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Book Reviews

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Review of Shock Wave Reflection Phenomena, Second Edition

G. Ben-Dor, Springer, New York, 2007, 342 pp., $199.00

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In 1878, the distinguished philosopher and aerodynamicist Ernst Mach identified two distinctly different shock wave structures: now called regular reflection and Mach reflection. Over 200 equally distinguished aerodynamicists have dedicated their careers to closely related problems in the last 130 years, Professor Ben-Dor, a student of Professor I. I. Glass, being one of them. He has authored or coauthored over 200 refereed papers, 30 book chapters, three books, and one handbook on shock wave phenomena. His first edition of *Shock Wave Reflection Phenomena* was published by Springer in 1991. It contained a phenomenological survey of the state of knowledge of shock reflections up to that time. Both the first and second editions have five sections entitled 1) General Introduction, 2) Shock Wave Reflections in Steady Flow, 3) Shock Wave Reflection in Pseudosteady Flows, 4) Shock Wave Reflections in Unsteady Flows, and 5) Source List. The order of Secs. 2 and 3 has been interchanged from that of the first edition. Dr. Ben-Dor has updated sections 2, 3, 4, and 5, primarily by including material on 1) hysteresis in the transition between regular and Mach reflection, 2) new analytical models describing transitional and double Mach reflections, and 3) resolution of the von Neumann paradox.

Section 1, *General Introduction*, provides a historical perspective. It then introduces and describes regular reflection (RR) and irregular reflection (IR) shock structure, ,as well as a veritable zoo of subspecies and sub-subspecies of the latter, labeled MR, vNR, VR, GR, DiMR, StMR, InMR, TRR, SMR, PTMR, TMR, DMR, DMR^{+}, DMR^{-}, and TerDMR, all neatly organized into a "family tree." Convincing physical arguments are presented for the necessity for shock reflections, along with the applicability of governing equations describing the underlying two- and three-shock confluences. Pressure/deflection polars, often used to explain shock reflection occurrences, are introduced. Four different $\mathrm{RR} \leftrightarrow \mathrm{IR}$ transition criteria are discussed. This section is a must-read for anyone needing an overview, taxonomy, and a crisp and concise introduction to the fundamentals of plane oblique shock wave reflection.

Section 2, *Shock Wave Reflection in Steady Flows*, has been moved up because it is easier to understand than the pseudosteady and unsteady reflections treated in Secs. 3 and 4. It briefly categorizes two types of steady flow shock reflections. Transition criteria and real gas effects (both viscous and chemical-kinetic) are discussed. Most of the rest of Sec. 2 is new and deals extensively with the analytical prediction of Mach reflection wave geometry and a description of the "dual region" where hysteresis is possible in the $\mathrm{RR} \leftrightarrow \mathrm{MR}$ transition. The discussion includes asymmetric shocks, axisymmetric shocks, and numerical experiments on the stability of RR and Mach reflection (MR) flow in the dual region. Hysteresis, now proven experimentally, has seen the application of high-resolution, computational, time-accurate techniques in which perturbations have been introduced to trigger transition. Numerically, transition has been triggered by changes in upstream Mach number, incident shock angle, and perturbations in local density. However, the underlying causes of this interesting and challenging facet of shock wave dynamics have yet to be fully understood.

Section 3, *Shock Wave Reflection in Pseudosteady Flows*, deals with the flow of a plane incident shock moving over a plane wedge. In a laboratory frame, shocks and induced flow change in time so that the flow is unsteady. However, because both the incident shock and the wedge are plane, the flow has no length scale and is thus self-similar in time and can be described by time-independent equations: hence, it is referred to as pseudosteady. A preponderance of both experimental and analytical work on moving shock waves has been done with flow in pseudostationary motion. The first part of Sec. 3 presents 10 schlieren pictures of the various different types of reflection. There is a discussion of the boundaries between the different types that relies on the shock reflection process, but neglects the flow deflection process: the "Old State of Knowledge." It then goes on to describe a shock diffraction process that accounts for both shock reflection and flow deflection. With this "New State

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of Knowledge," there is now derived an analytical model that better fits the experimental data. Also, two new shock configurations are posed, Vasilev reflection (VR) and Guderley reflection (GR), which explain the long-standing discrepancy between experiment and shock polar intersections: the von Neumann paradox. Even then, there remains a domain of shock reflection "… inside which a yet not fully understood reflection takes place." The rest of Sec. 3 deals with flow aspects which are refinements of the idealized two- and three-shock solutions, namely, nonsteady effects, curved discontinuities, real gas effects, viscous effects, unusual (rough, perforated, slitted, porous, deformable) surfaces, thermal conduction, thick shear layers, and non-self-similar flow. The section concludes with additional considerations, one of which shows that the boundary between the region of existence of regular and Mach reflection differs for steady and pseudosteady flow.

Section 4, *Shock Wave Reflections in Unsteady Flows*, deals with shock reflections in which one or both of the incident shock or the reflecting surfaces are curved, or where the incident shock is accelerating. These flows are not self-similar; time is an important independent variable as well as a complicating factor. Here, a plane shock, passing over a circular/cylindrical, concave, or convex surface, transits through several shock configurations in its movement over the cylinder. Good analytical predictions exist for these flows. A table of reflection-type possibilities is given for a plane shock moving over a concave or a convex double wedge. Analysis and experiment are in good agreement. Shock reflection-type transitions for spherical shocks moving over flat surfaces are presented at the end of Sec. 4.

Section 5, *Source List*, contains an extensive bibliography of publications dealing with various aspects of shock wave reflection phenomena, ranging in time of publication from 1887 to 2006. An additional section contains a list of reports from institutions and universities that have been involved in the study of shock wave reflection.

Material presented in this monograph is applicable to hypervelocity impact of munitions and meteors, detonation of explosives, blast waves from explosions in air and water, aerodynamics of vehicles in tubes and tunnels as well as in the atmosphere, sonic boom prediction and alleviation, supersonic engine air intakes, and in situ destruction of gall bladder and kidney stones. The book is essential reading for anyone working in these areas. It is for a graduate level reader who needs to come up to speed in shock reflections. Its extensive list of references, in itself worth the book's price, is a good source of material for further studies.

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