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FINITE ELEMENT ANALYSIS OF THERMALLY BONDED NONWOVEN MATERIAL

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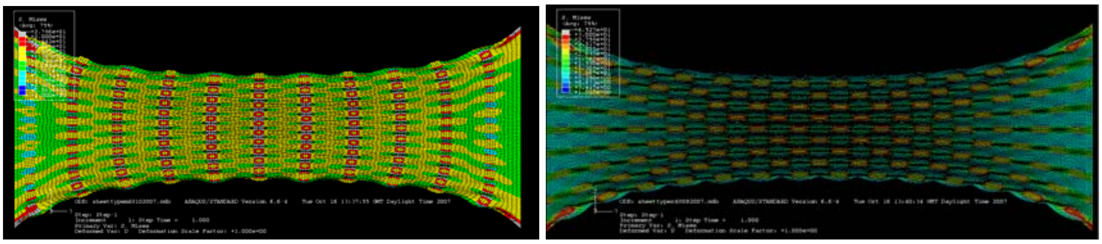
ABSTRACT

A tensile behaviour of a thermally bonded nonwoven material is simulated using finite element method at various scales. The nonwoven material is manufactured by interlocking the fibres through the use of heat energy employing the thermoplastic properties of synthetic fibres such as polypropylene [1]. In last 20 years researchers have done many efforts to summarise deformation mechanisms of such materials and to develop a numerical model in order to describe their deformational behaviour. But due to the random structure of a fibrous network, non-uniform local material properties and non-linear behaviour of single fibres, there is currently no established numerical model that accounts for the random microstructure of the material and describes the material performance on its basis.

Due to the manufacturing process, a thermally bonded nonwoven material can be treated as consisting of two components: bonding points and fibrous network. At macro scale, if the random fibrous network is isotropic [2], the information on bonding points (shape, size and spacing) is the only factor, which causes anisotropic mechanical performance of the nonwoven material in different principle directions. To predict the effect of bonding points on the material, a macro-level FE model has been developed based on the classic composite theory. In this model, the fibrous network is treated as a uniform sheet material, and the bonding points differ significantly in mechanical properties from it. The model demonstrates different deformation performances of the material in both machine direction and cross direction (Figure 1).

Although the first model could reproduce the observed mechanical performance, it is still a qualitative model due to the lack of parameters of mechanical properties of the fibrous network. To describe the strain- and time-dependent behaviour of the thermally bonded nonwoven material and to predict its quantitative mechanical properties, a finite element model with a random fibrous structure is developed (Figure2). It is different to Mueller's model [3], which only introduces a periodic fibrous network. The network of

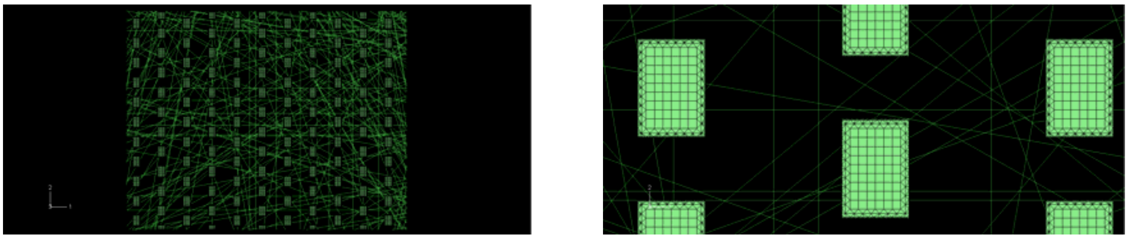


(a) (b)

Figure 1: Macro FEA model for nonwoven material: machine direction (a), and cross direction (b)

fibres in the suggested model is arranged according to the experimentally measured orientation-distribution function. Truss elements are used to represent fibres, and bonding points are meshed using shell elements. Real mechanical properties of fibres are introduced into this model by a subroutine programme to reproduce the observed mechanical response of the fibrous network.

Finally, the stress-strain plots obtained by means of finite-element simulations are compared with those from tensile tests for both machine and cross directions to validate the developed model.



(a) (b)

Figure 2: Micro FEA model (a) and detail of mesh (b)

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