Active Dense Tensegrity Structure: A Novel Concept For Shape Morphing Structures

Zhiwei Wu, Purdue University and Thomas Siegmund, Purdue University

Shape morphing is of relevance for advanced engineering systems such as future aerospace vehicles. Tensegrity structures, a structure comprised of a set of discontinuous compressed struts held together with a continuous web of tensioned cables, can function as the foundation of a shape morphing system (Keith et al, 2007). However, the classic tensegrity structures may not be ideal in all configurations because the space within the structure is not utilized. As an alternative, the present work proposes a dense tensegrity system as an assembly of cables carrying tensions only and polyhedral elements under compression only. An active dense tensegrity can be achieved by equipping the dense tensegrity with active cables. Shape Memory Alloy (SMA) wires are capable of working as the actuation cables in the dense tensegrity.

As a potential solution to shape morphing wings, active dense tensegrity structures are desired to possess significant differences in bending stiffness (K) when considering the bending direction (up or down). Active dense tensegrity structures were 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. For assemblies of regular tetrahedra the tensegrity possesses the same stiffness in both deflection directions (K, upward/K, downward=1 due to symmetry), while for the tensegrities 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 are realized. A basic theory for the mechanical response of the passive dense tensegrity systems is presented.

SMA wires were integrated into the tensegrity in a span-wise manner as the actuation systems. Experiments were performed on the tensegrity with truncated tetrahedra. The results show that the actuation system using SMA wires is capable to induce controlled bending deflection into dense tensegrity structure. Various types of Truncated tetrahedral were generated with different percent of cut-off portion in order to make several active dense tensegrity structures. They are 33%-off, 25%-off, 15%-off, and 0%-off (regular). Passive deflection tests are performed on these samples and results were generated for analyzing stiffness. Active response from bending tests revealed that the maximum bending deflection are 24 mm, 14 mm, 8 mm, and 0 mm for above four different samples in respect.

The active dense tensegrity has been demonstrated as a potential solution for shape morphing wing concepts. In the future, the active dense tensegrity will be modified into active shape morphing wings for Ornithopter applications. Also, the extra space created within the dense tensegrity structure has the potential capability for the wings to store fuels for the Ornithopters.