

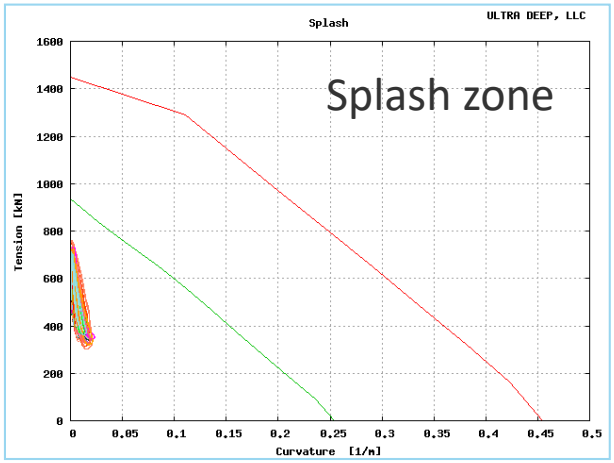
  - where:

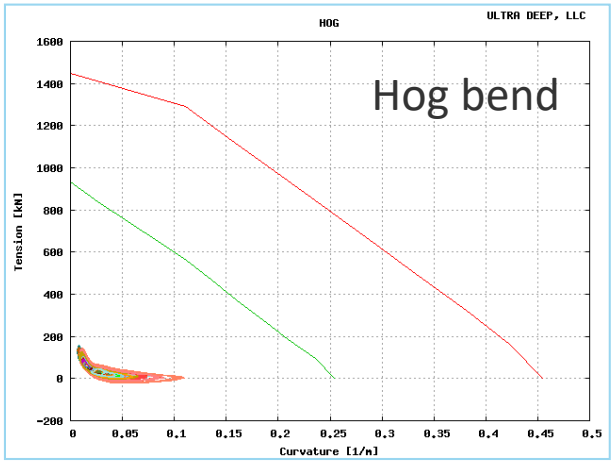
σ_a	-	axial stress
σ_h	-	hoop stress
σ_r	-	radial stress
τ	-	shear stress ($\tau^2 = \tau_{ah}^2 + \tau_{ar}^2 + \tau_{hr}^2$)

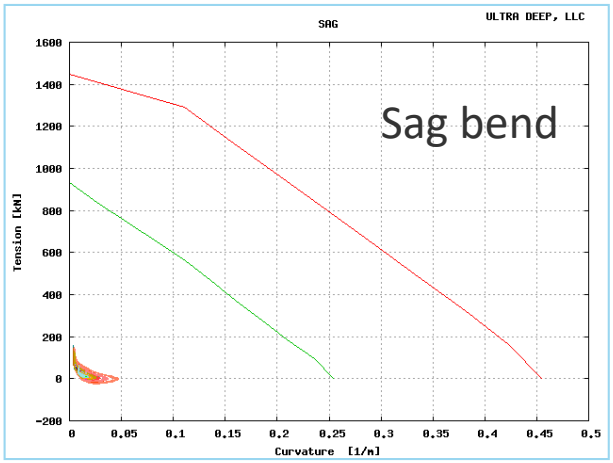
- The capacity curve presents all load combinations that result in the specified maximum allowable equivalent stress due to:
  - Tension
  - Pressure
  - Bending
  - Torsion
- All cross-section members are considered

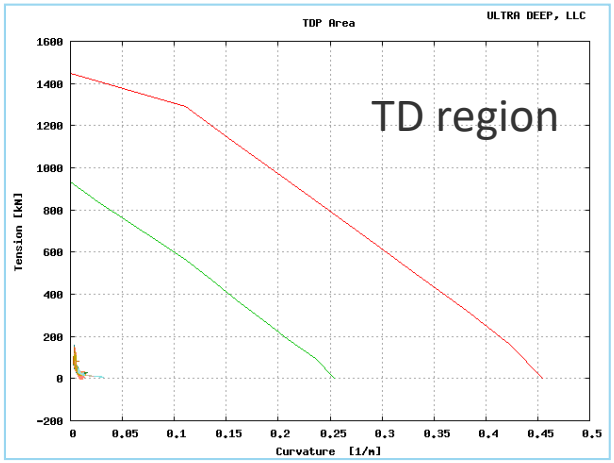


Practical use of the capacity curve









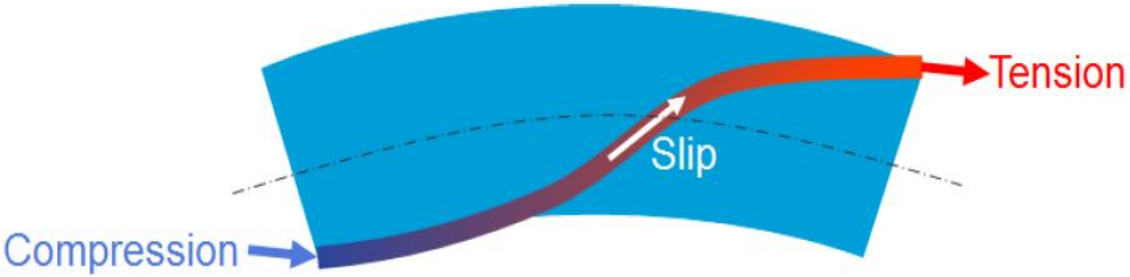
Assessment Challenges

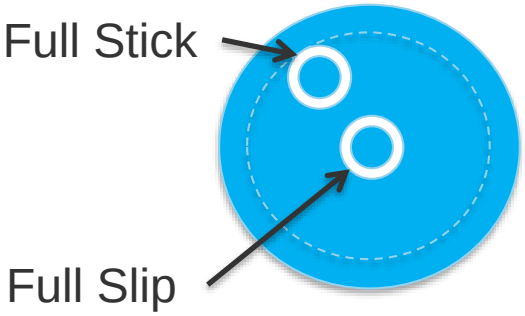
- Strength/functional elements arranged in helix geometry
- Slip of helix elements in bending to release stresses is essential to obtain the required high bending flexibility
- Complex fatigue stress picture due to the stick/slip bending
- Fatigue governing design criterion for many applications

Common Industry Practice

- Straight Tube Analogy
- Ignore stick/slip behaviour
- Full slip or Full Stick

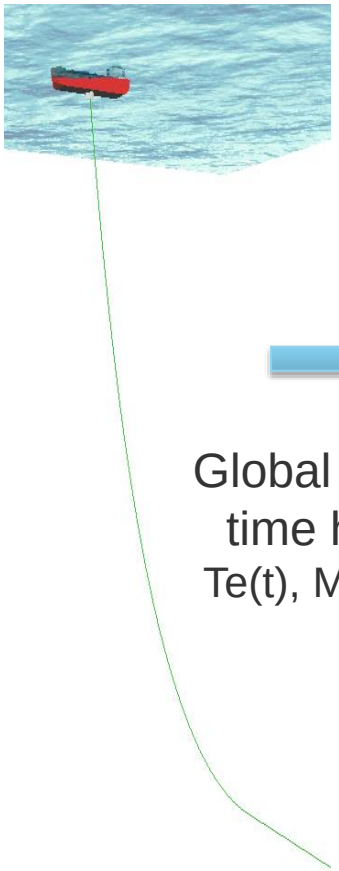
Full Slip: Non-conservative
Full Stick: Conservative





