ZESZYTY NAUKOWE POLITECHNIKI ŚLĄSKIEJ 1994

Seria: MECHANIKA z. 116 Nr kol. 1231

Ctirad KRATOCHVIL
Institute of Mechanics of Solids
Technical University of Brno

ANALIZA I SYMULACJA DYNAMICZNYCH WLASNOŚCI ELEKTROMECHANICZNYCH SYSTEMÓW NAPĘDOWYCH ZE SPRZĘŻENIAMI ZWROTNYMI

Streszczenie. W referacie zajęto się problemem symulacji systemów napędowych ze sprzężeniami zwrotnymi. Symulacji organizacji strukturalnej dokonano za pomocą modelu urządzenia napędowego jako całości, jak również przez wyliczenie wewnętrznych i zewnętrznych oddziaływań, mających wpływ na reakcje podsystemów.

ANALYSIS AND SIMULATION OF DYNAMICAL PROPERTIES OF INTERACTIVE ELECTROMECHANICAL DRIVE SYSTEMS

Summary. The paper deals with the problem of simulating of interactive drive systems. The simulation of the structural arrangement is defined by a correct assessent of the internal and external interactions, influencing the reaction of model systems, and also the model of the drive as a whole.

ANALYSE UND SIMULATION VON DYNAMISCHEN ELEKTROMECHANISCHEN EIGENSCHAFTEN DER ANTRIEBSSYSTEME MIT RÜCKKOPPLUNGEN

Zusammenfaßung. Das Referat behandelt das Problem der Simulation von Antriebssystemen mit Rückkopplungen. Die Simulation der Strukturorganisation wurde mittels des Modells einer als Ganzes betrachteten Antriebseinrichtung sowie durch Berechnung der inneren und äußeren Einwirkungen, welche die Reaktionen von Subsystemen beinflussen, durchgeführt.

1. INTRODUCTION

The objective social need to bring the design sector closer to the needs of the operating conditions makes it necessary to analyse a number of informations on possible future effects, on internal and external interactions of the analysed system, and last but not least to seek answers to questions regarding the dynamic properties of the system, and its reactions to the standard and break-down situations. If possible, all this should be already acquired at the stage of design.

In case of dynamic analysis of the drive systems these requirements are complicated by the fact that we have to do with a complex dynamic system, whose basic structural parts have various physical aspects (mechanical, electronic, hydraulic, etc.). Especially, in the case of controlled drives, these interactive systems are combined with bassically multi-stage feedback subsystems. Machine drive systems, in the narrower technical sense, contain as a rule: systems of driving motors, transmissions, the working machines, feedback and control systems and information transfer systems.

2. SPECIAL PURPOSE AND PARTIALLY STRUCTURED DYNAMIC SYSTEMS

The answers to the questions regarding the properties of new machine drives, and how they react on a number of operating conditions, can be acquired through experiments with mathematical models, defined on actual systems, e.g. [1], [2], [3]. The noting "dynamic system" has itself not yet been univically defined. We shall stick to the definition of it according to ZADEH [4], in sense with the identification of the actual (primary) object and of the abstract (secondary) object, represented by the general dynamic system, represented in this case by a mathematical model.

The basis of the success of experimenting with this mathematical model is a correct functional definition of the system, with special view to solving a concrete problem. The "functional definition" of the system does not mean that it is fully defined by its functions and manifestations only, on the very contrary. We presume, that all these functions have their bearers, that should also be comprehended as a black box. Therefore we define at least the approximate degree of structural complexity, power output and informative capacity of the system. Thus the system has a certain target and some informative functions, on higher level some control functions. In view of the fact that the actual models of machine drives are of varying complexity, we have defined the motion "purpose-formulation of the system on the actual object" [2]. We comprehend it in the sense that some system elements, system links and properties may be a smplified or even neglected in connection with the concrete situation. Further, the dynamic system will always be reagarded as "imperfectly structured". According to the concrete purpose we can create, if need be, several structural qualities. At that we can make even of some extreme principles, faciliating the description of the state of the system in marginal cases, e.g. in cases when the permitted load level has been exceeded, in case of deformation, breakdown, etc.

All this is done to enable the functional definition of the system, to acquire the basic dynamic characteristics, principles of configuration, parameters of functioning, and eventually of the development of complex systems that could be quantified, at least partially.

