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MODELING APPROACH FOR ANALYZING BRAIDED SHIELDING STRUCTURES IN HV CABLES UNDER BENDING LOADS

Simon Pelletier[1,*], Alexandre Mongrain[1], Sébastien Lalonde[1,†]
[1]Department of Mechanical Engineering, École de technologie supérieure, Montréal, Canada
*simon.pelletier.5@ens.etsmtl.ca, †sebastien.lalonde@etsmtl.ca

ABSTRACT

As industries transition toward electrification, the demand for high-performance electrical systems continues to rise. High-Voltage (HV) cables are critical components of these systems, ensuring power transmission between the main electrical power units. Often exposed to harsh operating conditions, HV cable durability is a key industry concern. HV cables are composed of multiple bunched wires wound in concentric layers as conductor core, surrounded by polymer insulation. In addition, several HV cables include a braided shielding to mitigate electromagnetic interferences. These braided structures exhibit numerous wire contact interactions, from which fatigue and wear damage may initiate under cyclic motions, potentially compromising the integrity of the shielded protection. Currently, HV cable fatigue resistance is primarily assessed through experimental testing. However, this approach has limitations in providing a comprehensive understanding of the internal loading related to braided shielding degradation mechanisms.

To better understand the internal loading conditions leading to damage in HV cable braided structures, this work proposes a 3D finite element modeling approach that describes the braid wire solicitation at contact points while incorporating the nonlinear effects of the full cable structure. The methodology first considers a simplified conductor core by modeling bunches as beam elements using properties estimated from analytical multilayered wire strand models. The interactions between these homogenized bunches are then modeled with beam-to-beam contacts that include frictional effects. This approach reduces the computation time while capturing key nonlinear behaviours of the core structure. Subsequently, each wire of the braided structure is modeled from parametric curves and then discretized with beam elements. Lateral and radial braid interwire contacts are also modeled using a beam-to-beam contact approach. Finally, the outer and inner polymer insulation layers are modeled with shell elements and their interactions with the braid and core structure are considered through beam-to-surface contacts.

To assess the modeling approach, the numerical solution is compared to experimental measurements obtained from cantilever bending tests performed on two different HV cables. The comparison demonstrates the model's ability to reproduce the complex nonlinear behavior of HV cables under bending, due to internal contact interactions. The analysis also highlighted the influence of interlayer pressure exerted by the polymer and braid layers on the global cable response. At the wire level, the model solution allows the extraction of the loading conditions at each interwire contact point of the braided shielding, thus opening the possibility for a deeper understanding of the damage mechanisms in HV cables.