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REVIEWS

Selected Papers on Rheology. By M. Reiner. Elsevier, 1975. 463 pp. Dfl 110.

For half a century Markus Reiner has occupied a unique position in the field of rheology and is widely regarded as one of the very few people who were responsible for the recognition of rheology as a distinct field of physical science. This book is a collection of 46 of the approximately 125 papers published by Reiner and is issued under the auspices of the Israel National Academy of Sciences and Humanities and the Technion-Israel Institute of Technology.

At the time of Reiner's earliest papers in rheology, non-Newtonian liquids, viscoelastic solids, and even elastic materials obeying nonlinear laws were regarded by most academic scientists as being improper subjects for serious scientific study. There were, of course, exceptions, particularly among physical chemists concerned with the study of colloids. Despite these, it was perfectly possible to hear a distinguished fluid dynamicist assert, as recently as thirty years ago, that all fluids are Newtonian.

The early rheologists, such as Reiner, were therefore working largely in a virgin field and outside the orbit of academic physics. Their backgrounds were varied: physical chemists, engineers, physicists, and technologists with expertise in various industries; Reiner himself was a civil engineer. It is not surprising, therefore, that for a long time, and to some extent even today, works in rheology have reflected a wide variety of scientific idioms, of mathematical competence, and even of conceptions of what constitutes an acceptable scientific investigation.

In the earliest period of rheology, prior to the Second World War, most rheological research was purely descriptive in character. On the experimental side it abounded with measurements of load-deformation relations for nonlinear viscoelastic materials, whether solid or liquid, often by means of experimental arrangements for which no tractable theory was possible.

On the mathematical side a great deal of the effort was devoted to fitting the experimental results by empirical formulae. Much of Reiner's early work in rheology was advanced for its time in its conscious seeking for constitutive equations which would describe in an intrinsic fashion the mechanical properties of non-Newtonian fluids and other materials which are 'anomalous' from the point of view of classical fluid dynamicists or elasticians. Indeed this interest provides a recurrent theme throughout the collection of his papers. By present standards the mathematical equipment which Reiner brings to bear on the problem appears unsophisticated, and the conclusions which he reaches require considerable modification. Nevertheless his work in this area has a seminal relationship to the mathematically more sophisticated theories of constructive equations which we have today.

It is interesting to trace the development of Reiner's ideas on this subject.

The first nine of the reprinted papers in the collection deal with the calculation of various viscometric flows of non-Newtonian fluids, under different assumptions regarding the relation between shearing stress and rate of shear, and the corresponding viscometric measurements.

In the tenth paper, "The theory of non-Newtonian liquids", published in 1933, we find for the first time Reiner's appreciation of the importance of developing a constitutive equation, or "rheological equation of state" as he calls it, for a non-Newtonian fluid. However, having appreciated this fact, Reiner proceeds as in previous papers to discuss viscometric flows, in terms of a purely "one-dimensional" theory. In the thirteenth paper, "Outline of a systematic survey of rheological theories", published a little earlier (in 1932), Reiner explicitly stresses the need for constitutive equations of a general character. However, his own significant contribution to this proposed programme was not made until 1945 in his paper "A mathematical theory of dilatancy" (the twenty-second of the present collection). In this he proceeds from a constitutive assumption that the stress tensor is an isotropic function of the strain-velocity tensor to show, by using the Hamilton–Cayley theorem, that it can be expressed in canonical form as the sum of three tensors, the strain-velocity tensor, the square of the strain-velocity tensor, and the unit tensor, with scalar coefficients which are functions of three independent isotropic invariants of the strain-velocity tensor. Reiner also formulates the constitutive equation in an analogous inverse form, in which the stress is taken as the independent variable and the strain-velocity as the dependent variable. He shows that this constitutive equation indicates a change in volume which increases with time when the material is subjected to a shearing stress. He also shows that under shearing stress the material will exhibit effects of a type which are now known as *normal stress effects*. He was apparently not aware that at the time when the paper was published such effects had already been observed in a variety of fluids, but not yet reported in the open literature. While, for many reasons, the constitutive equation advanced by Reiner does not provide a possible basis for a phenomenological theory of either dilatancy or normal stress effects, it remains of fundamental importance for two reasons. First, it raises the possibility of passing from a constitutive assumption which relates tensors in a manner which is arbitrary, apart from restrictions imposed by material symmetry, to a constitutive equation expressed in canonical form. Second, it draws attention to the fact that even in an isotropic matrix relation, as a result of the nonlinearity of the relation, the off-diagonal elements of the independent variables can make non-zero contributions to the values of the diagonal components of the dependent variable and hence yield a prediction in the materials modelled of effects which are qualitatively different from those which are predicted by the classical linear theories.

