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Fractal Approach to Tribology of Elastomers

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About the Book

This book summarizes the results of years of research on the problem of strength and fracture of polymers and elastomers. It sets out the modern approach to the strength theory from the standpoint of fractals, the kinetic and thermodynamic theories, as well as the meso-mechanic destruction.

The dimension reduction method is applied to model the friction processes in elastomers subjected to the complex dynamic loading. Finally, it analyzes a relation between the fracture mechanism and the relation phenomena, and provides new experimental data on the sealing nodes in accordance with their specific working conditions where the effect of self-sealing is observed.

The book is intended for researchers, graduate students, and engineers specializing in the field of tribology, and also for senior students of technical colleges.

Contents

Introduction

The physics and mechanics of polymers widely use the ideas and methods from solid- and liquid-state physics, thermodynamics, and statistical physics. For example, solid-state physics and polymer physics are both focused on the relationship between the physical properties and the structures of materials.

Solid-state physics observes two ultimate conditions: *super-state* for different classes of crystals (superconductivity, ferromagnetism, and superplasticity for metals, ferroelectric state of dielectrics); *super-fluidity* for quantum liquids (helium). In the same way, polymers have their own super state, which is called the *highly elastic state*. The highly elastic state is explained not only by the structure of polymer molecules, but also by the internal rotation, the well-known property of simple molecules from molecular physics. The theory of high elasticity is built on the application of conformational statistics of macro-molecules, which is a study of statistical physics as part of polymer physics. The relaxation and thermal properties of fluxed polymers and liquids are mainly similar across many aspects (vitrification, rheology). And the crystalline polymers have a structure similar to solids, however, besides the crystalline phase within volume they also have the amorphous phase in the interphase layers. Based on the electrical properties, polymers are dielectrics and they are characterized by the electret state; from their magnetic properties, we can say that polymers are diamagnetic, and from their optical properties that they have the profound birefringence at the molecular orientation. At the same time, all polymers have unique mechanical properties, among which the highly elastic properties take the most important role. In the solid state, polymers are close, in terms of mechanical properties, to those solids that are studied in the mechanics of deformable solids. In the highly elastic state, as well as in the viscous-fluid state, the mechanics and rheology of polymers are successfully supplemented and developed.

Approximately for every 10 years, the physics and mechanics undergo radical changes creating new branches within science: polymer biophysics, rigid-chain polymer physics, relaxation spectrometry of polymers, phonon destruction of polymers, and so on.

Hence, there is a necessity at every stage of development of the physics and mechanics of polymers to generalize scientific results with respect to fractals, kinetic and thermodynamic theory, and meso-mechanics of destruction.

Finding frictional force between the rough solid surface with a given topology, and elastomer is still a complex and not fully resolved problem. Its complexity is primarily defined by the fractal relief of the contact surfaces. In order to correctly calculate friction, the fractal approach at the nanometric and macroscopic levels is required with respect to surface roughness, as well as the wide range of the elastomer relaxation time differing up to nine orders of magnitude, which determines the multiscale of problem in time.

The hierarchically organized memory is used to solve the problem of multiscale in time, which plays an important role in the friction of elastomers. The combination of the dimensionality reduction method with the hierarchical memory allows creating an effective numerical method for calculating friction between the rough surface with arbitrary topology and elastomer with arbitrary linear rheology. The verified results show an applicability of the method for solving a number of actual tribology problems.

As a result of theoretical and empirical studies, as well as numerical calculations, the authors analyzed the mechanics and mechanism of elastomers in the mobile and stationary hydraulic systems. The book explains the mechanical behavior of various elastomers, their deformability, and strength under complex dynamic loads, which are characteristic to oil and gas equipment. The authors also partially used the results from work done with support of Science Foundation at State Oil Company of Azerbaijan Republic (SOCAR).

The authors would like to thank reviewers, Prof. S. G. Chulkin and D. G. Agalarov, for valuable comments, O. A. Dyshin (Ph.D.) for helping to prepare individual chapters, as well as N. Z. Askerova and A. M. Denzieva for assisting in publication of this monograph.

The authors hope that this work will have a positive contribution in solving problems of tribology of elastomers, and would be grateful for any comments from readers.