REVIEWS

Viscometric Flows of Non-Newtonian Fluids; Theory and Experiment.

By B. D. Coleman, H. Markovitz and W. Noll. Springer-Verlag, 1966. 130 pp. 44*s*.

High polymer solutions and melts possess a variety of rheological properties which have been studied at an increasing rate during the past twenty years or so. This monograph treats one particularly important topic: the determination (to within an unimportant additive isotropic term) of the stress tensor in steady laminar shear flow (at low Reynolds number).

The theory (46 pages) is developed for an incompressible 'simple' fluid, i.e. a fluid for which the extra stress is determined by a functional (whose form is restricted by a 'principle of material objectivity') of the deformation gradient. It is shown that, in steady rectilinear shear flow, the extra stress tensor components, referred to a suitable co-ordinate system, reduce to three functions of shear rate, one being a shear component, and the other two being differences of normal components. A generalization to 'curvilinear' flow is given, and applied to particular cases of interest: flow through a channel; 'helical' flow between concentric cylinders in relative rotation and relative axial motion: flow through a tube of circular cross-section; flows between cone (or plate) and plate in relative rotation. In each case, formulae are derived which relate the three functions to measurable torques, forces, or pressure distributions.

Experimental data at present available for some of these cases are then discussed in a useful chapter (28 pages). The monograph ends with an historical outline (8 pages) and an appendix (16 pages) which presents the cartesian vector and tensor analysis used throughout.

The authors are to be congratulated on having produced a concise and lucid text in which special pains have been taken to present the theory in a form which makes less mathematical demands on the reader than does the form given in some of the authors' published papers; this monograph should help to make the authors' approach more readily available to a wider audience. Much of the subject matter has, however, been covered more simply from a different but physically equivalent viewpoint in two recent books (Frederickson 1964; Lodge 1964), which seem not to be known to the authors. Furthermore, the authors' treatment is restricted (in this monograph) to steady flow, and thus does not encompass oscillatory shear, for which there is a considerable amount of data; the statement on page 29, lines 3–6 (implying the possibility of generalization to non-steady flow) is incorrect: for, if κ (in (9.1)) depends on t, then calculation shows that $\mathbf{M}$ (defined by (10.1)) must depend on s, as well as on t, and so the last step in (10.2) cannot be taken.

There are only a few minor criticisms to be made. An explicit statement as to whether $(\nabla\boldsymbol{\chi})_{ij}$ (A. 9.5) means $\partial\chi_i/\partial x_j$ or $\partial\chi_j/\partial x_i$ would help the reader. Minus signs are needed on the left-hand sides of (21.17) and (21.18). While it is true that (as stated on page 78) some of the data of Adams & Lodge (1964) support the theory, it should also be stated that some (namely, the different values for $p_{22}-p_{33}$ obtained from rim pressures and from pressure gradients) do not.

The 'first to formulate a properly invariant general theory applicable to finite deformations' was surely Oldroyd (1950), not Green & Rivlin (1957) as stated on page 86. Priority for recognizing that 'the behaviour of a fluid in several viscometric flows is governed by three material functions of the rate of shear' should be given, not (as stated on page 87) to Markovitz (1957), but to Weissenberg and Russell. Russell's (1946) thesis contains not only experimental data (referred to by the authors on pages 78, 91) but also a theoretical treatment (based on the simplification in the stress tensor due to the symmetry of shear flow) which leads to the basic equations for normal stress effects in cone/plate and plate/plate systems when (as indicated by data obtained with a narrow-gap concentric cylinder system) one normal stress difference is zero.

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A. S. Lodge

Molecular Thermodynamics. By James A. Fay. Addison-Wesley, 1965. 468 pp.

Whenever a new set of instructors takes over the teaching of a subject there results a flood of new text-books. This is true for thermodynamics today. The rapid and radical change in the physics curriculum for undergraduate students together with the elimination of graduate courses in thermodynamics in physics has had a pronounced influence on the teaching of thermodynamics in the engineering and applied science divisions. New instructors with different backgrounds and different interests have taken over and are experimenting with the courses. As in any other scientific or technical subject today one is faced with the problem of having to increase both the breadth and the depth of instruction, keeping the number of contact hours fixed. The much improved preparation of the students today is, partially at least, compensated by shifting the courses to earlier years.

For a considerable number of students the one course is likely to be the only contact with thermodynamics and statistical mechanics and hence the proper sequence and balance between phenomenological thermodynamics and statistical thermodynamics is not easy to find, and about equally difficult is the choice of a limited number of typical applications.

Prof. Fay's book written for the third- or fourth-year student is called *Molecular Thermodynamics* to express the author's conviction that the molecular structure of matter and its statistical treatment should form the basis for a thermodynamics course: the principal laws of classical thermodynamics should follow rather than precede the statistical approach. The macroscopic or microscopic point of view is then adopted, depending on the problem at hand, and an attempt is made to give nearly equal space to each. Thus the first six chapters of the book prepare the student for the introduction of the microcanonical ensemble in the seventh. Entropy, temperature and chemical potential are defined. In the following chapter the scope is restricted to systems of independent particles and the partition functions are introduced. These first eight chapters form the basis for the remaining approximately two-thirds of the book. The concepts of thermodynamics, in particular heat, work, reversibility, etc., are now introduced followed by three chapters on perfect gases and perfect gas mixtures. The thermodynamics of chemical and phase equilibrium is taken up next, followed by chapters on crystals, radiation and magnetization; all three of these treated essentially statistically. The following two chapters on heat engines and fluid flow are based on the conventional, macroscopic approach. The last chapter gives a brief survey of kinetic theory and transport phenomena.

Nobody will deny the importance of statistical mechanics and the need for a statistical basis of thermodynamics. In a text-book, and an undergraduate text in particular, one can however argue about the proper place for the introduction of statistical mechanical concepts as well as the type and depth of this introduction. Classical thermodynamics does require a certain subtlety in defining its concepts and processes. It does not require much detailed knowledge and technique in physics and mathematics. The introduction of statistical mechanics requires both; indeed the conceptual difficulties which arise in thermodynamics are not more easily resolved in statistical mechanics, only easier hidden, and the mathematical and physical background necessary for a satisfactory derivation of ensemble theory from first principles is considerable.

In Prof. Fay's text approximately 90 pages out of a total of some 460 is used to set the stage for a derivation of Liouville's theorem and the microcanonical ensemble. These introductory paragraphs have to tread a narrow path between a review and a short derivation. For example, the paragraph on Schrödinger's equation is probably too short to introduce a student who has not been exposed to quantum mechanics before and too elementary for a student who had a term or a year course in quantum mechanics. The introduction of the distribution function and the classical derivation of Liouville's theorem without a subsequent discussion of the density matrix and the quantum mechanical equivalent of the theorem may baffle an advanced student. Similarly the exclusive use of the microcanonical ensemble without a thorough discussion of its place relative to the canonical and grand canonical ensembles together with their thermodynamical interpretation may well be misleading. These are, in the reviewer's opinion, examples of the difficulties which the text faces. The user has to decide whether or not these difficulties are over-compensated by the advantages: the early and direct introduction of entropy as related to phase volume, the great variety of applications which are treated and in general the considerable insight into the interrelation between molecular mechanics and macroscopic behaviour which the text offers. Much will depend upon the place of the course in the curriculum for which the text is to be used. It certainly can be made the basis for a very stimulating course for fourth- or maybe even third-year engineering students provided the instructor is aware of the fact that the text will invite probing criticism on many points and is prepared to defend himself there.

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