20th European Mechanics of Materials Conference - EMMC20
Florence, Italy | May 27th-29th, 2026
www.emmc20.unifi.it

Mesoscopic finite-element model of a stranded nylon rope for FOWT mooring lines; internal dissipated energies due to fatigue loadings.

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Paper ID: 267
Symposium S9: Fatigue evaluation: modelling and characterisation at different length scales

Abstract

To achieve the goal of carbon neutrality by 2050, Europe is growing the floating offshore wind turbines sector. In such technologies, mooring lines are one of the critical components. Polyamide (nylon) ropes offer a promising solution, thanks to their reduced weight, reduced price and minimal impact on the seabed, compared to steel chains. However, their mechanical behavior remains complex. First, ropes are structured materials composed of several scales in interaction. Moreover, their response depends heavily on the duration and intensity of the loadings encountered. Polyamide 6 stands out for its ability to mitigate tension peaks, especially in shallow waters, thanks to its low stiffness and damping properties. Mooring lines are supposed to have a 25-year lifetime. Therefore,

it is necessary to understand well their fatigue behavior. Due to large-scale strains of ropes, it is very difficult to accelerate experimental test frequency because of machine control limitations. Therefore, an approach able to speed-up the evaluation of fatigue behavior and lifetime is needed. As fatigue involves phenomena occurring inside ropes, such as friction and abrasion, intrinsic dissipated energy is a marker of the ropes response to cyclic solicitation and to fatigue lifetime. Nonetheless, experimental evaluation based on thermal analysis cannot dissociate phenomena responsible for dissipation. Therefore, a model describing the contributions of nylon visco-elasto-plastic behavior, structure rearrangement and friction between scales is necessary. This is one of the goals of BAMOS project that gathers academic and industrial partners. This project is driven by France Energies Marines and ENSTA and funded by France 2030 ANR program. Bles et al. (2025) developed FiBuLa meso-scale finite element model (FIber BUndle LAw). It represents a bundle of rope-yarns as the reference elementary volume, considered to be a continuous, homogeneous and transverse isotropic material. Inspired from the work of Criscione et al. (2001), FiBuLa behavior law is based on hyperelastic potentials deduced from the decomposition of the deformation gradient into independent strain modes: a volume change mode, an axial elongation mode, an along-fiber shear mode and a cross-fiber shear mode. So far, hyperelasticity is included in volume change and axial elongation modes, and plasticity modeling friction between rope-yarns is included in shear modes. Finally, friction between strands is considered in the finite elements using a contact law. To better represent the complex behavior of ropes and the dissipation measured experimentally, viscosity of the rope-yarns in tension will be added in the axial elongation modes. A method will be developed to identify FiBuLa parameters from experimental data, thanks to cyclic tensile tests on rope-yarns underwater and diametral compression tests on strands. Finally, the model shall be validated by comparisons with experimental tests performed on 4-ton sub-ropes with different lay-lengths. Bles, G., Civier, L., Marco, Y., & Hamila, N. (2025). Transversely isotropic hyperelastoplastic constitutive model for large deformation analysis and simulation of fiber yarns and stranded ropes. IJSS, 113532. Criscione, J. C., Douglas, A. S., & Hunter, W. C. (2001). Physically based strain invariant set for materials exhibiting transversely isotropic behavior. JMPS, 49(4), 871-897.

Keywords:

FOWT moorings Polyamide 6 Fatigue Dissipation Mesoscopic-scale model Finite elements