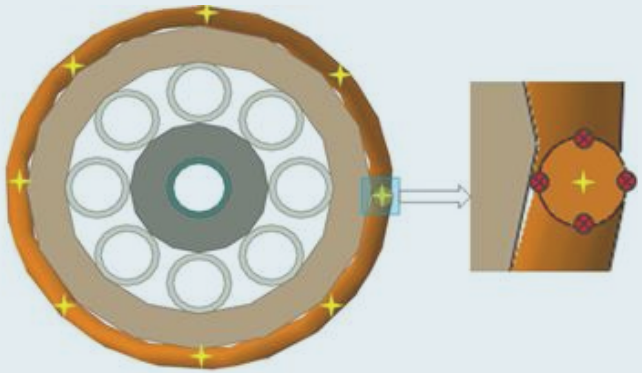
Consistent Helix Stress Calculation

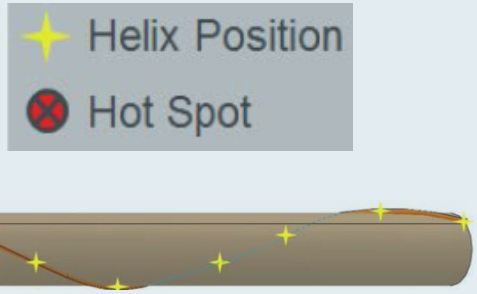
Global Model



Global response time histories
Te(t), My(t), Mz(t)

Local Model

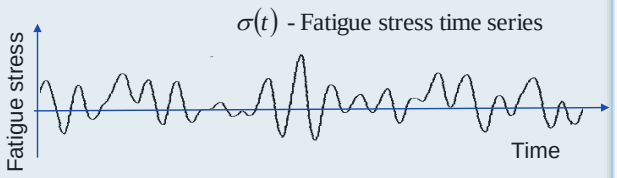


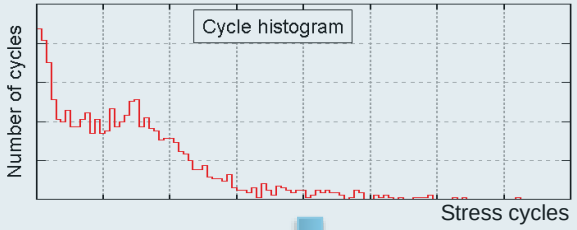


Helix Position
Hot Spot

DNVGL Tool - HELICA

Fatigue Stress

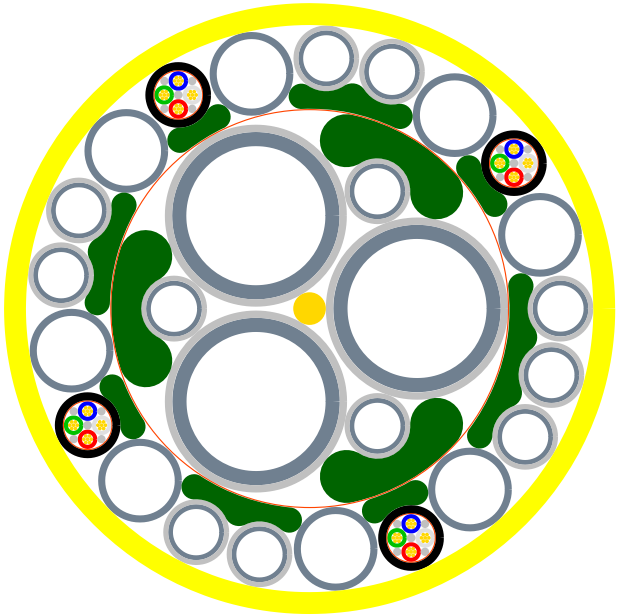




Short term fatigue damage for all hot-spots and helix positions

HELICA – Key Features

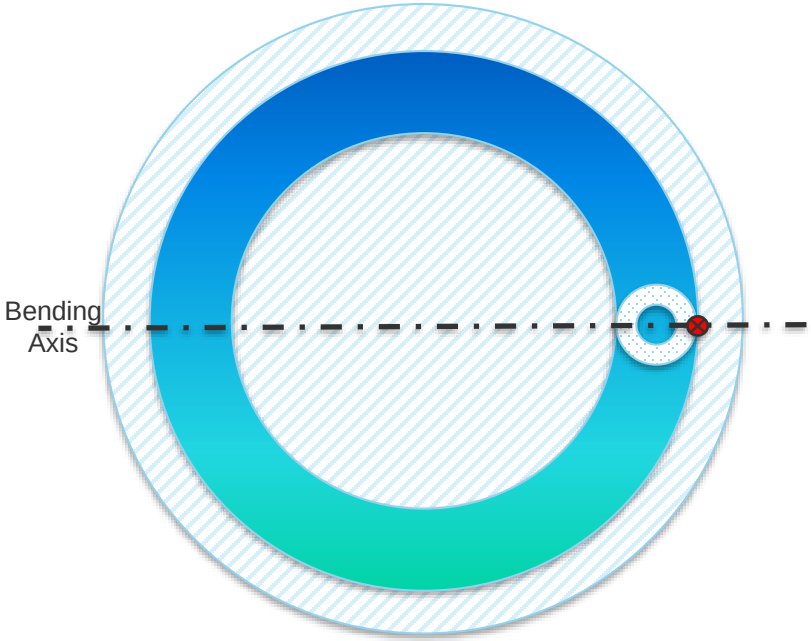
- Based on published analytical formulation
- Applicable to umbilicals, flexible risers and similar unbonded structures
- Efficient analysis scheme
- Stick-slip behavior of helix elements in bending
- External loading application capability
  (global response time series)
- Short-term fatigue life including RFC
- Long-term fatigue life calculation



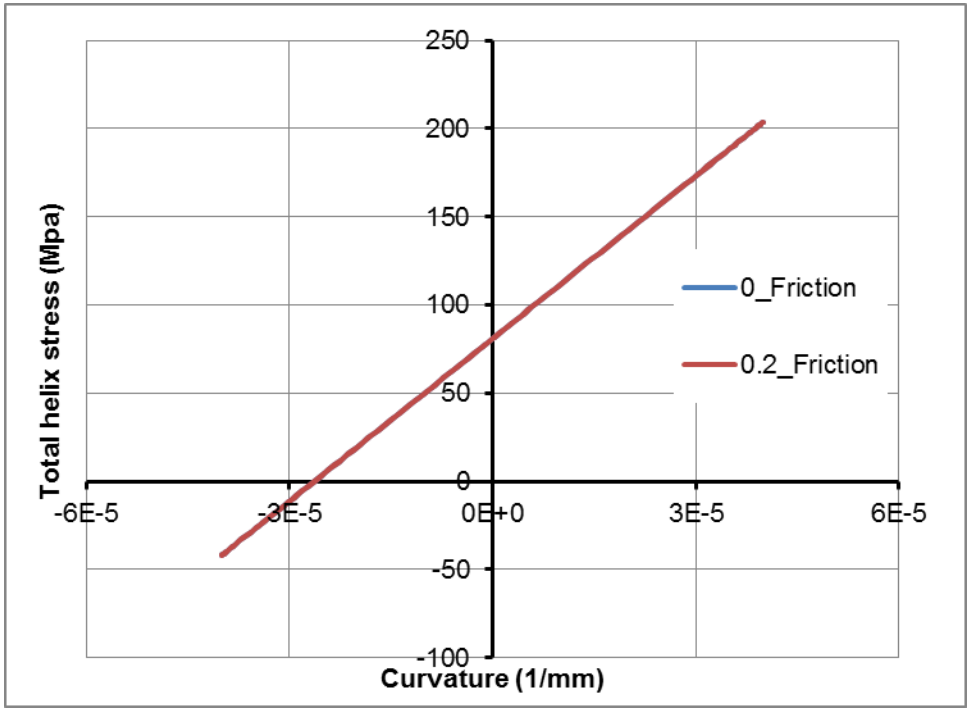
Compatible with UmbiliCAD®
By Ultra Deep LLC

