Alexander Tesár
Civ.Eng., PhD., DrSc., assoc.prof., FEng.
Chief scientific worker, Slovak Academy of Sciences
Authorized Engineer of Slovak Chamber of Civil Engineers
Institute of Construction and Architecture, SAS
Dúbravská cesta 9
845 03 BRATISLAVA 45

Tel.: 02 59309212
0905 408905
02 54791085
Tel./Fax: 0254791080
E-mail: usarate@savba.sk
atesar@pobox.sk
alexander.tesar@gmail.com

Prof. Ing. Josef Vičan, PhD.
dean
Faculty of Civil Engineering
Technical University Žilina
Univerzitná 8215/1
010 26 ŽILINA

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REVIEW ASSESSMENT

of habilitation thesis

ANALYSIS OF SELECTED WAVE PHENOMENA IN CONTINUOUS COMPRESSIBLE AND INCOMPRESSIBLE HYPERELASTIC STRUCTURES

submitted by

Mrs. Izabela Major, Civ.Eng., PhD.,
Częstochowa University of Technology, Faculty of Civil Engineering

By the letter of prof. Ing. Josef Vičan, PhD, dean of the Faculty of Civil Engineering, Technical University Žilina, dated 26.05.2014, I have been proclaimed as a reviewer for above habilitation thesis of Mrs. Izabela Major, Civ.Eng., PhD., Częstochowa University of Tech-nology, Faculty of Civil Engineering. My comments:

The habilitation thesis was developed in scope of applicant's activity on the Department of Applied Mechanics, Faculty of Civil Engineering, Częstochowa University of Technology. The aid of thesis was to analyse selected wave phenomena in continuous hyperelastic structures adopting the propagation of linear and nonlinear acceleration waves and travelling waves. Studied was the distribution of the disturbance effects in elastic nonlinear compressible and incompressible materials.

The habilitation thesis is the product of intensive treatment of the topic in duration of several years. Thesis contains the general information on wave phenomena studied, together with available mathematical facilities for analysis and with corresponding applications. Specified are the constitutive equations for hyperelastic materials, nonlinear elastodynamics as well as the approaches for the treatment of the waves of discontinuities and running waves. For illustrations are studied the propagations of acceleration waves in thin rods with slowly changing cross-sectional area as well as the nonlinear distributions of running waves in rods and elastic layers. For numerical examples is used a model of hyperelastic material described by the Zahorski elastic potential and compared with the Mooney-Rivlin material. The numerical assessments were made by the ADINA-software, being modified in order to take into account the properties of the Zahorski material.

From formal point of view thesis satisfies high international standards The results obtained are actual and contribute to present knowledge level in corresponding field of structural mechanics.

Remarks and suggestions:

1. The process of propagation of a disturbance is modelled as a surface of discontinuities moving in a material continuum studied. The laws governing the continuum mechanics, with particular focus on those which specify the motion of the continuum, allow the modelling of the wave as a surface moving in a material and in structural continuum. Adopting such approach, the propagating wave represents a disturbance being strictly reduced to the surface. The advantage of such concept lies in the opportunities for considering the wave phenomena from the standpoint of a relatively uniform theory that does not require any simplification assumptions. However, above concept pays only for simple, more or less homogeneous materials and structures. The application on nonhomogenous materials and structures appears there as limited.
2. The wave phenomena appearing in three-dimensional waveguides, such as are the thin rods and layers, based on the assessment procedures adopted in the habilitation thesis might be reduced to equivalent single-dimensional structures with a scalar parameter connected with transverse dimensions of the waveguide. However, the application of such approach for advanced 3D materials, for example carbon fiber composites, is limited.
3. Page 11 Citation: ... acceleration waves propagate in elastic material, which before the front of the wave is homogeneously deformed and remains at rest. If it is deformed, it cannot be at rest. Well, something is not quite clearly explained.
4. Page 11 ... the process of propagation is accompanied by the transport of energy connected with deformation of network of atoms in the micro-scale. Well, in such case there can appear quite new material.
5. Page 11 ... for the physical properties analysed, the medium is not homogeneous and isotropic. In such case there appear the inhomogeneities and disturbances in the material and structure, which influence the propagation of waves.
6. In the wave propagation of rods with slowly changing cross-section the intensity of acceleration wave is decreased, is compressed and transmitted into chaotic reflections and interactions. In such case the analysis and numerical assessments are complicated.
7. Page 13 - Mechanical energy balance of hyperelastic materials is valid for the deformations of the material caused by stress. In such context what about the energy balance in nonlinear displacement amplitudes of wave motions?
8. Page 33 – The non-monochromatic waves, appearing as a result of superimposing of monochromatic waves with different frequencies, consist of real and imaginary components which leads the solution into the systems of complex differential equations. There appear also the dispersive wave groups interacting together. What about the solution of such equations?
9. Kinematic forcing (travelling waves) is specified by moving wave forces or moments acting on elastic body. The velocities and accelerations of such forcing are variable, they transport the forcing energy and from mathematical point of view they represent a

