Society of Engineering Science 51st Annual Technical Meeting

1–3 October 2014

Purdue University, West Lafayette, Indiana, USA

Damage evolution in a bonded nonwoven glass fiber network under cyclic compression

Siegmund, Thomas; Chen, YingLong, Purdue University, United States

ABSTRACT

This study is concerned with nonwoven materials are made of network of glass fibers and consolidated by local bonds, such as geometric entanglement, local thermal fusion, or chemical binders. The objective of the study is to gain understanding of the damage accumulation processes during cyclic compression. The micromechanisms of damage during tensile loading of nonwoven materials have widely been studied and it is found that fiber–fiber bond failure followed by frictional sliding between fiber bundles, leading to the localization of damage is a dominant failure mechanism. However, the fracture mechanism a fiberglass network under compression is less understood. The compressive load response is nonlinear due to fiber-to-fiber contact. Comparing microCT images of samples before and after loading, we infer that fiber fracture is the dominant failure mechanism. Based on these observations, we hypothesize that the damage accumulation under cyclic compressive loading emerges indeed from fiber fracture, but that due to the accumulations of such fractures, high-stress locations are successively eliminated from the microstructure. In order to establish the validity of the hypothesis, the study reports on cyclic loading experiments on a range of strain ranges, in combination with acoustic emission measurements, as well as on a computational modeling effort. Strain-controlled cyclic (low-cycle fatigue) compression tests were carried out on samples of extracted from nonwoven fiberglass mats to determine the evolution of the stress–strain response and the degradation of the material. A global damage variable, D, is introduced to account for the change in modulus with cycle number N. It was found that the degradation is well described by with the degradation exponential k. It was found that although the modulus exhibits noticeable interspecimen variation, k remained consistent for multiple specimens from the same material system; however, it is dependent on the applied strain. In order to further elucidate the fracture mechanism of the fiber network associated with the global strain, in-situ investigation by monitoring the fiber fracture in the structure with the strain history is hereby proposed using acoustic emission (AE) detection technique. In contrast to AE where the system is directly coupled to the sample, here the AE signal is acquired indirectly via the load platens. Based on microCT imaging, the association between acoustic events and fiber fracture can be made. The measurements therefore allow us to link the damage onset with global strain and the influence of AE activity level during multiple load cycles on the material deterioration. Finite element models based on microCT images are used in conjunction with the XFEM approach to further obtain insight into the damage accumulation process. This approach will finally enable us to provide an explanation for the damage evolution law.