ABSTRACT

Thesis of doctorate
"CONTRIBUTIONS TO THE COMPUTATIONAL MODELLING OF THE MECHANICAL SYSTEMS VIBRATIONS"

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In the last time, the interest in the calculators utilization in diverse activity domains has increased considerable because of the elaboration of means programmed for the proper programmes elaboration for the different problems solution purpose. As a result, the analytical calculations electronic systems – as for example Mathematica, MatLab, Maple or Mathcad – have, in their composition, thousands of commands included and functions united in libraries, as well graph charts tracing process visualization possibilities. Thus, the mechanical systems conception becomes very automated as part of the Mechanical Conception Assisted by Calculator.

The mode in which the mechanical structures vibrate is often an essential point in the mechanical conception of the complex systems from reasons of security, comfort and performance. In this way, the recent necessities in the vehicles domain in security matter in the collision moment led – still from design stage – to the foresight of the behaviour according to structures submissive to big deformations in dynamical system, for enough.

For the mechanical models validation, the dynamical tests and, especially, the modal experimental analysis problems have an important role. The reverse problems are used large in mechanics and, in particular, in the vibrations mechanics. Among the applications and the methods tackled in this meaning we can cite the reverse problems of the sources, the form optimization, the active control of the fluids transport devices or, finally, the integrals equations methods much used in mechanics and acoustics.

In the same context, it is remarkably that the dynamical behaviour rules parameters determination, the dynamical structures modelling actualizing going

from measured dynamical measures as well the defects identification through nondestructive methods (waves) constitute important examples of the such named reverse problems (the systems identification) in the structures dynamics.

The vibrataing behaviour of some complex mechanical structure is very well represented at low frequencies through the her proper modes of vibrations, this having a practical importance notable for all what means the internal and/or external acoustics of the transport vehicles: motors – cars, railage, aeronautics.

The fine estimate of the errors united of modelling and of the perturbations influence has an important role, whenever some more efficient strategies of control of the complex mechanical structures vibrating behaviour are treated in thesis. As a result, the mastery of the different vibrating phenomena in the complex mechanical systems raises up fundamental research problems, as it is the knowledge of the phenomena from diverse vibrations sources. In the way, new efforts are introduced in the search of some innovating methodologies from the point of view of the modelling, on the one hand, and, on the other hand, from the point of view of some pertinent thought concerning to the objectives united of different applications in which some compulsions appear in the pursuit of the performances higher and higher whenever these system are used. A research activity in this way refers to the modelling and the study of the vibrating phenomena in the manufacturing systems, being orientated to the integration of the dynamical behaviour of these systems in the manufacturing lines development process. A such research project can not conceive than in relation with other scientific preoccupations of the researcher or of the researchers team, but it requires a series of competences, as for example:

- determination, in the designing phase, of the dynamical behaviour of the complex mechanical systems;

- development and evaluation of quick and solid techniques for the delay systems stability study (the semblance in the temporal domain, multifrequency methods, roots regrouping techniques - root clustering);

- modelling of the specific phenomena (the metals cutting) and of the interactions from factory in the vibrations presence;

- development of technique of active control of the vibrating phenomena in the mechanical processing (techniques of control systems with delay);

- taking in consideration of the dynamical compulsions in the phase of the machines designing;

- integration and management of the models at different scales.

The dynamical behaviour of the mechanical systems is affected often by the nonlinear effects, that, in numerous cases, is situated at the level of the interfaces of coupling between different components (dynamical exciting generated by the contact in the organs of transmission of the motion and of the efforts, instabilities connected of the friction in the mechanical systems) that can lead to undesirable effects (noises) or than can harm to the maintenance into service of the mechanism (excessive wear).

