prof. Ing. Jozef BOCKO, CSc. - Technical University of Košice, Faculty of Mechanical Engineering, Department of Applied Mechanics and Mechanical Engineering, Letná 9, 041 00 Košice

REFEREE'S REPORT

on the dissertation thesis titled

Truncated conical shells as absorbers of impact force

Author of thesis:	**M.Sc. Erdem ÖZYURT**
Educational institution:	**University of Pardubice, Faculty of Transport Engineering, Department of Mechanics, Materials and Machine Parts**
Programme of study:	**P3710 Technique and Technology in Transport and Communications**
Branch of study:	**3708V024 Technology and Management in Transport and Telecommunications**
Supervisor:	**doc. Ing. Petr TOMEK, Ph.D.**
Supervisor specialist:	**prof. Ing. Petr PAŠČENKO, Ph.D.**

Up-to-dateness of the dissertation theme

In the thesis author analyses energy absorption capabilities of steel-based truncated conical shells with low base angle and end caps under axial dynamic loading. The effect of change of conical angle, impact velocity, absorber thickness and impact mass on the energy absorption of the conical shells was analysed by the finite element program Abaqus. The results of simulations were evaluated by several methods - peak reaction force *Fp*, mean reaction force *Fm*, absorbed energy *EA* specific energy absorption (SEA), crash force efficiency (CFE) and dynamic amplification factor (DAF). The dissertation also gives some guidelines on the design of a truncated conical shells with low base conical angle used as an energy absorbers. The topic of the dissertation is highly actual and modern.

The analysis of thesis, the methodology, methods of writing

The structure of dissertation thesis follows a prescribed standard of doctoral dissertations. The dissertation consists of 7 chapters and at the end is given Bibliography and the list of publications of the author. The dissertation has 131 pages.

The first chapter introduces reader to the solved problem, gives information concerning energy absorbers, methods of solution and briefly described aims of work.

The second chapter is devoted to the description of terms that are used in this field of study - crash energy and its absorption, management of crash energy, requirements for design of absorbers, reaction forces, and so on.

The third chapter gives the reader information concerning current state of problem. The literature review is specially oriented to description of conical energy absorbers. At the end of the chapter are described aims of dissertation.

The chapter four is devoted to the description of the nonlinear finite element method. The subchapters deal with types of nonlinearities, FEM software and terminology, Johnson-Cook plasticity model, mass scaling, and data processing.
The fifth chapter describes numerical model and simulations. Here, the information concerning model geometry, material, model assembly, loading, boundary conditions, sensitivity analysis, and meshing is given.
The chapter six represents the results obtained from both quasistatic and dynamic simulations for different performance parameters such as force-displacement curves, absorbed energy, specific energy absorption, and crash force efficiency. Moreover, here are investigated and presented the effects of varying loading conditions and model geometry. Besides of this, some basic comparisons of the simulation results to the current literature are given here.
The chapter seven summarizes results of work and gives final conclusions.

The achievements of defined aims and objectives

The main goal of dissertation is to determine the usability of the conical geometries of low base cone angles as an energy absorbing structure.
Detailed goals of the study author characterises as follows:
• to evaluate series of various numerical models for cones of different base angle and thickness values in order to simulate the axial impact of various impact velocities and impact masses by using the Abaqus/Explicit finite element software;
• to perform analysis on the structures modelled as energy absorbers with variable impact velocities, impact masses and geometrical parameters such as the absorber thickness and base conical angle. The numerical simulation results will also be used to develop an understanding of the detailed behaviour of structures under impact loading depending on the various parameters;
• to process the data from the numerical results with respect to different result parameters to investigate the effectiveness of structures under impact loading to be used as energy absorbers;
• to generate an opinion on the usability of the structure as an energy absorber by taking into consideration of both commonly used structures.
All aims of the dissertation thesis are fulfilled on an excellent level. I do appreciate the amount of work which Mr. Özyurt accomplished. The work demonstrates his ability to formulate aims and he fulfilled them at adequate quality.

A statement on the results of dissertation thesis

In the dissertation are given results of investigation of dynamic behaviour of the conical energy absorber. The simulations were realised by the finite element program Abaqus. The most important conclusions formulated by author of investigation are:

- The dynamic force-displacement response of the conical structure is affected by the absorber thickness, base conical angle and the impact velocity. On the other side, the impact mass of the striker has no effect on the dynamic force response of the structures.
- The three above mentioned geometry parameters should be used to control the dynamic response of the structures. The conical angle and the absorber thickness are the most effective with respect to the energy absorption of the selected geometry.

- The crash force efficiency values of the current study do not have an explicit and stable behaviour. CFE values have a decreasing trend as the impact velocity increases, CFE values do not seem to be affected by the absorber thickness.
- The specific energy absorption ability is strictly affected by the base conical angle. Increasing conical angle leads to increases resistance to any bending action.
- In order to increase the absorbed energy within a given deformation length the conical angle of the structure can be increased for the same absorber thicknesses and/or impact velocity, absorber thickness of the structure can be increased for the same conical angle and/or impact velocity, increasing the impact velocity also increase the amount of the absorbed energy, changing the impact mass has no significant effect.

A statement on the significance for profession or scientific development

The author has developed several FE models for the selected parameters in order to simulate the response of individual conical absorbers. It gives a good opportunity to investigate and compare dynamic response of truncated cones. The results of dissertation can help designers to understand relation between main parameters of conic absorbers. Accordingly, the dissertation thesis is significant for theory as well as for practice.

Remarks

Thesis is well organized and easy to read with a nice graphical layout, but it contains relatively many misprints and errors. The author should be more careful in this aspect of his work in future.

Some remarks to the dissertation thesis:

- Page v etc. ... Use ... 4 mm ... no ... 4mm ...
- Page 18 etc. Sign for literature reference in text, e.g. [2] belongs to sentence. It should not be outside of it.
- Page 24 etc. (Fig. 2.3) Use empty space between word and sign for literature reference, e.g. Voith [16] (similarly numbers and units of some quantities, words and parentheses, etc.).
- Page 37 The last sentence in Section 4.1 does not have sense.
- Page 51 There is no information about thickness of steel sheet specimen in Fig. 5.3.
- Page 59 Unreadable small text in Fig. 5.12.
- Page 71, etc. Lack of units for horizontal axis in Figs. 6.5, 6.8, 6.10, etc.
- Page 76, etc. Inconsistent description of horizontal axis, labels and plain text in Figs. 6.10, 6.12, etc.
- Page 105 ... %12 ... should be probably ... 12% ...
- Page 125 etc. There are several errors in individual items in Bibliography list, e.g. [3,8,9].

Question and demand to the author:

1. In several graphs are different abscissas for end points of computed curves, e.g. in Fig. 6.6, 6.7 (in comparison with Fig. 6.9). What is the reason (computational instability, ...)?
2. What do you think about possibility to fill the absorber cones at least partially by aluminum foam?

A statement on the extend and quality of publications related to the dissertation thesis

Mr. Özyurt published as author or co-author several papers in foreign journals. Especially, I appreciate paper "Empirical equations to estimate non-linear collapse of medium-length cylindrical shells with circular cutouts" published in journal Thin-Walled Structures. The extend and quality of publications is good.

Conclusion

The work represents an extensive theoretical and numerical study combining a serious methodological work with collection of interesting results and their proper interpretation. I think that the author, Mr. Erdem Özyurt, fully satisfies the requirements of the PhD. degree. I recommend to submit the dissertation thesis for defence and to award him the degree „**philosophiae doctor** (**Ph.D.**)".

Košice, 11. 1. 2019

prof. Ing. Jozef Bocko, CSc.