Funded and developed by DNVGL

Illustration of Bending Hysteresis



Helix position = 0 deg
Hot-spot = 0 deg



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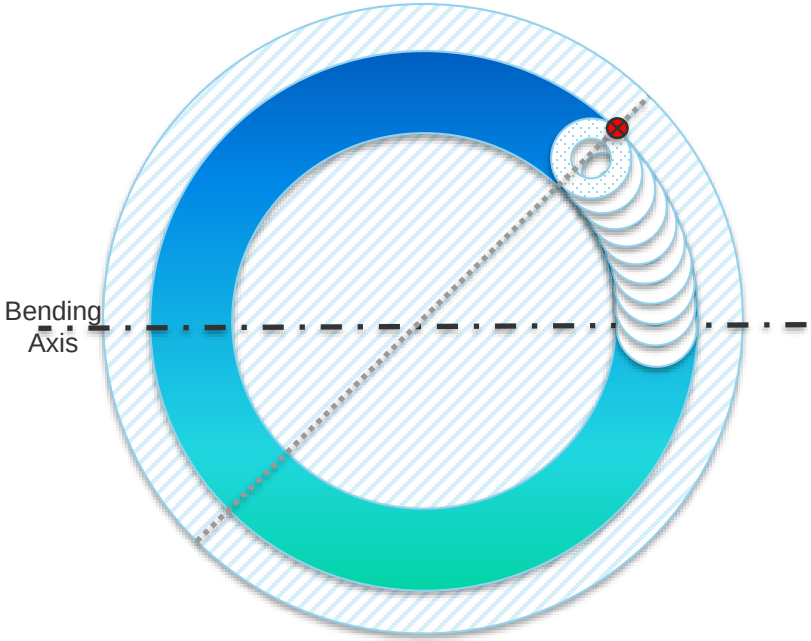


Helix position = 45 deg
Hot-spot = 0 deg

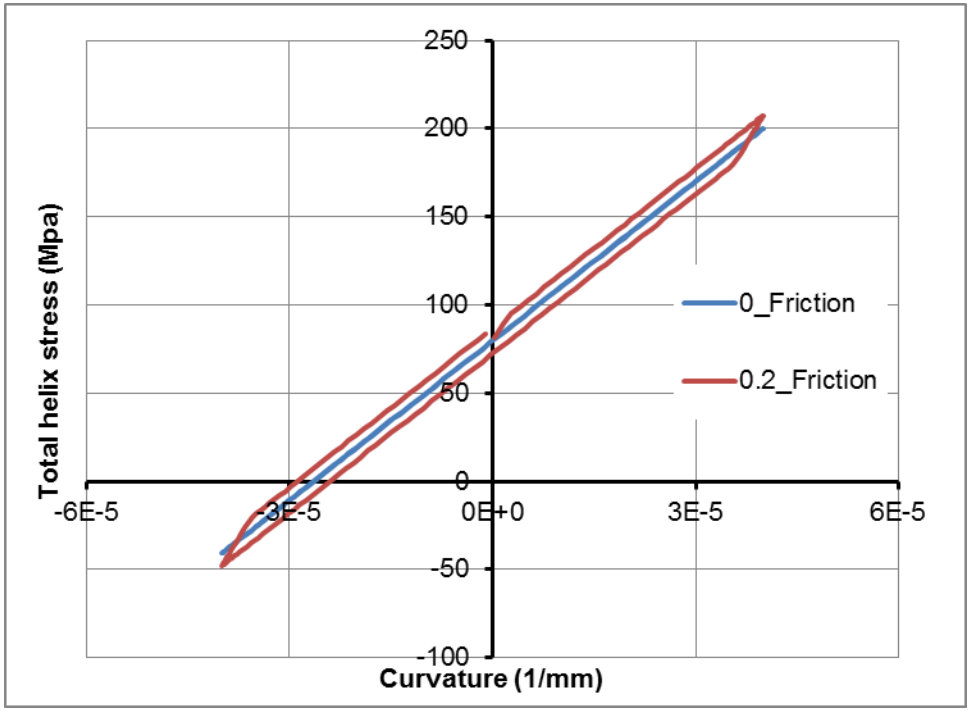
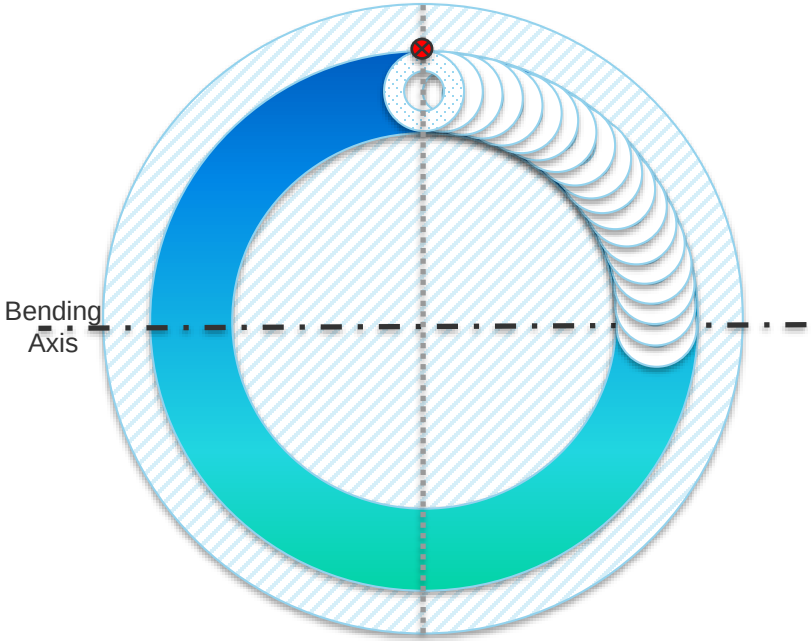
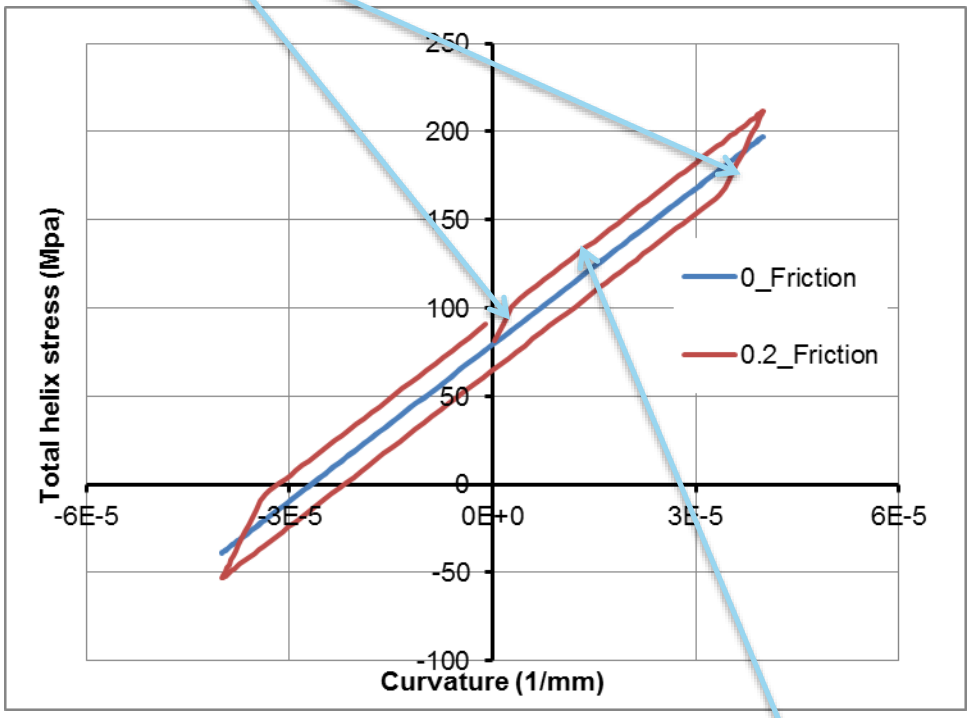


