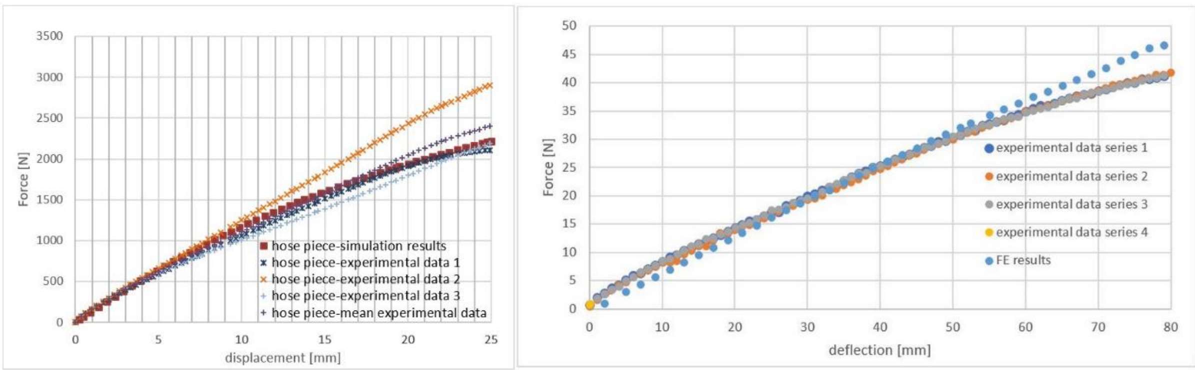
Structural behaviour analysis of cord-rubber composite tubes

Cord-rubber composite tubes are widely used in automotive and railway industry, aeronautics and offshore applications. High specific strength, high specific strain and corrosion resistance are among their most advantageous properties. The most frequent loads are internal pressure, uniaxial tension, biaxial tension and bending.

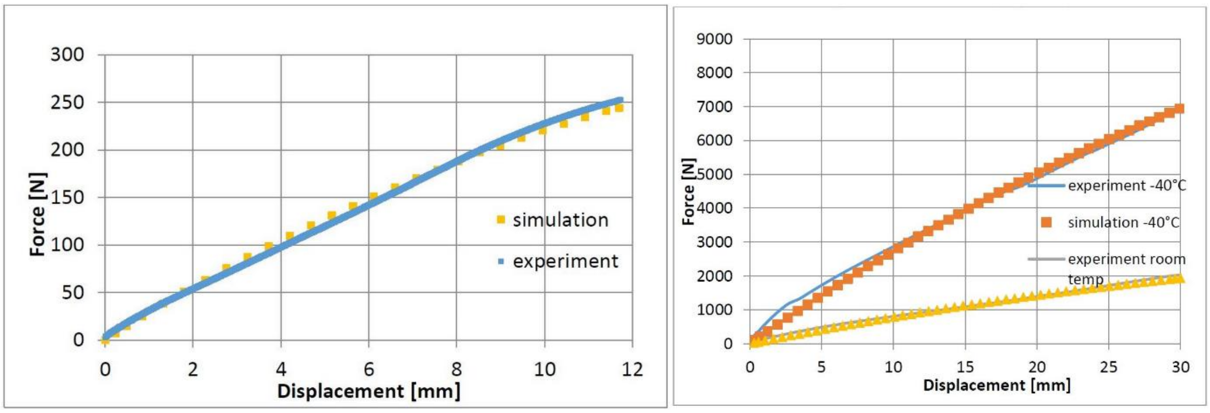
The aim of this research is to create FE models for describing material behavior of composite tubes in case of the aforementioned load cases at room temperature, at low temperature for static and cyclic loads so as to increase cold-proof property and fatigue strength of these parts. The composite tubes are utilized by Knorr Bremse Rail Systems Hungary in air brake systems.

Firstly, material properties of the composite tube have been determined at room temperature based on the stress-strain curves of uniaxial tension of the components and fiber volume fraction assuming transversal isotropy for the reinforcement layers and utilizing a 2 parameter Mooney-Rivlin model for rubber liners. These material models have been validated by tensile tests and FE models of uniaxial tension of standard test specimen and tube piece. [1]. For further experimental validation, three-point bending test and standard bending test for air brake pipes have been conducted. [2]



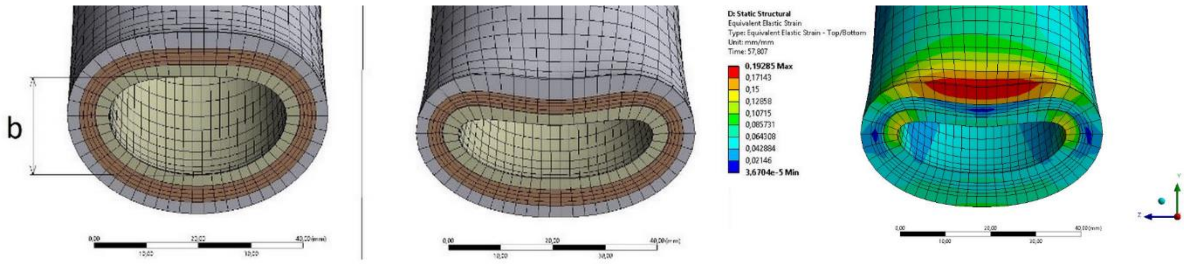
Force-displacement curves of tube piece subjected to uniaxial tension (left), force-displacement curves of three-point bending (right)

At low temperature (-40°C), material properties have also been determined, validated by uniaxial tensile tests on standard test specimens and tube pieces, comparing the mechanical behavior of the tube with that of at room temperature. [3]



Force-displacement curves of standard test specimen at -40°C (left), force-displacement curves of tube piece at -40°C and at room temperature (right)

Instabilities, being potential causes for failure, have been further analysed (global buckling and cross-section instability) of composite tubes subjected to compression/bending by utilizing the material models verified before. The results have been validated by an experiment. Characteristic curves have been determined (force-displacement, curvature-displacement, oblateness parameter-displacement). It has been found out that probable failure mode is yarn-matrix debonding based on stress and strain states. (Instability analysis of a filament-wound composite tube subjected to compression/bending, Advanced Composites Letters, manuscript submitted)



Ovalized cross-section just before and at the start of cross-section instability (left), equivalent strain at cross-section instability in nonlinear buckling simulation, in plane YZ (right)

Publications

[1] Szabó G., Váradi K., Felhős D. Finite element model of a filament-wound composite tube subjected to uniaxial tension, Modern Mechanical Engineering, vol. 7, no. 4., pp. 91-112., 2017
[2] Szabó G., Váradi K., Felhős D. Bending analysis of a composite tube, Modern Mechanical Engineering, vol. 8, no. 1, pp. 66-77, 2018
[3] Szabó, G. and Váradi, K. Uniaxial Tension of a Filament-wound Composite Tube at Low Temperature, Acta Technica Jaurinensis, vol. 11, no. 2, pp. pp. 84-103. 2018 doi: 10.14513/actatechjaur.v11.n2.456.