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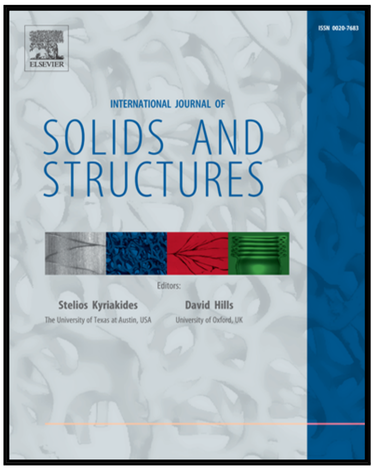

Enhanced Piola–Hencky discrete models for pantographic sheets with pivots without deformation energy: numerics and experiments

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ENHANCED PIOLA–HENCKY DISCRETE MODELS FOR PANTOGRAPHIC SHEETS WITH PIVOTS WITHOUT DEFORMATION ENERGY: NUMERICS AND EXPERIMENTS

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ABSTRACT. The problem of the synthesis of second gradient (meta)materials, via architectured microstructures made of micro-lattices, has been solved [1, 2] by choosing ideal pivots as preferred constraints. The obtained homogenized macro-equations [3, 4]) show some pathologies that reflect the exotic behavior of the considered metamaterials, even if they are of interest by themselves [4]. The theoretical issues that they raise not only represent an intellectual challenge but also means for disclosing potentially interesting new phenomena. To make such disclosure evident, the related technological demand arose, namely, to find an innovative design and production process to construct [5], by using additive manufacturing, some pantographic sheets (made in this instance of polyamide but hopefully later also using metals or alloys) whose pivots do twist practically without deformation and with negligible dissipation. Remarkably the specimen could be printed in a monolith and required no post-assembly but only an easily standardized run-in procedure. In this paper, in order to introduce a mathematical description for pantographic sheets with perfect pivots and to avoid to face the aforementioned pathologies, a discrete, finite dimensional, Lagrangian model is formulated. Moreover, in order to include the case in which the beams interconnecting the pivots are long enough to store non negligible bending energy between the closest pairs of pivots, an enhanced Piola–Hencky discrete model is introduced. Two types of nodes are distinguished, the first one interconnects two pantographic fibers, the second one simply interconnects two different segments of the same fiber. The *Vietnam long neck* peculiar deformed shape experimentally observed in standard extension bias test, is obtained with very short computing time, so that the innovative code which has been elaborated can be used as subroutine in more complex computation schemes. A preliminary digital image correlation analysis, see [6, 7], is performed and shows that a remarkable agreement between theoretical predictions and experimental evidence can be obtained. This circumstance is easily explained by observing that said numerical code is based on a discrete model directly inspired by the mechanical properties of pantographic sheets and that, therefore, the passages to a continuum model via homogenization [8] and then to the subsequent re-discretization, via the introduction of more or less suitable finite elements, are avoided. In our opinion a *theory driven* formulation of a directly discrete numerical model presents many advantages and it seems suitable for attacking future structural optimization problems.

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Key words and phrases. Mechanics of materials, pantographic sheets, discrete models, nonlinear analysis.