# DMaC

## Dynamic Marine Component Test Facility

UNIVERSITY OF EXETER

A PURPOSE-BUILT TEST FACILITY TO INVESTIGATE MECHANICAL RELIABILITY OF MARINE COMPONENTS IN HARSH OFFSHORE CONDITIONS

# INTRODUCTION

The Dynamic Marine Component (DMaC) test facility is a purpose built test rig that aims to replicate the forces and motions experienced by marine components in offshore applications. The test facility is based within the Renewable Energy Research Group of the University of Exeter at Penryn Campus, Cornwall.

The test rig comprises of a linear hydraulic cylinder at the tailstock that applies the tension and compression forces or displacements. At the other end of the rig, the headstock with three degrees of freedom can apply bending moments (torque) and angular displacements. The combination of forces and motions from the headstock and tailstock simulate the loads and displacements experienced by a floating body. The working principles are illustrated in figure 1. For example, the tailstock can replicate heave motion (Z) and the headstock can replicate pitch ($\varnothing_x$), roll ($\varnothing_y$) and yaw ($\varnothing_z$) motions.

The rig is capable of replicating dynamic tensile forces up to 20 tonnes, static tensile forces up to 40 tonnes, and displacements up to 1 m. The maximum bending angle at the headstock is ±30° for pitch and roll with up to 10 kN·m of bending moment. The maximum torque or yaw is 10 kN·m with an infinite rotational displacement. Beyond that, the rig has the unique feature that components can be submerged in fresh water to allow testing in a wet environment. These features allow dynamic testing of large-scale components under controlled conditions with realistic motion or load characteristics.

This unique combination of features have allowed the DMaC test facility to support studies in to a variety of marine components including: conventional mooring ropes, compliant mooring components, subsea power cables, bend restrictors for power cables, aquaculture components, power take off devices for MRE and even acoustic monitoring of components. These studies are commonly part of national and international collaborative projects and are used to inform performance characterisation, peak or fatigue load assessment, reliability studies and accelerated test campaigns. Furthermore, test work has been conducted to international standard.

# SPECIFICATION

### Headstock

- X-axis ($Ø_X$) and Y-axis ($Ø_Y$) rotation
  - ±30° angular displacement
  - 0.25 Hz cycle frequency
  - 10 kN·m bending moment
- Z-axis rotation ($Ø_Z$)
  - Infinite angular displacement
  - 70 rpm rotational speed
  - 10 kN·m torque

### Test sample

- Wet or dry test
  - Submerged in fresh water
- Adjustable test bed length
  - 6m max sample length during wet testing
  - Longer sample length during dry testing
- 800 mm (max) sample diameter

### Control system

- Automated, programmable test profiles
  - Force or displacement control mode
  - Regular or irregular profiles
  - User-supplied time-series (eg. measured tensions)
- NI cRIO control system
  - 120 kHz control frequency
  - 32 digital outputs
  - 12 analogue outputs

### Tailstock

- Z-axis displacement
  - 1 m stroke at 0.1 Hz
  - 0.1 m stroke at 1 Hz
  - 0.01 m stroke at 10 Hz
- Z-axis force
  - Double-in-series hydraulic cylinder
  - Variable force range
    - from -200 kN to 200 kN
    - from 0 kN to 400 kN

### Data logger

- NI cRIO data logger
  - 250 kHz (max) sample frequency
  - 32 analogue voltage inputs
  - 64 digital voltage inputs
  - 8 strain gauges inputs
  - 8 thermocouple inputs
    - Results viewed in real time
    - 3D motion track system

### Hydraulic power supply

- Electrical power supply
  - Power 130 kW
  - Voltage 415 V
- Hydraulic power unit
  - Flow rate 362 l/min
  - Drive circuit pressure 140 bar
- Buffer accumulators for smooth flow

