EXPERIMENTAL AND NUMERICAL EXAMINATION OF BRAKE CYLINDER MEMBRANE

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1. Introduction
The present work shows the standard uniaxial tensile testing of a rubber-cord composite membrane structure used in railway brake systems. The membrane transforms air pressure growth to unidirectional movement within a wide temperature range. After the material characterization the authors studied the whole composite membrane structure using specimen level compression tests. Having repeated the measurements at different temperatures it can be concluded that the whole membrane produces the same hardening by decreasing temperature as the reinforcement layer in the membrane. The measurements were also analysed using commercial FE software.

The paper points out the importance of temperature and orientation on an orthotropic structure and highlights the necessity of a reliable material law especially for rubber-cord composites.

2. Tensile tests
Uniaxial tensile tests required for setting up the material law were performed on standard specimens on a Zwick 005 tensile testing machine at the Laboratory of BUTE Department of Polymer Engineering. Figure 1 represents the cross-section and main dimensions of the cord-reinforced rubber membrane, while figure 2 shows the specimens cut out in the grainline and at 45°.

Figure 2. Specimens cut in the grainline and at 45°

Figure 3. Average measured force vs. displacement curves

3. FE modelling of tensile tests
A 3D FE model was designed to verify the correctness of the orthotropic material model constructed from the detailed measurements. Figure 4 shows the FE model of the specimen and surroundings while table summarizes the identified material properties.
4. Structural level compression test

The membrane to be examined during the compression test was laid on a plane steel sheet and displacement load was exerted from above, through a shaft of 35 mm diameter, while the membrane’s force reactions were measured. The deformed shaped from measurement and calculation can be compared to each other in figure 6 and figure 7.

5. Summary

Tensile tests were performed on specimens cut in the appropriate directions and made ready for the tests. Afterwards, an evaluation method was developed which can be used for the approximate determination of the essential material properties of a numerical model substituting for the sandwich structure, based on the stress vs. strain curves of tensile tests. Finite element model was also developed which is suitable for modelling specimens of discretionary orientation simply by changing the main material direction of the orthotropic element series integrated in the model. Based on a comprehensive modelling of the tensile tests performed, it was established that the material properties specified are suitable for modelling the composite structure accurately. Furthermore, simulations pointed out the different stress and strain states of specimens cut out in the grainline and at 45° thereto, respectively, as well as the substantially different deformation states the collectively of which induces direction-dependent behaviour as customary for composite structures.

As a second step, an experimental analysis was performed to examine the membrane behaviour under special compression. The numerical modelling was also implemented which was highly hampered by the presence of extensive geometric non-linearity. The study showed that a membrane can be properly modelled at room temperature and at low-temperature the membrane became much stiffer than at room temperature.

6. References