Illustration of Bending Hysteresis



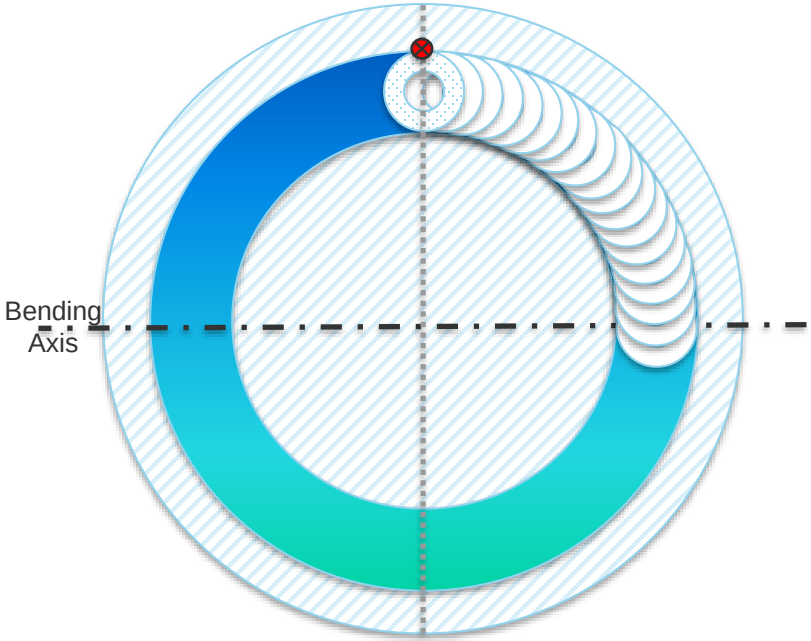
Helix position = 90 deg
Hot-spot = 0 deg

Stick

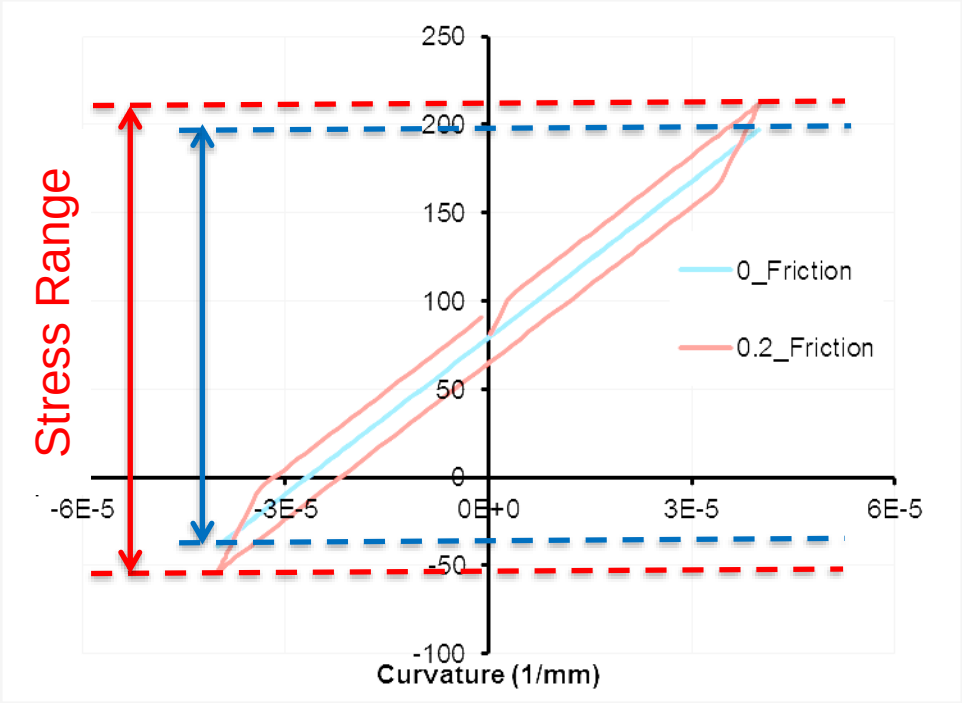


Slip

Illustration of Bending Hysteresis



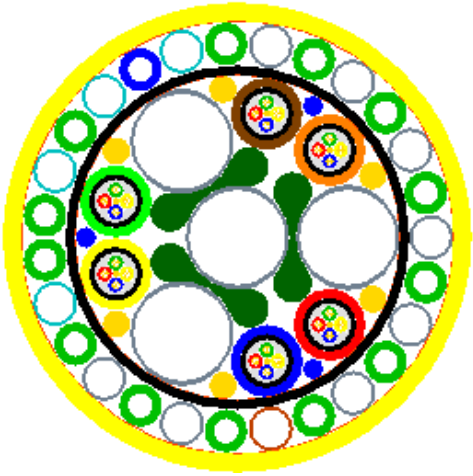
Helix position = 90 deg
Hot-spot = 0 deg

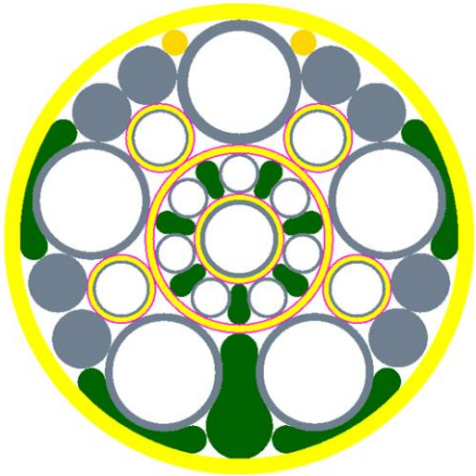


Full Slip Stress range ~ 240 MPa
Stick-Slip (μ=0.2) Stress range ~ 265 MPa

HELICA validation JIP

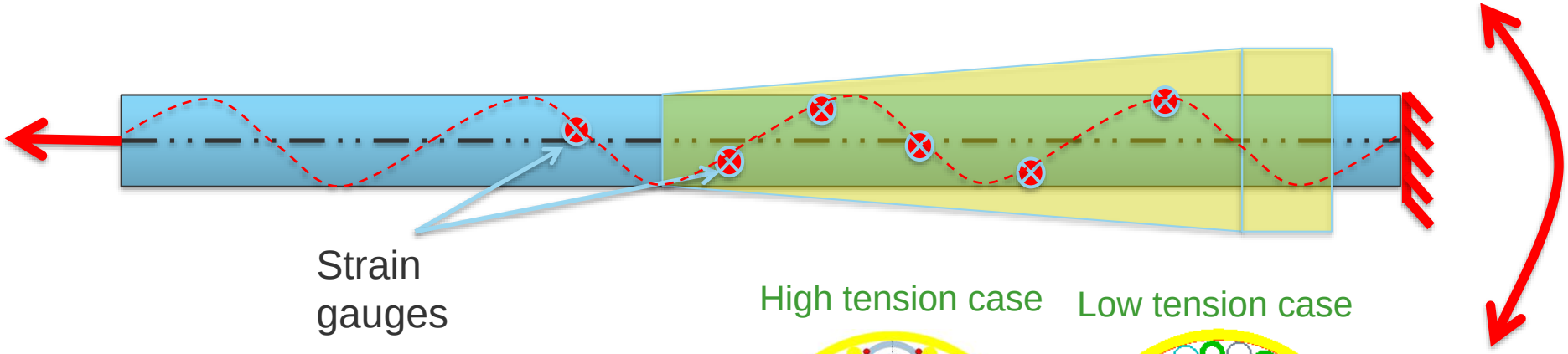
- Participants :



