MODELING OF DEFORMATION AND FRACTURE OF NON WOVEN FELTS

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Summary A micromechanical model was developed to simulate the mechanical behavior of non-woven felts. The material is represented as a bidimensional network of straight fibres of finite length. The intersection between fibers formed the nodes of the model. Adjacent nodes were connected through rods that transferred load in the fiber direction. Additionally, torsional spring elements were added to penalize the angle variation between crossing fibers. Fibers were assumed to behave as non-linear elastic solids taking into account inelastic effects such us fiber buckling, fracture and fiber sliding. Computational simulations were compared with experimental data available on a non-woven felt made up of polyethylene fibers with different testing configurations.

INTRODUCTION

In the actual state of technological progress, it is well established that the strongest and stiffest materials are processed in the form of fibers of small diameter. These fibers are not used individually, they have to be performed in complex 2D and 3D fabrics where the fibers are orientated along the design loading directions. Moreover, fibers usually have to be infiltrated with a matrix to protect them from chemical environment or light exposure. As a result, fabrics production is cost expensive and several alternatives arised to overcome this problem. A very simple way is the fabrication of the non-woven felts where the fibers are distributed randomly and clamped together thought thermally fusion points or mechanical needling punching. As a result, felt production is cheaper although their mechanical performance is seriously decreased. Several examples of application of his materials are protection against fire, the geotextiles used to increase resistance of soils and fragment impact protection.

Mechanical properties of non-woven felts are strongly dependent on fiber length and orientation. Several models has been developed to understand and predict the mechanical properties of felts from the mechanical properties of the fibers, distribution, etc. beginning from the early work of Cox to the more sophisticated models of Termonia. Most of these models were adapted from the paper science community which is in essence another kind of non-woven felts. In this work, we have developed a new model to predict the mechanical behavior of a non-woven felt with finite fiber length and orientation that includes deformation mechanisms such us fiber fracture, buckling and fiber sliding.

COMPUTATIONAL MODEL

It was assumed that the felt was adequately represented by a bidimensional network of homogeneously dispersed straight fibers of equal length L, Fig. 1. Centers coordinates (x_c, y_c) were computed assuming a homogeneous distribution through the rectangle felt surface BxH. The mechanical anisotropy of the felt was controlled by fiber orientation. The orientation angle of the fibers θ with respect to the loading axis was assumed to follow some *a priori* well known statistics based on descriptions of chain orientations in amorphous polymers. The felt network was constructed as follows: we generate three normalized random numbers corresponding to i-th deposited fiber. The first two ones were used to compute the fiber center and then respond to a uniform probability function. The third one was used to compute the fiber angle orientation according to the statistic described above. The intersection of the deposited fiber with previous deposited fibers were computed and considered as nodes of the model. 2D truss elements linking two consecutive nodes belonging to the same fiber were added to account for axial deformation of the fiber. Torsional spring elements were added to penalize the angle variation between neighbor fibers allowing load sharing between them. Non connected ends of the fibers were trimmed and eliminated from the model as they do not contribute to the mechanical behavior.

Both truss and spring elements were formulated under finite strains framework and include material non-linearity. The fibers were assumed to behave as non-linear elastic solids with different behaviors under compression and traction loads. Truss elements were allowed to buckle under very small compression loads as their length to diameter ratio (slenderness) was high and consequently their stiffness reduced significantly during the computations. The elastic traction behavior of the truss elements responds to a Langevin type function accounting for a more realistic representation of the real non straight fibers of the felt. The force carried by the fibers is limited by the deformation mechanisms. If the fiber is perfectly entangled to the model, it can support increasing stresses and attain the maximum load dictated by the strength of the bulk material. On the other hand, sliding limits the maximum load supported by the fiber and is dictated by roughness of the fibers with the others. The uniaxial force-elongation curves of the felts were computed incrementally imposing an increasing relative displacement of the edges of the felt. Mechanical equilibrium equations of the nodes was solved using a Newton-Raphson technique until fracture of the felt is achieved.

RESULTS AND CONCLUSIONS

The computational model provided the macroscopic response of the felt made up of ultra high weight polyethylene fibers as a function of the felt density, fiber orientation, and fiber mechanical properties. In particular, the model was used to ascertain the role of orientation and fiber length on the mechanical response on the felts. Figure 2. shows the configuration of a polyethylene felt network up to 70% of deformation. Initial fiber orientation and subsequent rotation along the loading axis as a result of deformation plays a critical role on the mechanical response of felts. Failure mechanisms are also affected by felt dimensions along the loading axis. When the specimen is larger than fiber length, fiber sliding dictates the failure mechanisms. On the other hand, fiber fracture was the dominant mechanisms of small dimensions felts as fibers were perfectly clamped along its ends. As a conclusion, the model can be used to isolate the geometrical parameters that play critical role controlling the deformation and fracture mechanisms.

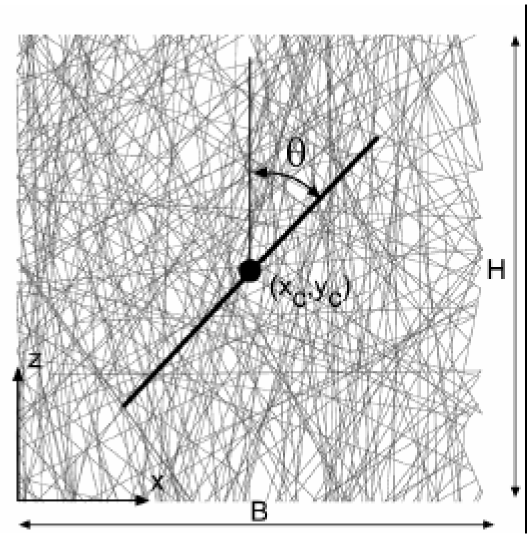

Figure 1. Geometric representation of the felt and fiber center and orientation definition.

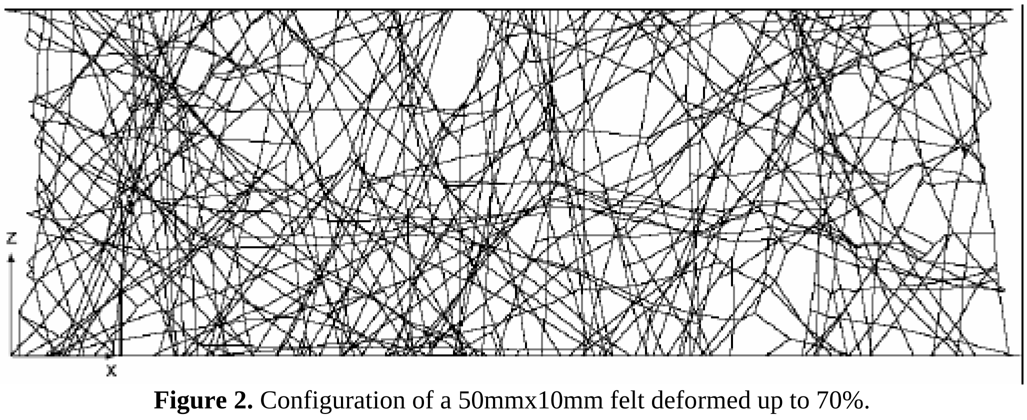

Figure 2. Configuration of a 50mmx10mm felt deformed up to 70%.