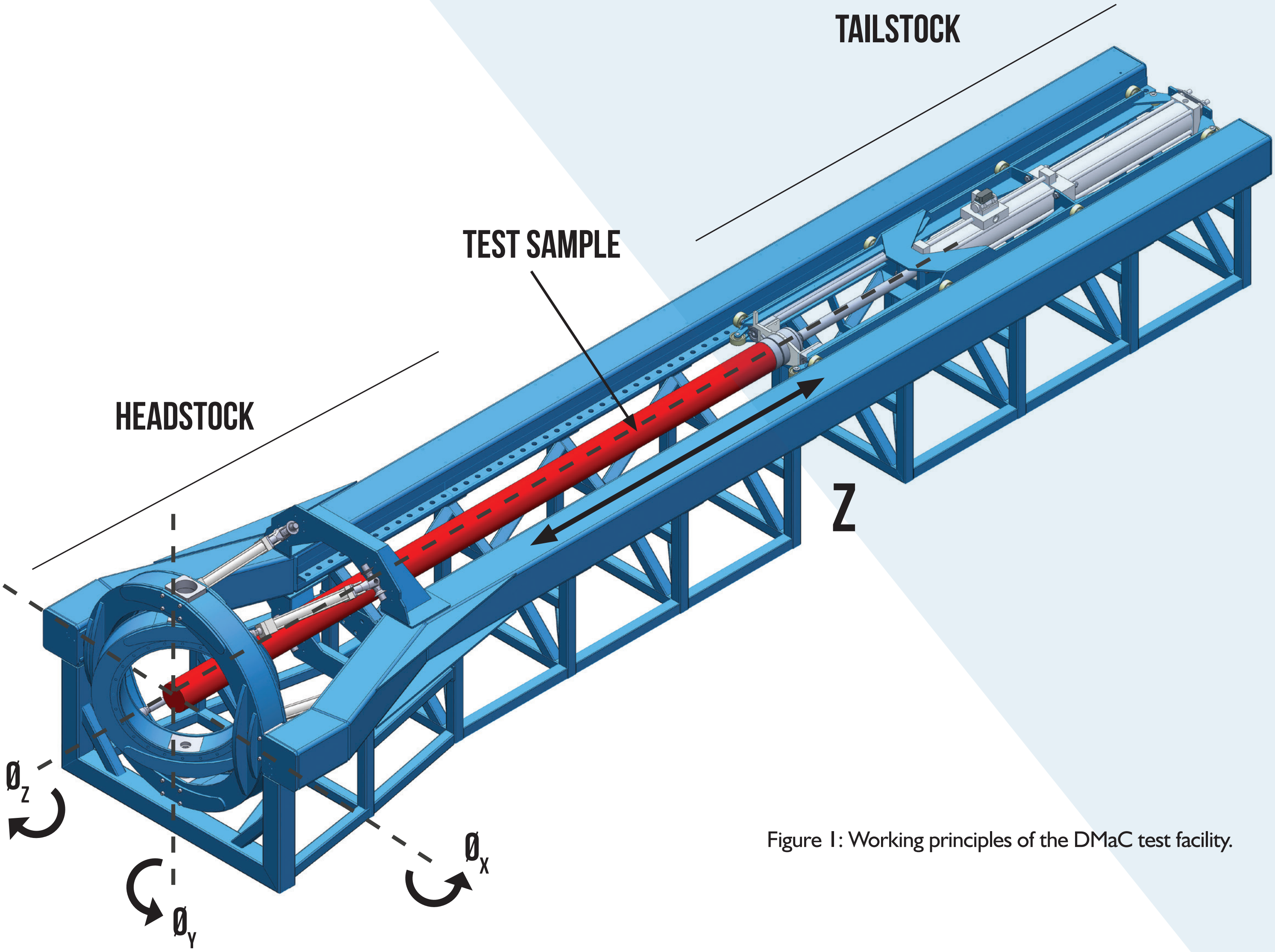


Figure 1: Working principles of the DMaC test facility.

| **Axis** | **Z** | **$\theta Ø_x$ and $\theta Ø_y$** | **$\theta Ø_z$** |
|---|---|---|---|
| Force | 400 kN (max) | 10 kN·m | 10 kN·m |
| Displacement | 1 m | 30° | Infinite |
| Speed | 0.1 m/s | 120 °/s | 70 rpm |

# EXAMPLE PROJECTS

- Synthetic fibre ropes
- Highly compliant elastomeric mooring components
- Mooring load control systems
- Marine power cables
- Cable bend restrictors and stiffeners
- Power take off devices
- Conventional mooring components (e.g. chain and shackles)
- Aquaculture components
- Acoustic monitoring of marine components
- General tension and bending assessments

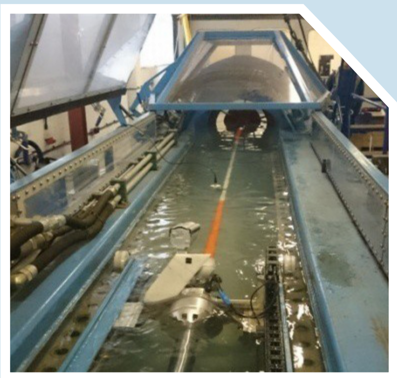

Figure 2: Submerged testing of Lankhorst mooring rope.

