Dynamics of Detonations and Explosions: Detonations

Edited by
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and W. A. Sirignano

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Preface

The four companion volumes on *Dynamics of Deflagrations and Reactive Systems* and *Dynamics of Detonations and Explosions* present 91 of the 149 papers given at the Twelfth International Colloquium on the Dynamics of Explosions and Reactive Systems (ICDERS) held at the University of Michigan in Ann Arbor during July 1989.

These four volumes are included in the Progress in Astronautics and Aeronautics series published by the American Institute of Aeronautics and Astronautics, Inc. *Dynamics of Deflagrations and Reactive Systems: Flames* (Volume 131) and *Dynamics of Deflagrations and Reactive Systems: Heterogeneous Combustion* (Volume 132) span a broad area, encompassing the processes of coupling the exothermic energy release with the fluid dynamics occurring in any combustion process. *Dynamics of Detonations and Explosions: Detonations* (Volume 133) and *Dynamics of Detonations and Explosions: Explosion Phenomena* (Volume 134) principally address the rate processes of energy deposition in a compressible medium and the concurrent nonsteady flow as it typically occurs in explosion phenomena. The colloquium, in addition to embracing the usual topics of explosions, detonations, shock phenomena, and reactive flow, includes papers that deal primarily with the gasdynamic aspects of nonsteady flow in combustion systems, the fluid mechanic aspects of combustion (with particular emphasis on turbulence), and diagnostic techniques used to study combustion phenomena.

In this volume, *Dynamics of Detonations and Explosions: Detonations*, the papers have been arranged into chapters on gaseous detonations, detonation initiation and transmission, nonideal detonations and boundary effects, and multiphase detonations. Although the brevity of this preface does not permit the editors to do justice to all papers, we offer the following highlights of some of the especially noteworthy contributions.

In Chapter I, Gaseous Detonations, *Bauer et al.* present an extremely useful review of research and publications on detonation waves prior to 1922—many of which have been overlooked previously. The chronological review includes references to "high explosives" dating back to the fifteenth century. In the "discovery phase," the work of Abel (1869), Berthelot (1870–1871), Nobel (1873–1874), Berthelot and Vielle (1878–1883), and the work of Mallard and Le Chatelier (1883) play a primary role. They also show that the Chapman-Jouget (C-J) theory is based on the pioneering work of Michelson (1890), Berthelot (1891), Dixon (1893), Chapman (1899), and Vielle (1900), as well as the independent development by Jouguet (1901–1905). In addition, this chapter contains articles on the detonability of hydrocarbon fuels at ambient pressure, and the detonation characteristics of methane-oxygen-nitrogen mixtures at high initial pressures (100–400 bars).

Chapter II, Detonation Initiation and Transmission, begins with articles on the initiation of detonations in unconfined clouds of gaseous mixtures by *Murray et al.* and *Borisov et al. Frolov and coworkers* describe the initiation of a detonation wave due to multistage self-ignition. *Borisov et al.* report on the critical energy required for direct initiation of detonations in gaseous mixtures, while *Dupré et al.* provide a limit criterion for detonations in circular tubes. This chapter concludes with articles on the transmission of detonation waves by *Desbordes and Lannoy, Dabora et al.*, and *Jones et al.*