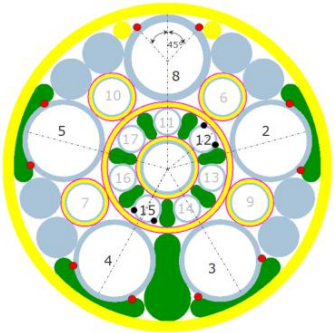


- Objective : Validation of umbilical stress calculation
- Validation basis: High quality bending tests of steel tube umbilicals
- Completed and work published (2018)

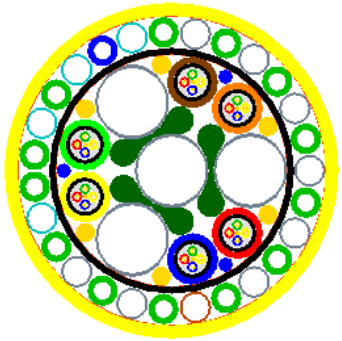
HELICA Validation: High Quality Test Data - JIP



High tension case



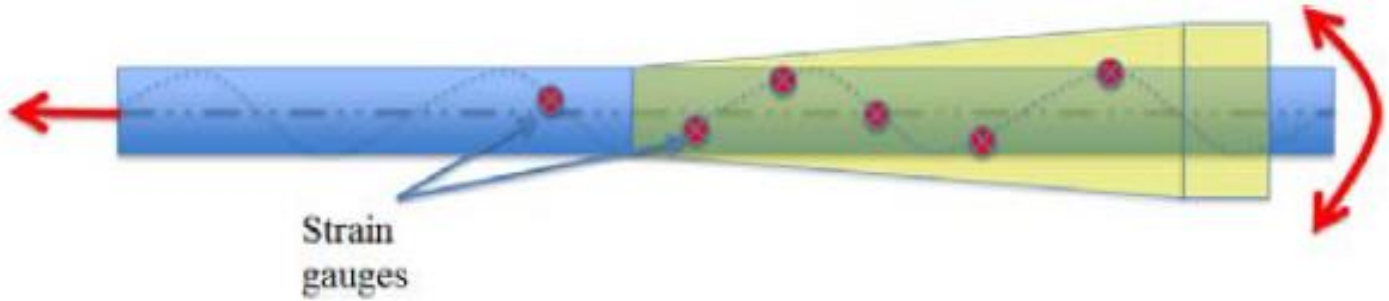
Low tension case



Test ID	Water depth	Tension	Cyclic rotation
Low-tension	500 m	54 kN	17 deg
High-tension	1200 m	235 kN	17 deg

- Steel tube umbilicals manufactured by Oceaneering
- Test performed by TMT on behalf of ExxonMobil

Instrumentation



- The strain gauges are attached to the umbilical tubes during manufacturing
- The strain gauge readings are recorded during the full-scale test.
- The strain gauge locations, orientations and positions are recorded manually during dissection of the umbilical test sample after conclusion of the full-scale test.

- High level of accuracy and detailed planning required.
- Results very sensitive to sensor location

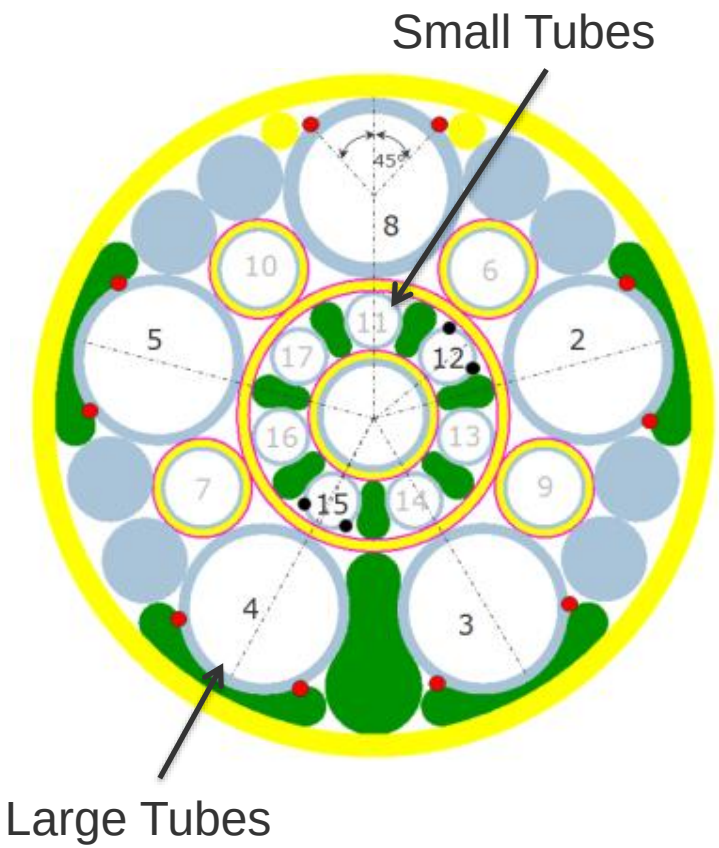
Dynamic flex fatigue test

- Flex fatigue load case matrix:

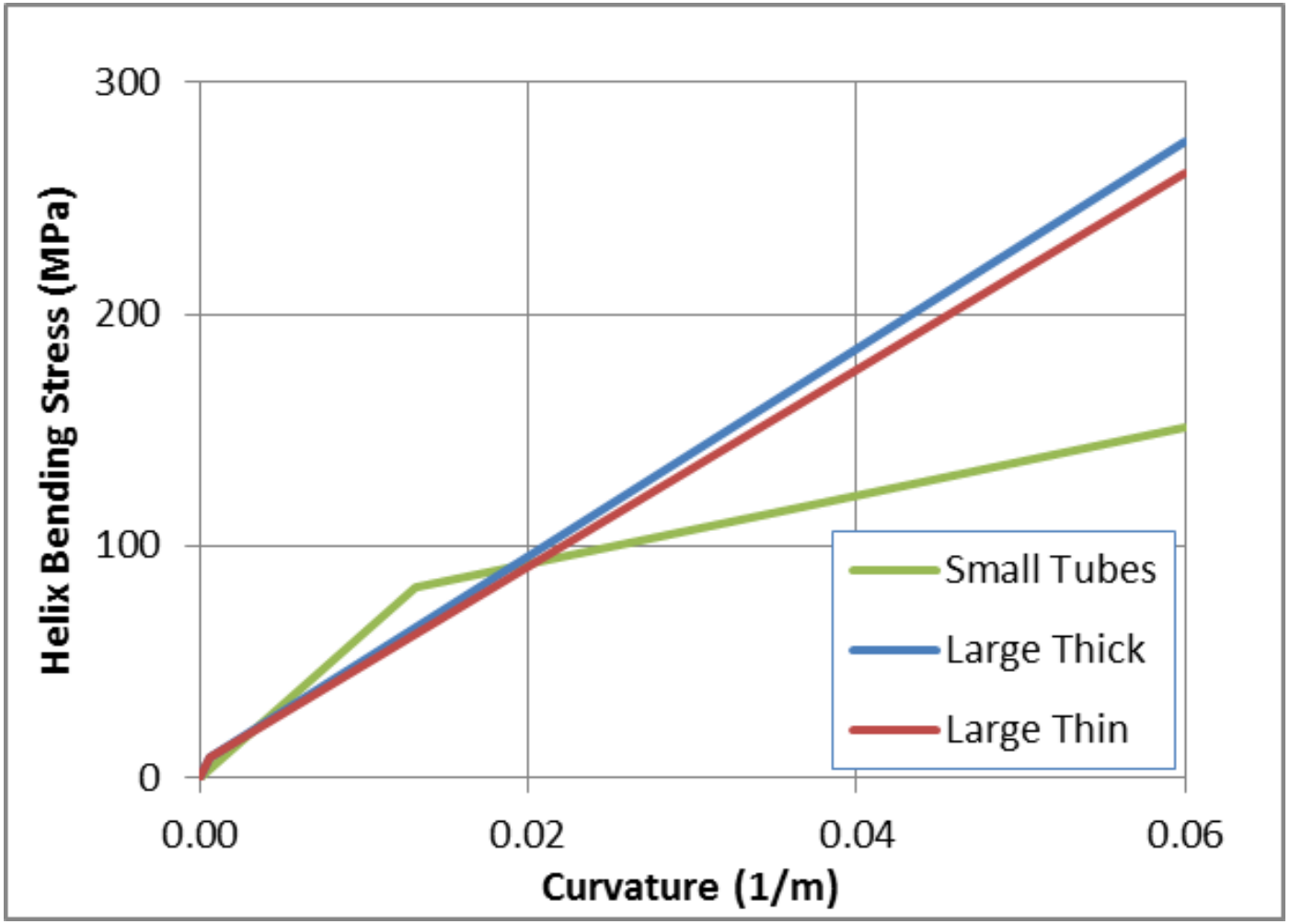
Phase	Tension (kN)	Angle (deg)	# Cycles
1	234.5	±2, ±4, ±6	564,000
2	234.5	±5, ±7	160,200
3	234.5	±10, ±12	152,840
4	234.5	±17	88,840