Figure 3: Submerged testing of the Exeter Tether mooring component using optical tracking equipment.

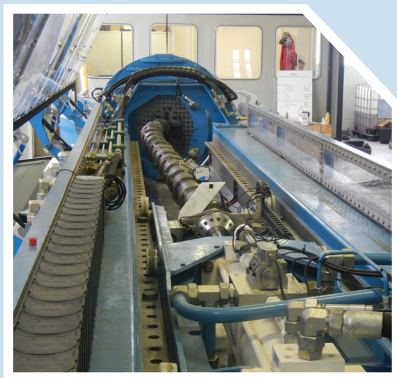

Figure 4: Fatigue testing of CNPL subsea-cable bend-restrictor.

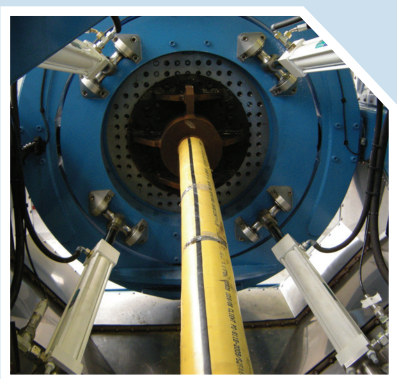

Figure 5: Reliability testing of subsea-cable.

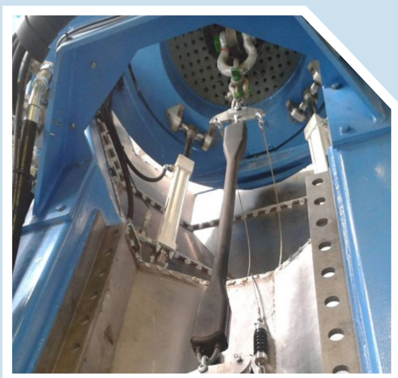

Figure 6: Performance characterisation of OPT compliant mooring line.


Figure 7: Intelligent Active Mooring load-control System (IAMS) by Teqniqa Systems.

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MARINET

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tfi technology from ideas

OPT
OCEAN POWER TECHNOLOGIES

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NSW
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Newton Fund

EPSRC
Engineering and Physical Sciences Research Council

Lankhorst Ropes

PRIMaRE
Partnership for Research In Marine Renewable Energy

cp/nl
engineering

SUPERGEN
UKCMER

European Union
European Regional Development Fund

Funded by the Horizon 2020 Framework Programme of the European Union

# COLLABORATIONS

# EXETER TETHER
# CASE STUDY

**The Exeter Tether is a novel mooring tether designed and developed by the 'Renewable Energy Research Group' at the University of Exeter [1]. The tether offers distinct advantages over conventional rope design including:**

- Increased compliance: leading to a reduction in peak and fatigue loads, see figure 11.
- Customisable stiffness profile: by de-coupling the stiffness profile from the strength of the tether, the mooring stiffness can be optimised for a particular application, see figure 11.

**The DMaC test facility has been used throughout the development of the Exeter Tether including:**

- Quantifying Minimum Breaking Load (MBL).
- Establishing the stiffness profiles for a series of tether prototype variants.
- Reviewing the effect of load cycle frequency and duration on the stiffness profile.
- In combination with the South West Mooring Test Facility (SWMTF) establishing the effect of marine operational exposure on tether performance characteristics.
- Long term, high load, fatigue endurance tests, following the Thousand Cycle Load Level (TCLL) testing protocol.
- Sub-component testing of tether components using a bespoke collet to review the effect of long term fatigue cycles on an anti-friction membrane.
- Reviewing tether performance during prototype tests of 4 scaling iterations increasing the MBL from 23kN to 1598kN for the H2020-funded OPERA (Open Sea Operating Experience to Reduce Wave Energy Cost) project [2].

