Review on Ph.D. thesis on:

Motorcyclist Biomechanical Model

written by:

Lic. Eng. Pedro Migguel de Almeida Talaia, MSc

This review is written on the base of the letter ID: ZCU 031970/2013/FAV-Ton dated October 2nd, 2013. Evaluated is the printed form of the thesis.

The report has 190 pages, 3 appendixes and the list of References. It is written in understandable language, graphical shape is very good, the work is systematic a logic. Main chapters are:

- Introduction – describing MYMOSA project and basics of biomechanics
- Modeling the human body – dealing with the dummies and their software modeling
- Anatomy, physiology and trauma – aimed to the motorcycles injuries and strategy of modeling of
- Body segments – in this chapter. It includes detailed models of the head, the spine, the thorax, the abdomen, the pelvis and extremities.
- Multibody model formulation – contains the theory of system dynamics.
- The multibody human body model – develop the theory to the crash simulations with special attention to PTW drivers.

The report utilizes the MYMOSA project results to the comprehensive work with high added value done by the author.

Main notes of the review:

a) The dissertation work enriches the PTW passive safety research by the systematic approach and provides the knowledge with valuable computer simulations
b) The author utilizes advanced research methods based on mathematical simulation, he adopted correct research methodology and reached valuable results. He achieved pre-defined target of the research.
c) The results bring new interdisciplinary achievements in the deep biomechanical analysis of traffic collision with participation of vulnerable road users. The author developer and synthetized useful tools for sensitivity analysis and problem optimization.
d) The PhD thesis is good value publication done by skilled author. All formal features are correct. The page 116 missed in the evaluated print.

Topics for the discussion:

The next print of the work (if planned) should be corrected by the English language expert.

Derivation of HIC parameters (page 56 and following) should be better explained. The symbols are not correct in some cases (intervals, indexes in text, units).

It is impossible to check chapter 5.2.3 due to the missing page 116.

Results and animations (pg. 174 and following) do not provide enough information (CD with movies would be very welcome). There are not clear the motorcycle design details and their contact analysis with both driver body and car, including plastic deformation of structures. The role of front wheel is not explained and final deformations are not presented.

Conclusion:

I recommend the Ph.D. thesis of Lic.-Ing. Pedro Miguel de Almeida Talaia to the defense procedure.

Praha 17.10.2013

prof. Ing. Jan Kovanda, CSc.

Dr. Ing. Pavel Polach
Výzkumný a zkušební ústav Plzeň s.r.o.
Section of Materials and Mechanical Engineering Research
Tylova 1581/46
301 00 Plzeň

Expert Opinion

Doctoral thesis in the branch "Applied Mechanics"

Motorcyclist Biomechanical Model

Author: Lic. Eng. Pedro Miguel de Almeida Talaia, MSc.

Supervisor: Ing. Luděk Hynčík, Ph.D.

The presented doctoral thesis deals with the scope of problems of the human body injuries focused on motorcycle riders. The multibody approach was chosen for the modelling of the motorcycle with a rider and the simulation of the traffic accident. The thesis consists of eight chapters and four appendixes (software implementation). The thesis and its supplements are written in English.

In Chapter 1 – "Introduction" – of the thesis the contents of the thesis is briefly presented and the motivation and goals are given. The thesis is part of the MYMOSA (MotorcYcle and MOtorcyclist Safety) European network project. A brief presentation of this project is given in the introduction, too. A statistical analysis of accidents and casualties in the roads in Europe with the special attention paid to the motorcycles are presented. The way of evaluation of human body injury according to different criteria is generally mentioned.

The thesis goals are:

1. Getting information in the fields of multibody dynamics, anatomy and physiology, trauma and accidentology applied to a motorcyclist;
2. Implementation of one multibody human dummy model for crash simulation using a commercial software;
3. Computation of injury criteria from the multibody human model;
4. Analysis of the effect of the human body impact from the physiology point of view by means of finite element analysis;
5. Creation of tool for a fast simulation of human body impact focusing on a detailed analysis of critical body parts.

Chapter 2 "Modelling the human body" is focused on computer human body models and dummies models, which describe primarily the human body behaviour in the course of crash. Human models used in the MYMOSA project are introduced.

In Chapter 3 "Anatomy, physiology and trauma" the basic ideas concerning principles of anatomy, physiology and trauma related to motorcycle users are presented. Human body details are described in brief.

In Chapter 4 "Body Segments" selected body segments are described in detail. This chapter is very comprehensive and gives the impression of an encyclopaedia.

It is stated that in Chapter 5 "Multibody model formulation" a two-dimensional model of the motorcycle with a rider should be presented. In fact in this chapter there are equations describing motion of multibody model of a general two-dimensional system. The general equations of motion of the two-dimensional multibody system are derived using the principle of a virtual work. The principle of the virtual work is used finally in the Lagrange's equation derivation. The Baumgarte's stabilization method for the stabilization of numerical integration of the equations of motion is presented.

In Chapter 6 "The multibody human body model" a three-dimensional model of the human body created in the Virtual.Lab Motion simulation tool is presented. This model parameters are tuned on the basis of a van crashing into a pedestrian scenario. This chapter and Chapter 7 "Results and discussion: Injury assessment and accident reconstruction" can be considered fundamental.

Chapter 7 "Results and discussion: Injury assessment and accident reconstruction" analyzed results of FEM calculation in more detail. The RADIOSS software is used for the FEM calculation of pedestrian impact and two scenarios of motorcyclist impact into the van.

