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BOOK REVIEW: SHORR'S *THERMAL INTEGRITY IN MECHANICS AND ENGINEERING*

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Boris F. Shorr
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A number of books and papers reporting theoretical and experimental research in mechanics of structures and materials functioning at high temperatures were published during the last fifty years. The range of thermostrength applications widens all the time due to the generation of thermal stresses and inhomogeneous thermal fields in many modern technologies.

The reviewed monograph starts from analytical generalization of research done by a multidisciplinary academic community, including a substantial contribution from the author. Professor B. F. Shorr is a leading Russian scholar in the area of material and structure thermostrength. He has been affiliated with the Baranov Central Institute of Aviation Motors (CIAM) in Moscow for many years and participated in the design of a number of high temperature gas turbines.

This book has several peculiarities which distinguish it from other publications on the subject. It brings the general ideas of modern approaches to basic thermostrength problems and appeals to both academic and engineering communities. The phenomenological treatment of thermostrength phenomena in solids adopted in the book is based on the thorough analysis of data from numerous experiments, revealing most typical and verified models of material behavior. Preference is given to models characterized by a minimal number of experimentally evaluated parameters. An obvious advantage of the book is that it combines rigorous formulations and solution methods with a user friendly presentation style. This makes it attractive for audiences with various levels of theoretical background.

The first and second chapters deal with the basics of thermoelasticity, which are necessary for strength analyses of machine parts. The content of these chapters is crucial for understanding the rest of the book. Here, the conventional energy principles and variational equations underlying the finite element method (FEM) are introduced.

The problems of thermoplasticity and nonisothermal creep, including cyclic loading, are central to the book. They are considered in six of the twelve chapters based on the detailed analysis of experimental

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results. In particular, data from the author's colleagues from CIAM are incorporated in the chapters. The importance of a material property's adaptivity is emphasized. This results in the stabilization of material response in case of long-term or cyclic mechanical and thermal loading.

The author shows that well known theories of plastic flow, plastic deformation and isotropic and anisotropic hardening have certain restrictions when applied to modeling nonstationary processes. The novel theory of stabilizing anisotropic ray hardening is suggested for implementation in thermoplasticity and nonisothermal creep. It takes into account the history of loading trajectories and operates only with measured material parameters.

Chapter nine is devoted to evaluating the strength and life span of machine parts and structures under nonisothermal loading. This distinguishes the book from numerous publications analyzing stress and strain calculation only. Along with local strength, load carrying capacity of the whole mechanical system is also studied. The design of uniform strength structures is also discussed. The weak link approach used for avoiding global catastrophes is also mentioned. A robust methodology for a statistical analysis of thermostrength using a limited amount of experimental data under the conditions simulating the operational environment is proposed.

The next two chapters deal with the loss of elastic and nonelastic stability of isotropic mechanical systems and the strength of anisotropic structures, respectively. Basic methods are addressed, and the peculiarities of the side buckling of compressed rods are also discussed, taking into account the effects of plasticity and creep. The von Mises frame example clearly demonstrates a jump of a mechanical system to a new equilibrium due to the variation of its temperature field.

A monocrystal nickel alloy used in high temperature gas turbine blades is considered as a typical anisotropic material. Theoretical arguments and experimental evidence are presented to show that the maximal value of the Schmid factor characterizing shear stress levels along monocrystal yield surfaces cannot be generally chosen as a reliable strength characteristic. Better results are achieved by making use of the maximal shear stress as a characteristic.

Researchers in solid mechanics and academics interested in a better understanding of material and structure behavior in the presence of high temperatures will benefit from reading the last chapter treating special issues in thermostrength, which is mainly ignored in other publications. In particular, it is shown that variations of contact conditions as well as thermal stresses may change the overall stiffness of the system. This is especially true for thin walled structures. For the latter, the associated frequency spectra may be strongly affected. The author also clarifies without referencing hard-core mathematics that the decay of elastic vibration may be caused by the thermodynamic coupling of mechanical and thermal phenomena and an infinite heat propagation speed in the classical theory of heat transfer.

The author pays tribute to the theoretical and experimental considerations of his predecessors without avoiding the criticism of some established statements. In particular, he argues that the modeling of elastic-plastic flow without its separation into elastic and plastic parts is justified only for special types of loading. He also demonstrates that the Odqvist parameter in the case of cyclic loading varies over broad limits and is hardly an adequate measure of damage and fracture.

Limited attention in the book is given to purely computational aspects because of the relatively easy access to modern commercial FEM software. A detailed numerical procedure is only described for nonstationary thermoplasticity and thermocreep problems within the framework of the aforementioned theory of stabilizing anisotropic ray hardening.

The monograph might be criticized for not covering several interesting topics: low temperature strength is not considered, and the range of analyzed materials is often restricted to those used in aviation. At the same time, the content of the book is dictated by its size and originates from the author's research interests.

This book will be of obvious interest to researchers, engineers, university lecturers and postgraduate students specializing in the design and modeling of the thermostrength of materials, machine parts and structures, as well as those dealing with various applications related to thermal stress analysis. The solid mechanics academic community will also benefit from this book.

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