# Numerical Modelling of Mechanical Response of Fibrous Materials under Out-of-Plane Loading

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## Abstract

Characterization of mechanical behaviours of randomly distributed fibrous networks is cumbersome since they incorporate a variety of complexities such as random fibre distribution, fibre curvature, time-dependent material response of their constituent fibres.

In this research, a nonwoven fibrous medium was chosen as a case study and its finite element model was developed using a novel parametric 3D Finite Element Algorithm. Through-thickness mechanical response was simulated under out-of-plane loading conditions. This Fibrous network model is superior to existing numerical models in literature , which are incapable of simulating and explaining through thickness mechanical behaviour properly, though some models could simulate tensile mechanical response of fibrous networks [1-2].

The selected fibrous material was scanned by micro CT and reconstructed by a post-processing software. A fibre orientation distribution function (ODF) was computed based on the obtained 3d volume data from the scan. In order to realise a realistic 3D computational microstructure of a fibrous network, 3d curved fibres with various alignments were generated with ODF and discretized in Finite Element environment using a newly developed script written in Python®. This novel 3D model incorporates fibre to fibre interactions such as normal and tangential contacts as long as curvature and ODF.

Single fibres extracted from the fabric were tested at micro tensile tester to obtain elastic, plastic and viscous properties. To validate the new model, the chosen fibrous material was subjected to out-of-plane loading experimentally and the same test was repeated in Finite Element simulations. Through-thickness mechanical behaviour was assessed and contribution of fibre to fibre interactions to out-of-plane mechanical response was quantitatively analysed. Consequently, the model generated by the novel algorithm was found as superior to the existing FE models since it could give account for the complex mechanisms such as fibre-to-fibre interactions, straightening of curved fibres and then their contribution to overall load carrying capacity of the nonwoven.

**Keywords:** Fibrous Networks, Orientation Distribution Function, Finite Element Modelling, Out-of-plane Loading, Through-thickness Mechanical Behaviour, Nonwovens

## References

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