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N. V. Banichuk · D. M. Klimov
W. Schiehlen (Eds.)

Dynamical Problems of Rigid-Elastic Systems and Structures



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Preface

The International Union of Theoretical and Applied Mechanics (IUTAM) initiated and supported an International Symposium on Dynamical Problems for Rigid-elastic Systems and Structures held in 1990 in Moscow, USSR. The Symposium was intended to bring together scientists working in the fields of multibody system dynamics and finite element systems with special emphasis to modeling, simulation, optimization and control.

A Scientific Committee was appointed by the Bureau of IUTAM with following members:

N.V. Banichuk (USSR),
E.J. Haug (USA),
Y. Hori (Japan),
S. Kaliszky (Hungary),
D.M. Klimov (USSR), Chairman,
L. Lilov (Bulgaria),
F. Niordson (Denmark),
B. Roth (USA),
W. Schiehlen (Germany),
G. Schmidt (Germany),
J. Wittenburg (Germany).

The chairman invited the participants on recommendation by the Scientific Committee. As a result 48 active scientific participants from 11 countries followed the invitation, and 32 papers were presented in lecture sessions. The available manuscripts were reviewed by the Scientific Committee after the Symposium, and 24 of them are collected in this volume. At the Symposium a tour to the Institute for Problems of Mechanics, USSR Academy of Sciences, was arranged.

The scientific lectures were devoted to the following topics:

- Modeling and Optimization,
- Dynamics of Systems with Elastic Constraints,
- Vibrations,
- Multibody Systems.

The papers in this volume are arranged in alphabetical order with respect to the authors. They indicate the importance of multibody and finite element modeling with respect to many applications in mechanical engineering. The phenomena of elasticity or flexibility of the systems, respectively, require improved simulation and optimization methods. Further, the aspects of control engineering in highly dynamical systems are of major importance. The presentations and discussions

during the Symposium will certainly stimulate future investigations in the field of mechanical systems. The publication of the proceedings will contribute to this development.

Generous financial and material support was of great help for carrying out the Symposium. The help of two sponsors is gratefully acknowledged:

International Union of Theoretical and Applied Mechanics (IUTAM),
Institute for Problems of Mechanics, USSR Academy of Sciences.

The Symposium was arranged by a Local Organizing Committee recruited from the Institute for Problems of Mechanics under the chairmanship of N.V. Banichuk and D.M. Klimov. The social programme included a banquet and an excursion providing excellent opportunities for further scientific discussions.

In the editorial work for this volume the help of D. Bestle from the Institute B of Mechanics, University of Stuttgart was especially valuable. In addition, we would like to express our sincere thanks to all members of the Local Organizing Committee who contributed to the Symposium. Furthermore, thanks are due to the Springer-Verlag for the sympathetic cooperation.

Moscow and Stuttgart, December 1990

N.V. Banichuk, D.M. Klimov, W. Schiehlen

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Opening Address

D.M. Klimov, Symposium Chairman

Ladies and gentlemen!

Dear colleagues!

Today we open IUTAM Symposium on dynamical problems of rigid-elastic systems and structures. There had been a few symposiums in this field already. The first of these, under title "Dynamics of Multibody Systems", took place in Munich/Germany in 1977. The chairman of this conference was professor K.Magnus.

In response to industrial needs and as a result of the ever growing power of computers, the subject of mechanics of elastic-bodies-systems and structures is developing rapidly. Major steps are being taken to exploit new capabilities for improved modeling, computer-aided analysis and design, computerized formulation of equations of motion, and advanced solution techniques. Methods of structural optimization, control and identification are receiving extensive attention. Notable progress is achieved in dynamic studies of mechanical systems taking into account the effects of elasticity, viscosity, temperature deformations. Methods for dealing with deformable bodies and efficient determination of interaction forces are being developed particular in the fields of robots and large space structures.

Further development of these investigations is stipulated by the important problems of quality growing for mechanical systems, improving of dynamical characteristics, reduction of the cost, weight and material consumption for mechanical systems and structures.

The aims of the Symposium are to generate knowledge, to stimulate research, to disseminate new ideas, and to

acquaint the scientific community in general with the work currently in progress in the area of dynamic of mechanical systems and structures. For the above reason, the following topics are proposed:

- Modeling in dynamics and the problems of identification for mechanical systems and structures. Effects of viscosity, elasticity and temperature strains.

- New methods and algorithms for computer-aided analysis of complicated elastic systems. Application of symbolic calculation.

- Design and optimization of mechanical systems and structures for dynamic condition.

I'd like to say that local committee tried to do all necessary preparations. And my colleagues from the Institute of Problems in Mechanics and I hope that this Symposium will be useful for the international scientific community.

So welcome everybody.

Opening Address

W. Schiehlen, Secretary-General of IUTAM

Mr. President, Mr. Chairman, Academicians,
Ladies and Gentlemen,

On behalf of the International Union of Theoretical and Applied Mechanics I would like to welcome you at the Symposium on

Dynamical Problems of Rigid-Elastic Systems and Structures.

The proposal to arrange this Symposium was accepted in August 1988 by the General Assembly of IUTAM at the Grenoble meeting. Since that time the chairman, Professor D.M. Klimov, and his colleague, Professor N.V. Banichuk, have done a hard job preparing a challenging scientific programme.

The International Union of Theoretical and Applied Mechanics expects that the members of the Scientific Committee participate in the Symposium, too. And therefore, I will especially mention the scientists: Professor Lilov from Bulgaria and Professor Wittenburg from West Germany (FRG).

All of you know that it is not easy to organize an international symposium. There have been problems in contacting the members of the Scientific Committee for selection of participants and papers. But finally looking at the result, a challenging scientific programme was obtained.

