Compressive Behavior of Fiber Assemblies

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We are characterizing compressive behavior of fiber assemblies (e.g. carpets, nonwovens, pillows) with modeling and experimental techniques.

Compressive behavior of fiber assemblies plays an important part in carpets, home furnishing products, nonwoven geotextiles, spun-bonded nonwovens and in fiber mass used in other specialty products such as pillows. Many of the materials used in these applications fail because the material looses its ability to recover from deformation due to fiber failure and slippage. Although this behavior has a very important practical value, no established theory exists to characterize the compressive behavior of these systems adequately. Having a systematic and thorough insight of the compressive behavior will aid in designing fiber assemblies with better resilience resulting in a significant impact in a growing market.

We are focusing on a systematic analysis of the compressive behavior of fiber assemblies in order to characterize their behavior as a function of fiber properties and fiber architecture, and to provide capabilities for predicting this behavior under a prescribed repeated reversal of loads. Compressive behavior of fiber assemblies mainly depends on properties of individual fibers, architecture of fiber assembly, strength of fiber-to-fiber bonds, and fiber-to-fiber friction. Accurate models to capture the behavior of fiber assemblies under compressive loads tend to get very complicated due to the various possibilities associated with these parameters. Simplifying assumptions, such as in van Wyk's approach, have predicted results that sometimes do not agree with experimental results. Most available theoretical and experimental data deals with tensile behavior of fiber assemblies, where non-linear effects become predominant mainly for large deformations. However, to account for compressive behavior, non-linearity and dissipative effects (such as fiber sliding) have to be incorporated in the theory.

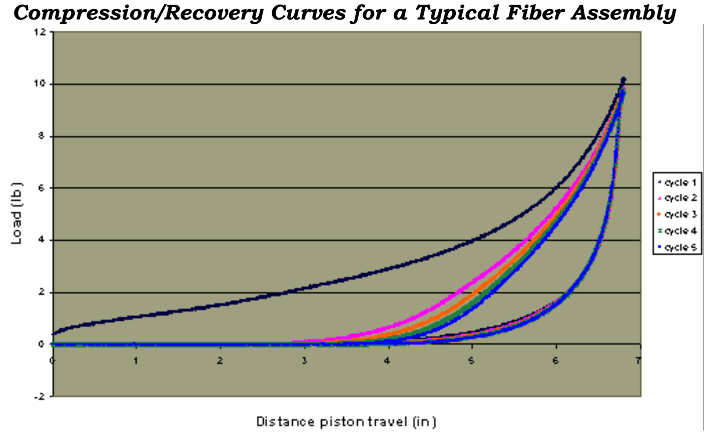
We are, therefore, developing a model that incorporates (1) non-linear effects from large deflections and rotations of fiber segments (2) fiber crimp (3) fiber slippage (4) recovery behavior (5) variable degree of fiber-to-fiber bonding, (6) anisotropic structures (7) two and three dimensional domains and (8) time-dependent deformation and recovery behavior. We are applying lattice methods, general spring network models, micropolar lattice and elastic beams, lattice models with Euler beams or Timoshenko beams, nonlocal and gradient elasticity and other micromechanical techniques to develop a useful, yet simple, model. We are also modifying Matsuo's bending approach by incorporating the compressive fiber segment buckling for a better, yet simple, model to study compressive properties.

Systematic Experimental Studies

We designed an apparatus to measure the compressive and recovery properties of fiber assemblies. A sufficient force is applied to cause compressive deformation of a fiber assembly in a cylinder. Trapped air is removed quickly through the holes on the surface of the cylinder to eliminate the time dependent effect of the consolidation of a fiber assembly due to removal of trapped air from the system. We measure or calculate force, deformation, stress and strain.

The compressive cycle is followed by a recovery phase, where the applied load is removed and the fiber assembly is allowed to expand naturally. Recovery is done by removing the force suddenly or at a certain rate (relaxing) and measuring the time dependent recovery of the assembly. In our experiment, the fiber assembly goes through several cycles of compression and recovery before the effects of fiber slippage and damage of the fiber assembly can be isolated. Compression resulting from fiber slippage is not generally recoverable, thus the loss of resilience in the fiber assembly is a direct measure of fiber slippage and damage, both undesirable effects for many end uses of fiber assemblies. With increasing cycles of compression/recovery on the fiber assembly, resilience and recovery progressively decrease, however, the rate of decrease diminishes (See Graph).

Compression/Recovery Curves for a Typical Fiber Assembly



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Industry Interactions: 1 [DuPont]

Other Non-NTC Academic Interactions: ; Government:

Project Web Address: to be activated
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Karl I. Jacob, Associate Professor in Textile and Fiber Engineering at Georgia Tech, joined the faculty in 1995 after 6 years in mechanics of composites and molecular modeling of polymers with Dacron* Research and Central Research & Development at DuPont. He earned a B.S. in civil engineering in 1978 from University of Kerala (India) and a Ph.D. in engineering mechanics from Ohio State in 1985. Karl's research interests include polymer solidification, flow induced morphological instabilities, molecular modeling and mechanics.

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