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V. A. Svetlitsky, Statistical Dynamics and Reliability Theory for Mechanical Structures

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Translated by N. L. Reshetov

With 189 Figures

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Preface

The monograph text is based on lectures delivered by author during many years for students of Applied Iechanics Department of Bauman Ioscow State Technical University. The monograph includes also analitical results of scientific research obtained in collaboration with industry.

Progress in developing new equipment has called for a better understanding of the physical peculiarities pertaining to the action of designed structures in real conditions. This is necessary for increasing the accuracy of the analysis and making these structures more reliable.

It has been found that classical determined perturbations are not principal and that determinism-based methods of classical mechanics prove insufficient for understanding and explaining physical effects that arise at the operation of instruments located on moving objects, the vibration of rocket engines, the motion of a vehicle, and the action of wind and seismic loads. Therefore the necessity arose for devising a new physical model to analyze these dynamic processes and, in particular, for creating a new mathematical apparatus that would allow us to take into account non-deterministic external excitations. The theory of random processes that had been developed well enough as applied to problems of radio engineering and automatic control, where the effect produced by random excitations appeared to be commensurable with that of deterministic excitations and where the ignoring of the random excitations would bring about incorrect results, became such an apparatus. Therefore the theory of random processes began to be used for the solution of specific problems relevant to radio engineering, in particular, earlier than for the analysis of mechanical systems where the random excitations were frequently being ignored. In many applied problems such ignoring of random excitations, the more so really small ones, is quite allowable and their solution does not require the use of statistical mechanics. If, however, random excitations are comparable (in probability characteristics) with known forces and especially when only random excitations act on the system, the classical methods of analysis become unacceptable and the obtainment of numerical results demands the use probability-based methods. Therefore introducing statistical methods of analysis in practical design is a necessary condition of making reliable structures.

It is impossible to increase the reliability of new equipment designed for operation in extreme conditions and meeting the most stringent requirements to operation accuracy and reliability, and at the same time to achieve a reduction in the material input per unit of consumption, without the use of statistical mechanics.

The first four chapters are devoted to the fundamentals of the theory of probabilities and random processes. Consideration is given to random quantities and functions and their probability characteristics; probability density distribution functions; and mathematical expectations and variances. Different types of distribution laws encountered in practical problems are expounded. Non-stationary and stationary random processes that are of practical importance in analyzing the vibrations of mechanical systems are examined. Principal results of the special theory of stationary random functions and the implementation of spectral presentation of stationary random functions at steady-state vibration analysis are described, and the theory of Markovian processes is discussed.

Chapters 5 – 8 are concerned with the random vibrations of systems with a finite number of degrees of freedom and of systems with distributed parameters. The theory of random vibrations is presented similarly to the classical theory of vibrations that allows us to establish in the most obvious manner in what way these sections of mechanics (determined vibrations and random vibrations) are related and where they differ. The methods of analyzing random vibrations presented in the textbook make it possible to investigate dynamic processes that arise in mechanical systems (i.e. to determine the probabilistic characteristics of the generalized coordinates of a system and of their derivatives for a system with a finite number of degrees of freedom, and to obtain the probabilistic characteristics of the state of stress and strain of a system with distributed parameters).

The ninth chapter deals with the fundamentals of the theory of reliability and analyzes numerical methods of determining the probability of no-failure operation of mechanical systems under a single or small number of loading cycles and at a confined time of the process.

The use of methods of statistical mechanics in practical design becomes a possibility only when statistical information about random perturbations is available, but there are cases where we cannot obtain such information to the extent required for the design. In our presentation of the theoretical fundamentals of statistical mechanics we assume that the necessary information about random perturbation is known. In engineering practice, however, the situation may be different due to a very large volume of experimental investigations involved that sometimes turns out to be unfeasible because of technical difficulties or inadequate financing. The problem of obtaining the probability characteristics of perturbations is much more difficult than that of finding a subsequent solution to equations of the state of a system. Therefore this textbook contains a chapter expounding the theory and numerical methods of analyzing problems of the dynamics of mechanical systems when the available information about random perturbations is insufficient for a design that uses statistical mechanics.

Moscow, June 2002 *Valery Svetlitsky*

Contents