Universitatea *Transilvania* din Braşov

HABILITATION THESIS

SUMMARY

Title: Contributions to the progress and application of some numerical methods used in the simulation of pulses and continuous elastic waves propagation in homogeneous and inhomogeneous media

Domain: Materials Engineering

Author:.Nicolae Constantin CREŢU

University:Transilvania Brasov

BRASOV, 2015

The present work presents the main scientific contributions of the author, the approached research topics and achievements illustrated by published scientific papers and books. It can be distinguished few stages and research topics over the years.

The first stage contains preoccupations in the preparation and ellaboration of polycristalline garnets in order to be used in passive microwave circuits. In the same time the autor made theoretic and experimental studies of the propagation phenomenon in such materials and also performed some microwave oscillators with semiconductor devices with YIG and Ytrium and Dysprosium garnets. The scientific activity from that period was corelated with the doctoral thesis, title obtained in 1998. In the same period author the author has build an electronic device, Magnetic Fluxmeter FIM02, in order to be used to magnetic measurements of ellaborated materials. The device was tested, calibrated and was also the subject of the metrological approval at the National Romanian Office for Standards Bucharest. The device was subject of a scientific contract with Electromagnetica Bucharest, and also it was sold to several interested companies (S C Mobistil Urziceni, Electroprecizia Sacele) .

The next stage contains research in the area of propagation of elastic waves and pulses in semiinfinite inhomogeneous media, for which the inhomogeneity can be mathematically described by a continuous function which can be subjected to a series expansion. Research activity from that period was connected to the research activity in a scientific european COPERNICUS project, coordinated by Professor P.P Delsanto, Polytechnical Institute Turin Italy. The partners in this project were scientists from Italy, Czech Republic and Romania. Within this project I benefited from two resarch internships to the Turin Politechnic, the scientific results being communicated in special workshops held in Italy, Romania and Czech Rpublic. The main results of this period was the extension and improvement of the series expansion, method to be apllied as simulation method of the propagation of the elastic pulses in inhomogeneous elastic media. The respective method was quickly recognized by the specialists and published in a prestigious journal Journal of the

Acoustical Society of America. Scientific reports about this topic were oral communicated also at special international conferences such as COMPAC-Aquasparta Italy and IMSE Michigan USA.

The method of series expansion of the solution and of the inhomogeneity function was generalized to include any type of continuous inhomogeneity, a special approach was dedicated to harmonic media, subject which was later developed in the sonic cristals studies. The research of this stage is presented in Chapter 1.

The method of series expansion has limitations, because it cannot be applied to finite elastic media and elastic media with discontinuities. In order to study the propagation in such media another metod was approached, the transfer matrix method which is more general and more appropriate. I studied this method and by introducing of Fourier transformations of elastic perturbation it was possible to improve the matrix method such as to obtain a transfer matrix for Fourier components. The transfer matrix for Fourier components becomes at list for 1D case very simple and simetric. It is knew that matrix algebra is much more suitable for computational calculus, and when we study a multilayer medium the simulation implies a product of transfer matrix, each layer being characterized by his own transfer matrix. Reserach on this topic was published in Ultrasonics, Computational Materials Science. A lot of researches were dedicated to magnetoelastic media, for which the magnetostriction introduce a spatial inhomogeneity of the elastic characteristic impedance. Such studies can be useful in acuostics and NDT technics. The activity from this stage is presented in the Chapter 2.

The next stage can be considered as the stage of the intrinsic transfer method. By studying multilayered media, obtained by many metallic cilinders I obseved that the Fourier analysis is highly reproductibile, from the point of view of the Fourier components. Certainly it comes from eigenfrequencies of the eigenmodes of the whole elastic system, in which the elastic wave is confined. Starting from a simple case of a single elastic rod, and considering 1D case, by excluding the semiinfinite external media, in case of stationary wave, I introduced a special transfer matrix propre only to the elastic system. I named this matrix intrinsic transfer matrix and the main property of this matrix is that the eigenvalues becomes real at the eigenfrequencies. Such a behavior is important and the method of the intrinsic transfer matrix provides a way to determine the longitudinal waves velocities. So, the intrinsic transfer matrix can be useful to estimation of the elastic constants for such materials which are inadequate to be measured by clasical resonance methods (such as for example special ceramics). For such a materials, small embedded cylindrical samples in an elastic system, which contain also gauge materials, the finding of the eigenfrequencies and a numeric estimation, permits the finding of the elastic constants. Research on this topic were pulished in Mechanics of Materials and Journal of Sound and Vibration (Elsevier). Studies on this topic are presented in Chapter 3.

The next stage contains research dedicated to improve the intrinsic transfer matrix in order to include the attenuation (this phenomenon must be considered when the samples dimension is significant), dispersion and the influence of the experimental arrangement. The studies have shown that experimental setups with ternary systems are suiable in elastic constants estimation, with two gauge materials and the sample of interest. Research studies on this topic were sent for publication to the review Case Studies in Mechanical Systems and Signal Processing (Elsevier). This research is presented in Chapter 4.

The intrinsic transfer method is very suitable to be combined with optimization algorithms, especially for multilayered media, in order to obtain acoustical structures for acoustic filters or in acoustic pollution. Together with my team I developed an optimization metod to design desired acoustical structures based on simulated annealing algorithm.In that case the cost function of the algorithm is obtained by means of the transfer function of the system, finally is considered such design which minimize the cost function. Transfer function is obtained by considering for the acoustic arrangement the intrinsic transfer matrix. Papers on this topic are communicated at International Congress on Ultrasonics Santiago de Chile, DAAAM Symposium Vienna and published in Computational

Materials Science, Physics Procedia. The research activity from this stage is presented in Chapter 5.