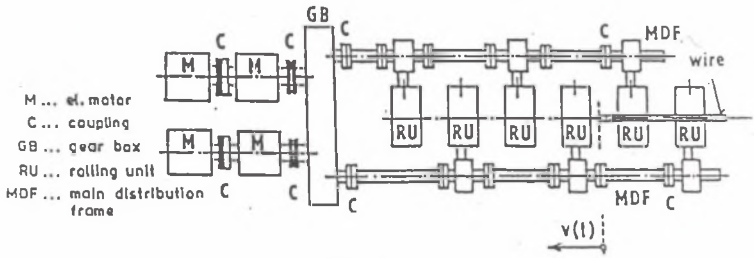

Fig. 1.
Rys. 1.

3. CONCRETE EXAMPLE

The scheme of the drive of an experimental wire-drawing mill we can see in Fig. 1.

The task was to check the dynamic properties of the drive as a whole, and the specific dynamic properties and behavior of the motor subsystem. Here we face problems in synchronizing the revolutions of the individual motors on starting the run of the mills, in idle run on entering the mill by the material, and following problems, on account of the purpose-formulation of mathematic models are suitable.

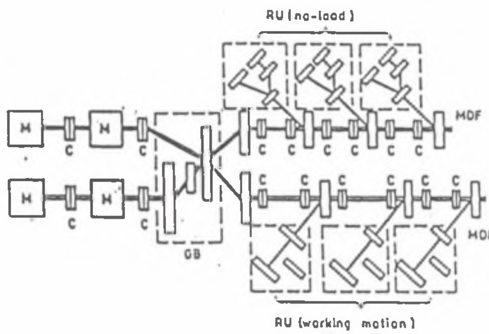

Fig. 2.
Rys. 2.

For example, the first problem, the analysis of basic dynamic properties of the drive as a whole, can be solved with the help of a model of a branched discrete system presented in the Fig. 2. The mathematic model is a system of differential equations of movement (linear or linearized - the couplings between motors may have a nonlinear characteristic). Another problem to be faced is the detailed analysis of the dynamic system of the motor subsystem. A suitable purpose-model in this case is presented in Fig. 3. Technological part is reduced on the technological moment MT . Here we have to consider a controlled drive systems (the total speed is controlled).

It has been therefore necessary for each motor to set up model comprising sub-models of a thyristor converter for feeding the armature of the motor of the power regulator in armature circuit and motor speed regulator [5]. The possible ways of controlling the motor subsystem have been defined in Fig.4.

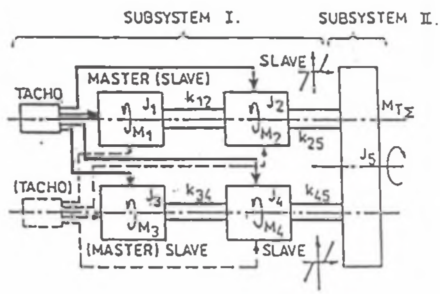

Fig. 3.
Rys. 3.

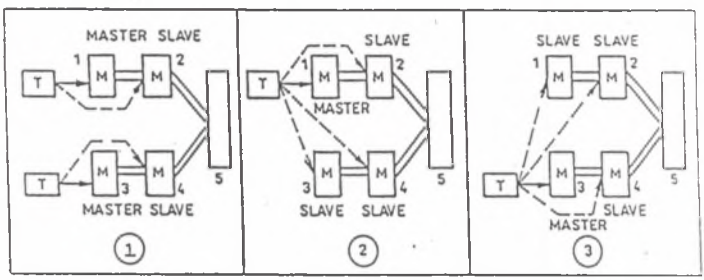

Fig. 4.
Rys. 4.

The results of dynamic analysis of the train drive, acquired with the help of described models, can be found in [2] and [5]. Only two examples computer simulations are demonstrated here. In order to suppress the parasitic effects of non-linear characteristic of flexible couplings have been used. This has lead to the limitation of parasitic affect only on the beginning of the simulate rolling proces (see courses of the flexible moment M45 in the train drive, without clearance on the Fig. 5a and with clearance on the Fig. 5b.

In the consequence of the disengagement of the drive system (clearance in the mechanical couplings), thyristor converters may generate very complicated parasitic components. Then, the clearance in the flexible couplings, namely the size of the clearance, causes changes in the parameters of the couplings. These changes make rise to complicated motions - for example phase portraits in coupling (2-5), see Fig. 6a,b,c, (a...very little clearance - state of deterministic chaos; b, c... an increase of the clearance in the coupling).