class of solutions given by the system of nonlinear differential equations which generally cannot be treated in a closed mathematical form.

10. Such travelling waves are given in technical seismicity by accelerograms and spectral response parameters acting in the four dimensional space (x, y, z and t) and forcing the structure. Such parameters are obtained via long-termed measurements and are adopted in the assessments of the reliability of materials and structures. The comparison of the approaches in habilitation thesis with such techniques could be interesting and fruitful especially in comparison with experimental verifications.
11. In actual hyperelastic materials and structures there appear nonlinear interactions between reflecting acceleration waves and travelling waves, which influence the resulting structural response. What about the treatment of such interactions?
12. Chapter 6 – Ineresting are the results of wave propagation in steel and aluminium rods which are compared with the results of Klepaczko obtained quite long time ago, in 1970. The connection between steel and aluminium is not defined, It can be welded, screwed or glued, however, in each case in such contact points there appears the artificial obstacle distinctly influencing the wave propagation. There appear local reflections of linear and nonlinear travelling waves with various velocities and accelerations and with chaotic topology of their propagation. There can be made immense amount of theoretical discussions and speculations concerning the problem, however, the experimental assessment of the problem is inevitable. There pays the philosophy:

The bookish mind is quicker to concoct theories thick and thicker,
but for each theory guessed one good test is the best,
to put an end to bicker.

13. Page 71 - If the vibrating system has one degree of freedom, the phase space is reduced to the phase plane treated in the thesis. The equilibrium on the phase plane in nonlinear approach can have several positions in singular points. In Fig. 7.2.2. such points are defined as nod and focal point, saddle and centre. Citation: Two first points can be stable or unstable, the saddle is always unstable and the centre is always stable. Well, if saddle is always unstable then the centre, as function of the saddle, cannot be always stable. It corresponds with the variety of travelling waves in present case.
14. Actual nonlinear materials and structures operate with a number of variable degrees of of freedom and with many impedances, which influence the structural response with consideration of interactions between all linear and nonlinear forcing and structural elements available. Such elements can have different physical parameters. Can the approaches presented in the thesis be adopted also for treatment of the problems of such real structures?
15. In the border between rod and layer there appear the wave reflections with local nonlinear microvibrations added to general wave distribution in such points. How to study such structural behaviour adopting the facilities in the thesis?
16. In modern composite materials on the basis of carbon fibers appear actual problems in the wave propagation in 3D visco-elastic structural mediae. Can the approaches in thesis be adopted for the analysis of such problems in visco-elasticity?
17. Finally, there is to be mentioned the motto:

Don't spoil our theory by experiment,
or even by application ... ,

formulated by self-proclaimed "theoreticians", and in accordance with the formulation of Bruce Irons in his book *Techniques of Finite Elements*:

The brain-cells dye in middle age, formulae disappear,
but physical images are surprisingly persistent,

I believe that further developments of the approaches and obtainings specified in the habilitation thesis of Mrs Major will be continued and will successfully contribute to knowledge level of modern structural wave mechanics.

Conclusions

The applicant, Mrs. Izabela Major, in her habilitation thesis excellently managed the treatment of special problems of wave mechanics and documented her abilities to deal with actual problems of advanced structural mechanics. High cognitive nature of the results obtained in the habilitation thesis is to be emphasized and appreciated.

The habilitation thesis submitted satisfied all aids specified and in accordance with actual legislative rules documented high scientific abilities of the applicant.

In case of succesful results of the academic discussion in scope of habilitation process I recommend to graduate Mrs. Izabela Major by the title

docent (or associated professor)

in the branch of structural mechanics on Technical University in Žilina.

Alexander Tesár