Unfolding of a bistable tape spring: analogy with a regularizd Ericksen bar with nonconvex potential and extended Lagrangian

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Abstract

The motivation of this work is to better understand the dynamic behavior of bistable structures presenting an analogy with regularized Ericksen bars. The archetype of such structures is the bistable tape spring, which exhibits a particular scenario of deployment, from the stable coiled configuration to the straight stable configuration: at each time of the deployment, the geometry of the tape is similar to a two-phase bar with a coiled part and a straight part separated by a transition zone that moves along the tape. One goal of this work is to show that a regularized and bistable Ericksen bar model contains all the properties to reproduce such a dynamic behavior. The mathematical structure of this model presents a locally non-convex potential with two minima and a dependence of higher order terms. Some similarities exist between this model and the Euler- Korteweg system with a Van der Waals equation. To study numerically the dynamic behavior of such models, it is necessary to solve a dispersive and conditionally hyperbolic system. For this purpose, the Lagrangian of the regularized bistable Ericksen model is extended and penalized. Variable boundary conditions are deduced from Hamilton's principle and are used to control the evolution of the system. Dispersion analysis allows to determine the numerical parameters of the model. The obtained non-homogeneous hyperbolic system can be solved by standard splitting strategy and finite-volume methods. Numerical simulations illustrate how the parameters of the model influence the width and the propagation speed of the transition zone. The effect of energy dissipation is also examined. Finally, comparisons with an exact kink wave solution indicate that the extended Lagrangian solution reproduces well the dynamics of the original Lagrangian. [1] S. Bourgeois, N. Favrie, B. Lombard, "Dynamics of a regularized and bistable Ericksen bar using an extended Lagrangian approach", to be published in International Journal of Solids and Structures (2020).

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