REVIEW OF DISSERTATION THESIS

Dissertation topic: **Proposal of a computer model for simulation of car tires under dynamic loads**

Name of student: **Sadjiep Tchuigwa Baurice Sylvain**

Supervisor: Prof. Ing. Jan Krmela, Ph.D.

Specialist supervisor: Ing. Jan Pokorny, Ph.D.

The subject of the opponent's review is the dissertation thesis "***Proposal off a computer model for simulation of car tires under dynamic loads*** "(author Sadjiep Tchuigwa Baurice Sylvain). The submitted thesis contains 7 basic chapters and 2 enclosures. Aims of this thesis are defined and described in detail in chapter 2. Theoretical knowledge of kinematics and mechanical properties of tire materials and proposed FEM numerical models are described in chapters 3 and 4. In the second part of this thesis (chapters 5 and 6) are described the practical outputs and results of FEM numerical models and experimental results measured on real specimens. The dissertation thesis is supplemented with a list of used literature and the author's publications.

The following sub-questions are assessed by the reviewer:

1. **The actuality of the chosen dissertation topic.**

The aims of dissertation (propose a material-consistent and computationally stable FEM-based model for modeling and simulating tires under dynamic loads) are defined based on analysis of current state of science and technology in chapter 2. Currently, the requirements and demands for tire development are constantly increasing. For these reasons, it is necessary to develop more accurate FEM models for simulating tire behavior. The chosen topic "Proposal of a computer model for simulation of car tires under dynamic loads" is therefore an actual topic.

2. **Fulfillment of stated objectives of the dissertation thesis**

The main aim of the dissertation thesis is to propose a material-consistent and computationally stable FEM-based model for modeling and simulating tires under dynamic loadings. The scientific methods used by the author are numerical FEM models and verification of the results by experiments on real test specimens. Achievement of the defined aims is presented in the dissertation by large quantities of results. I can state that the objectives of the dissertation have been met in the required extent.

3. Processing and procedure for solving the problem defined in the dissertation

The presented work demonstrates a very good level of the author's knowledge and his ability for the application in the field of tire modeling. Selected methods for solving the problem are at appropriate level and correspond to the current knowledge of current science and technology. The large number of results and experiments performed in the laboratory demonstrate the complexity of the task and the amount of work done in this research. However, there are noticeable differences in the level of elaboration, level of detail of information and the number of formal errors between some chapters. Text or paragraphs in some parts of the dissertation seem as to be missing.

As a reviewer, I have the following comments on individual parts of the submitted thesis:

- A formal note: Not all symbols used in the dissertation are listed in the list of symbols.
- A formal note: The nonstandard sign is not suitable for indicating strain (see formula 4.2).
- A formal note: The Force-strain dependence of PA66 is shown in Figure 2.10 not stress-strain.
- A formal note: The use of the term dynamic FEM analysis for static load calculation is not appropriate.
- Some references for figures in the text are incomplete because of reference numbers missing (for example reference of the Figure on page 27, page 40, page 75 etc.).
- Some parts of the text seem as to be missing. For example, Text on page 73: "*In this method, rubber compounds are meshed with the following finite element:* "But any information about finite element does not follow. The sentence at the end of paragraph (materially approach) on page 76 etc.
- The following phrase often appears in dissertations: *incompressibility of tire rubber, considering four types of incompressible constitutive laws for rubber compounds: elastic (EL), hyperelastic (HE), visco-hyperelastic (VH), and hyper-pseudoelastic (HM).*
- The author describes the deformation parameters at the nodes of the chosen elements. However, no coordinate system is shown in Figure 4.7. Therefore, it is not clear in which directions the described deformation parameters are acting.
- The author's statement: "*Geometrical nonlinearity: the fact that the material undergoes large deformation obviously implies that in the course of the dynamic loading .....*" on page 85 is not exactly correct. Geometrical nonlinearity is not directly about large deformations of material. In short, Geometrical nonlinearity expresses the change of stiffness due to change of geometry of construction.

- One of the author's comparison criteria is CPU time required for FEM solution. But the author does not comment on the parameters of the hardware used for FEM analysis. Autor described only some general terms such as 7 CPU + 1 GPU (on page 161) in the final part of dissertation thesis. Without a description of the hardware, the evaluation criterion CPU time is insignificant and unverifiable.
- I have a comment regarding to the finite element mesh described in Figure 5.3 and 6.4. Autor uses linear volume element for simulation of rubber material (probably the element size is the same as the thickness of layer). This is possible procedure. But linear elements use simple approximate and shape functions. Therefore, I consider it necessary to verify the required size of the elements used for the FEM analysis (convergence of the FEM mesh). Comparison of results (especially mechanical stress, distribution of pressure in contact surface etc.) for different element sizes is a very important part of creating a FEM model (mesh convergence method). Then the results may contain some inaccuracy or distortion. Optimalization of FEM mesh is performed in chapter 6 (on pages 125 and 126) but only in modal analysis (evaluation criterium used for suitable mesh specification is the value of eigen frequency).
- In figures from 5.5 to 5.8, it is not possible to determine the reduced stress in individual parts of the tire. Author's description is only the stress in the tire in time one second.
- In chapter 5.4, the author describes the outcomes from the published journal article [184] and the conference paper [185], respectively referred to as P1 and P7. However, apart from the general paragraph in this chapter, nothing is mentioned in Chapter 5.4. It is not possible to use only links of the author's publications as a substitute for all text and description of the problem or summarization of outputs. Therefore, I cannot evaluate the results mentioned in chapter 5.4.
- The author describes the measurement of pressure distribution in the contact surface of a tire on page 113. But the only general information "*using a thin film*" is mentioned instead of describing the sensor, way of measurement and evaluation methodology of results. It would be appropriate to state the specific procedure and equipment used for measurement of the pressure (type, resolution, etc.).

At the end of the review, I state:

1) The submitted dissertation thesis demonstrates the author's very good ability to solve more difficult nonlinear problems as is the tire upon a dynamic loading.
2) I can state that the objectives of the dissertation have been met in the required extent.
3) Some comments in this review are purely formal and can be justified by the large scope of the dissertation.
4) However, some shortcomings (see comments above) should not appear in the text, and they unnecessarily lower the level of the dissertation.
5) **Based on the conclusions I recommend this dissertation thesis for defense.**

Questions:

1) Can you explain differences in the values for Steel cords between Tab. 5.1 (15.724 MPa) and 6.1 (160 000 MPa).
2) For experiment with quasi-static loading, you have used a static adhesor located within Alexander Dubček University of Trenčín. Can you specify in which laboratories the other experiments (dynamic adhesor, eigen frequencies etc.) and FEM simulation (hardware) were performed?
3) Can you describe experimental measurement of pressure distribution in the contact surface of real tire (sensors, evaluation methodology of results etc.)?
4) Explain the difference between the use of linear and the other higher quality elements on the accuracy of results and optimization of FEM mesh.
5) Can you briefly describe vectorized algorithm mentioned in chapter 5.4?

Pardubice 26.11.2025

doc. Ing. Petr Tomek, Ph.D.
Department of Mechanics, Materials and Machine Parts
Faculty of Transport Engineering
University of Pardubice