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HABILITATION THESIS

KINEMATIC AND DYNAMIC ANALYSIS OF THE MECHANICAL STRUCTURES FOR SELF-PROPELLED EQUIPMENTS

Abstract

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The habilitation thesis titled *Kinematic and dynamic analysis of the mechanical structures for self-propelled equipments* represents a part of the research activity of the author, performed after the obtaining of the scientific title of PhD in Mechanical Engineering in 1997, at the Politehnica University of Bucharest; the tile of the PhD thesis was *Contribution at the elasto-dynamic study of the spatial mechanisms with bars*, the director of thesis being Prof. PhD Eng. Nicolae PANDREA.

The habilitation thesis is structured in three parts, name it:
- a short presentation of the candidate's professional activity
- the main realizations in the fields of science and research
- perspectives concerning the evolution and development of his career

The professional evolution of the author of this habilitation thesis was as follows:
- 1984, double repartition, at I.A.T.S.A. Dacia Piteşti and I.C.S.I.T.A Piteşti. At I.A.T.S.A. Dacia Piteşti the occupied job was as *Instructor Engineer* in the department C.T.C. - Laboratories.
- 1987, after the job regular schedule, I was tutor Assistant Professor at the "Institute of Superior Teaching " in the department of "Applied Mechanics " at the disciplines: Mechanical Vibrations, Mechanics, Strength of materials.
- 1990, transferred at the University of Piteşti in the department of "Applied Mechanics" as tutor Assistant Professor at the disciplines: Mechanisms, Mechanics, Strength of materials. As the result of the contest for the position of assistant professor at the disciplines "Mechanisms and Mechanics ", position 22 in the pay roll of the department of "Applied Mechanics ", since January, 9, 1991, I was declared admitted with the general score of 9.44.
- 1992, unique participant at the contest for the position of Lecturer at the discipline Mechanisms, position 16 in the pay roll of the department of "Applied Mechanics ". The commission for the contest, appointed by the Order 1358/25.05.1992 of the Rector of the University of considered that "by the results obtained in the professional, didactical and scientific activity it is confirmed the fulfillment of the conditions to occupy the position of Lecturer".
- 1999, I occupied by contest the position of Associated Professor at the disciplines "Mechanisms, Control and attenuation of noises and vibrations at automotive " position 12 in the pay roll of the department of Electro-mechanics, Faculty of Engineering, University of Piteşti, position published in the Official Monitor of Romania, nr. 83 from April, 5, 1999.
- 2003, I occupied by contest the position of Professor at the disciplines Mechanisms, Computer Assisted Design of the mechanical systems, Assisted graphics, position 7 in the pay roll of the department of "Applied Mechanics", Faculty of Mechanics and Technology, University of Piteşti, position published in t he Official Monitor of Romania, nr. 166 from April, 8, 2003.

The performed scientific activity concretized in 248 scientific papers, 12 courses, 3 monographs, 4 textbooks for laboratory and 30 research contracts at 10 of them being director or responsible of contract. The themes were varied as follows:
a) kinematic, dynamic and elasto-dynamic study of the spatial mechanisms with the aid of the theory of screws and the plűckerian coordinates;
b) dimensional analysis and synthesis of the cam mechanisms used at the adaptive engines;
c) the use of the Computer Assisted Design in problems of modeling of the elements and dimensional analysis of the planar and spatial mechanisms;
d) the use of the Computer Assisted Design in problems of kinematic, kineto-static and dynamic analysis of the planar or spatial mechanisms;

f) models for the study of the automobiles' vibrations;
g) dynamics of the bi-mobile mechanisms used for the coupling of the power sources;
h) reduction of the pollution effects produced by automotive by using the laser equipment for the ignition of the fuel in thermal engines etc.

The habilitation thesis titled *Kinematic and dynamic analysis of the mechanical structures for self-propelled equipments* is the result of the research in the field, of the published books and papers and of the experience obtained by finalization of the research contracts obtained by competition. The habilitation thesis consists in 4 chapters and a bibliographic list which certify the preoccupations in the field.

At the beginning of the chapter 1 are presented some advantages which recommend the update of the graphical methods in a CAD soft. In this way, one maintains the simplicity of the graphical methods, and the obtained results have the precision of the analytical methods. The problem of great volume of the graphical constructions is avoided using AutoLisp, a programming language implemented in AutoCAD. The graphical methods of synthesis of the lever curves for the crank-shaft and four-bar mechanisms are upgraded with the aid of AutoLisp functions. In the case of the approximation of the lever curves one updates the graphical methods of K. Hain in order to obtain the dimensions of a mechanism when a curve approximates a curve by three, four and five points. In the case of the positional synthesis, with the aid of AutoLisp functions one obtains: poles of finite rotations considering four positions in the plane of the rocker, positional synthesis of the four-bar and crank-shaft mechanisms, the curve of the centers in the case of the four positional synthesis, the dimensions of the four-bar mechanism in the cases of four and five positional syntheses. In the case of the walking mechanisms the basic used mechanism is a four-bar one, the dimensions are obtained by synthesis, so that a point of the shaft describes a segment of straight line on a certain portion of the rocker curve. Further on, are presented two constructive variants of walking mechanisms for which are performed the kinematic and dynamic analysis. The first one is the mechanism known in the bibliography as "Tchebyshev Horse", while the second one is a self-propelled equipment containing four four-bar mechanisms. The system is acted by an DC electrical motor by mean of a worm gear mechanism. In order to be able to turn the system one used two frames. The first frame (the rear frame) contains the propulsion system and two four-bar mechanisms. The second frame (the forward one) also contains two four-bar mechanisms. The motion is transmitted from the rear frame to the forward frame by a bi-cardan mechanism. The bi-cardan mechanism permits the turn and the boost of the forward frame when it is acted by two moto-reducers situated in perpendicular planes. The command of the three motors: acting, turning and boosting of the forward frame is realized with the aid of an electronic device acted by radio waves from distance and charged from the same source with the three motors. The elements of the mechanisms are modeled with solids in AutoCAD, obtaining easily the mechanical characteristics of the elements of the mechanism. In the end of the chapter one presents the algorithm used for the animation of the considered mechanisms.

