Perversions in Helical Rods and a Plant-Inspired Phase Transition

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Abstract

Helical rods (elastic springs) provide a simple system that highlights complex non-linear phenomena occurring right at our fingertips. The unwinding of helical rods leads to the formation of a *perversion*. This topological defect connects a helix of positive chirality to one of negative chirality, as seen in the tendrils of climbing plants such as cucumbers or vines. Upon rotation, the perversion can migrate along the rod, enabling a complete reversal of helix chirality. Mechanical measurements conducted during chirality reversal revealed that the perversion migration occurs at a pseudo-constant axial torque, drawing an analogy to fluid phase transitions, where the two phases-helices with opposite chiralities-are connected by a perversion acting as the interface, resulting in the emergence of an analogous Maxwell plateau. Within the framework of this biphasic expansion, the overall mechanical behavior, including a phase diagram detailing the existence of the conformations with helices of opposite chiralities, was reproduced. The stability of the perversion solution was also studied as a function of the imposed axial load. Experimental observations revealed that the perversion solution destabilizes at low axial loads, leading to self-touching conformations. This destabilization was also captured numerically using shooting methods and continuation techniques. The shooting method also enabled the recovery of configurations featuring multiple perversions, consistent with experimental observations. Examples include configurations with two perversions and periodic perversion patterns, also known as godet solutions.

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