**Further information on these investigations can be found in [3, 4] and [5].**

References


1. Parish, D. and L. Johanning, 2012. Mooring limb. US Patent Application Pub. No. US 2012/0298028 A1.
2. OPERA Project, funded through the European Commission's Horizon 2020 programme, grant agreement No 654.444.
3. Gordelier, T., et al., 2015. A Novel Mooring Tether for Highly-Dynamic Offshore Applications; Mitigating Peak and Fatigue Loads via Selectable Axial Stiffness. *Journal of Marine Science and Engineering*. 3(4): p. 1287-1310.
4. Parish, D., et al., 2017. Reducing peak and fatigue mooring loads: A validation study for elastomeric moorings, in *European Wave and Tidal Energy Conference Series*. Cork, Ireland.
5. Gordelier, T., et al., 2018. Assessing the performance durability of elastomeric moorings: Assembly investigations enhanced by sub-component tests. *Ocean Engineering*.

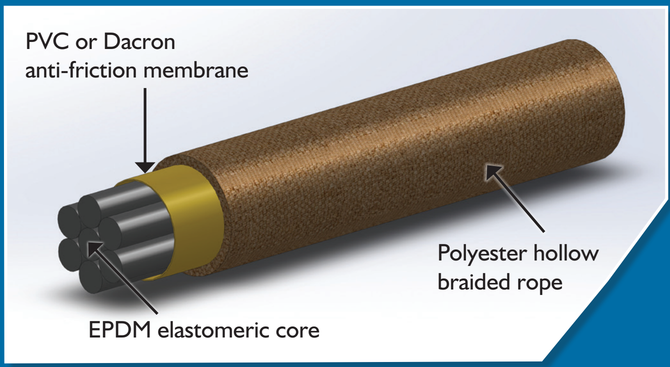



Figure 8: Annotated cross section of Exeter Tether.

Figure 9: Annotated cross section of Exeter Tether.

Figure 10: Exeter Tether installed in DMaC.

