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Bending and Torsion of Twisted Cable Strands Accounting for the Effect of Friction

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EXTENDED ABSTRACT

Cables make up the nervous system of modern cars as they connect the various electronic components and sensors with electronic control units. Depending on the specific application, cables vary in their wire cross sections, insulation material and thickness as well as shape. In this work, we focus on unshielded twisted pairs (*UTPs*) which are mainly designed to handle higher frequency signals with minimal interference. They consist of two conductors which are intertwined with a specified pitch length, see Figure 1. As their beneficial electrical properties depend on the regularity of their twist, they can be disturbed by mechanical deformation, i.e. by torsion or locally small bending radii, [1].

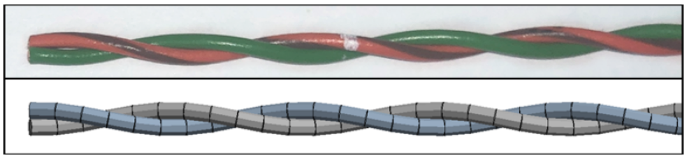

Figure 1: Example of a twisted pair of two conductors. Top: Photograph. Bottom: FE mesh using two helices discretized with beam elements to implement the double wire strand

We aim at the simulation of bending and torsion of twisted pairs with finite beam elements accounting for the effect of friction on the deformation behavior. The multi-wire FE model presented in [2], specifically the double wire strand model, is used to simulate twisted pairs. In order to capture the nonlinear phenomena in the simulation, we model the two conductors using finite beam elements with quadratic shape functions. Contact between cables is taken into account using a Coulomb friction model with pure penalty formulation. We avoid superposition of geometrical and material nonlinearities by restricting the material model to linear elasticity. The correct parameter identification, i.e. determination of the effective Young's modulus of the two conductors, from experiments is crucial, but not straightforward in this case. We will discuss different methods of parameter identification in this work and investigate their impact on the simulation results, which will furthermore be compared to results from experiments on twisted pair cables.

Cables are typically subject to large spatial bending in applications. Therefore, we perform the geometrically nonlinear bending load case presented in [3] for bending of strands of three parallel elastic wires on twisted pairs. As shown in Figure 2, the specimen is clamped on both ends, with a roller support on one and a pinned support on the other end. A cycle of loading and unloading is then performed by applying a displacement on one end. The force necessary to achieve this displacement is measured.

The second load case is implemented as standard torsion with pre-tension. The specimen is clamped on one end and controlled on the other end. In the first step, an axial force is applied to the end of the specimen to achieve pre-tension of the UTP. Afterwards, a full cycle of torsion is implemented by applying a torsion angle θ_T on the controlled end, see Figure 3. The torsion moment and torsion angle are the measured quantities.

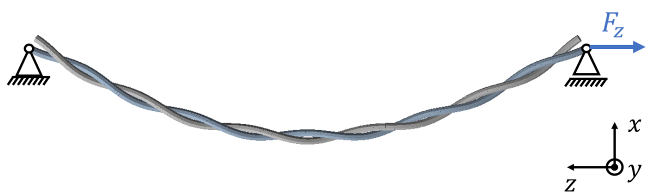

Figure 2: Boundary condition for geometrically nonlinear bending of a twisted pair. The reaction force F_z is measured during bending.

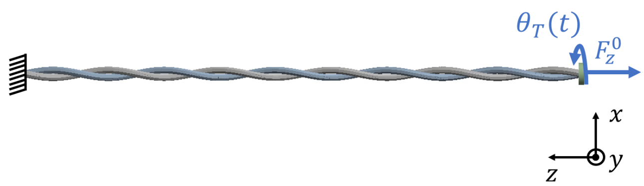

Figure 3: Standard torsion with pre-tension of a twisted pair. The left end of the specimen is clamped. Torsion is applied on the right end by applying a torsion angle θ_T about the z-axis.

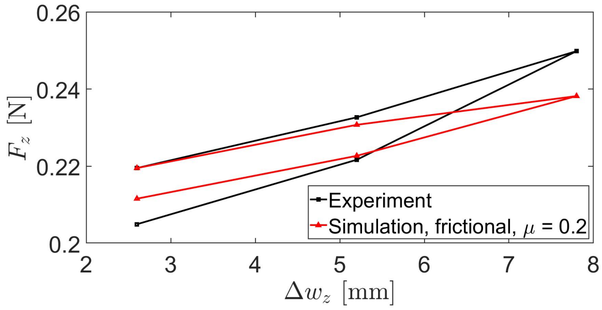

Figure 4: Comparison of experimental and simulation results for bending of a twisted pair.

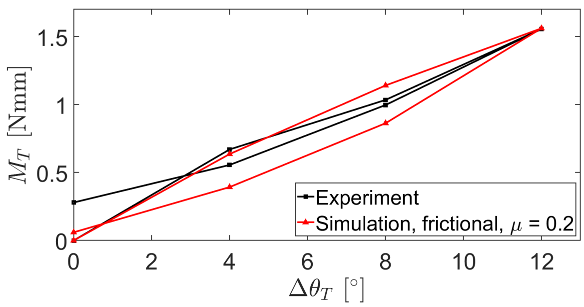

Figure 5: Comparison of experimental and simulation results from torsion experiment on a twisted pair.

A first comparison of experimental and simulation results of bending and torsion on unshielded twisted pairs are shown in Figures 4 and 5. They show that the virtual and real experiment are in general in acceptably good agreement for both load cases. In bending, the areas under the respective hysteresis are of similar size which indicates that the influence of frictional contact is captured well in the simulation. Considering that the hysteresis in the FE simulation only stems from friction between the cables and inelastic material effects are not modeled, we conclude that geometry and friction are the dominant effects for UTPs under bending. While the global spatial displacements of the UTP specimen are large, local material deformations of the two conductors remain small due to their helix shape. Thus, material inelastic effects such as plasticity do not contribute to the inelastic response of the UTP.

The presented modeling approach allows for detailed investigation of mesoscopic inelastic effects such as friction in comparison to material inelasticities, which cannot simply be separated in experiments. Here, we apply it for the first time to technically relevant objects allowing for an interpretation of the observed inelastic phenomena in comparison with experiments.

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