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Modelling of large plastic deformation of polyethylene for geomembranes

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Being a versatile material with many advantageous properties, polyethylene is used for making various structural parts in many applications. However, modelling the mechanical behavior of structural parts made of polyethylene is more demanding, as it often requires slightly more complicated material model that includes specific types of behavior like viscoelasticity or plasticity. This contribution is concerned with finite element simulations of tensile test specimens made of polyethylene for geomembranes.

The geomembranes (or geosynthetic barriers) are used as waterproofing elements in construction of civil structures like buildings, roads, railroads, tunnels, solid waste storage sites, reservoirs and many more. Among other tests, the geosynthetics are a subject to tensile tests of specimens directly cut out of the extruded membrane sheets. In these tests, the specimens must achieve a certain level of ductility, which is usually no problem for specimens cut out of smooth-surfaced membranes. However, the surface is often structured on one side or on both sides. The surface features cause the specimens perform worse in the tensile tests. The work described in this contribution is aimed at finding a method for prediction of the performance of real specimens in tensile tests. The prediction should be based on FEM simulations of tests of specimens with various combinations of surface features. The ability to predict the specimens would save substantial costs in developing new types of surface structures for the membranes.

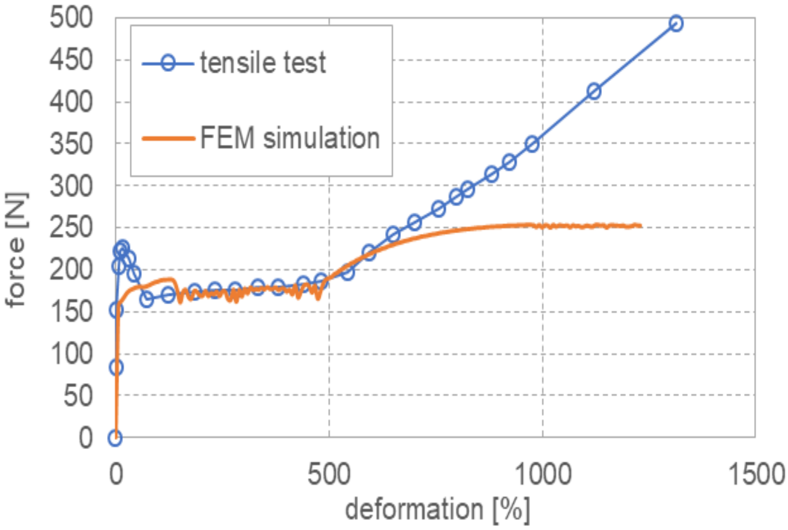

Fig. 1. Comparison of force-deformation dependancy from experiment and FEM simulation

FEM simulation of the specimen was carried out in ANSYS. The material model used in the simulation was based on the tensile test results of the smooth surfaced specimens. The force-deformation dependency obtained from the tests is shown in Fig. 1 (marked as *tensile test*). It has typical features of tensile test results of ductile semicrystaline polymers [3]. The first part is almost linear elastic, then there is the yield point, after which necking occurs. This is marked by a shear drop in the force. In the second part, the neck propagates until the chain molecules of the material become straight. After that, hardening occurs followed by ultimate failure. Note that the elongation at break goes up to 1200 %. This dependency was recalculated to form a true stress-true strain dependency which was used to define the multilinear material model in the simulation. Isotropic hardening rule was used. Other features of polyethylene material, like viscoelasticity and effect of strain rate, were neglected in the model. The strain rate of the tensile tests was 50 mm/min, which should not influence the results substantially [1, 2], and the viscoelasticity is not playing any significant role in this type of problem.

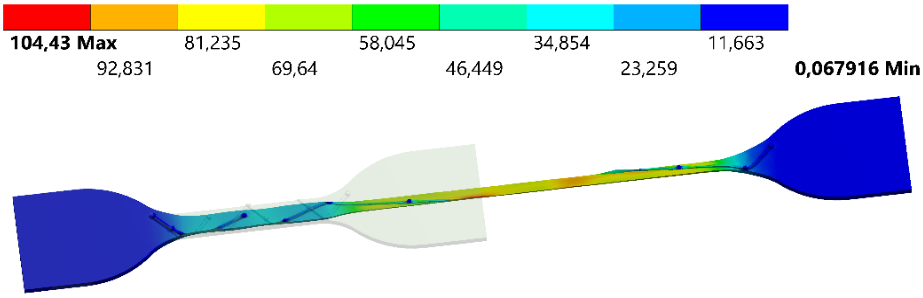

Fig. 2. Simulation of structure-surfaced specimen tensile test

As a first step in the simulations, the tensile test of a smooth specimen was modelled. The ANSYS Autodyn explicit solver had to be used for the solution because of the very large deformations. The force-deformation dependency was obtained and compared to the dependency from the real tensile test (see Fig. 1). The simulated dependency lacks the force increase before the necking but then the necking propagation takes place at identical force as in the experiment and also the final hardening starts in the right moment. However, the hardening part is not described accurately at all in the area of very large deformations. This might be caused by the fact that only simple logarithmic relationships were used to calculate the true stress and strain for the model and their validity is limited to smaller deformations. This problem will be addressed in further work.

The second step was modeling the structured-surfaced specimens (see Fig. 2). So far, it seems that the models can predict the place, where the necking starts in the tensile tests of structure-surfaced specimens. It can be observed in both the failed specimens and the simulation, that the necking starts in the area, where there is the largest space with no surface features. However, a criterion must be formed to assess where the specimens break and the ability of the specimens to achieve a certain deformation after necking.

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