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INELASTIC DEFORMATION OF NONWOVEN TEXTILES DUE TO THE FRICTIONAL SLIDING OF BONDED FIBERS

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Nonwoven textiles are composed of long slender fibers laid on a plane surface and bonded together to form a random network-like structure. Often its integrity is provided by mechanical contact of entangled fibers that restrain fiber motion via friction. Once the friction limit is exceeded fibers will start to slide one relative to another as shown in Figure 1a up to the complete pullout of fibers from entanglements. Such behavior leads to ductile failure of textile with energy dissipated on friction [5].
We propose a numerical study of this phenomenon based on discrete element modeling of the fiber felt. The fabric geometry is represented by a Mikado-type random network trimmed to the shape of the entire macroscopic specimen on a plane. The entanglement density is controlled via placing nodal junctions at a certain fraction of fiber intersections. The segments of long fibers between two subsequent nodes are represented by cable-type discrete elements. They respond to the nodal displacements by an axial force that is linear to the strain in tension and is zero otherwise. Up to some loading the reference contour length of the segments is constant and the fabric is deforming reversibly when subject to quasistatic loading as in Figure 1b.
When the difference between tension forces in two subsequent segments of the same fiber reaches certain yield limit sliding will occur. Some part of the less loaded segment will slip through the entanglement reducing the tension from the opposite side. Unlike in [5] we solve this mechanical problem by a two-level procedure. On the upper level we iteratively update the nodal displacements in order to reach static equilibrium. This task is performed by dynamic relaxation with kinetic damping [7]. The segment forces are determined for the current iteration on the lower level of single fibers presented in Figure 1c. There we compute the junction slips and the updates of segment contour lengths and forces for the given increments of the node-to-node distances. In principle this problem is similar to the stress update in multisurface plasticity [2] although it requires special treatment of fiber pullouts. It will occur when the slip in one of the terminal junctions will exceed the remaining length of the free tail.

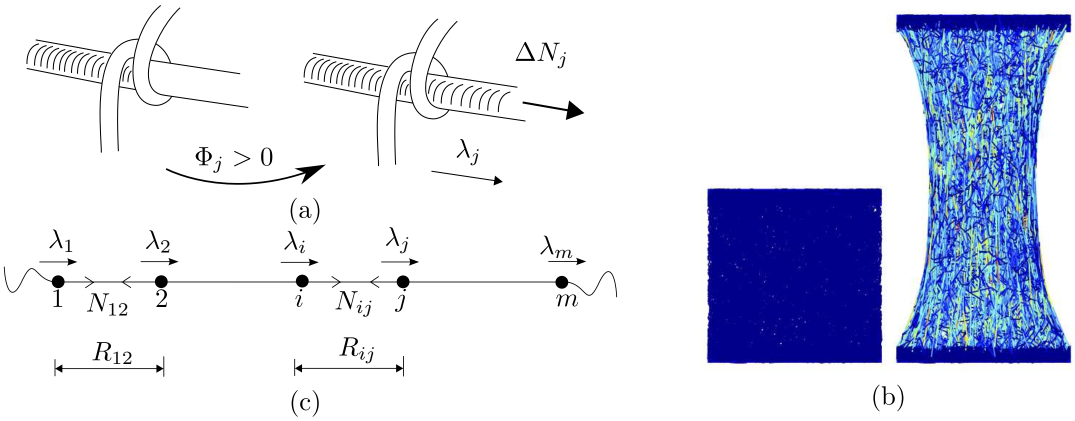

Figure 1: Discrete modeling of plane non woven textiles: (a) schematic representation of fiber sliding through an entanglement; (b) deformed shape and axial fiber forces for quadratic fabric sample stretched between to narrow clamps; (c) sliding subproblem for a single fiber with multiple entanglements.

This numerical framework allows to investigate the relevance of the proposed mechanism for the failure of nonwoven textiles. We can predict when fabrics of short or long fibers can break by fiber sliding and pullout completely without fiber rupture depending on the entanglement density and relation between strength of fibers and interfiber friction. Furthermore it provides insights for the micromechanically motivated homogenized models of fiber-based materials such as [1, 3, 6, 4].

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