

DOCTORAL THESIS EVALUATION REPORT

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Doctoral Thesis: Design and Validation of the Methods for Comprehensive Characterization of the Hyperelastic Properties of Elastomers

Reviewer: prof. Dr. Ing. Petr Horáček

1 Assessment of the aims and the use of an appropriate methodology

1.1 Aim of the work

The aim of this work is to better understand the hyperelastic behavior of elastomers and to obtain an accurate material constant for the characterization of hyperelastic material. I fully understand and support the approach of experimental testing of the stress-strain relationship and data fitting by a suitable model function. Nevertheless, I expected that the goal is to determine the actual materials constant describing the behavior of the material, e.g. the modulus of elasticity and transverse deformation coefficients. This helps us to establish a material model more usable for example in the FEM calculations.

1.2 Methodology

The work is logically based on the theory of mechanics of a deformable body, in this case on the nonlinear elasticity under static multiaxial stresses. The choice of correct phenomenological model based on strain energy density is the cornerstone. The Mooney-Rivlin model in particular was chosen, which I am in favor with it. The model is determined by strain invariants and matrices of material constants C and D , or stretch ratios. Here I miss the explanation or definition of material constants C and D (are these stiffness matrices or simply regression coefficients?).

The second key point there is the option of methodology for testing the mechanical properties of materials – here the uniaxial and biaxial loadings, and pure shear. I agree with the choice of load for all modes.

Last but not least, it is the processing and interpretation of measured data and their fitting with mathematical models. Here I would appreciate a deterministic approach generally valid for any of the elastomers instead of a stochastic model based on the minimum residuals (and therefore different exponents in the resulting functional relation between stress at biaxial load and deformation at uniaxial load).

I expected that the nonlinear model consists on modulus of elasticity and transverse deformation coefficients, similar to the establishment of rheological models for example. In addition, due to the temperature-dependent mechanical response of the polymer to the load, I methodically lack a description of the effect of temperature on hyperelastic behavior. Please explain why this fact was not taken into account if the temperature of the glass transition temperature is taken into account in chap. 3.3. On contrary, any material data for elastomers are missing.

Finally, I appreciate the use of the DIC method. The DIC is a known and proven method used for more than 30 years, however, its standard use in material testing is not common. The author successfully tried to do that with his work. He mainly dealt with experimental determination of deformations under uniaxial, biaxial and shear loads. In the thesis I lack an explanation how specifically the DIC method was utilized.

2 The results of the work and the contribution of the doctoral student

Based on strain energy density functions, author offers the method how to provide secondary data set which resembles biaxial data. He used mainly empirical approach, yet he was able

to describe the hyperelastic behavior of elastomers quite precisely. Nevertheless, some points remain to be explained.

First, I am missing any hypothesis statement that are tested by experiments. The method how to obtain “material constant” whenever only uniaxial data is available, is just a tool. The approach is limited to the temperatures far above glass transition temperatures, what is seen as a limit of delivery.

Second, although suitable mathematical hyperelastic models are chosen, it is not clear what material constants were used to them.

Third, the relationship between uniaxial and biaxial data distributions is still material dependent and it lacks a bit of generalization.

Fourth, the fitting data to appropriate model is seen to be necessary, nevertheless independent models for uniaxial and biaxial loading modes are still required.

To conclude, this thesis has improved our knowledge of the hyperelastic behavior of elastomers, particularly the rubbers. New information was gained through the study of uniaxial and biaxial loading in relation to the stress-strain relation. It helps us to understand the mechanical characterization of hyperelastic materials. However, the proposed procedure is still valid for given type of material only.

3 Thesis general quality

The text of thesis is coherent because it develops its subject matter in an easy-to-follow line of thinking. Finally, the style is appropriate to its purpose of presenting both general and detailed description of the process of artificial data generation through uniaxial data.

Author is often tempted to include everything that could be relevant to his subject (e.g. chapters 3.1-3.4, 3.7-3.8 might be omitted), rather than merely everything that is relevant to the communication task at hand. The thesis is concise in its use of minimum of words to express the basic idea. It is not wordy, and it does not digress from the point being made. The text accuracy refers to the proper coverage of the topics in appropriate details and focuses clearly on a problem. It is cultivated by a clear problem statement and by a preliminary outline. Author promote coherence of the thesis by making his material logically and stylistically consistent, and by organizing and expressing his ideas in specific patterns. Table of content, problem statements and strategic repetition in the end promote structural clarity. Graphs and tables are effectively designed and placed, they help focus and clarify information.

4 General comments

The research goals defined in the doctoral thesis have been achieved. The method used are based on current standards. The formal requirements for a dissertation vary within the EU universities, but it fits to the standard of Czech ones. Regarding the structure and number of accepted (published) papers with peer-reviewed process the doctoral thesis of Rohitha Keerthiwansa meets obviously the requirements and conditions of Czech universities.

Taking into account both topicality of the research and the use of innovative methods, the reviewer recommends the doctoral thesis for the defense process.

Brno, November 2nd 2020

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