REVIEWS

Rheology : Theory and Applications, Volume I, edited by F. R. EIRICH. New York : Academic Press, 1956. 761 pp. $20.00.

The volume under review is the first of three which will attempt to set out the current position of rheological theory and practice. The scope of the individual volumes has been given by the editor as follows: " . . .the reader will find two introductory chapters, one from the physicochemical and the other from the physics and engineering angle, followed by five chapters on various phases of the deformations of solids. The paper on flow under high pressures leads to those on the mechanism of liquid flow, large elastic deformations, viscoelasticity, and melt flow. Four chapters on the basis of the rheology of disperse systems and one on acoustic responses of liquids complete this part.

Volume II will open with an integrated survey which will serve to link the fifteen chapters, woven through the three volumes of the book, that deal with various fields and aspects of linear viscoelasticity. Volume II will continue with relaxation theory and three chapters on experimental techniques; then there follows the series of chapters on special types of materials or behaviour such as the relaxation of polymers, the rheology of elastomers, glasses, cellulose derivatives, and fibers; it will include also chapters on concrete and on seismic measurements.

Volume III will contain more specialized chapters, on crystalline and on cross-linked plastics, polyelectrolytes, latexes, inks, pastes, and clay. This part will conclude with a series of technological articles on lubrication, spinning, molding, extrusion, and adhesion and a survey of the general features of industrial rheology."

No artificial attempt has been made to force a unity on the subject matter for which it is not yet ready, and the various authors of the different chapters have had considerable freedom in the manner of presentation.

Although the behaviour of materials under stress has been one of the most important characteristics of the human environment, from the earliest prehistory of man, it is only in the last thirty years that ' rheology ' has grown up as a separate field of study. Much of the subject matter of rheology originally fell within the control of the craftsman, who developed considerable skill in the subjective assessment of the state of the materials with which he worked. Certain aspects, such as the behaviour of elastic solids when undergoing small deformations, and the flow of Newtonian liquids, were developed early as branches of physics and applied mathematics. This was possible, because they combined practical importance, in a wide range of applications, with a formal simplicity which rendered them amenable to mathematical analysis.

The last thirty years has seen a similar trend of historical development in most researches on substances whose mechanical behaviour has practical and theoretical interest. The first step is the replacement of the subjective judgment of the craftsmen by a simple test designed to give quantitative results, although these are usually only of the pointer reading

type. Secondly, attempts at precise correlation of these tests with performance can lead to modified test methods better able to predict the behaviour of the material in use. Up to this stage it can barely be said that a scientific analysis of the problem has been commenced. At the next stage, however, the problem becomes a physical study in which the relations between stress, strain, rate of strain, and the dependence of these relations on the physical variables, may be undertaken. Mathematical analyses are required, to express the relations in the simplest manner, and to permit the solution of particular problems. Finally, the macroscopic properties are regarded as the outcome of the structure of the material, down to atomic and molecular dimensions, and theories can be constructed to give quantitatively the macro-behaviour in terms of molecular and atomic magnitudes.

This course of development is almost invariably followed in research on traditional materials. With new materials made through the intervention of science, the early stages can be by-passed to some degree and the investigation may, from its inception, be studied on a strictly scientific basis.

Different materials have now reached widely varied stages of study, determined in part by the complexity of the problems involved, and in part by the research effort available. This is well illustrated by the contrast between metals and polymers on the one hand, and soil, concrete and related building materials on the other. Although the rheological properties of the latter are of the greatest practical importance, research has gone little beyond semi-empirical measurements. Much of the work on metals and polymers is now concerned with the relation between properties and micro-structure, and real progress has been made in developing adequate theories.

The uneven state of the subject is already reflected in this first volume. It will become even more noticeable when the second and third volumes have been published. Six of the seventeen chapters in Volume I are concerned almost solely with polymers either directly or by implication. This is not an unfair proportion in relation to the amount of published work—on the contrary it represents in some instances a difficult exercise in selection and compression (e.g. in Frisch and Simha's chapter on "The viscosity of colloidal suspensions and macromolecular suspensions"). On the other hand it unavoidably fails to convey the relative practical importance of rheology in other fields.

It remains to consider the purpose the whole work will serve and the extent to which the first volume fulfills it. The preface states that "The contributions ... are so planned that scientific workers are introduced to well-demarcated areas of rheology through introductory and descriptive material which then leads into integrated surveys of the present knowledge in these areas". The readers whom the book will serve primarily are the experimental physicists, chemists, and to a lesser degree biologists and others, who require to make rheological measurements or use the results of such work. The small group of applied mathematicians who have been responsible for much of the modern mathematical theory of rheology would not expect to derive their knowledge of each other's work

from this volume. It follows that their accounts of the mathematical basis should attempt to be of value to the experimentalist. Two deductions follow, the first being that, wherever possible, the end result of a theoretical calculation should be in a form amenable to experimental verification or use, with any limitations imposed by the theory clearly indicated. The second is that the presentation should be one which does not introduce, for reasons of brevity or mathematical elegance, notations or steps which are needlessly difficult to follow, and which are not of general value. This does not mean that the real difficulties of some parts of the mathematical theory can be avoided, but only that it should not be written in a form suitable only for fellow-mathematicians.

R. S. Rivlin, in his chapter " Large elastic deformations ", has given an object lesson in how to present the theory satisfactorily. He has used a notation free of tensors, equations being written out in full in terms of the co-ordinates. Although this renders them bulky and rather forbidding, a little patience will enable almost any research worker to follow his argument. He solves particular problems and even indicates where the experimental checks of the theoretical results may be found. In contrast, the chapter by J. Riseman and J. G. Kirkwood, " The statistical mechanical theory of irreversible processes in solutions of macromolecules ", would defeat most experimentalists, and might need rather careful study even by fellow applied mathematicians. It is therefore out of place in the present work, however important a contribution it may be to its subject.

The absence of an adequate account of the bases of classical elasticity theory and of the hydrodynamic treatment of Newtonian viscous flow is presumably deliberate, although it might have been of some help to experimentalists if well carried out.

The remaining chapters, apart from an Introduction by Eirich, are: " Phenomenological macro-rheology " by M. Reiner, " Finite plastic deformation " by William Prager, " Stress-strain relations in the plastic range of metals—experiments and basic concepts " by D. C. Drucker, " Mechanical properties and imperfections in crystals " by G. J. Dienes, " Dislocations in crystal lattices " by J. M. Burgers and W. G. Burgers, " Mechanical properties of metals " by J. Fleeman and G. J. Dienes, " Some rheological properties under high pressure " by R. B. Dow, " Theories of viscosity " by A. Bondi, " Dynamics of visoelastic behaviour " by Turner Alfrey and E. F. Gurner, " Viscosity relationships for polymers in bulk and concentrated solution " by T. G. Fox, Serge Gratch, and S. Loshaek, " Streaming and stress bi-refringence " by A. Peterlin, " Non-Newtonian flow of liquids and solids " by J. G. Oldroyd, and " Acoustics and the liquid state " by R. B. Lindsay. Inevitably these are uneven in merit but a generally high standard has been maintained.

While the volume indicates that the complete work will fall short of rendering other texts unnecessary, it will be a valuable stand-by for all working on this subject. Unfortunately the cost per volume is so high that it will deter many individuals from acquiring the whole set.

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