Preface

Of prime concern in this book are combustion systems – confined fields of compressible fluids where exothermic processes of combustion take place. Their purpose is to generate motive power. In their course, exothermic energy* is created by chemical reaction and deposited in the field, both actions carried out concomitantly and referred to popularly as ’heat release.’ Particular examples of such systems are cylinders in internal combustion engines, combustors of gas turbines and rockets, as well as explosions engendering blast waves - non-steady flow fields bounded by incident shock fronts that impose on them the constraints of confinement.

The process of combustion is carried out, as a rule, at a high rate, the life time of chemically reacting component being of an order of microseconds, while the exothermic reaction of the whole system is accomplished in few milliseconds. For that reason, its execution has been considered so far to be beyond the intervention of interactive controls – a hindrance that, in our age of microelectronics for which a millisecond is a relatively long time, can be eliminated.

The technological objective of the book is to pave the way towards this end by bringing forth the dynamic features of combustion systems. Their properties are expressed therefore as those of dynamic objects – entities amenable to management by modern tools of control technology.

Sensible properties of combustion systems are displayed in a three-dimensional *physical space*, while their processes are disclosed in a multi-dimensional *thermo-physical phase space*, where the states of components of the working substance are identified and the transformations of its constituents are disclosed. The dimension of the latter is equal to the degrees of freedom - the number of reaction constituents plus two, as specified by the Gibbs phase rule.

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* potential energy of thermal kind known as ‘heat of reaction’ and measured in terms of ‘heating value’ determined by the change in internal energy taking place at NTP (normal temperature and pressure)

Equilibrium states of the working substance and its components are specified in the *thermodynamic phase space* – a three-dimensional subset of the thermo-physical space, provided that the internal energy, *e*, is one of its coordinates, as pointed out by Gibbs[1] and Poincaré[2]. If *e* is expressed in units of energy per mole, it is compatible with temperature, *T*, as its concomitant coordinate. If *e* is expressed in units of energy per unit mass, as appropriate for mass conserving chemical reactions, its dimensionally compatible coordinate is the *dynamic potential*, $w \equiv pv$ - a parameter providing principal service of liaison between the physical space, where it is established, and the thermodynamic space, where it is employed as a fundamental coordinate of state. The concept of *pv* is well known in the literature as 'flow work', without realizing its pivotal role in thermodynamics.

The subject matter of the book is exposed in three parts, each consisting of four chapters, Part 1 -. *Exothermicity* – considering the thermodynamic effects due to evolution of exothermic energy in a combustion system; Part 2 – *Field* – exposing the dynamic properties of fields where the exothermic energy is deposited; Part 3 - *Explosion* – revealing the dynamic features of fields and fronts created by deposition of exothermic energy.

In Part 1,

Chapter 1 - *Thermodynamic Aspects* - presents the evolution of the combustion system by a model consisting of two parts: (1) the *dynamic aspects*, dealing with the properties of combustion in the physical space, and (2) the *thermodynamic aspects*, treating the processes of combustion in the phase space.

Chapter 2 - *Evolutionary Aspects* – elucidates the fundamental features of evolution.

Chapter 3 - *Heat Transfer Aspects* – describes experimental and analytical studies of energy loss incurred in a combustion system by heat transfer to its surroundings.

Chapter 4 - *Chemical Kinetic Aspects* – furnishes a résumé of analytical technique for resolution of chemical kinetic processes of combustion.

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[1] Gibbs JW (1875-1878) On the equilibrium of heterogeneous substances. Transactions of the Connecticut Academy, III (1875-76) pp. 108-248; (1877-78) pp 343-524 [(1931) The Collected Works of J.W. Gibbs, Article III, Longmans, Green and Company, New York, 2: 55-353, esp. pp.85-89 and 96-100]

[2] Poincaré H (1892) Thermodynamique, Gothiers-Villars, Paris, xix + 432 pp [1908 edition, xix + 458 pp]

In Part 2,

Chapter 5 - *Aerodynamic Aspects* – provides a fundamental background for fluid dynamic analysis of flow fields at the limit of infinite Peclet and Damköhler numbers commensurate with inadequacy of molecular diffusivity and thermal conductivity to affect the rapid process of combustion taking place in *exothermic centers* – sites referred to in the literature as 'hot spots.'

Chapter 6 - *Random Vortex Method* – presents the analytical technique, introduced by Chorin[3, 4], that provides an insight into the mechanism of turbulent flow fields in terms of random vortex motion, mimicking the physical nature of turbulence as a phenomenon due to random walk of vortex elements called blobs.

Chapter 7 - *Gasdynamic Aspects* - describes classical analysis of compressible flow fields, featuring the method of characteristics for solution of hyperbolic equations in terms of which their gasdynamic properties are expressed.

Chapter 8 – *Fronts and Interfaces* - furnishes analytical treatment of gasdynamic effects produced by shock and detonation fronts, as well as by interfaces (impermeable fronts) and simple waves that act as border between different state regimes.

In Part 3

Chapter 9 - *Blast Waves* – provides a fundamental background for the analysis of far fields created by an explosions, with respect to which sizes of their kernels, where the exothermic energy was deposited, is negligibly small.

Chapter 10 - *Self-Similar Blast Wave* - presents salient features of linearly, cylindrically and spherically symmetric fields created by point explosions whose fronts propagate into a vacuum.

Chapter 11 - *Phase Space Method* - ushers in an analytical technique for treating blast waves propagating into atmospheres of finite pressure and density.

Chapter12 - *Detonations* - displays the dynamic properties of fronts associated with exothermic processes.

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[3] Chorin AJ (1973) Numerical studies of slightly viscous flow. J. Fluid Mech. 57: 785-796

[4] Chorin AJ (1978) Vortex sheet approximation of boundary layers. J. Comp. Phys. 27: 428-442.

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