Chapter 2 is assigned to the cam mechanisms. The analysis of the displacement of followers is unitarily presented, in a table in which the classification is realized function of the motion of the cam and the motion of the follower. Essentially, the problem of the analysis of the displacements of follower consists in the determination of the parameter of displacement of the follower (the angle φ_2 or the displacement s_2) in function of the parameter of displacement of the cam which is either the angle φ_1 for the rotational cam or the linear displacement s_1 for the translational cam. Further on, one presents a general calculation

method for the displacement of the follower, the results for different types of mechanisms being presented in table form. In the paragraph of kinematic analysis one presents the algorithm for the determination of the absolute and relative velocities and accelerations for the cam and follower. I also realized numerical applications for the most used cam mechanisms. In the synthesis, one establishes the criteria and the calculation methods for the design of some cam mechanisms which fulfill certain imposed requirements. One presents a mechanism with cam and bars named robot mechanism, for which one imposes the requirement that states that a point of an element of the mechanism describes a certain curve. One obtains, by synthesis, and by using these requirements the double cam of the driving mechanism. Based on these algorithms are thus obtained the cams of the mechanisms which later are dimensionally optimized in function of certain requirements of design.

The generation of gears with the aid of a CAD soft is discussed in Chapter 3. The work with solids and the existence of Boolean operations permitted the obtaining of the composite solids in AutoCAD. These facilities are used to obtain the solids, which materializes the gears. The procedure to obtain the tooth in AutoCAD is "copied" from practice. The most used procedure in practice, the procedure of rolling without sliding, assumes the toothing between the tool and the raw material that is manufactured. The profiles in toothing move of equal circular arcs or distances. The tool may be a cylindrical gear or a jack, Further on, one presents the five steps algorithm to obtain gears in AutoCAD no matter the shape of them. One will have to perform minimum 360 operations of extraction of the tool from the raw material. Comparing to the classical technologic procedure, in AutoCAD the gear is obtained after one single rotation, the complete extra material being eliminated in one step. In order to perform the operations with solids previously presented I wrote AutoLisp functions for: the generation of the spur cylindrical gears, with inclined and curvilinear gears, the generation of the conical gears, and the generation of the elliptical gears. In the case of the elliptical gears one also performs numerical applications for the kinematic analysis, dynamical analysis and the analysis of the torsional vibrations of an assemble of two gears situated in a mechanical system. In the last part of the chapter are presented the aspects considered for the design of the non-circular gears. These non-circular gears are design in order to ascend or descend stairs; they could enter the mechanical structure of a moving chair.

Chapter 4 is dedicated to the mechanical systems used for the coupling of power sources. These mechanisms are preferentially used in the construction of the hybrid automotive, where the sources of thermal and electrical power must be coupled. The coupling mechanical system, the essential component of the system, is the link between the source of thermal energy (transformer of irreversible energy), the source of electrical energy (transformer of reversible energy) and the driving wheels of the vehicle. It consists in a planetary mechanism with two degrees of mobility SMC, at which are linked: the thermal engine MT, two reversible machines (motor/generator) ME1 and ME2, respectively, a gear mechanism with four gears and a differential mechanism which transmits the motion to the driving wheels. One thus realizes the possibility of using more such systems in different configurations, and, finally, one establishes the optimum variants of the mechanism. For the presented mechanisms I realized the kinematic and dynamic analysis. In order to obtain numerical results one designs such mechanisms, models their elements with solids in AutoCAD, obtains the mechanical properties of the elements and solves the differential equations of motion. The results are presented as diagrams. In a separate paragraph one realizes the study of the stability of the motion considering different modes of functioning of the hybrid automotive. One also presents a prototype of the mechanical system that couples three sources of power. It can be used in the construction of an automobile which moves with a maximum speed of 110

km/h, has an own mass of 600 kg and may transport 200 kg. Finally, one presents the equations of motion of a hybrid automotive for which one knows the dynamic parameters.

The last part of the habilitation thesis *Perspective concerning the evolution and the development of the career* contains the future directions of scientific development of the author in the field of mechanical engineering.