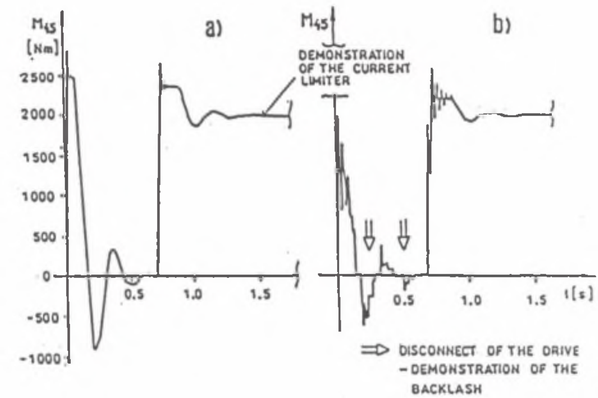

Fig. 5.
Rys. 5.

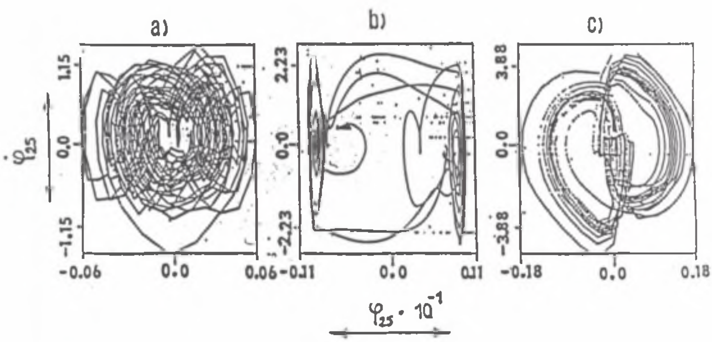

Fig. 6.
Rys. 6.

4. CONCLUSION

The problems connected with the simulation of the dynamic properties of interactive movement systems contain, as an analysis of the properties of each complex system, certain moments of uncertainty, inconclusiveness and still have an open character. The development of the present level of scientific knowledge, however, makes it imperative to follow the problem's areas too, include certain disputed moments. We could mention here e.g. the formulation of purpose - structured mathematic models of drive systems. We also demonstrated the links between functional manifestations of drive submodels and their organized structure, arising in the process of discovering new release, new context.

Such a methodic approach to the solution of practical problems can be already done at the stage of designing the basic structural components of the drive systems.

REFERENCES

[1] KALMAN,R.: Algebraic Aspect of the Theory of Dynamic Systems, in: Differential Equations and Dynamic Systems, Academc Press, New York 1967.

[2] KRATOCHVIL,C.: Digital Simulation of the Dynamic Properties of Electromechanical Systems Drive of Machine, doct. thesis TU Brno 1990.

[3] VAN BRUSSEL,H.,JANKOVSKI,K.: Mathematical Models for System Dynamics and Controll, in: Computer Controlled Motion, Heverlee, Belgium 1992.

[4] ZADEH,L.:The Concent of State in System Theory, in: Views on General Systems Theory, Willey, New York 1964.

[5] KRATOCHVL,C. and others : Some Problems of Dynamic of Electromechanical Drive Systems, Research Rep. No M-7/90, Inst. of Mech. of Solids TU Brno 1990.

Recenzent: Prof. dr hab. inż. Eugeniusz Świtoński

Wpłynęło do Redakcji w grudniu 1993 r.

Streszczenie

Analizę dynamiki systemów napędowych komplikuje fakt, że oprócz zjawisk czysto mechanicznych mamy do czynienia ze zjawiskami elektronicznymi, hydraulicznymi i innymi. Dodatkowo, w przypadku napędów sterowanych, musimy brać pod uwagę przepływ informacji w systemie. Odpowiedzi na wiele pytań dotyczących własności nowych urządzeń napędowych, ich zachowań w rozmaitych sytuacjach (na przykład awaryjnych) można uzyskać przez symulację numeryczną. W pracy przedstawiony jest konkretny przykład analizy dynamicznej walcarki do drutu, napędzanej czterema silnikami elektrycznymi. Wzięto pod uwagę różne możliwości sterowania silnikami. Zamodelowane nieliniowości (luzy) w sprzęgłach generują chaos deterministyczny, możliwy do zaobserwowania na płaszczyznach fazowych.