However, the real success of a Symposium can be achieved only if all participants use the opportunity to exchange ideas on new developments, this week especially with respect to dynamical problems of multibody systems, vibrations and optimization.

Therefore, I would like to encourage all participants to lively discussions. The USSR is a member of the International Union for Theoretical and Applied Mechanics since 1956 and it is one of the leading countries in mechanical sciences.

First, I have to mention the 13th World Congress on Mechanics held 1972 in Moscow. This congress was, even until today, the world's largest meeting in the field of mechanics.

Secondly, there have been organized 10 IUTAM Symposia in the USSR in Solid and Fluid Mechanics. And today, we call to order the eleventh IUTAM Symposium in this country. Especially, the activities of the Sowjet scientists in the field of multibody systems are honoured internationally by this Symposium.

The science of multibody systems dates back to the sixties of this century when the space programme required improved modeling, simulation and optimization techniques. In connection with the increasing power of computational facilities during the last two decades, the multibody formalisms represent new tools for computer aided engineering, or CAE-techniques, respectively.

Two IUTAM Symposia have been devoted to multibody system dynamics. Professor Magnus organized 1977 a very successful symposium on this topic in Munich, FRG. Later in 1985 Professor Bianchi and myself held a IUTAM Symposium on multibody systems in Udine, Italy. And this week we will deal with recent developments in multibody systems combining rigid and elastic bodies as well as structures.

Ladies and Gentlemen, enjoy the honour and pleasure of being invited to a IUTAM symposium which means a first class symposium. Thank you.

Opening Address

K.V. Frolov, Deputy President of USSR Academy of Sciences

Dear Colleagues, Comrades,

I am glad to use this opportunity to greet you on the occasion of opening of the IUTAM Symposium on Dynamical Problems of Rigid-Elastic Systems and Structures.

The scope of this Symposium includes complex problems of mechanics. Their solutions provide scientific basis for further progress in most advanced and promising fields of modern technology, such as robotics, development of large space systems, in particular orbital structures, vibration technology and vibration protection systems.

Research and solution of dynamical problems in the above-mentioned fields demand the efforts of numerous and mighty teams of scientists. Research institutes of the USSR Academy of Sciences also pay much attention to the solution of these problems. The results of fundamental research of non-linear vibration made it possible to develop new promising wave technologies, and to create high-performance resonance robots and high-precision manipulators. Essential results have been also achieved in the theory of automatic control. The methods of synthesis of continuous non-linear control laws based on Lyapunov vector functions technique have been developed, as well as the method of stochastic programmed synthesis for the control with instantaneous and integral constraints.

Results of fundamental and applied research in the field of mechanics have been used in design and construction of space system "Energia - Buran", new aircraft IL-96-300, TU-204, AN-255 as well as in realization of FOBOS-2 spacecraft.

Nowadays, modern computers present a powerful additional means for theoretical investigations, simulations, calculations, optimal design and control. Their use enriches modern mechanics with new qualities and potential which were beyond the boldest dreams of scientists in the past.

Today one of the priority issues is the problem of safety in the wide sense of the word. This includes environmental safety, reliability of nuclear reactors and major power and transport systems, security of chemical industries, search and rescue of ships in trouble, faultless flights in civil aviation, ergonomic problems solution and more productive work of a human-operator.

In view of the large scope of research in dynamics devoted to the fundamental studies and solution of practical problems (especially those connected with safety insuring) summing up of results, analysis of recent achievements, and personal contacts with the outstanding world-wide known scientists acquire a special importance. The IUTAM Symposium provides favorable conditions for such an exchange of scientific ideas and results.

At this Symposium we hope to discuss, report and learn many latest results obtained in various fields of dynamics. The Symposium opens up opportunities for joint efforts and agreed activity of scientists belonging to different schools. In the reports and discussions at the Symposium original results and state-of-the-art reviews will be presented in a number of important branches of dynamics which attract now the attention of scientists from various countries.

Collaboration of scientists promotes both the progress of science and mutual understanding among nations in their strive for peace and security on Earth. Progress in international scientific and technical cooperation in future implies the creation of favorable conditions for the establishment of closer relations between Soviet enterprises and institutions, and their counterparts in Western Europe on the basis of common European home concept. It will also facilitate the establishment of joint ventures and common scientific programs involving the efforts of major companies, universities and societies in USA, Japan and other countries in the spirit of new thinking and priority of human values.

I wish you every success in your fruitful work at the Symposium for the benefit of science and mankind.

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Oscillations of a Rigid Body with a Cavity Containing a Heterogeneous Fluid

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USSR Academy of Science, Moscow, USSR

Summary

Oscillations of the mechanical system with infinite (countable) number of degrees of freedom and internal resonance is considered. This system consists of a rigid body with a rectangular cavity containing a heavy heterogeneous ideal fluid. The body is attached to a fixed base by means of a spring and can move in a horizontal direction. Using asymptotic technique analytical solution for the equations describing joint oscillations of the body and the fluid was obtained in both resonant and nonresonant cases. Some qualitative features of the system were found. We present here not only theoretical results but also the experimental data which reveal beating and changing the frequency of oscillations of the body.

Analysis of oscillations

A heterogeneous fluid consisting of two layers of different densities $\rho_{1,2}$, $0 \leq \rho_1 < \rho_2$ occupies a rectangular cavity inside the rigid body. Particles of the fluid are exerted by the gravity force. Depths of the layers are equal to h_1 and h_2 ; d and r are the length and the width of the cavity respectively. The fluid is assumed to be ideal and incompressible. The rigid body is exerted by an elastic force and can move in a horizontal direction. At an initial instant the body is given a small displacement s_0 from the equilibrium position, the boundary between the layers of fluids is horizontal and the whole system is at rest.

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