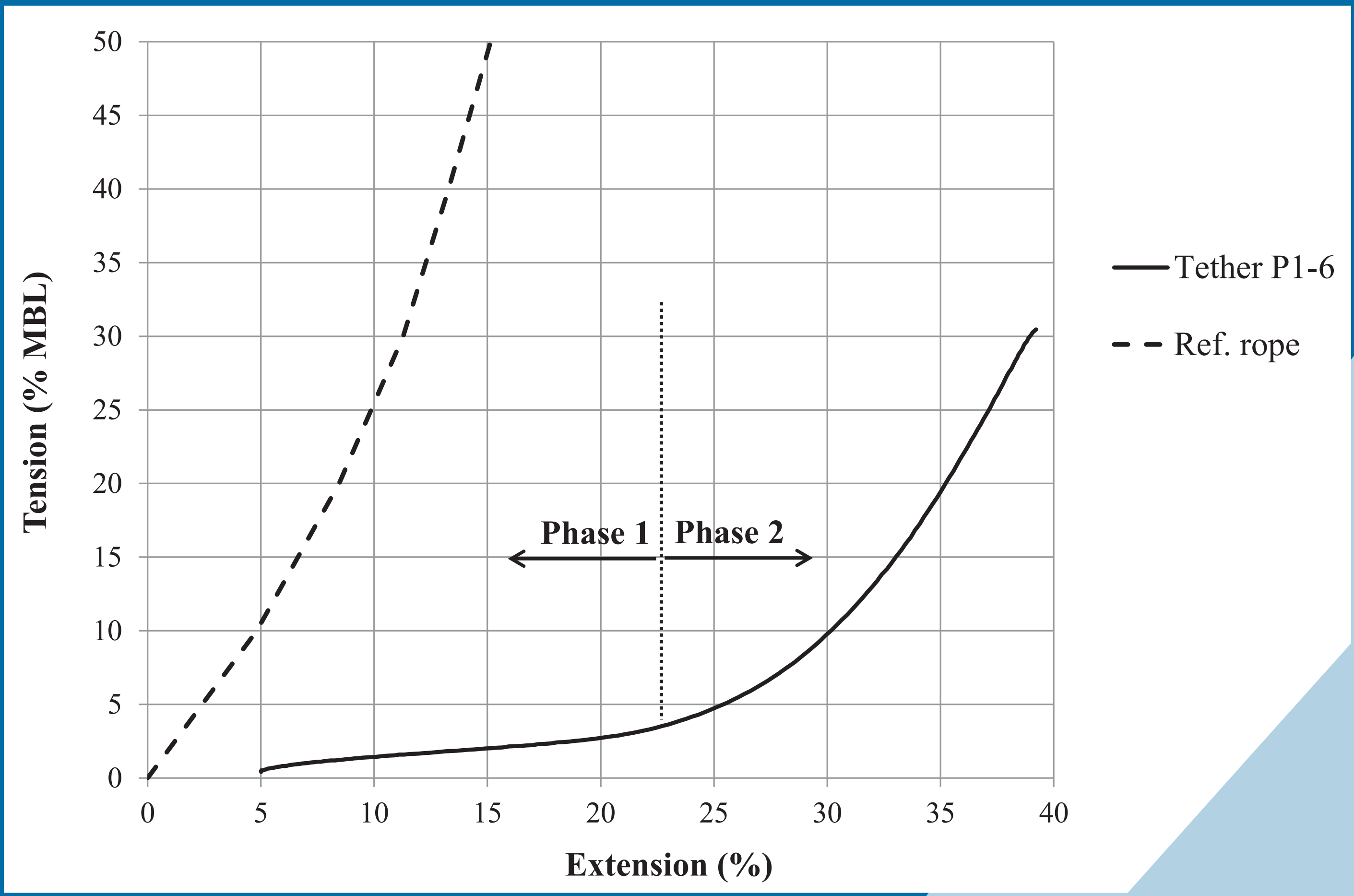
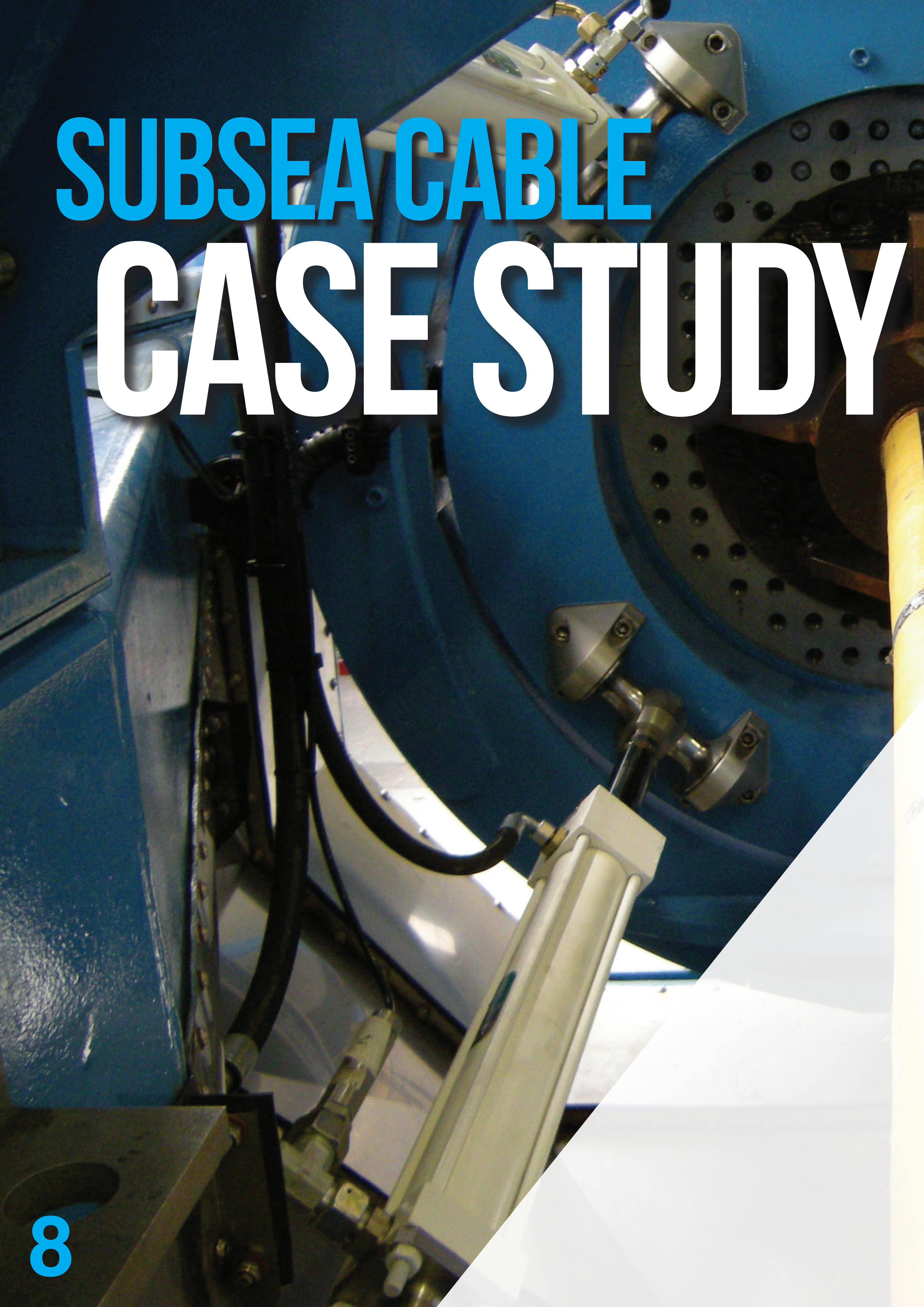



