



CHARACTERIZATION OF A SHAPE MEMORY POLYMER BASED SYNTACTIC FOAM

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ABSTRACT

Syntactic foams are currently being used in marine and aerospace systems due to their low weights, ease of formability, and higher compressive strength [1]. Shape memory polymers (SMPs) have recently found applications in the medical industry due to their unique shape changing capability and low biological reactivity [2]. They also have the potential for use with textiles, sensors, and actuators [3].

One of the distinct advantages SMPs have over other shape memory materials is their ability to withstand large deformations while still retaining good shape memory properties (up to 100% strain recovery vs. ~10% for shape memory metals) [4]. SMPs utilize an entropic elasticity known as the shape memory effect, which arises during a programming phase when the material is deformed above its glass transition temperature. It is possible to store strain during this phase and to later retrieve it during a subsequent recovery step.

This study seeks to bring syntactic foams and SMPs together to create a low-density smart composite, which retains characteristics from both groups. Eventually, the composite foam material will serve as the core of a grid stiffened sandwich structure capable of healing impact damage as discussed elsewhere [5].

To this end, the current work focuses on the characterization of a shape memory polymer based syntactic foam.

Our composite material consists of a cross-linked styrene resin matrix to which hollow glass microspheres and multi-wall carbon nanotubes are added. Bulk material is fabricated using a multi-step mixing process, employing hand, ultrasonic, and shear methods followed by a curing cycle, which was developed in house [5]. This procedure produces foam specimens that are 42% less dense than the pure resin. This reduction makes our composite a good candidate for applications where weight is a concern.

Two important shape memory parameters, shape fixity and shape recovery, are determined for an array of strain levels, temperatures, and material compositions. For strain levels of 5, 30, and 60% we find respective fixity values for the foam of 78, 95, and 97%, retaining 92, 98, and 98% compared to the pure SMP resin. Correspondingly, 100, 87, and 84% of the stored strain can be recovered.

A 1-D compressive loading method is used to find the stress-strain response during programming and how it is affected by material composition and temperature up to strain levels of 60%.

Additionally, a fully gauged thermomechanical cycle is presented to show the stress-strain-temperature relationship during programming and recovery steps (Fig. 1).

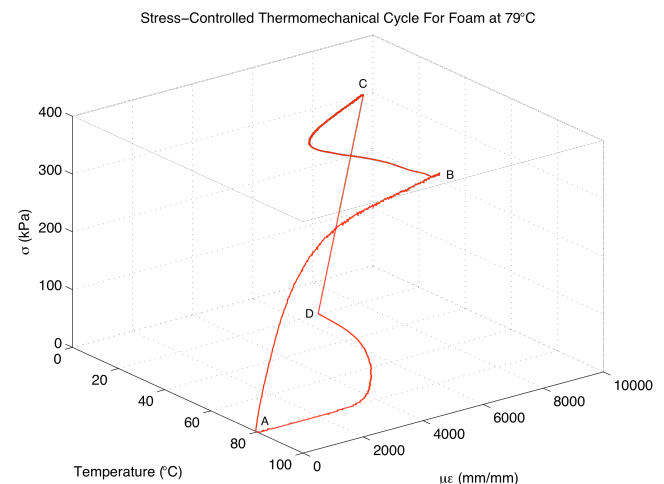


Figure 1. Four-step thermomechanical cycle for foam specimen showing programming and full recovery at 79°C.

SEM imaging is used to show the microstructural features and changes.

We conclude that our shape memory polymer based syntactic foam is able to achieve shape memory performance approaching that of pure SMP resin while being 42% less dense. The addition of glass microspheres improves the strength versus open-celled foams while only marginally adding to the weight. The stress-strain-temperature relationship will help to optimize programming and recovery and tailor these steps for specific applications.

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