Origami based composites: A metamaterials investigation by finite element analysis

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According to Lv et al [1], a mechanical metamaterial is a man-made material with mechanical properties defined by their micro-structure instead of the properties of each component. To be able to achieve such characteristics a new design paradigm must be introduced. The traditional concept of mechanical properties based on materials' constituents must be avoid. The ancient art of paper folding, i.e. Origami, is evolving as one branch of these new design paradigms. The work developed by Miyashida and Ruas [2] employed origami techniques to create self-folding structures based on uniform heating of polymeric materials, in their case PVC. The same concept of origami folding structure was applied by Tolley et al. [3]. In this case, shape memory alloys (SMA) were employed as the main source for the activation system. The same concept was also applied by Peraza-Hernandez et al. [4], the activation system, however, was based of two outer layers of SMA wires and an inner compliant insulated layer. In this case, the folding patterns based on origami were design in such way that uniform heat is the main source for SMA activation. In all cases, origami-like metamaterials are based on the premise of rigid folding. However, as pointed by Saito et al [5], the folding and unfolding process is complemented by elastic deformations in real structures. This paper investigates the stress and strain fields, using finite element analysis, developed during the folding and unfolding of an origami-like composite micro-UAV wing. To be able map the stress-strain fields a 3D model was developed where creases were simulated by wide and narrow gaps located at outer layers. Moreover, as metamaterials are independent of materials' properties the model was based on combination of craft paper (density varied from 180 g/cm^2 to 300 g/cm^2) and natural latex, which provide the perfect combination of stiffness and compliance for folding and unfolding.

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