BOOK REVIEWS

P. M. Ogibalova and A. Kh. Mirzadzhanzade

NONSTEADY MOVEMENT OF VISCOPLASTIC MEDIA*

Reviewed by B. M. Smol'skii, N. N. Verigin, and Z. P. Shul'man

In the monograph a systematic presentation is given of the modern concepts concerning the movement and heat and mass exchange of viscoplastic liquids, which involves petroleum and many of its derivatives, highly viscous fuels, suspensions of nuclear fuel, mineral and organic oils, and concentrated suspensions, emulsions, and solutions of various substances. The flow of these liquids in pipes, channels, and thermochemical apparatus and their filtration through porous media are an obligatory element in many manufacturing processes and are widespread in a number of branches of industry.

The principal mechanical models of viscoplastic media and the systems of differential equations characterizing them are examined in the monograph (Chapters I and II). Then exact and approximate solutions of these equations are given for straight-line and circular movement of a viscoplastic liquid, as well as several other cases (Chapters III and IV). Then problems of viscoplastic flow in the presence of impact loads and with allowance for hardening and thixotropic effects are studied (Chapter V).

The sections of the book devoted to calculations of processes of nonstationary heat exchange (Chapter VII) and nonsteady diffusion (Chapter IX), which are very interesting and important for application, are of special interest. The self-similar problems examined by the authors (a plane-parallel slot channel and a round cylindrical pipe) are extremely complicated since they require the conjugation of the temperature and and heat fields at the boundaries of the zones of viscous flow and the quasisolid core. These boundaries are not known in advance and their determination even for simple steady flows is connected with cumbersome and difficult calculations.

In diffusion problems the movement of suspended particles through the carrying medium is studied, as well as the displacement of viscoplastic media in a round cylindrical pipe with a structured mode of flow.

A considerable part of the book is devoted to the consideration of applied problems, including pipeline transport (Chapters VI and VIII), the drilling of deep wells (Chapters VIII and X), and the exploitation of oil deposits (Chapter XI).

The authors employ the most varied operational methods for the solution of nonstationary problems of the movement of viscoplastic media: the method of the potential of a single and a double layer, boundary layer theory, integral transformations, and the Kolodner method.

The exact solutions, as a rule, are self-similar and are used by the authors to estimate the degree of accuracy of the approximate methods.

Along with a systematic presentation of the known results the authors present a whole series of new solutions (Chapters VI, VIII, and IX). In Chapter VI (pp. 233-243) the authors show, using the method of N. A. Slezkin and S. M. Targ, that when a drilling instrument is dropped into a well containing a clay solution the inertial forces considerably affect the hydrodynamic pressure.

The theoretical and experimental studies of hydraulic shock during the movement of a viscoplastic liquid in a pipeline made of viscoelastic and viscoplastic material is covered in Chapter VI, Part 2. The effect of the coefficient of viscosity of the pipe material and on the shock pressure in the liquid is explained by this study.

* Izd. Mosk. Gos. Un-ta, (1970).

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 27, No. 4, pp. 747-748, October, 1974.

The movement of an ordinary viscous liquid is examined in Chapter VIII, and while it does not generally pertain to the theme of the monograph the individual results are used later to simplify the solutions of a number of problems on the flow of viscoplastic liquids, to estimate the effect of the initial conditions, and in other cases.

Examples of the application of hydrodynamics to the study and analysis of a number of technological problems of the petroleum industry are presented in Chapter X. Attention is particularly attracted here by the formulation and method of solution of inverse problems of hydrodynamics pertaining to well drilling suggested by the authors.

Solutions are also given for problems on hydraulic shock during the lowering of a column of casing pipes into a well, on the effect of rotation of a drill on the hydrodynamic pressure and its extremal values, on the effect of pumping on the hydraulic resistance, on the movement of a clay solution in a perforated pipe, and on the rapid withdrawal of the solution from the well and the conditions of the appearance of hydraulic destruction of the stratum in this case.