At present, the activities of research concentrate on the development of the experimental, theoretical and numerical multidisciplinary competences taken in consideration whenever the structures, the machines elements or, in general, the mechanical systems are conceived. The research purpose consist in: the improvement of the knowledge about the materials and structures behaviour, the development of the models and of the instrument useful in the structures and machines designing process, the capitalization of some technical culture concerning to the methodologies of analysis, of conception and of production. These researches are based upon the next domains: the materials science, the nonlinear mechanics of the solids, of the fluids and of the coupling systems, the acoustic, the technics of forming and processing, experimental measurement methods and the numerical modelling.

For to treat better the flexibile mechanical systems semblance, we can appeal to technics of corps systems analysis and to technics of modelling of the deformable corps as finit elements. Combining the two technics, that will take on their the treatment of the great displacements associated with the corps assembly movement and respectively with the expression of the small displacements as a result of the deformation, the position and the orientation in any matter point can be determined. Thus, the differential equations that direct the dynamical behaviour of the system can be determined, too. Taking in consideration the corps flexibility, this shall lead inevitably to a volume increase and to the differential equations systems complexity, because the deformations modelling introduces a supplementary number of liberty degrees.

An approach as more comprehensive of the semblance supposes the intimate combination of three loads:

- the establishment of some representative model of the studied system;
- the dynamical equilibrium equations determination;
- the numerical integration of the dynamical equilibrium equations.

Thus, the finale solution efficaciousness can be remarked and it depends, in principal, on the existent coherence between the methods selected for the finalizing of the each load partly.

The doctorate thesis is structured in seven chapters.

The first Chapter ***"Introduction",*** presents the present stage of the researches regarding to the computational modelling of the mechanical systems vibrations, and the other contributions in this domain being personal contributions.

The ***Chapter 2 "Mathematical models in displacement of the bar type and thin plane plate type cinematic elements vibrations"*** presents, first of all, the movement equations of the cinematic elements of bar type or slim plane plate type, with elastic linear behaviour. The Hamilton variational principle from elastodynamics was used for the deducing of these equations. For the viscouselastic cinematic elements vibrations, a first group of mathematical models is constituted by the models obtained through the discreteness of the temporal interval of the motion observation. This discreteness allows than, in the base of the elasto – viscouselastic analogy enunciated by Alfrey and Lee, the unilateral Laplace transform in comparison with the time is applied to the elastic linear cinematic elements notion equations deduced with the Hamilton principle. If the equations in elastic linear displacements have the constant coefficients, which it happens in the case of some particular motions, then the mathematical models of the viscoselastic cinematic elements can obtain through the direct application of the Laplace transform, without to be necessary this discreteness.

Mathematical models that neglects deliberated the coupling terms, as well these terms that been having coefficients as time functions, obtain in a first approximation through the direct application of the Laplace transform, too.

An other group of mathematical models of the elastic linear cinematic elements vibrations is constituted of these models that have a finite number of

liberty degree. Taking some considerations into account, that assures the dynamical equivalence between a viscouselastic linear solid and a system attached by concentrated masses and that permit the use of the elasto - viscouselastic analogy enunciated by Alfrey and Lee, the mathematical models of the vibrations according to the viscouselastic cinematic elements with a finite number of liberty degrees was obtained. Like before too, and from the same grounds, these models can obtain through the direct or indirect application of the Laplace transform to the mathematical models of the elastic linera behaviour cinematic elements vibrations.

In the end, if the unilateral Laplace transform in comparison with the time applies formally to the linear elastic behaviour cinematic elements motion equations, then $\dot{E}(s)$ introduces in the E place and it inverts, the mathematical equations systems which describes the linear viscouselastic behaviour cinematic elements vibrations.

All mathematical models are putted in the operational shape, with the purpose of the computational treating of the problems proposed by me for study.