Figure 11: Tension against extension of Exeter tether compared to a conventional polyester reference rope [5].

# SUBSEA CABLE
# CASE STUDY



Subsea power cable failures for offshore marine energy applications are a growing concern since experience from offshore wind has shown repeated failures of inter-array and export cables. These failures may be mitigated by improved mechanical design and/or dedicated cable protection systems, such as bend restrictors. The DMaC test facility is collaborating and consulting with subsea cable manufacturers and cable protection manufacturers to research mitigation measures.

## Cable Design

Norddeutsche Seekabelwerke GmbH (NSW) collaborated with the DMaC test facility to help develop highly dynamic inter-array medium voltage power cables [6]. The test conditions, see figure 12, were defined by industry's recommended practices (i.e. DNV-FP-F401 and Cigre TB 623). The utilisation of DMaC test facility included:

- Measurement of bending stiffness and structural damping, see figure 15.
- Validating failure mode assumptions.
- Assessing validity of a fatigue life estimation model.

## Cable Protection

CPNL have been developing an articulated pipe bend restrictor since 2009 and perform accelerated reliability tests at the DMaC test facility to provide evidence of its expected lifespan [7, 8]. The tested conditions were accelerated extreme events from an estimated 1:50 years extreme load case that was accelerated between 1.25 and 6.67 times and repeated for up to 25,000 bending (50,000 tension) cycles, see figure 13. The accelerated reliability tests were able to:

- Establish fatigue behaviour and observe failure modes, see figure 14.
- Measure wear rate on articulated pipe contact regions.
- Analyse frictional wear between elements and the cable.

## References


6. Mueller-Schuetze, S., et al., 2015. Development of new highly dynamic power cables design solutions for floating offshore renewable energy applications. *MARINET infrastructure access report: HDPC4FMEC.*

7. Thies, P.R., et al., 2016. Accelerated reliability testing of articulated cable bend restrictor for offshore wind applications. *MARINET infrastructure access report: Bend restrictors.*

8. Thies, P.R., et al., 2016. Accelerated reliability testing of articulated cable bend restrictor for offshore wind applications. International *journal of marine energy*, 16, pp.65-82.

# SUBSEA CABLE CASE STUDY

Figure 12: Cyclic bending test of NSW cable [6].

Figure 13: Cyclic bending test of CPNL bend [7].

Figure 14: Failure modes of CPNL bend restrictor [7].