- For ±17 deg,
  - Small tubes: lower stress range (~250 MPa)
  - Large Tubes: higher stress range (~450 MPa)

- Flex fatigue test result:
  - Small tubes failed before large tubes!



HELICA results Tension = 234.5 kN, Tube Orientation = 90°



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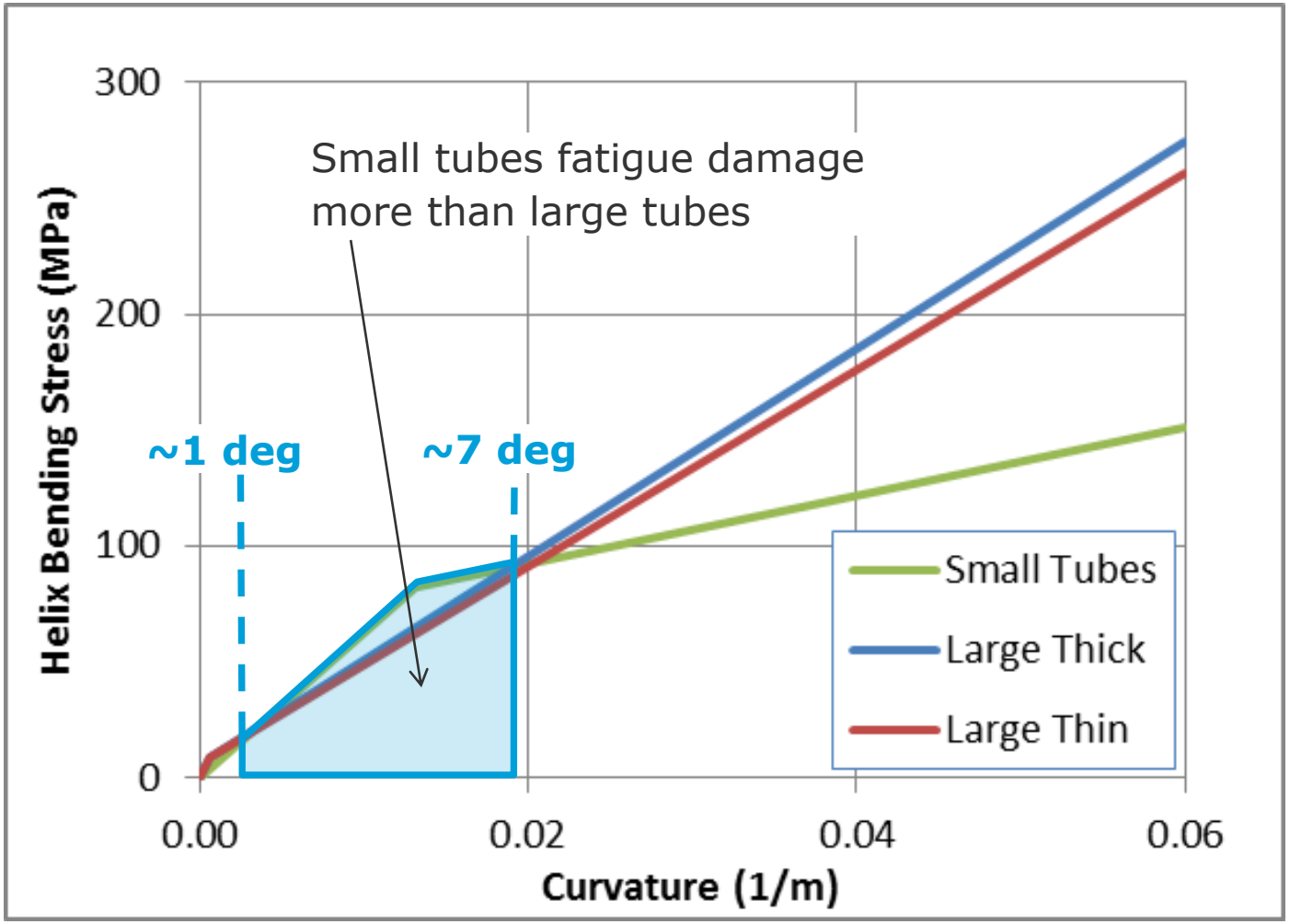
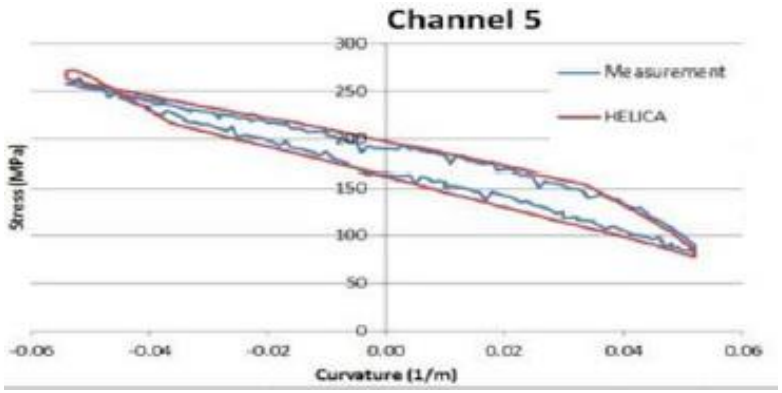
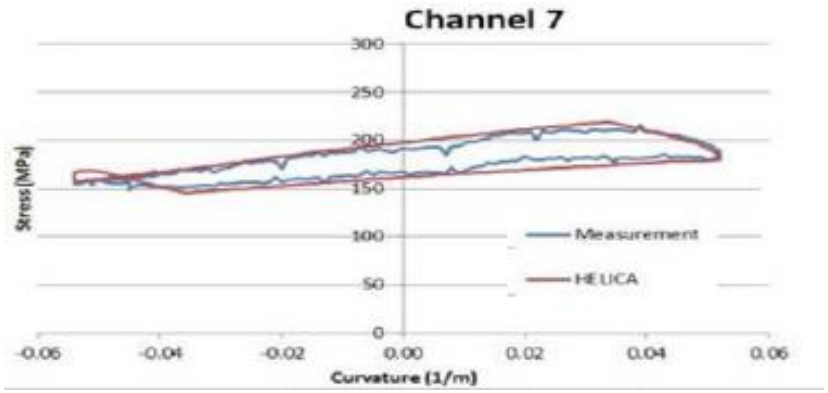


