Towards viscoplastic constitutive models for Cosserat rods

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Abstract

Flexible, slender structures like cables, hoses or wires can be described physically correct by the geometrically exact theory of Cosserat rods [1]. The principal constituents of the rod model are: geometrically exact kinematics relating configuration variables and objective strain measures, balance equations that govern the dynamic equilibrium of the sectional kinetic quantities, and constitutive equations which yield the sectional forces and moments in terms of the deformation.

Finding an appropriate constitutive model is especially necessary to enable a realistic simulation of the deformation behavior of a structure. While a standard (hyper)elastic description may be sufficient to represent geometrically nonlinear deformations in academic test examples, every day experience shows that e.g. electric cables behave quite differently. Due to their complex internal structure, which consists of several twisted metallic wires, insulating layers, etc., inelastic effects like viscoelasticity, friction and plasticity cannot be neglected. In our contribution we focus on viscoplastic effects and present first steps towards an application oriented modeling approach on the level of sectional quantities similar to Simo et al. [2].

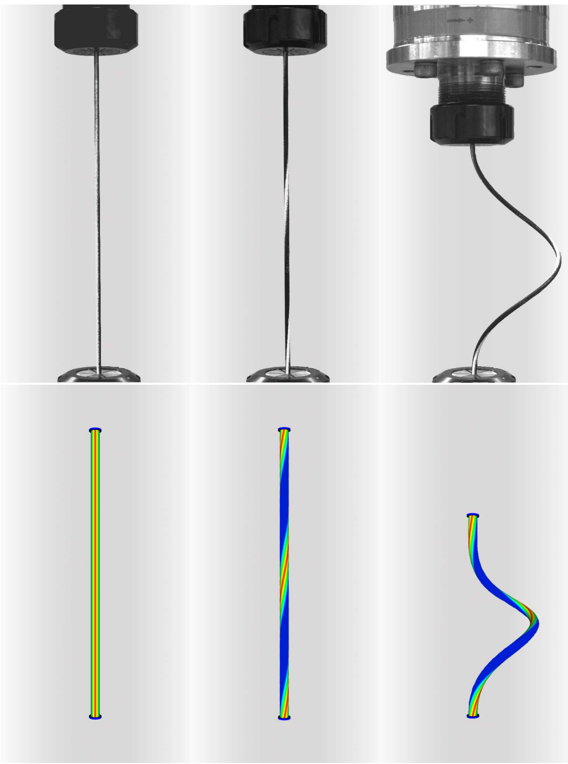

Figure 1: Experimental and simulated configurations of an undeformed cable (left) after one clamp is rotated by 720° (middle) and the distance between the clamps is shortened by 30 % (right).

We test straight clamped cables in large deformation experiments combining bending, torsion and tension. The ends of the cables are fixed in parallel clamps, as shown in Figure 1. One of the clamps is rotated around the longitudinal axis, or moved along the axial direction towards the other one during loading. These load steps can be combined arbitrarily and lead to complex three-dimensional configuration sequences of the cable. Simulations of these experiments based on our implementation of a Cosserat rod model have been performed as well. Experimentally obtained and simulated configurations can be compared in figure 1. In addition, axial forces and moments were measured during the experiment.

Similar experiments have been performed by van der Heijden et al. [3] with superelastic metallic wires, with a comparison of the experimental results to semi–analytical computations using an inextensible Kirchhoff rod model (i.e.: a constrained variant of the Cosserat rod with inhibited longitudinal extension and transverse shearing). Our sequentially measured values of the axial forces and moments deviate qualitatively from the experimental and theoretical results shown in [3], while the spatial configurations we observed during our experiments with the cables match the kinematic effects described for the metallic wires quite well. This motivates the necessity to include inelastic effects in the modeling of cables under complex deformation. Besides classical standard tests to measure bending, tensile and torsional stiffnesses, proper experiments to identify model parameters beyond the elastic range have to be designed. Our work aims at first steps in this direction.

References

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