# BENDING MOMENT VS CURVATURE

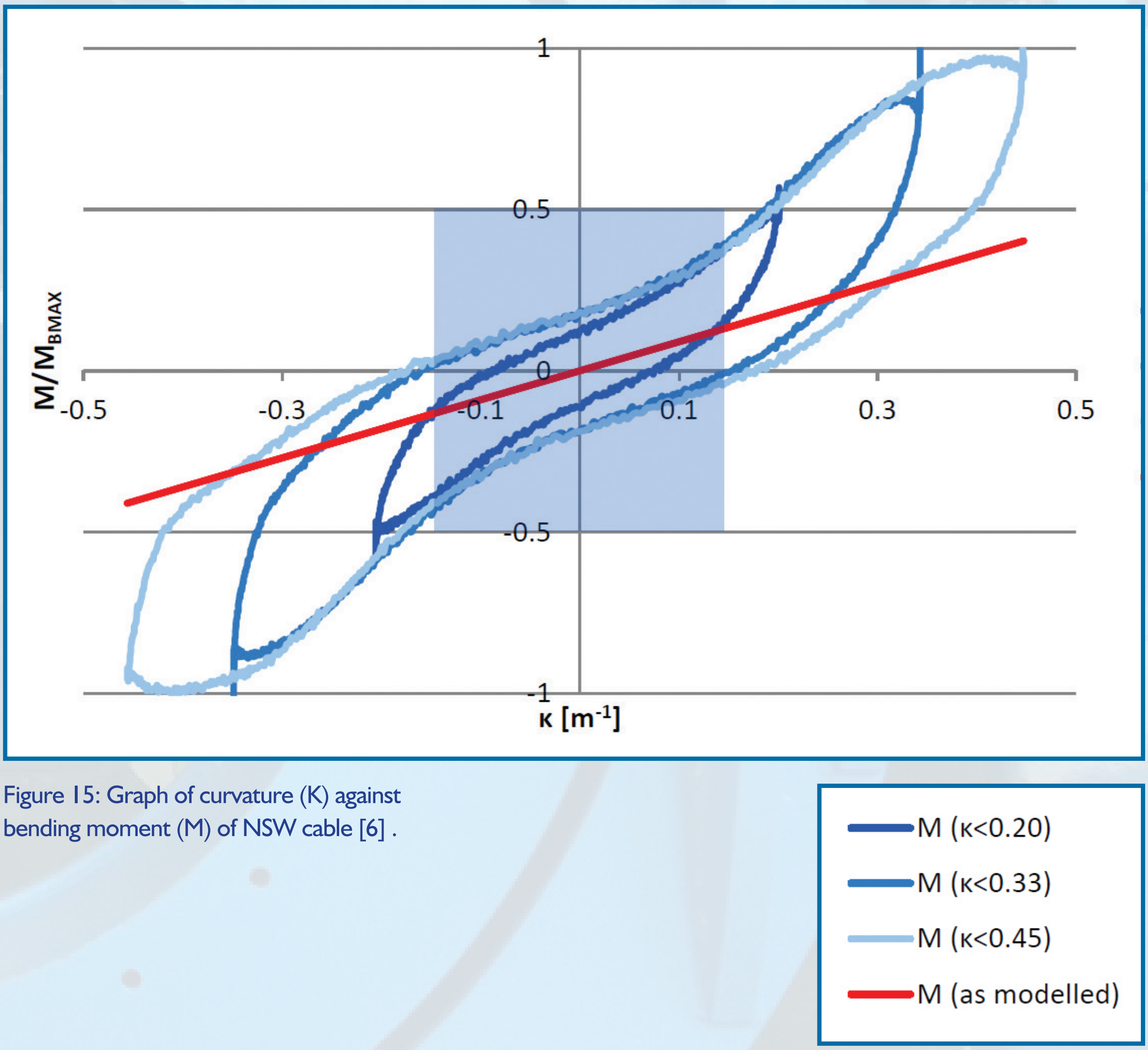



Figure 15: Graph of curvature (K) against bending moment (M) of NSW cable [6] .

# CERTIFICATION AND STANDARDS

The Quality Management System of DMaC test facility is accredited to ISO 9001:2015 by the British Standards Institute. The accreditation is applicable to:

**THE DESIGN, TEST AND REPORT ON EXPERIMENTAL SERVICES OF MARINE COMPONENTS.**

The DMaC test rig aims to provide a Class I uniaxial testing machine, according to ISO 7500-1:2004. Class I test machines have relative errors of accuracy and repeatability less than ±1% and 1% respectively.

Test work has been conducted to international standards. For example, fibre ropes for offshore stationkeeping (ISO 19336:2015 and ISO 18692:2007) and subsea power cables (DNV-RP-F401 and Cigre Technical Brochure 623).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Certificate of Registration

By Royal Charter

QUALITY MANAGEMENT SYSTEM - ISO 9001:2015

This is to certify that:

University of Exeter Dynamic Marine
Marine Component
Test Facility

**Please contact the DMaC team to discuss your experimental requirements:** from collaborative research projects to consultancy; standardised tests (e.g. ISO) through to fully customised experimental setups with tailored test programmes; including performance characterisation, fatigue, load assessments and reliability studies.


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