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Elastica Arm Scale and Torsional Locomotion

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The Eshelbian (or configurational) force is the main concept of a celebrated theoretical framework associated with the motion of dislocations and, more in general, defects in solids [1]. In a similar vein, in an elastic structure where a (smooth and bilateral) constraint can move and release energy, a force driving the configuration is generated, which therefore is called by analogy 'Eshelby-like' or 'configurational'. This force (generated by a specific movable constraint) can be derived both via variational calculus and, independently, through an asymptotic approach [2]. Its action on the elastic structure is counterintuitive, but is fully substantiated and experimentally measured on a model structure that has been designed, realized and tested. These findings open a totally new perspective in the mechanics of deformable mechanisms, with possible broad applications, even at the nanoscale. Two applications are presented:

- A 'deformable arm scale' (completely different from a traditional rigid arm balance, Fig. 1, left). The idea is not intuitive, but is the result of nonlinear equilibrium kinematics of rods inducing configurational forces, so that deflection of the arms becomes necessary for the equilibrium, which would be impossible for a rigid system. In particular, the rigid arms of usual scales are replaced by a flexible elastic lamina, free of sliding in a frictionless and inclined sliding sleeve, which can reach a unique equilibrium configuration when two vertical dead loads are applied. Prototypes realized to demonstrate the feasibility of the system show a high accuracy in the measure of load within a certain range of use.
- The 'torsional gun' and torsional locomotion (Fig. 1, right). One edge of an elastic rod is inserted into a frictionless and fitting socket head, while the other edge is subject to a torque, generating a uniform twisting moment. It is theoretically shown and experimentally proven that, although perfectly smooth, the constraint realizes an expulsive axial force on the elastic rod, which amount is independent of the shape of the socket head. The axial force explains why screwdrivers at high torque have the tendency to disengage from screw heads and demonstrates torsional locomotion along a perfectly smooth channel. This new type of locomotion finds direct evidence in the realization of a 'torsional gun', capable of transforming torque into propulsive force.

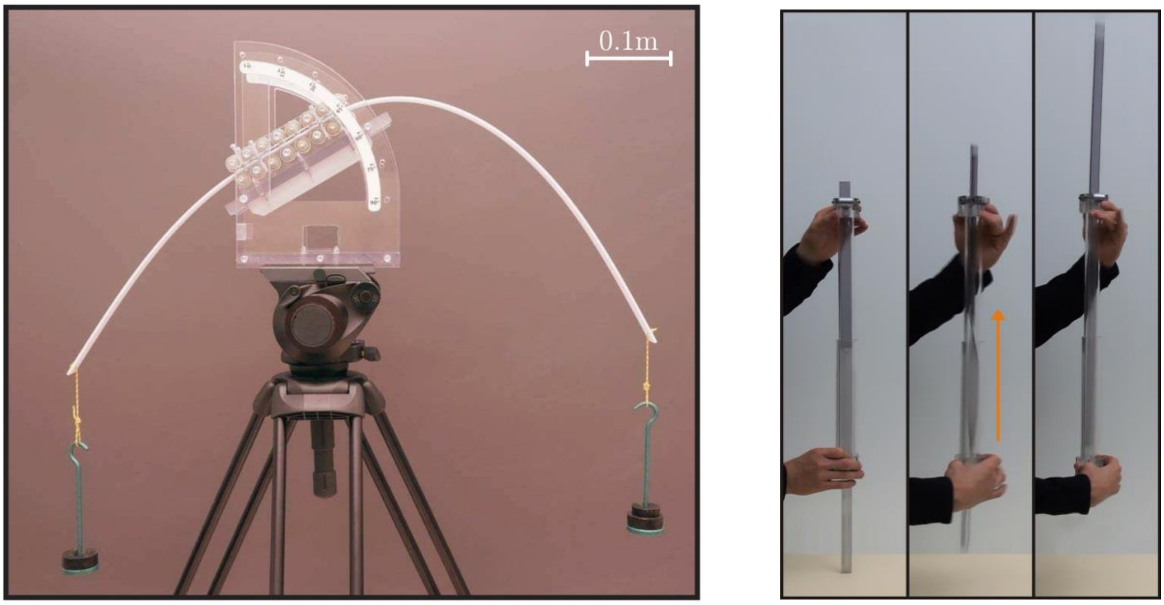

Figure 1: Two applications of configuration mechanics concepts: (left) an elastic arm scale and (right) the torsional gun showing longitudinal propulsion from twist.

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