The presented work is summarized in the thesis conclusion (Chapter 8).

In the supplement ("Appendix 1 – Software implementation") selected parts of the two-dimensional multibody model programmed in the MATLAB system are described and the short examples of numerical results are presented. In "Appendix 2 – Close-loop control" a close-loop control is presented.

Now factual comments:

The thesis is very comprehensive. As it has been stated some parts even give the impression of an encyclopaedia.

The level of English language in which the thesis is written is not quite good. The thesis seems to be "slapdash".

In the thesis in some cases it is not unambiguously evident if the author of the contributions is the thesis author or the MYMOSA project working team (I mean especially fundamental Chapters 6 and 7 – most sentences are written in first person plural).

Some thesis parts make a heterogeneous impression. Especially in Chapter 4 "Body Segments" and in Chapter 5 "Multibody model formulation" it is evident that the author used various sources and pieces of information are not put in a consistent style.

The whole of Chapter 5 "Multibody model formulation", including mistakes, to which the author's attention was drawn in expert opinion to Essay to the state doctoral degree examination, was copied from the Essay word by word! E.g. equation (5-1) "$\overline{\mathbf{u}}_P^i = \left[\overline{x}_x^i \; \overline{y}_y^i\right]$" instead of the correct "$\overline{\mathbf{u}}_P^i = \left[\overline{x}_P^i \; \overline{y}_P^i\right]$" – see page 107, first equation (5-31) "$\left(\mathbf{F}^i - m^i \cdot \mathbf{a}^i\right) \cdot \delta\mathbf{R}^i = \mathbf{0}$" instead of the correct "$\left(\mathbf{F}^i - m^i \cdot \mathbf{a}^i\right) \cdot \delta\mathbf{R}^i = 0$" – see page 112, the relations (5-26) are uncorrected – see page 111, the vectors used in the equations from $\mathbf{R}^i + \mathbf{r}^i - \mathbf{R}^j - \mathbf{r}^j = \mathbf{0}$ (5-122) to $\mathbf{p}^1 = \mathbf{R}^i + \mathbf{A}^i \cdot \overline{\mathbf{u}}_P^i - \mathbf{R}^j - \mathbf{A}^j \cdot \overline{\mathbf{u}}_P^j$, $\mathbf{p}^2 = \mathbf{R}^i + \mathbf{A}^i \cdot \overline{\mathbf{u}}_P^i - \mathbf{R}^j$ (5-125) are not completely drawn in the schemes of the revolute and prismatic joints in the figures 5-6 and 5-7, etc.

And now some minor comments: in the heading of Chapter 3 it is stated that Chapter 4 is concerned, similarly Chapter 4 is 5, Chapter 5 is 3, in the heading of Chapter 7 is wrongly "Results e discussion ..." instead of "Result and discussion ...". In the thesis copy page 116 is missing. Abbreviations are defined illogically, e.g. at page 105 the MBS abbreviation is mentioned three times (twice it means "Multi-Body Simulation" and once "Multi-Body System"), FEM abbreviation is introduced in Chapter 2 (nevertheless it is quoted in the list of abbreviations and used in Chapter 1), etc. Writing of items in the list of references (why is not refreshed "cited 2007" ?) lacks unity. Meanings of points A and B in relations 6-3 and 6-4 are not sufficiently explained (or possibly given scheme) in Chapter 6.

It is possible to conclude from the doctoral thesis of Lic. Eng. Pedro Miguel de Almeida Talaia, MSc. that the targets set in the doctoral thesis were achieved. It can be stated that the doctoral thesis gives evidence of the author's good knowledge of the problems of biomechanics and multibody dynamics. The thesis theme is topical and useful.

There are several supplementary queries for the author as follows:

1. Which pieces of knowledge in your thesis are most useful in the sciences of biomechanics and multibody dynamics.
2. Explain how you have obtained equations $\delta \mathbf{r}_P^i = \mathbf{r}_{q^i}^i \cdot \delta \mathbf{q}^i$ (5-25) and $\mathbf{r}_{q^i}^i = \left[\left(\mathbf{R}^i\right)^{\mathrm{T}} \theta^i\right]^{\mathrm{T}}$, $\delta \mathbf{q}^i = \dfrac{\partial \mathbf{r}^i}{\partial \mathbf{q}^i} = \left[\mathbf{I} \quad \mathbf{A}_\theta^i \cdot \overline{\mathbf{u}}_P^i\right]$ (5-26). The relations (5-26) are uncorrected (these mistakes were mentioned v expert opinion to Essay to the state doctoral degree examination!).
3. Explain how you have obtained equations $\delta W^i = \int_{V^i} \rho^i \cdot \left(\ddot{\mathbf{r}}^i\right)^{\mathrm{T}} \cdot \delta \mathbf{r}^i \cdot dV^i$ (5-43), $J^i = \int_{V^i} \rho^i \cdot \left(\overline{\mathbf{u}}^i\right)^{\mathrm{T}} \cdot \overline{\mathbf{u}}^i \cdot dV^i$ (5-62). The equation is defined or derived? If the equation is defined quotation of related sources misses.

Publications by Lic. Eng. Pedro Miguel de Almeida Talaia, MSc. are on a good level.

By writing the thesis the author proved to have a good professional knowledge, which extends the knowledge in the fields of biomechanics and multibody dynamics. I recommend the doctoral thesis, despite the above mentioned comments, to be accepted for defence.

Plzeň, 21 October 2013