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A Simplified Numerical Model for Assessing the Residual Strength and Deformation Capacity of Asymmetrically Damaged Ropes

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ABSTRACT

A simplified nonlinear mechanical model is proposed to estimate the residual strength and deformation capacity of ropes with asymmetric damage distribution. In this study, damage corresponds to the complete rupture of one or more rope components that belong to the outermost layer of a particular rope cross-section. In the proposed model, the damaged rope is assumed to behave as a nonlinear beam under biaxial bending and axial load with Bernoulli´s kinematic hypothesis [1]. Biaxial bending arises from the unbalanced radial contact forces within rope cross-section, which are related to the initial helical geometry configuration of the rope components, due to the asymmetric damage distribution [2]. An iterative cross-sectional numerical algorithm is implemented to estimate the asymmetric damaged rope capacity curve, stress and strain distributions throughout rope cross-section and rope geometry deformation for a prescribed axial displacement of the rope. This model is capable of predicting the strain gradient on a given asymmetric damaged rope cross-section in which the strains concentrate in rope components adjacent to the broken ones. This strain concentration can cause the premature failure of rope components and reduce the maximum load and failure axial strain that a damaged rope is capable of resisting relative to that of an intact rope. The analyses are focused on homogeneous small-scale ropes with nonlinear constitutive laws and overall diameters equal to 6 mm that are damaged at ropes midspan location. Ropes with a wide range of degree of damage (percentage of the broken components of the damaged cross-section with respect to the intact rope) and degree of asymmetry (change of the center of stiffness of the damaged cross-section with respect to the intact rope) are considered in this study. Preliminary results given by the proposed model are found to be in good agreement with available static tension tests on asymmetrically damaged polyester ropes [3] and 3D finite element simulations [4] with lower computational cost. Compared to the solutions obtained by previous analytical models reported in the literature [2,5], the range of applicability associated to the degree of damage to rope cross-section (number of broken rope components) is extended.

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