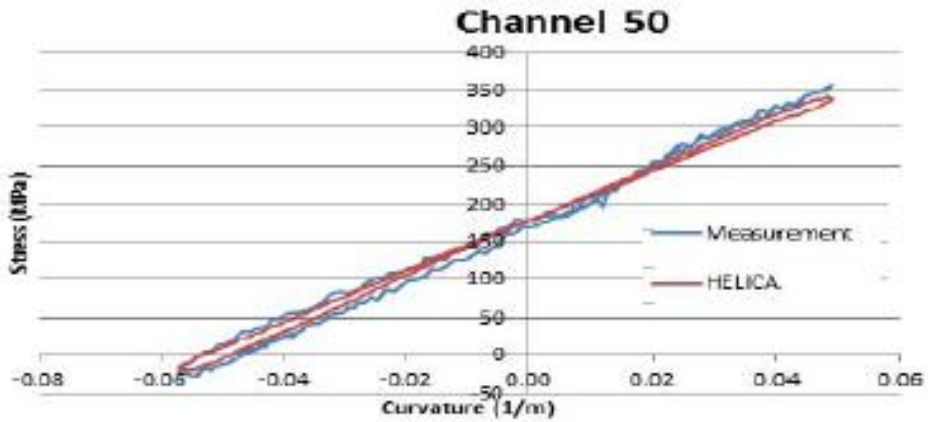
High tension case - Helica vs test results

