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Space Structures II Development and Verification (Orbital deployable and dimensionally stable structures, including mechanical and robotic systems and subsystems) (2)

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A MULTI-OBJECTIVE OPTIMIZATION APPROACH TO DESIGN BISTABLE COLLAPSIBLE TUBULAR MAST

Abstract

The collapsible tubular mast (CTM) is a deployable structure made of two omega shaped shells, where each omega is composed of three arcs and is mirrored to the other. Recent effort has been placed to induce bistability in CTM. In a bistable boom, along with the strain energy wells associated with the stable deployed state, another strain energy well can be found which correspond to the boom stable coiled state. The arcs' geometries of the two shells affect the existence of second strain energy well and its associated physical property, which is the stable coiled radius responsible for the boom packaging efficiency. Along with packaging efficiency, many other metrics, such as bending stiffness and weight, depend on the arcs' geometries. The relative performance indices (high packaging efficiency, high bending stiffness and lightweight) are severely competing. A single-objective optimization offers only one optimal solution, narrowing the optimization to one performance index at a time, while a multi-objective optimization provides flexible solutions for conflicting performance indices to achieve a global optimization. In this work, the effect of varying arc geometries on the bistability behaviour, stiffness properties and weight were determined for boom cross-sections formed by circular segments. Particularly, an in-extensional analytical model describing the bending deformation mechanics of shells was used to capture the arcs' geometry influence on the stable coiled radius, while the stiffness properties are evaluated through the area moments of inertia about the principal axes. Then, a multi-objective optimization approach is used, by applying a multi-objective particle swarm optimization (MPSO) algorithm. The full design space is explored, with all the arcs' geometric parameters acting as free design variables with the only constrain of equal length between the shells. The MPSO algorithm gives in output the Pareto front, a set of the non-dominated design points, which showcases different trade-offs solutions tailorable for different space-applications. Trade-offs solutions are discussed and optimized designs are chosen based on higher-level considerations.