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REVIEWS

Physics of Shock Waves in Gases and Plasmas. By M. A. LIBERMAN and A. L. VELIKOVICH. Springer, 1986. 385 pp. DM 135.

Unsteady Interaction of Shock and Detonation Waves in Gases. Edited by V. P. KOROBEINIKOV. Hemisphere, 1989. 231 pp. £62.

Shock Wave Reflection Phenomena. By G. BEN-DOR. Springer, 1992. 309 pp. DM 138.

These three books complement each other by exploring different aspects of the wide spectrum of phenomena associated with the propagation of shock waves, including reflection at surfaces and ionization or chemical reaction in gases. They are therefore relevant to fields as diverse as nuclear fusion and hypersonic propulsion, as well as to the study of shock and detonation waves in themselves. The first book explores the basic physics of modelling the structure and propagation of hydrodynamic and electromagnetic jumps in ionizing media; the second, which is more of a research monograph, aims principally at discussing the interaction of shock waves and detonations with obstacles; while the third book provides a thorough discussion of the various possible patterns of shock wave reflection at solid surfaces.

Liberman & Velikovich systematically present an outline of the theory of shock waves in gases and plasmas. Each topic is explored in a well-structure progression that takes the reader from normal gasdynamic shocks to shocks with extreme Prandtl number, to detonations, to shocks in ionized and ionizing media, and finally to ionizing shocks in plasmas within electromagnetic fields. Where possible, the authors draw on experimental results to substantiate and sometimes contrast with the theory; they carefully note the limitations of any theoretical simplifications (used with pedagogical effect) as these are steadily replaced with more realistic and more complex models. The actual structures that can be realized under given external conditions must depend on questions of stability and what the authors call 'evolutionarity'. The book illustrates this point with a final discussion of the dynamics of shocks in electromagnetic shock-tubes, as generated by a 'magnetic piston'. In a very brief summary, the authors then make it clear that many issues remain unresolved and that a great deal of research is still to be done. At each point, they use the same attention to detail, building on earlier discussions to offer the reader a coherent presentation that will be of value both as a research reference and as an advanced teaching text.

The second book, edited by Victor Korobeinikov, in fact represents the combined authorship of a team of active Russian scientists, describing the study of shock waves with ionization and chemical reaction. Because of this, a range of different approaches and interests are juxtaposed around a common theme. In contrast to the first book, the authors dwell little on basic theory, preferring to leave this to their extensive list of references. Thus, after a brief outline of the energetics and electromagnetic properties of a shocked gas, and of wave processes in a gas with relaxing electronic and vibrational states, the book enters into much more detailed descriptions of some experimental studies and their interpretations. These concern: the unsteady behaviour of oblique shocks created by a disturbance in a shock-tube wall; the effect of a boundary layer on shock reflection; reflection of a shock by a porous compressible wall; various configurations with which a shock can reflect from an oblique wall; and the processes of diffraction of a shock around a sharp corner and around a rounded corner. After this, the book turns to a numerical study of shock waves propagating around obstacles, highlighting some of the same situations described in the experimental studies. The focus then shifts from relaxing gases to exploding gases; with a positive release of energy behind a shock wave, detonations arise. Experiments are presented describing both the diffraction and reflection of detonations at corners and obstacles. While lacking some of the cohesion of the first book, this text does have the advantage of drawing together a highly illustrative range of experimental and numerical investigations into the unsteady behaviour of shock and detonation waves when they interact with obstacles.

The third book, by Gabi Ben-Dor, looks in detail at the wide range of ways in which shocks can reflect from obstacles. Although Ernst Mach first reported on shock wave reflection in 1878, many of the discoveries of different possible patterns of shock reflection were made in the last decade. There are at least ten distinct dynamical or stationary patterns arising in different circumstances for planar shock reflections from planar surfaces alone. Ben-Dor introduces the basic concepts within an historical review, outlining the various observable structures, the continuity and jump conditions that make them possible, and the nature of the relevant gasdynamic changes in terms of shock polars. By far the largest chapter in the book examines reflections connected with shocks propagating over wedges, or 'pseudo-steady' reflections for which structures are well approximated as being self-similar in terms of distance divided by time. The relevant reflection patterns within the space of wedge angle and incident Mach number are described both from theoretical and experimental perspectives, taking into account ideal and imperfect gas behaviour. Of particular interest are the transitions between different patterns such as regular and Mach reflection for which a variety of explanations are reported, not all being found to be relevant in all circumstances. The effects of viscosity, conductivity, real gas behaviour and different surface properties are all addressed. 'Steady' reflections from wedges and walls in supersonic flows are described next and the book concludes with a discussion of unsteady reflections, drawing usefully from the rich range of situations seen in pseudo-steady reflections. With its clear explanations this book provides a thorough and useful review of existing knowledge of shock reflection phenomena in gases.