The ***Chapter 3 "Methods of solving of the cinematic elements vibrations mathematical models",*** presents a series of proposals for the solving of the mathematical models according to the vibrations from the cinematic elements of right bar type or slim plane plate. This solving I have been done it, in principal, with the helping of the integral transforms. In the case of the cinematic elements of continous average type. I have been applied, first of all, the Laplace transform in comparison with the time, to the partial derivatives equations that describe the vibrations of some such elements. Then, I have been applied one from the simple or double Fourier transforms, finite in sinuous or cosine, to the equations thus obtained, depending on conditions at limit (see types of supports), after how the cinematic element taken in consideration is right bar, respective slime plane plate. This method leads at the solution of some systems of algebrical equations that have the displacement in their images type Laplace and Fourier as unknown. In the end, the Fourier and Laplace transforms inversion was lead to the obtaining of some series type solutions.

In the case of the mathematical models invariant in time, the used method is that of the successive approximations. With the help of the integral transforms, the solutions are given in Laplace and Fourier images of the displacement, in the *"j"*

certain approximation, the longitudinal and transversal displacement fields following to result in the shape of some series, too. An iterative method solves too the mathematical models deduced in the integro – diferential variant.

The algorithm of solution of the mathematical models with a finite number of liberty degree is reduced to the solution of some algebrical systems having as unknown the displacement in Laplace images of some points that belong to the cinematical element submitted to the study. The Laplace transform inversion leads, in the end, to the longitudinal and transversal displacement fields determination.

In ***Chapter 4 "Vibrations of the right bars and of the slim plane plate",*** constitutive elements of some mechanisms, at first, the fields of displacement of the cinematic elements with linear elastic or viscouselastic behaviour of some plane mechanism (for example the parallelogram mechanism and rod – crank mechanism) are determined analytically, appling the calculation system Mathematica. Then, the fields of speeds and of accelerations as well the components of the specific deformations tensors and of the tensions.

Appealing to the same calculation system Mathematica, for concrete numerical cases, the displacement and accelerations diagrams are determinated.

I consider that it is usefully as the results obtained through exact methods compare with the obtained through approximate methods on the one hand, and on the other hand the results obtained for the linear viscouselastic behaviour elements.

In ***Chapter 5 "Mathematical models and their solution for the machines vibrations study",*** is presented the study of the rod – crank assembly of some motor with disposal in V.

Concerning to the motor cars vibrations, a mechanical model of some vibrating system operated by the cam, accompanied of the him mathematical model. The motion rule of this mechanical systems is determined appealing to the calculation system Mathematica.

In continuation, the analysis of the vibrating behaviour of some machine – tool makes presenting the case of some late with continuous variation of revolution and dynamical absorber and appealing to a model with seven liberty degree. All elements are considered that effect vertical oscillatory translations having a big influence on the dimensional precision and on the wear of the organs what

compose the subassemblies of the lathe or of the respective machine – tool. The mathematical model solution was maken with the Laplace integral transform.

The variations diagrams of the displacement in function of time was achieved, too, in the calculation system Mathematica.

In this chapter, I have considering necessary too the study of some mechanism with toothed wheels, presenting thus the dynamical model of the gearing for the model vibrations study, in the functioning time.

The ***Chapter 6 "Experimental tests",*** presents the experimental verifications that had, like support, the mechanism from the Chapter 4, they having the role of to confirm the correctness of the mathematical models deduced theoretical and of the exact or approximate solving methods of these mechanism.

In ***Chapter 7 "Conclusions. Original contributions. Subsequent directions of research",*** are presented the personal contributions in the vast domain of the mechanical systems vibrations computational modelling, as well a part of the future research directions in this domain.