There are defects in the monograph. There are no persuasive arguments in favor of the application of rheostable mathematical models to problems of nonsteady flow and heat and mass exchange. The works of G. D. Rozenberg, A. A. Movsumov, R. M. Sattarov, and others have experimentally confirmed the applicability of the viscoplastic model to nonstationary processes. In soil mechanics there are experiments which confirm this model for clays and muds (N. N. Maslov and others). The results of these experiments should have been presented in the book.

All the conditions of the problems examined are not always clearly discussed. For example, on p. 91 (paragraph 3) and in other such problems, the movement of a viscoplastic liquid between parallel permeable plates is considered and here it is not mentioned that there is a constant velocity component normal to the plates. In the problem on p. 95 it is not pointed out that there is a linear source located at the axis of the pipe. This can produce an incorrect impression concerning the breakdown of the flow continuity.

Insufficient attention is paid to the estimate of the errors of some of the approximations introduced by the authors (for the dependence of the filtration rate on the pressure gradient, for example) and of the methods of calculating viscoplastic flow based on the neglect of individual terms in the equations (for long times, for example).

The book is the first monograph which generalizes the literature on nonstationary problems of heat and mass transfer in rheologically complex media. It will undoubtedly attract the attention of investigators, teachers, engineers, and technicians.

Robert W. Fox and Alan McDonald

INTRODUCTION TO FLUID MECHANICS*

Reviewed by L. P. Orlov

The branch of physics most dignified by age, fluid mechanics, continues to be a dynamically developing science constantly enriched by new ideas, methods, and problems. The intensive scientific research work in the field of hydromechanics demands of university teachers the continuous refinement of the content and structure of the corresponding academic disciplines. No easy task is set before them — from the enormous volume of accumulated information to select and include in the lecture course a reasonable minimum of material in order to acquaint the students with the fundamental concepts of modern hydromechanics in a fixed and relatively brief time. Usually the process of repeated reading of a lecture course is completed by the writing of a new textbook reflecting the scientific teaching credo of the lecturer. The book under review was written on the basis of an experiment in the teaching of hydromechanics for a number of years at Purdue University.

The content of the book is arbitrarily divided into four parts: 1) the physical model of a fluid in hydromechanics (the first chapter "Introduction" and the second "Fundamental concepts"; 2) a description of the mathematical apparatus (the fourth chapter "Fundamental equations in integral form for the reference volume", the fifth "Introduction to differential analysis of fluid motion", and the seventh "Dimensional analysis and similarity"); 3) the dynamics of an incompressible fluid (the third chapter "Hydrostatics", the sixth "Dynamics of incompressible nonviscous flow", and the eighth "Incompressible viscous flow"); 4) gas dynamics (the ninth chapter "Introduction to compressible flow" and the tenth "One-dimensional compressible flow"). The consistency of the presentation is uniform in the good sense of the word: the careful formulation of the basic equations with the necessary indication of the conditions of their applicability precedes their use in concrete situations.

The introductory chapter begins with a definition of the term "fluid", which in English implies both a liquid proper and a gas. Then the sphere of technological applications of hydromechanics is outlined schematically. The concept of the reference volume and the Lagrangian and Eulerian methods of describing fluid motion are introduced in this chapter. The various systems of measurement units are discussed in conclusion. Judging from the content of the first chapter, the authors assume that the reader is already familiar with courses in classical mechanics and thermodynamics and possesses the methods of differential and integral calculus. Continuing the description of the physical model of a fluid adopted in hydromechanics, in the second chapter the authors validate the correctness of the applicability of continuous representations in macroscopic physics. The following concepts used systematically later appear here: the velocity field, the stress field, viscosity, streamlines, surface and volumetric forces, and laminar and turbulent modes.