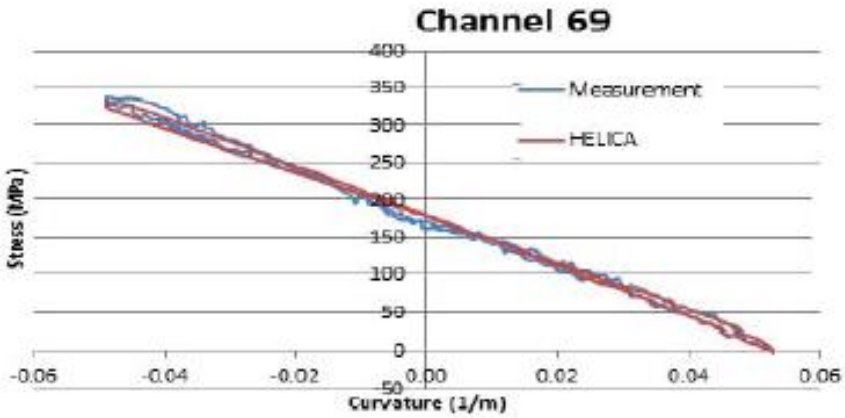
Small tubes



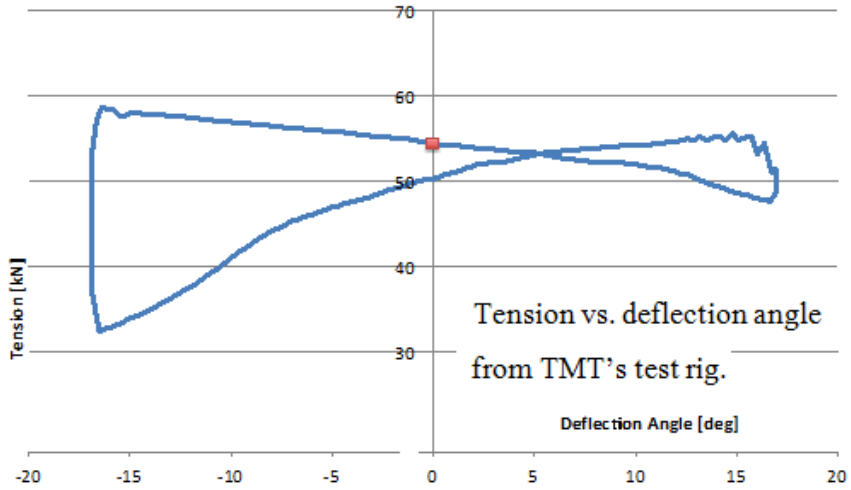


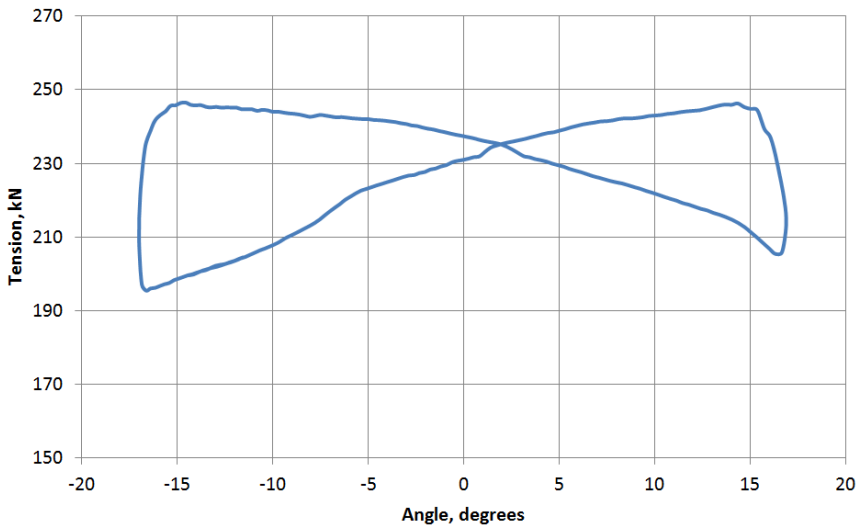
Large tubes





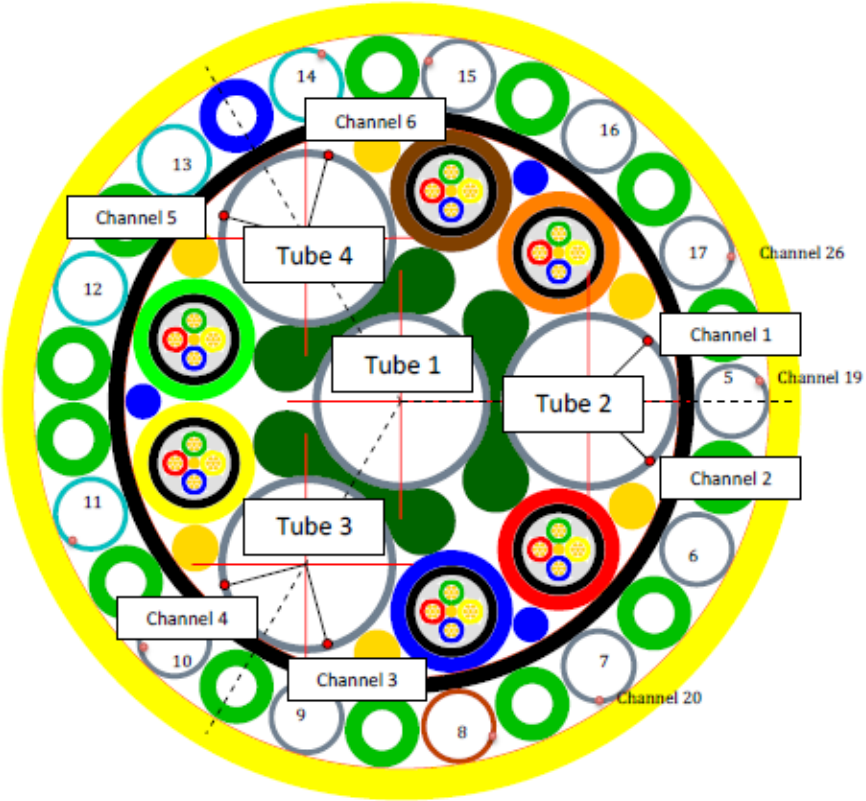
Tension/Rotation Correlation

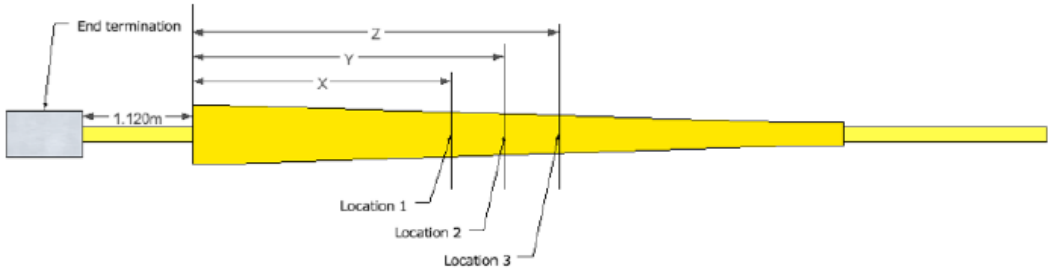




- Tension/rotation angle correlation due to test set-up
- Time series applied as loading in Helica for correlation studies
- Un-intended effect that actually improves the value of the full-scale test for validation purposes

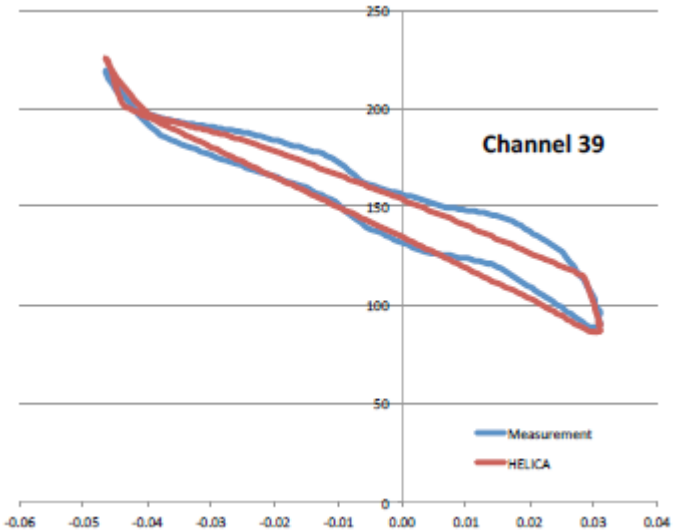
Helica JIP – Low tension validation test

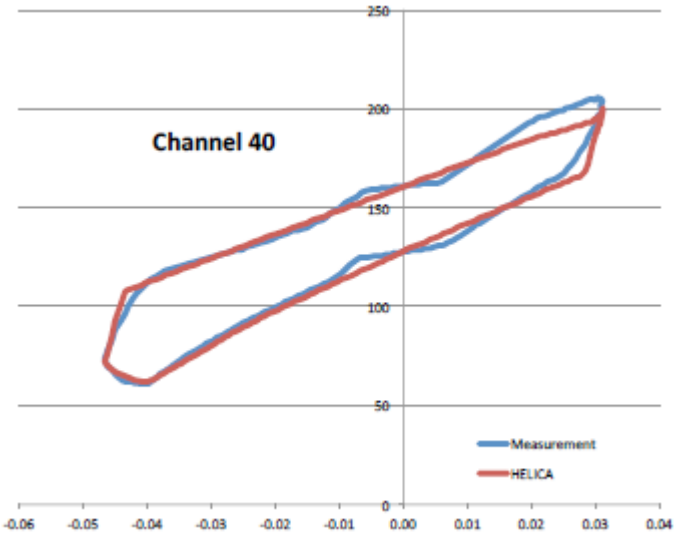




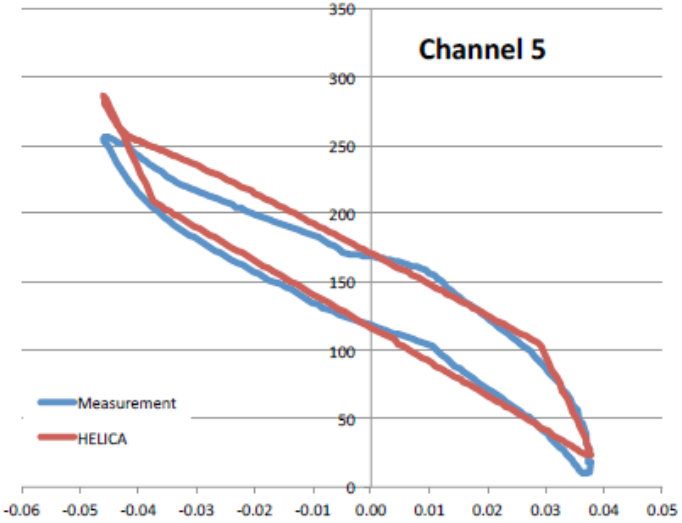
Stress measured at 42 locations

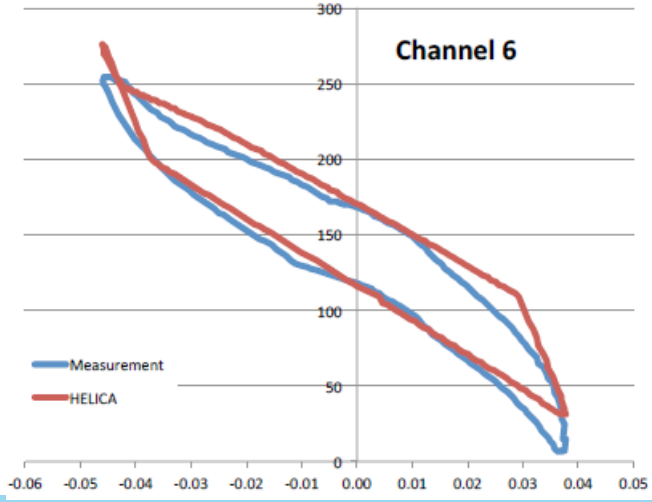
Low tension case - Helica vs test results





Small tubes





Large tubes

Conclusions / Future work

- Despite certain challenges and sources of uncertainty, excellent agreement between HELICA calculations and measurements have been found, both qualitatively and quantitatively.

- The presented work has demonstrated that HELICA is a validated and efficient tool for establishing internal stresses in umbilical components, which also implies a good fatigue damage prediction capability.

- Consistent assessment of Wave induced fatigue of umbilicals / flexibles / power cables is well established. VIV induced fatigue need to be explored for consistent fatigue assessment.

More information

Helica – theoretical basis

- OMAE 2010-21012 Efficient fatigue analysis of helix elements in flexible risers and umbilicals. Nils Sødahl, Geir Skeie, Oddrun Steinkjer, Arve Johan Kalleklev
- Journal of Applied Mathematics 2012. Efficient fatigue analysis of helix elements in umbilicals and flexible risers. Theory and application. Geir Skeie, Nils Sødahl, Oddrun Steinkjer

Validation studies

- ISOPE 2016-TPC-1294 ‘ Validation of the Loxodromic Bending Assumption Using High-quality Stress Measurements’
- ISOPE 2016-TPC-1307 ‘Validation of the Loxodromic Bending Assumption Using High-quality Stress Measurements – High Tension Case’
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Thank you!

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