Mechanics of Damage Propagation in Thermally Bonded Non-Wovens

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Abstract

Non-woven fabrics find applications in diverse fields such as geotechnical engineering, biomedical engineering, naval and aerospace industries. In this work, we study the dependence of damage initiation and propagation on the bond geometry in a non-woven fabric. In thermally bonded non-wovens, the cross-link/ bond point is artificially introduced by applying heat to the fibres at discrete positions in the random fibre networks. Fibres melt locally, connect and congeal to form cross-links. Therefore, non-wovens with a high network density contain stiff bonded domains that restrict fibre rotations while non-wovens with low network densities result in point cross-links that allow fibres a certain degree of rotational flexibility. The geometry and strength of the bond point plays a crucial role in determining the extent of fibre reorientation and recruitment occurring in the network following damage initiation. Fibres tend to rotate and realign along the direction of the applied tension in order to compensate for the damaged fibres. We aim to highlight the mechanisms by which fibre damage accumulates and propagates in non-wovens with different fibre densities and bonding patterns.

To this end, we introduce **cross-link fraction**, a parameter which is given by the area covered by the cross-link/bond points per unit area of the fabric (assuming that the fabric thickness equals the link thickness). The *cross-link fraction* is proportional to the network density and the area of heat application to achieve the bonding. We consider a stochastic model based on this parameter and study the mechanics of fibre reorientations due to damage of the material.

For our study, we have taken two polypropylene based commercially available non-woven fabrics, one with a high network density and the other with a low network density for validating the developed model. The non-woven fabric structure observed under a microscope was digitized to obtain fibre connectivity and the bond geometries. The constitutive behaviour of a single polypropylene fibre was adopted from the literature. A finite element model of the non-woven is then constructed with fibres modelled as trusses and the cross-links modelled as two-dimensional plane stress elements. The computational model is validated with uniaxial tensile tests upto failure conducted on both fabrics and their responses are compared. The computational model is then employed for a stochastic analysis of the effect of cross-link fraction on damage propagation in non-woven fabrics with varying network densities.

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