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Manipulating the snap-through behaviour of bistable scissor structures through computational design and optimisation

Liesbeth I.W. ARNOUITS*, Thierry J. MASSART, Niels DE TEMMERMAN^a, Péter Z. BERKE

*Structural and Material Computational mechanics (SMC), BATir Department, Université libre de Bruxelles (ULB)
50, avenue Franklin Roosevelt, 1050 Brussels (Belgium)
larnouts@ulb.ac.be

^a Department of Architectural Engineering, Vrije Universiteit Brussel (VUB)

Abstract

Bistable scissor structures consist of beams connected by hinges. They are transportable, reusable and can rapidly be transformed from a compact bundle of elements to a deployed configuration, offering a huge volume expansion. These *self-locking* scissor structures avoid the need for external manipulation to ensure stability in the deployed configuration. By the satisfaction of certain geometric constraints, scissor structures can have straight members in the folded and the deployed configuration while geometric incompatibilities exist during transformation responsible for the self-locking feature [1]. This design strategy results in a *bistable* structural response which is caused by the bending of some specific members due to the geometric incompatibilities during transformation. The structural response is characterized by a controlled *snap-through* behaviour that ‘locks’ the structure and assures instantaneously some structural stability in the deployed configuration [2].

Because of their transformable bistable nature, their design requires assessing both the non-linear transformation behaviour, as well as the service state in the deployed configuration. A proper structural design has to provide sufficient stiffness in the deployed state, while providing flexibility during deployment to limit the force required for transformation; these are in fact contradicting requirements. Due to this complex structural behaviour, which prevents the formulation of any straightforward design methodology (closed form), existing applications of bistable scissor structures are rare. The requirement of a low force during transformation and the opposing high stiffness requirement in the deployed state were formulated in previous work as a multi-objective non-linear optimisation problem with different material combinations and beam cross-sections as design variables [3].

As complement to this past work, this computational contribution elaborates a novel, data-based step preliminary to the final structural optimisation procedure in which the snap-through behaviour can be estimated and adjusted at a low computational cost. This original approach yields a fast prototyping of design configurations that are realistic input data for the subsequent structural optimisation step.

Keywords: structural engineering, non-linear computational mechanics, transformable structures, deployable structures, scissor structures, bistability, snap-through, multi-objective optimisation.

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