J. W. Dold

Fluid Dynamics of Viscoelastic Liquids. By D. D. Joseph. Springer, 1990. 755 pp.

Rheological Phenomena in Focus. By D. V. Boger and K. Walters. Elsevier, 1993. 156 pp. Dfl. 225, US $128.50.

Both of these books are about viscoelastic fluids, and in practice are about polymeric liquids. They are complementary in the sense that some of the photographs reproduced in Boger & Walters' book illustrate some of the flows analysed in Joseph's. They bring together information – theories in one case and visualizations in the other – that has not been collected together before.

Boger & Walters (B & W) have aimed to do for viscoelastic liquids what Van Dyke did for Newtonian fluids in his *Album of Fluid Motion*. The balance of phenomena is not quite the same, but there are many equivalent flows for direct comparison, among them flow past obstacles, jets and Taylor vortices. Viscoelastic flows are often dominated by nonlinearity in the constitutive relation for stress, and so creeping flows of polymeric liquids can display the sort of secondary flows and instabilities associated with inertia in Newtonian liquid flows. Much of the interest in the analysis of polymeric flows is motivated by a desire to separate the effects of inertia, shear thinning and elasticity. This is partly demonstrated in B & W by the separate variation of Reynolds number and Weissenberg number in some sequences of photographs, though there is no separate variation of shear-thinning index.

Van Dyke's selected photographs are of rather higher quality than B & W's, and his interpretations are sometimes easier to follow, but this is readily explained by the far larger set he had to choose from, and the much greater understanding we have of Newtonian flows. It is interesting to note that B & W make no mention of the elastic Mach number introduced by Joseph and so there is no suggestion that any of the shock wave effects so beautifully illustrated for compressible flow have potential analogues for vorticity shocks in viscoelastic flow. B & W distinguish between Weissenberg and Deborah number in the introductory chapter, but disappointingly they make little use of this distinction in their illustrations.

The use of the very general term rheological is unjustified, in that, by their own definition, a very large number of other phenomena involving deforming materials could have been included. I hope that they will change the title in any later editions, or else include photographs of flowing plastics and pastes, gels and soft metals, and a range of suspensions. However, that is to cavil at inessentials: many will find the photographs in the book stimulating and helpful.

Joseph's volume is not so easy to enjoy and digest. The very nature of the subject makes it hard going even for those who have followed his contributions on the subject of viscoelastic fluid dynamics over the past twenty years. Perhaps this explains why he has had less impact than his original insights and painstaking approach deserve. The text under review is not in any sense a complete treatment of the subject (not that any other author has even attempted the task), as Joseph states in the first sentence of his preface. It is largely about hyperbolicity in fluids displaying instantaneous elasticity, and the consequential instabilities and shocks in flow systems having that property. Although the author does not claim to have explained all the difficulties encountered in computational approaches to predicting the flow of Maxwell-like fluids, nor to have fully understood all the observations made on the irregular extrusion of plastics and polymer solutions, he has opened the subject up to incisive analytical treatment and has examined many flows in detail to show other workers how to proceed. There are many young workers in the field today who would benefit greatly from making a serious effort to master the ideas set out in Joseph's text.

That said, they must come to terms with his idiosyncratic style, which ranges from the almost folksy (some fluids or theories or models are 'good', some are 'bad') to the almost impenetrably pure mathematical. Precise theorems jostle with heuristic comments on imprecisely reported experiments using poorly characterized materials. Basic developments in constitutive modelling are given in appendices and late chapters even though the models are used freely throughout without sufficient referencing forward. Any given section may contain much elementary derivation as well as jumps in the argument involving tricky analysis. There is a danger that the reader will miss key statements because of the apparently repetitious nature of the writing, which encourages skipping.

