Three Dimensional Cellular Structures Enhanced By Shape Memory Alloys

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The technical literature abounds with lightweight structural concepts using periodic cellular structures such as honeycombs and lattice block materials. Lattice blocks, consisting of truss architectures at a micro-or meso-scale, are preferred over honeycombs when the loading situations are more three dimensional, or when honeycomb fabrication is not compatible with the desired material selection. In the past 5 years, an exciting outgrowth of these concepts is the development of “auxetic” structures, which are characterized by negative Poisson’s ratios (indicating that a material/structure gets thicker when it is stretched, the opposite of normal behavior). The combination of strength and flexibility of these structures enable many innovative lightweight structural concepts such as morphing wings and fan blades, and auxetics are also projected to have improved impact resistance and therefore have relevance to fan containment systems. Constructing the cellular structures from shape memory alloys (SMAs) provides even greater potential. SMAs can be used in two ways, depending on alloy selection and temperature. First, SMAs can be designed to take advantage of the shape memory effect. Here, the structure can change shape as a response to heating and cooling cycles to achieve morphing behavior, or alternately a self-healing concept where damage from an impact event can be recovered via a thermal treatment. Secondly, SMAs can be designed to be superelastic, where extremely high deformations and loads can be achieved while still behaving in a reversible manner similar to an elastic response (and thereby allowing long lives and durability in fatigue, gust and impact loading situations). We propose to apply SMAs to lattice and auxetic structures that will expand capabilities into three dimensional actuation, new lightweight and flexible flap and winglet designs, variable geometry inlets and nozzles, as well as highly-impact resistant structures. To date, lattice block castings have been fabricated from both a structural titanium alloy and a SMA. Individual ligaments extracted from the lattice have been tested to compare properties to those of conventionally processed material. Finally, a finite element based model has been constructed to predict the behavior of lattice structures under various loading conditions and will be compared to experimental results of lattice panels tested in bending and compression.