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Efficient semi-analytical method to assess contact conditions in multi-layered helical strand cables

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ABSTRACT

Multi-layered helical strand cables provide high strength and excellent tensile-to-flexural stiffness ratio. Applications include elevator hoisting, bridge suspension, funicular systems, overhead conductors and undersea mooring lines. Cables are subjected to cyclic bending caused by external forces, which can lead to fatigue and wear, and ultimately to wire breakage. To prevent such failures and better understand the cable structural response, fatigue tests have been conducted. However, because of the large cycle numbers required to represent field conditions, these tests are expensive. To detect points potentially prone to fatigue through numerical models, it is essential to determine the stress beneath the contact interface, define the stick and slip zones and calculate the corresponding local sliding distances. Numerous studies proposed multi-layer cable models. However, due to the large number of contact points, using methods such as the finite element method (FEM) on standard desktop computers is challenging. Developing more efficient models to determine stress distribution at contact points in multi-layered helical strand cables is thus essential.

This study develops a semi-analytical approach to evaluate distributions of contact stress at helical strand contact points and to determine stick and slip zones causing fretting conditions. The goal is to maintain high precision levels while minimizing calculation times. The proposed strategy is based on the half-space Boussinesq force-displacement relationships for normal and tangential point loads. For geometries, material properties, and load forces given at a contact point, the solution algorithm involves the following steps: first, convert the normal force into a pressure distribution; next, based on the pressure distribution, calculate the shear stress distribution caused by the tangential force. Since the shear and pressure distributions are coupled, this process is iterated until convergence. Finally, the stress distributions allow calculating the subsurface stresses, and combined with Coulomb Law, allow defining the stick and slip zones. The study compares the model predictions to FEM results and to experimental data. This validation shows that while offering high precision levels, the proposed model significantly reduces the calculation times. For instance, in average, MEF contact simulations required more than five hours, while, for equivalent precision, simulations realized with the proposed model on the same computer required less than 15 seconds. Finally, it is also worth mentioning that, in addition to convincing calculation time reductions, in contrast with FEM, the proposed strategy involves no time-demanding preprocessing operations.