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Hyperelasto-plastic model for analysing the frictions at the mesoscopic scale of laid-strand synthetic ropes

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Polyamide-fiber laid-strand ropes are candidate for the shallow-water mooring lines of the future floating offshore wind turbines [2]. Their mesoscopic scale follows a hierarchical architecture: subrope, strands, rope-yarns, yarns, filaments. Their mechanical behavior is the result of friction between components and the visco-elasto-plastic behavior of the filament matter. Under cyclic loading, a fatigue damage based on the component frictions occurs and is a matter of concern for a 20-year service life. Friction phenomena at the different scales are out of reach of experimental measurements. We adopted the Charmetant's approach [1] for modelling the subrope until the scales of the strand and rope-yarn. Actually, the subrope will be modelled by the quasi-static FEM as three helical strands in contact one with each other. Each strand will be meshed by volumic finite elements, at integration points of which a user-routine behavior law is implemented. As Charmetant et al. did, this behavior law will distinguish the friction strain modes from the filament matter strain mode within the global deformation gradient undergone by the pack of rope-yarns. For each of these strain modes, a dedicated and relevant behavior law is proposed. One friction strain mode is a differential displacement of the rope-yarns in the direction of their axis, identical to a shear mode. While Charmetant et al. considered one invariant scalar state variable as parameter of this mode, we proposed two scalar state variables because actually two shears in two orthogonal planes occurs in this mode. The second friction strain mode is a strain in the transverse plane of the rope-yarns. Charmetant proposed here only one scalar state variable as parameter of this mode, but this 2D strain has one independent eigenvalue and two orthogonal eigenvectors within the transverse plane. This is why we proposed a plane-strain deviatoric second-order strain tensor, as parameter of this mode. These improvements of the Charmetant's model will allow us to include plasticity dedicated to the friction behaviors.

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