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Book Reviews

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The Detonation Phenomenon

John H. S. Lee, Cambridge University Press, New York, 2008, 400 pp., $99.00

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Detonation in gases has been studied for over a century as a scientific and engineering phenomenon. Despite this long history, very significant advances in our understanding have been made in the past three decades and are in progress today. John Lee, professor of mechanical engineering and director of the Shock Wave Physics Research Group at McGill University has been one of the leaders in experimental and theoretical detonation research. His book is the most significant monograph in detonation since the publication of *Detonation: Theory and Experiment* by Wildon Fickett and William C. Davis in 1979. Lee's book fits the same niche as the work by Fickett and Davis in that it is not overly mathematical on one hand and not focused on practical applications on the other. Any researcher or student with even a passing interest in detonation will want to own Lee's book.

The book is self-contained, providing the necessary historical and technical material appropriate for a reader that has an undergraduate background in thermodynamics and compressible fluid mechanics but no knowledge of detonation. The first four chapters provide an overview of the history, the classical hydrodynamic model of detonations, the Chapman–Jouguet (CJ) theory, and the Zeldovich–von Neumann–D ring (ZND) model of the ideal detonation reaction zone structure. Appropriately, the treatment is more complete and detailed than the usual discussion found in combustion textbooks. For example, Lee treats both detonations and deflagrations and Taylor expansions for various geometries. He also presents the theories using two gammas (burned and unburned), which is far more useful for realistic computations than the overly idealized one-gamma model. The discussion of the hydrodynamic model emphasizes the role of the sonic condition of the CJ theory and the relationship of ideal models to physical flows. The discussion of the ZND model is concise but complete, covering extensions to the "pathological" case with a sonic point in the interior of the reaction zone, slightly curved waves, and the effect of friction.

Following this introductory material, the book offers comprehensive surveys on gaseous detonation instability from numerical and experimental viewpoints. These insightful discussions address the influence of boundary conditions, deflagration-to-detonation transition, and direct initiation. Chapters on each topic give historical background, the essential physical results, numerous graphical results, photographic flow-visualization images, and extensive bibliographies for readers seeking to delve deeper into theoretical, numerical, and experimental technique. These chapters provide a unique synthesis, particularly of the developments since 1979, collecting and connecting results from many investigations to provide the most comprehensive description of the gaseous detonation phenomenon available today.

Detonation instability is the dominant feature of gaseous detonations, and over one-quarter of the book is devoted to this topic. The presentation is divided into two chapters, the first focusing on numerical simulations and the second describing experimental results.

In the first chapter on instability, Lee emphasizes the nonlinear aspects of instability as revealed by one- and two-dimensional numerical simulations and completely avoids the mathematical complexity of linear stability theory. The key trends with activation energy, overdrive, and reaction zone shape are introduced through a sequence of results that show the onset of oscillation, the excitation of multiple modes, and, finally, the chaotic behavior for simplified reaction mechanisms. There are presentations of recent research on the relationship between idealized and realistic ZND reaction zone profiles as well as the statistical description of the flow behind two-dimensional unsteady detonation fronts.

In the second chapter on instability, a very clear and comprehensive discussion is given of the various types of flow patterns collectively described as the "cellular" structure. This includes both spinning and multifront detonations in planar and divergent geometries as well as the relationship of the characteristic instability "cell" size to the chemical composition as reflected in the ZND reaction zone length scales.

The chapter on the influence of boundary conditions begins with a discussion of the classical problem of detonation velocity deficit and the influence of tube or channel dimensions on the wave speed. The theory of Fay, based on stream tube expansion and the Wood–Kirkwood model of slightly curved waves, is compared with data for rigid smooth tubes and tubes with yielding walls. The phenomena of low-velocity and quasi detonations in rough tubes are covered as well as the effects of acoustically absorbing walls. The chapter closes with a careful discussion of the often misunderstood issue of detonation limits and the dependence on boundary conditions.

The chapter on deflagration-to-detonation transition (DDT) is essentially a self-contained update of the still-relevant review article by Lee and Moen in 1980. Following a short introduction to the gas dynamics of a flame pushing a shock, flame acceleration mechanisms, onset of detonation, and the criteria for transition are discussed.

The final chapter is on the various forms of direct initiation by sparks, high explosives, diffracting detonations (the “critical tube diameter”), incident detonations and reflected shocks, turbulent jets, and photoinitiation. The elementary theory of blast waves and related theories of detonation initiation are presented. The chapter concludes with a brief discussion of amplification of pressure waves to form detonations and the “SWACER” (Shock Wave Amplification by Coherent Energy Release) mechanism of detonation onset.

Throughout the book, Lee emphasizes the role of scaling and the importance of detonation instability in determining macroscopic behavior. The recognition of the ubiquitous nature of gaseous detonation instability and the exploration of the role of turbulence in detonation propagation are some of the key contributions of the McGill research group. As might be anticipated, there is extensive discussion of detonation instability and reaction zone structure, and the application of scaling to macroscopic critical parameters such as cell size, critical initiation energy, and critical tube diameter.

Lee’s perspective is that of a physical scientist, and, as the title indicates, the book emphasizes the phenomenology. The focus is on the physical phenomena rather than applied mathematics, chemical reaction kinetics, numerical methods, or experimental technique. This is not a traditional undergraduate textbook, and it contains no problems or worked exercises for the reader. Nevertheless, it should be extremely valuable to students, providing a scientific narrative detailing the historical progress and current understanding of detonations in gases. The mathematical material is broadly accessible to undergraduate and graduate students while at the same time providing a sophisticated tutorial for experienced researchers coming to detonation from other fields. Lee has drawn on his own work and that of others in order to richly illustrate the text with photographs and graphs for many different aspects of the detonation phenomenon.

Lee’s treatment is extensive but deliberately not encyclopedic. Researchers interested in applications to propulsion or high explosives, and theorists specializing in mathematical analysis will find that their topics are intentionally not covered. Specialists in gaseous detonation may also take exception to omissions of their contributions to the research literature. However, as Lee states in his preface, he has deliberately chosen the set of topics and level of treatment “to render the book readable for beginners.” In meeting this goal, I think he has admirably succeeded.

Joseph E. Shepherd
California Institute of Technology

Paul Thibault
Time-Scales Scientific, Ltd.