In subsequent papers of the collection, Reiner, together with collaborators, attempts to develop the implications of his ideas on nonlinear constitutive equations. While some of these papers were anticipated by other workers, a number of them evidence Reiner's highly imaginative, but rather uncritical, approach to science. For example, papers 36–41, 44 and 45 are concerned with the possible existence of normal stress effects in air. Reiner's alleged demonstration of such effects was shown by Taylor and Saffman to be explicable on the basis of quite conventional aerodynamic theory, if certain types of imperfections in the apparatus were assumed to exist.

Taken as a whole, the importance of Reiner's papers lies in the fact that they raise questions and present ideas, albeit rather uncritically, which have some place in the mechanics of the materials with which rheology is concerned, rather than that they provide definitive answers to the basic problems of rheology.

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Coastal Engineering. By R. SILVESTER. Elsevier, 1974. Vol. 1, 457 pp. Vol. 2, 338 pp. Each Dfl 80.00 or $30.80.

The author of these volumes suggests in the preface that they are intended for use in graduate and higher undergraduate courses, but the reader is quickly put on guard by the statement that "unlike many other treatises on hydraulics and wave mechanics, these omit the differential equations and manipulations leading to the final formulae". The rationale for this approach is given by the explanation that "there are far too many practical problems for [an engineer] to be overly concerned with deriving, or redeveloping or checking theoretical analyses" although "he must, of course, be aware of the premises upon which they are based". It is hard for the present reviewer to see how these important judgements can be instilled by books such as this.

The introductory chapter outlines the nature and opportunities of the field. One will find information here on such varied questions as the annual expenditure for dredging in Japan, and the frequency of publication of the *Journal of Fluid Mechanics*.

The subsequent chapters of volume 1 cover wave generation by wind, wave forecasting, the theory of progressive and standing waves, effects of shoaling water, wave recording, and the effects of structures on waves and of waves on structures. No derivations are given and explanations of the underlying fluid mechanics are frequently misleading or erroneous. Students who retain a belief that the fluid is transported with the phase velocity must be the only ones who can understand "how fortunate [it is] for mankind that waves are slowed down as they approach the shore". The total amplitude of two progressive waves with equal frequency is said to be additive, without consideration of possible phase difference, and for the general case of unequal wavelengths one is told that the amplitude is given by the square-root of the sum of squares of the two component waves. In order to explain Sommerfeld diffraction an analogy is drawn with the two-dimensional motion past a breaking dam!

On the positive side, the following passage from the chapter on wave recording seems worthy of quotation in full: "Consultants or contractors who feel the need for recording waves, either before, during or subsequent to the construction of a project, should question rigorously the usefulness of this information. Not only are such data difficult and costly to obtain, but there is also the risk of it being mis-interpreted and mis-applied."

The second volume covers shoreline processes, littoral drift, coastal defence, long-period waves, estuarine problems, marine hydraulic works and modelling.

Here the author's descriptive style is somewhat better suited to discussion of the complex phenomena which occur on coastlines, and the occasionally counter-productive efforts of man to control these processes.

Each chapter includes numerous examples, problems, and references. Authors of papers in *J.F.M.* will find that they have been almost completely ignored, and one has the suspicion that most of the scientific papers cited are simply being passed on from other works in cascade. Thus, for example, Levi-Civita and Struik are included in the chapter on wave theory, but not Benjamin & Feir or Whitham. There are enough typographical errors to keep the reader amused, such as the introduction of the sinh, cosh, and tanh in terms of the "rectangular hyperbole"!

Both volumes contain extensive indices, as well as identical 14-page tables of the hyperbolic functions and associated parameters governing plane wave propagation. The tables appear to be taken directly from Wiegel's *Oceanographical Engineering*, with some columns omitted and no apparent acknowledgements. In any event the value of such extensive tables seems doubtful in the present era, when books such as these cost practically as much as a good pocket calculator.

J. N. NEWMAN