SINTEF Ocean NTNU

Nylon ropes for mooring of floating wind turbines

Improved lifetime, reduced costs and innovative mooring solutions by use of nylon ropes

Objective

The aim of NYMOOR is to develop and assess solutions for mooring of floating wind turbines (FWTs) with nylon ropes. Secondary objectives include:

- Improve the understanding and the modelling of nylon rope mechanical properties, with focus on creep, stiffness, strength, endurance, and the effects of degradation mechanisms.
- Assess long term reliability of nylon ropes accounting for the relevant degradation mechanisms and failure modes (step towards qualification).
- Develop and test procedures for mooring design analysis of FWTs with complex synthetic rope creep, stiffness and degradation models (e.g. nylon).
- Develop innovative mooring solutions based on nylon ropes.

Background

The traditional solution for mooring of offshore structures at relatively shallow to intermediate water depths (say from 60 to 400 m) is to use lines composed of chain or a combination of chain and steel wire segments. The steel segments solution works for FWTs as well, however with challenges, especially for relatively shallow water depths. The small water depth catenary combined with large mean horizontal wind thrust loads stretch the windward lines increasing very much the horizontal restoring stiffness – the lines become almost taut and the mooring system loses compliance with the wave frequency (WF) motions. Consequently, the lines are subjected to highly nonlinear and large load cycles under WF excitation. Large diameter designs are required to accommodate fatigue damage. Availability of chain to supply the expected exponential growth of FWT units to be installed has also been identified as a challenge.

Use of polyester ropes is one option being considered by the industry to improve flexibility of the mooring system under large mean wind loads. The accumulated experience within the Oil and Gas sector for deep water moorings brings confidence. Still, existing designs show that relatively long polyester segments are required to achieve adequate flexibility and the wave frequency loads remain higher then desired [1].

Nylon ropes are significantly more flexible than polyester ropes for the same minimum break load (MBL), which is an advantage for shallow water mooring (see Figure 1). On the other hand, there is no experience with use of nylon for mooring of floating structures. One of the reasons is that there was no need until recently. Furthermore, fatigue properties of standard nylon ropes were worse than polyester ropes. However, the last decade has seen large improvement in fatigue properties of nylon ropes [2], [3].

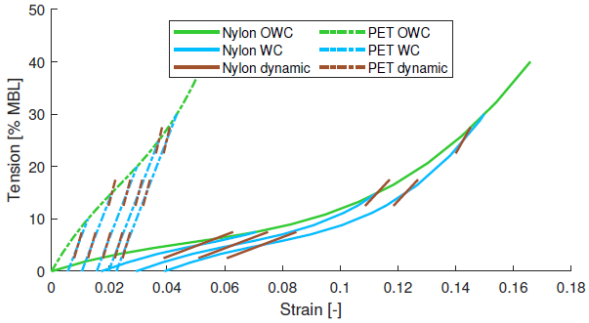

Figure 1: SYROPE model for nylon (solid lines) and polyester (dashed lines) [4]. OWC and WC stand for quasi-static working curves.

A recent study compared mooring system designs for a FWT based on polyester and nylon ropes [4]. Use of nylon reduces fatigue loads significantly, showing a potential for lowering the cross-section area of the chain segments by 40% (Figure 2). The fatigue life of the nylon ropes also exceeds that of polyester ropes due to reduced cycling loads. Extreme loads were also reduced.

Use of nylon for mooring of FOWTs has the potential to reduce the initial cost of the mooring system, as well as the handling costs. Furthermore, a much better compliance to WF motions of the platform opens new possibilities for optimization of the mooring system configuration, e.g. for reducing the anchoring footprint and for mooring of arrays.

Since nylon is a novel solution for long term mooring, research is needed to characterize the material mechanical properties and its long-term reliability under realistic loading environments. There is also the need to develop / adjust the numerical simulation tools and the mooring design analysis procedures. This is the scope of NYMOOR.

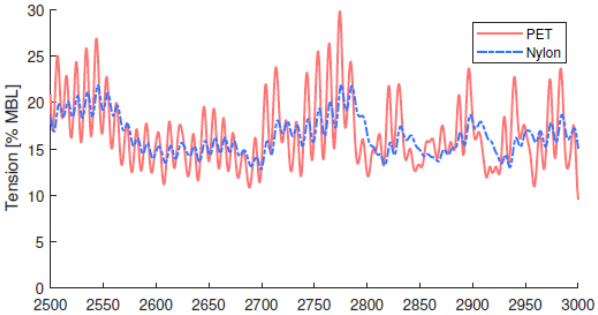

Figure 2: Tension time series in the fibre rope (rated wind speed = 11.4 m/s, Hs = 4.7 m, Tp = 10.1 s) [4].

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Methods and scope of work

The overall project methodology consists of:

(a) Produce and use lab data in combination with numerical modelling to identify the mechanical properties, the degradation mechanisms, the failure modes, the long-term performance and reliability of nylon ropes.

(b) Update time domain mooring analysis codes to consider new and more complex creep, stiffness and degradation models.

(c) Update mooring analysis procedures based on the new and more complex models; investigate novel mooring solutions.

The project will develop on four topics related to mooring of FWTs with nylon ropes. These are organized in work packages as follows:

WP1: Laboratory testing of ropes

WP1 will perform laboratory tests with sub-ropes and yarns aimed at identification of MBL, fatigue curves, creep behaviour and stiffness properties. The following effects on the mechanical properties and rope endurance will also be investigated: temperature, water absorption and hydrolysis and abrasion.

WP2: Num. modelling of mechanical properties

Develop and implement polymer material models for nylon ropes, which will, first, be validated by the using test results from WP1. Second, the new material models will be used to enhance the physical understanding of nylon rope behaviour and possibly to generate additional data.
The new models based on the mechanical properties of nylon ropes identified from the lab tests and material modelling will be implemented in time-domain mooring analysis methods.

WP3: Mooring analysis and innovative solutions

The new numerical models for material properties and updated simulations tools will be applied with a case study to assess and validate mooring analysis procedures. The results from the previous WPs will also be used to investigate new mooring solutions. Examples include: reduced footprint; shared anchors; shared mooring lines; avoid re-tensioning.

WP4: Long term reliability of nylon ropes

The lab tests of WP1, in combination with advanced material modelling, are designed to provide evidence on the degradation mechanisms, failure modes and long-term performance of nylon for mooring of FWTs. These results will be integrated into the mooring analysis, together with reliability methods.

Project Deliverables

- Characterization of nylon ropes mechanical properties, degradation effects and failure modes.
- Models for nylon rope stiffness accounting for: material creep and for the load level, load history and load rate. Integration into mooring analysis simulation tools.
- Identification of long-term reliability of nylon ropes for permanent mooring.
- Procedures for mooring analysis of FWTs with complex stiffness and degradation models.
- Innovative mooring solutions with nylon ropes.

Organization

NYMOOR is a knowledge-building project for the Industry. The project is coordinated by SINTEF and executed together with NTNU in cooperation with the following industry partners: Equinor, TotalEnergies, Bridon-Bekaert, APL Norway, AKER Solutions, Inocean, SOFEC.
The project started Q4 of 2023 and will have a duration of 4 years.

Financing

The project total budget is 18,7 MNOK. The Research Council of Norway finances 72 % of the project costs while the industry contributes with the remaining.

References

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[5] Sørum, S.H., Fonseca. N., Kent, M., Faria, R.P., 2023. Assessment of nylon versus polyester ropes for mooring of floating wind turbines. Ocean Engineering, 278, 114339.