Chapter III, Nonideal Detonations and Boundary Effects, investigates the fundamental propagation mechanisms of nonideal or quasidetonations that travel at a fraction of the C-J velocity. *Teodorczyk and coworkers* report on quasidetonations in H_2-O_2 observed in a narrow, two-dimensional channel filled with periodic obstacles. Photographic observations clearly reveal that autoignition by reflected shocks is the primary propagation mechanism for this type of quasidetonation. Depending on the obstacle height and spacing, three different types of shock reflection processes were observed: 1) reflection of the diffracted shock from the bottom wall; 2) normal reflection of a Mach stem from the front face of an obstacle; and 3) reflection of the transverse shock from the top wall. *Frolov and coworkers* present an approximate analytical theory (based on enhanced drag and heat transfer coefficients), to predict the attenuation of detonations in rough-walled tubes. *Thomas and coworkers* report on detonations propagating through tubes with tightly-packed, perforated steel foils. On the macroscopic scale, the tightly-packed foils completely destroyed the natural transverse structure of the detonation. However, flow interactions with the frontal area of the foils generated sufficient gasdynamic heating to cause autoignition that sustained the continued propagation of the wave. *Borisov et al.* describe low velocity (1.3 k/s) gaseous detonations propagating in tubes with thin water layers. The entrainment of droplets (caused by shock spalling of the water surface) quenches the heat release until the reaction wave decouples from the shock front. *Plewinsky and coworkers* report on surface detonation experiments in liquid tetramethyldihydrogen-disiloxane. Low detonation velocities (0.7–0.8 km/s) were measured.

Chapter IV, Multiphase Detonations, presents recent results on detonations observed in droplet clouds and dust clouds. *Benedick et al.* investigated the detonability of fuel-air clouds formed by the explosive dissemination of various liquid fuels into the air. They found that the detonability of such clouds depended not only on the sensitivity of fuel, but also on the amount of fuel that was in the vapor phase at the time of ignition. Very sensitive fuels such as propylene oxide, and low-vapor-pressure fuels such as nitrated hydrocarbons could be detonated quite readily, even in the aerosol form. Insensitive fuels such as hexane could only be detonated in the vapor phase. *Dabora* reports on shock tube tests that were used to determine the lean detonability limit of kerosene sprays in air. *Zhang and*

Groenig report on experiments with cornstarch particles suspended in an oxygen atmosphere. Steady, self-sustained detonations were observed. Also, spinning detonations were found to exist for a wide range of particle concentrations. *Dahab et al.* report on detonation experiments with dust-air mixtures. They found that Egyptian brown coal dust and linen dust were very easy to detonate, while it was practically impossible to detonate flour dust.

The companion volumes, *Dynamics of Deflagrations and Reactive Systems: Flames* (Volume 131), *Dynamics of Deflagrations and Reactive Systems: Heterogeneous Combustion* (Volume 132), and *Dynamics of Detonations and Explosions: Explosion Phenomena* (Volume 134), include papers on ignitions dynamics, diffusion flames and shear effects, dynamics of flames and shear layers, turbulent flames, flame propagation in combustion engines, combustion of dust-air mixtures, droplet combustion, combustion at solid and liquid surfaces, combustion diagnostics, vapor cloud explosions, blast wave reflections and interactions, and vapor explosions.

These four volumes will, we trust, help satisfy the need first articulated in 1966 and will continue the tradition of augmenting our understanding of the dynamics of explosions and reactive systems begun the following year in Brussels with the first colloquium. Subsequent colloquia have been held on a biennial basis: 1969 in Novosibirsk, 1971 in Marseilles, 1973 in La Jolla, 1975 in Bourges, 1977 in Stockholm, 1979 in Göttingen, 1981 in Minsk, 1983 in Poitiers, 1985 in Berkeley, 1987 in Warsaw, and 1989 in Ann Arbor. The colloquium has now achieved the status of a prime international meeting on these topics, and attracts contributions from scientists and engineers throughout the world.

To provide an enduring focal point for the administrative aspects of the ICDERS, the organization was formally incorporated in the state of Washington under the name Institute for Dynamics of Explosions and Reactive Systems (IDERS). Professor J. R. Bowen is serving as the current president. Communications may be sent to

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The proceedings of the first six colloquia have appeared as a part of the journal *Acta Astronautica*, or its predecessor, *Astronautica Acta*. With the publication of the Seventh Colloquium, the proceedings now appear as part of the Progress in Astronautics and Aeronautics series published by the American Institute of Aeronautics and Astronautics.

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Preparations for the Thirteenth Colloquium are now under way. The meeting will be held at Nagoya University, July 28–August 2, 1991. Professor T. Fujiwara of the University's Department of Aeronautical Engineering is chairman of the local organizing committee.

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