Much of this unevenness is entirely forgivable: the author has attempted to explain real phenomena using whatever theories and models he considers relevant; if in his estimation an explanation is best given in terms of Fréchet derivatives, then the reader is told so; he does not condescend; where abstract mathematical argument would be futile, he offers simple physical ones, but leaving no doubt that they are little more than suggestions. I find his iconoclastic approach refreshing and thought-provoking. His pedanticism, of which most of us academics are often guilty, is not without humour ('the field of nonlinear constitutive equations is a nightmare of possibilities') and irony.

Although it may appear that much of the text is just a collection of Joseph's work with his collaborators, a careful reading will show that he has made a very detailed and scholarly study of earlier work, which he quotes and reports judiciously. He rightly raises the question of how viscosity arises (chapter 18) and the role of timescales. Viscoelasticity to one observer is merely viscosity to another. Theoretical physicists have long struggled with problems of regularization and renormalization; some of these problems surface when trying to predict the behaviour of materials having a very wide spectrum of relaxation times. Recent work on pseudo-thermodynamics addresses the same issues. Reductionism has to make way for a more phenomenological approach when dealing with the chaotic behaviour of complex fluids (cf. S. S. Schweber, *Physics Today*, vol. 46 (11), 1993, p. 34).

The pattern of the book suggests that it is based on a lecture course for graduate students, with a large number of worked exercises. It is in camera-ready type, and so runs to rather more pages than would be the case for a traditionally set book. Notions of characteristics and wave speed for Maxwell and Boltzmann models are introduced in chapter 1 and are extended to Jeffreys models in chapter 2. The equations of motion are presented in chapter 3, particularly the important one for vorticity that is rarely used in viscoelastic flow analysis.

Chapter 4 introduces the key issue of Hadamard instability, and the method of frozen coefficients to deal with local catastrophic short-wave instability and ill-posedness. (I was a little confused by the fact that a uniform flow should reduce to a rest state – using Galilean invariance – so that some fixed observer is implied to derive the required results; this is not made clear in the text.) This leads on naturally to the important potential for hysteresis ('spinoidal') effects. Chapter 5 deals with classification of type, and the occurrence of characteristic surfaces in general three-dimensional flows. Special examples using standard steady flows are given in chapter 6. It is first shown that 'if the vorticity equation for steady flow is hyperbolic when the density is zero, then the unsteady vorticity equation is elliptic and the quasilinear system is ill-posed; conversely, if the vorticity of an inertialess steady flow is elliptic and (a certain parameter) is positive, the quasilinear system is well-posed'. Section 6.11 on 'numerical simulations and analysis of type' gives a clear summary of the impact of change of type in solving the equations of motion for viscoelastic systems.

Chapter 7 on 'supercritical flow past bodies' is the most significant in the book, in that it brings out clearly the role of dimensionless groups (it is worth noting that Weissenberg number, W, in this context of Joseph is the same as Deborah number in B & W) and gives a clear explanation of the elastic Mach cone that arises in otherwise uniform flow past an obstruction. It also sets in context the work of others. The arguments given are based on an Oseen-type linearization, but unfortunately real polymeric fluids are not simple Maxwell fluids, so quantitative comparison with experiment is neither close nor unambiguous. As Rallison and Chilcott have argued, following Astarita, Tanner and others, strong flows differ from weak flows in terms of chain extension, and more than a single constitutive number W is needed to discuss global flows. Chapter 8 on Mach wedges in flow over a flat plate might well have preceeded chapter 7.

Chapters 9–12 give further examples of characteristics for well-known flow fields. Chapter 13 covers the case of die swell, and particularly the delayed variety, which was viewed as an inexplicable anomaly for many years. Here is a case where Joseph's ideas of supercritical flow seem to be crucial to understanding.

Chapter 15 is the first of four chapters devoted to asymptotic behaviour of constitutive relations for viscoelastic liquids. Much of this is 'standard work', in that it is dealt with in several other well-known texts. Perturbation of rigid motion is little different from what others call slow flow. However, few authors make the point that a second-order fluid introduces a critical lengthscale, which helps to understand many observations. Chapters 19–20 on wave propagation appear to be an alternative way of presenting earlier issues.

All in all, I can recommended *Fluid Dynamics of Viscoelastic Liquids* as representing an interesting, if unusual, approach to many important issues in the subject.

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