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Active Dense Tensegrity Structure: A Novel Concept for Shape Morphing Systems

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Active shape morphing system is of relevance for advanced engineering devices such as artificial wing applications. The present work proposes an active dense tensegrity structure as the active system using Shape Memory Alloy (SMA) wire to induce shape morphing on dense tensegrity, a structure assembled of cables carrying tensions only and polyhedral elements under compression only.

The active dense tensegrity is desired to possess significant differences in bending stiffness (K) when considering the bending direction (up or down). Dense tensegrity structure was manufactured using tetrahedra-shaped particles as the compression elements, and carbon fibers were used as the tensional cables such that an assembly in a dense planar array was obtained. Three types of polyhedral elements were considered: regular and homogeneous tetrahedra, truncated tetrahedra, and "Janus-type" tetrahedra made of part soft and hard solid material. For assemblies of regular tetrahedra, the tensegrity possessed the same stiffness in both bending directions (K, upward/K, downward = 1 due to symmetry), while for the tensegrity of the truncated tetrahedra (K, upward/K, downward = 25.2) and of the "Janus-type" tetrahedra (K, upward/K, downward = 4.7), significant bending stiffness asymmetries were realized, and a basic theory for the mechanical response of dense tensegrity structures was presented.

SMA wires were integrated into dense tensegrity with a span-wise manner as the actuator. Experiments were performed on active dense tensegrity with truncated tetrahedra. Results showed that SMA wires were capable of inducing controlled bending deflection. Various types of truncated tetrahedra were generated with different percent of cut-off portions, and they are 33%-off, 25%-off, 15%-off, and 0%-off (regular). Active response from the experiments revealed that the maximum bending deflection are 24 mm, 14 mm, 6 mm, and 0 mm for samples with above cut-off portions, respectively.

The active dense tensegrity has been demonstrated as a potential solution for shape morphing system concepts. In the future, it will be further developed into wing applications.

Research advisor Thomas Siegmund writes, "Hybrids are an emerging class of materials that obtain properties from microarchitecture rather than from chemical composition. Tensegrity concepts are ideally suited for such developments. Our work on novel dense tensegrity systems expands the material property space."

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