Aluminium foil at multiple length scales, mechanical tests and numerical simulations in Abaqus

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To virtually reflect the anisotropic behaviour of aluminium foil a material model is calibrated after results from uni-axial tensile tests in three main orientations. The coefficient of determination between the virtual and experimental test turned out to be higher than 0.9, where 1 is a perfect fit.

The packaging material at Tetra Pak consists of several layers, such as polymers, aluminium foil and paperboard. In order to predict the behavior of the material during different load scenarios in the production process, virtual models of the processes are made and the load scenarios are simulated. However, there are some shortcomings with the existing virtual modeling approach of aluminium foil. The material is most often treated identical independent of what multi-axial stress state or strain rate that the material is exerted to. Furthermore there is limited knowledge and experience about the anisotropic material behaviour and how the properties in the smaller length scales actually affect the macro behaviour.

Aluminium foil is produced by a long rolling under pressure process. After which the material characteristics have changed. The thickness is reduced to five to ten micrometers and the crystallic grains in the material is squeezed together in lines oriented in the rolling direction (RD). The foil is partially recovered from the rolling in a heat treatment process called annealing, but some left over lines of crystallic grains in the same orientation can usually still be found. Thus there is a principal orientation in aluminium foil which lead to anisotropic material behaviour.

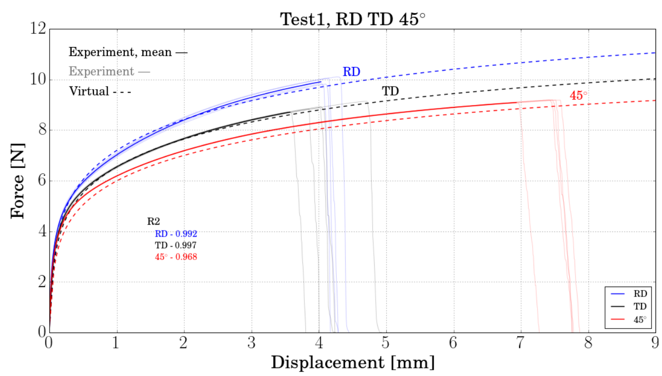

Figure 1: Results for both experimental and virtual testing, where R^2 is the coefficient of determination.

Uni-axial tensile tests were performed in three directions on aluminium foil. The results is shown in figure 1. The anisotropic behaviour of aluminium foil can clearly be seen. If aluminium foil was isotropic there would not be a difference between the curves.

To reflect the anisotropic behaviour of aluminium foil virtually, a material model was calibrated after key-values from the uni-axial tensile tests. The curve was parametrized with Ramberg Osgood model[1], and the plastic behaviour was described with Hill's yield criterion[2]. The Hill model was calibrated after three main directions, RD, TD (transversal direction, 90° from RD) and 45°. A virtual uni-axial tensile test with the calibrated material model was performed for the three main directions, shown in figure 1. The virtual results correlate to the experimental results very well, since the coefficient of determination is higher than 0.9 for every material direction, where one is a perfect fit. With this material model one can more accurately predict the behavior of aluminium foil in simulations with industrial applications.

[1] Walter Ramberg and William R Osgood. "Description of stress-strain curves by three parameters". In: (1943). URL: `http://hdl.handle.net/2060/19930081614`.

[2] R. Hill. "A Theory of the Yielding and Plastic Flow of Anisotropic Metals". In: *Proceedings of the Royal Society of London A: Mathematical, Physical and Engineering Sciences* 193.1033 (1948), pp. 281–297.