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ABSTRACT:

Non-Linear Inelastic 3-Phase FE Models for Calendered Nonwovens

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Nonwovens represent a unique class of engineered textile materials, offering a broad range of properties, including softness, strength, flame retardancy, washability, cushioning, and filtration, among others. In Europe alone, annual nonwoven production exceeds 3 million tonnes, with the hygiene sector representing the largest market segment.

To enable efficient product design processes, it is essential to understand and accurately model the underlying material structure in order to capture its influence on deformation behavior. Calendered nonwovens pose particular challenges in this regard, as their performance depends not only on the fiber properties and web formation process but also on the parameters of the calendering process itself.

Based on micro-computed tomography (μ CT) data obtained from real specimens, we propose a three-phase finite element (FE) modeling approach that combines GeoDict and Abaqus. The approach integrates beam-element representations of the fibers, separately volume-discretized models of the bond points, and dedicated connector elements representing the interphases surrounding the bond points. Within these interphases, low-density fiber regions connect to the much thinner bond points, resulting in steep gradients in material properties that are governed by the calendering process parameters and play a crucial role in determining mechanical performance.

When the constitutive models for all three components—fibers, bond points, and interphases—are accurately calibrated and adequately account for the relevant inelastic effects, such FE models offer the potential to provide fundamentally new insights into the structure–property relationships of nonwovens.