The equations of conservation of mass, momentum, and angular momentum and the first and second laws of thermodynamics in integral form and the equations of conservation of mass and momentum in differential form are formulated in the fourth and fifth chapters and the velocity potential and current function are introduced. An elementary outline of the theory of dimensionality and similarity is placed in the seventh chapter, the purpose of which includes the instruction of the reader in the application of the Buckingham pi-theorem to various problems, the explanation of the physical meaning of the most common dimensionless numbers, and providing a concept of the geometrical, kinematic, and dynamic similarities of physical phenomena.

* John Wiley and Sons, N. Y. (1973), 630 pp.

Translated from Inzhenerno-Fizicheskii Zhurnal, Vol. 27, No. 4, pp. 749-750, October, 1974.

Hydrostatics is the subject of the third chapter. The inventory of questions touched on in it is quite standard for textbooks on applied hydromechanics: the pressure distribution in a stationary fluid with different assumptions concerning the equation of state and the calculation of the pressure of the fluid at the surface of objects immersed in it. In the sixth chapter the Euler equations are introduced and the Bernoulli and Cauchy—Lagrange integrals are obtained. The dynamics of a viscous incompressible fluid are examined in detail in the very long eighth chapter. The chapter is divided into six sections. In "A" viscous flows are classified into internal and external, and it is indicated that both the former and the latter can exist in laminar or turbulent modes depending on the Reynolds number. The principles of developed laminar flow are studied in section B on the classical examples of Couette and Poiseuille flows. Pointing out that the irreversible conversion of mechanical energy into thermal energy occurs during fluid movement in pipelines, the authors in section C present methods of calculating mechanical energy losses caused by irreversible processes. Section D is devoted to elements of boundary layer theory and section E to the calculation of the forces acting on bodies in a fluid flow. A description of simple devices for measuring the flow rate of a fluid is given in section F.

The following questions are examined in the concluding ninth and tenth chapters: thermodynamics of an ideal gas, propagation of sonic waves, the Mach cone, the parameters of isentropically retarded flow, one-dimensional flows of a compressible gas, shock waves.

All this indicates that the authors were able to present in an educational text all the main problems comprising the basis of the mechanics of liquid and gas. The textbook produces a good impression as a whole. Two merits of the book worthy of attention should be distinguished to begin with. First, the book is saturated with a large number of interesting examples of the solution of problems. By such a methodological device the authors not only achieve a deepened understanding of the subject but also attain the practical mastering of its method. Second, it is very important that already in the first stage of instruction the fruitfulness of methods of the theory of dimensionality and similarity is demonstrated to the student, so that considerations using the properties of the invariance of relationships relative to the choice of the units of measurement and the physical scales of the phenomena become a more effective instrument for the study of physical reality. The fact that the physical essence of each newly introduced concept is illustrated with an analysis of simple situations should also be noted among the undoubted merits of the book. All the calculations are carried out in detail, which makes it possible to easily follow the course of the authors' discussions. The perception of the instructional material is facilitated by the presence of numerous accurate and expressive figures. A large number of problems of different degrees of difficulty are given at the end of each chapter for independent solution to make the study of the book more active. The authors have placed a valuable summary of the equations of vector analysis and auxiliary tables in an appendix, relieving the reader of the troublesome obligation of turning to other handbooks in searches for reference information. The literary style and the quality of the printing deserve a high estimate.

Unfortunately, despite the rather considerable size of the book (630 pages), no place was found in it for such interesting problems of modern fluid mechanics as the Navier—Stokes equations for a compressible viscous fluid, surface and internal waves, thermal gravitational convection, and the movement of a conducting fluid in an electromagnetic field. The absence of answers and hints to the problems deprives the reader of the possibility of quickly discovering errors. It would have been desirable to equip the book with a list of nomenclature.

The drawbacks mentioned do not reduce the pedagogical value of the book reviewed. It can be useful to students and teachers of higher educational institutions. The former can use it for the systematic study of the fundamentals of hydromechanics and the latter as a convenient basis for a lecture course. However, considering the presence of various native and translated manuals in Russian on the problems treated in the book under review, its translation into Russian is clearly inadvisable.