In november 2005 at my request I enjoyed a research stage at the New Jersey Institute of Technology USA, at my collaborator Mr. G. Nita, research Professor in Physics Department. The team coordinated by Professor Dale Garry made studies in astrophysics, by detection and analysis of the solar microwave spectrum. The team uses as method for analysis some statistical magnitudes, as Kurtosis and Spectral Kurtosis. A such analysis was able to detect transient signals in solar radiation correlated with solar storms and solar weather. I discussed with american scientists about the capability of the method to be used in NDT techniques if we are able to introduce a calculus of Kurtosis in Fourier domain. I improved the method and I applied to the magnetoacoustic emission, in order to detect defects inside of the magnetic materials, for example steel rods. Research on this topic were communicated at International Congress on Ultrasonics Vienna and NDT in Progress-International Meeting of NDT Experts Praga. The activity of this satge is presented in Chapter 6.

Because the intrinsic transfer matrix for 1D case has a very simple and simetric form, very similar with the matrix of a split cuaternion in matrix representation, and because transfer matrix of a system of two layers for example can be obtained as a product of the transfer matrices of layers, like the product of two cuaternions, from the mathematical point of view is possible to consider a multilayered medium as a product of cuaternions in matrix representation. Examination of the whole cuaternion matrix and his eigenvalues in the resonance case permits to estimate some defects in the layers arrangement of the medium. Research activities on this topic were communicated to Interantional Congress on Ultrasonics Metz France, published in Physics Procedia and also sent to publication in Computational Mechanics. The activity from this stage is presented in Chapter 7.

A significant part of my research activity I developed in scientific interdisciplinary collaborations with scientists from Transilvania University or INCDFM Bucharest. The main collaborations are exposed in the next topics:

a. Study of the influence of the ionic liquids on the properties of the poplar veneers
b. Studies and characterizations of some ceramic materials used as solid electrodes in IT-SOFC fuell cell.
c. Study of the influence of the wood quality on the performance of classical guitar
d. Studies and electrical measurements on the oxidic monolayers obtained by sputtering

The activity from this stage is presented in Chapter 9.

All my research activities must be correlated with a very intensive of procurement purchasing and providing activity in order to equip with modern and actual equipment my research laboratory Laboratory of Physical Acoustics and our laboratory from the Institute ICDT. The activity from this domain is presented in Chapter 8.

From the point of view of professional experience, my achievements are corelated to my activity as Associated Professor in the Department of Electrical Engineering and Applied Physics, department which was formed by merging Physics Dept. and Electrotechnical Dept. from Transilvania University. As special achievements I remember:

-I am author of 3 monographies:

1 Nicolae Cretu-*Fizica generală*- Editura Didactică şi Pedagogică, Bucureşti 2003 ISBN 973-30-2502-X

2. Nicolae Creţu- *Fizica si tehnica microundelor*- Editura Universitatii Transilvania din Braşov 2006,-ISBN 973-635-840-2 (978-973-635-840-1)

3.Nicolae Cretu, Ioan. Sturzu-*Electrodinamica si teoria relativitatii-vol.I*--Editura AXA Bucureşti 1998, ISBN 973-97408-4-7

-I am the author of 4 manuals for my students as follows:

1. Nicolae Cretu *Bazele Fizicii*, Editura Universităţii Transilvania Braşov, ISBN 978-973-598-716-9, 2010, 268 pagini
2. Nicolae Cretu, *Fizica pentru ingineri-* Editura Universităţii Transilvania Braşov, ISBN 978-606-19-0062-6, 2012, 267 pagini
3. Nicolae Cretu, *Fizica, Curs pentru Invatamant la Distanţă),* Departamentul pentru Invăţământ la Distanţă si Invăţământ cu Frecvenţă Redusă, Reprografia Univ Transilvania Brasov 2008, 159 pagini
4. Nicolae Cretu,*Fizica, Curs pentru Invatamant cu Frecvenţă Redusă,* Departamentul pentru Invăţământ la Distanţă si Invăţământ cu Frecvenţă Redusă, Reprografia Univ Transilvania Brasov 2008, 173 pagini

-I am co-author to a book of Physics Problems for students, a book of Laboratory Works and an on-line book of Parctical Laboratory Works for Physics as follows :

1. I.Inta, D.Jecu, S. Dumitru, N.Cretu-Culegere de probleme de fizica, Reprografia Universitatea din Brasov, Brasov 1990
2. Colectivul Catedrei de Fizică,Lucrări de laborator de Fizică, Reprografia Universităţii din Braşov, Braşov 1985
3. Cretu N- Lucrari de laborator de fizica on line-http://menelaus.unitbv.ro/laboratoare.htm

As professor in physics I teach to students the next courses:

1. Course of General Physics to the students in Computers, Electronics and Telecommunications, Faculty of Electrical Engineering and Computer Science, Transilvania University Brasov
2. Course of General Physics to the students in Environment Protection, Renewable Energies, Industrial Design, Faculty of Product Design and Environment
3. Course and applications on Mathematics and Physics for Engineering Knowledge, to the MASTER students , Faculty of Product Design and Environment
4. Course and applications on Mehanics Experiments, to the MASTER students Faculty of Mechanical Engineering.
5. Course of Special Course of Physics for Medical Engineering, Faculty of Product Design and Environment
6. Course and applications on Physics of Materials for students in Biomaterials, Faculty Engineering of the Materials