Runing through the thesis, the original contributions that draw from the present paper are the below:

- elaboration, in the operational shape, of some mathematical models in displacement of the vibrations what corresponding to the cinematic elements of right bar type and of slim plane plate type, with linear elastic behaviour;

- elaboration, in the operational shape, of some mathematical models in displacement of the vibrations what corresponding to the cinematic elements of right bar type and of slim plane plate type, with linear viscouselastic behaviour;

- elaboration of some mathematical models in the shape of the integro – diferential equations systems, that describe the vibrations what corresponding to the cinematic elements of slim plane plate type with linear viscouselastic behaviour;

- elaboration of some calculation methods, liked of computer, for the solution of the mathematical models in displacement, of the vibrations what corresponding to the cinematic elements of right bare type and of slim plane plate type, with linear elastic or linear viscouselastic behaviour;

- analytical determination, applying the calculation system Mathematica, of the fields of displacement what corresponding to the cinematic elements, of right bar type or slim plane plate type, with linear elastic or viscouselastic behaviour (the elements being constitutive parts of some plane mechanism);

- obtaining of the diagrams of variation of the displacement what corresponding to the cinematic elements of right bar type or slim plane plate type, with linear elastic or linear viscouselastic behaviour, through the Mathematica calculation system use, for concret numerical case.

- determination of the fields of speeds and accelerations of the cinematic elements of right bar type or of slim plane plate type, with linear elastic or viscouselastic behaviour;

- determination of the tensions tensor components and of the specific deformations, for the cinematic elements of plane plate type, with linear elastic, respective linear viscouselastic behaviour;

-elaboration of the mechanical and mathematical model of the rod – crank assembly of some engine with disposal in V, as well the mechanical system motion rule determination with the help of the calculation system Mathematica;

- elaboration of the mechanical and mathematical model of some vibrating system operated by cam, as well the mechanical system notion rule determination with the help of the calculation system Mathematica and Maple;

- determination of the relative displacement of the two toothed wheels of some suppositional mechanism with toothed wheels, in the gearing line direction, while the teeth make contact on the active or inactive flank of the tooth; determination of the relative displacement of the toothed wheels during the detachement (discontinuities in gearing) and the proper variation diagrams tracing in the calculation system Mathematica;

- experiences effectuations with the electronic system Spider 8, destined to the numerical measurement of the analogical date, he being a modern measurement system specialized for the numerical acquisition of the mechanical measures as follows: strength, mechanical tensions, pressure, accelerations, speeds, displacement, temperatures.

As a result of the exposed, it results a part from the subsequent research directions, as for example:

- elaboration, in the operational shape, of some mathematical models in displacement of the vibrations what corresponding to the cinematic elements of plane curved bar type and of slim curved plate type, with linear elastic behaviour;

- elaboration, in the operational shape, of some mathematical models in displacement of the vibration what corresponding to the cinematic elements of plane curved bar type and of slim curved plate type, with linear viscouselastic behaviour;

- elaboration of some mathematical models in the shape of the integro – diferential equations systems, that describe the vibrations what corresponding to the cinematic elements of slim curved plate type, with linear viscouselastic behaviour;

- elaboration of some calculation methods, liked of computer, for the solution of the mathematical models in displacement of the vibrations what corresponding to the cinematic elements of plane curved bar type and of slim curved plate type, with linear elastic or linear viscouselastic behaviour;

- analytical determination, applying the calculation system Mathematica or Maple, of the fields of displacement what corresponding to the cinematic elements of plane curved bar type or slim curved plate type, with linear elastic or viscouselastic behaviour (the elements being constitutive parts of some plane mechanism, as for example the parallelogram mechanism and rod – crank mechanism);

- obtaining of the diagrams of variation of the displacement what corresponding to the cinematic elements of plane curved bar type or slim curved plate type, with linear elastic, respective linear viscouselastic behaviour, through the calculation electronic systems use Mathematica or Maple, for concret numerical cases;

- determination of the fields of speed and accelerations of the cinematic elements of plane curved bar type or slim curved plate type, with linear elastic or viscouselastic behaviour;

- determination of the tensions tensor components and of the specific deformations for the cinematic elements of plane curved bar type or slim curved plate type, with linear elastic or viscouselastic behaviour;

- toothed wheels mechanisms vibratory behaviour analysis, applying at mechanical models with more liberty degree.

The elaboration of some mathematical models of the mechanical systems vibrations and their solution with the calculator's help constitute the final scope of the thesis.