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Book review

Yarin, L.P., Hetsroni, G., Combustion of Two-phase Reactive Media. In: Mewes, D., Mayinger, F. (Eds.), Heat and Mass Transfer Series, Springer 249 figures, 558 pages

There are many applications of two-phase reactive flows in industrial processes, and relatively few textbooks are available for researchers in this field. The book *Combustion of Two-phase Reactive Media* provides a unique collection of research results and advanced analysis methods that should be very useful to its intended audience: professional scientists and engineers interested in the combustion of two-phase flows. Much of the work is based on the extensive research papers previously published by the book authors, together with other important publications in the field, including papers originally published in Russian and not widely available. The selection of the material and its arrangement follows a logical progression starting from single particles (solids, liquid droplets or bubbles), followed by descriptions of combustion wave propagation in two-phase media, and concluding with applications of the concepts to combustion reactors.

The focus of the book is on fundamental concepts and analysis. The governing equations and the analytical methods of solution are presented subject to clearly stated assumptions for a variety of two-phase flow problems with heat transfer (including radiation) and reaction. One possible shortcoming is that there is virtually no discussion of experimental techniques, and only little comparison or reference to experimental data. The level of the material is quite advanced, and although the authors state that they have used the material in graduate courses at their institution, it is clear that the reader who will benefit most from the book would already have a strong background in combustion physics and analytical methods.

Due to the complexity of the topic material, the offered analytical solutions necessarily include restrictive assumptions. However, these solutions are still very valuable because they provide insight into the effect of parameters and guidance for the validation of numerical solutions for the complete system. In addition, the solutions provide methods for classifying combustion régimes in two-phase flows that would be difficult to identify using numerical solution methods alone.

The book is arranged into 11 chapters that are organized in three major sections entitled: Dynamics of a Single Particle, Combustion Wave Propagation, and High-temperature Combustion Reactors. The first section (298 pages, 5 chapters) reviews basic momentum (drag), mass (vaporization), and energy (heat transfer) physics for single particles. The functional forms of lift and drag correlations for deformable, vaporizing or devolatizing particles are introduced via dimensionless analysis, together with analyses based on the relevant mass, momentum and energy balance equations. The effect of combustion on particle trajectories is also described. This section also reviews relevant literature on the ignition and combustion of coal and metal particles, liquid

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droplets, and bubbles. Ignition/extinction régimes are described along with classical results. Important contributions on coal combustion published in the Russian literature in the 1980s are also summarized. These results could be very useful, since some readers may not be aware of that work. The section concludes with two chapters on the topics of hydro-dynamic interaction and mass transfer between arrays of particles (including envelope flames and burning particles), and particle–turbulence interactions. The presentation of particle–turbulence interactions is based mainly on three seminal papers that were published by the book authors in the International Journal of Multiphase Flow in the 1990s. The chapter includes discussions of the mechanisms of gas-phase turbulence modulation through the presence of particles. In addition, a very clear exposition is given of the effect of turbulence on chemical reaction rates in particle-laden flows. Unfortunately, there are also many typographical errors and undefined symbols in the first section of the book. These could introduce some confusion to readers new to the topic, and readers would be advised to check the equations against the original references.

The second section (145 pages, 4 chapters) addresses combustion wave propagation in two-phase media. Flame propagation and the influence of radiative heat transfer on flames are considered in the first chapter of the section. The review includes discussions of the classical thermal theory of combustion waves and combustion stability in homogeneous and inhomogeneous mixtures. The effect of particle size distributions on wave propagation régimes is also described. Combustion wave propagation in bubbly flows and porous media (smoldering or filtration combustion) are described in the next two chapters. The structure and speed of combustion waves in bubble suspensions and foamy flows is analyzed using classical analytical techniques and simplifying assumptions. However, this section would have been strengthened by including discussions of experimental validations of the theory and assumptions, where possible. Finally, the second section concludes with a discussion of heterogeneous flames in jets, and coal dust and liquid fuel spray combustion. Jet and spray flame combustion régimes are classified by considering the characteristic time scales for drop evaporation and combustion in turbulent two-phase jets.

The final section (85 pages, 2 chapters) deals with high-temperature combustion reactors, and includes presentations of well-stirred and displacement reactor models. The general characteristics of gas-droplet, gas–solid particle, and bubble and liquid combustion reactor operating regimes are described in the penultimate chapter on the well-stirred reactor. The analysis assumes infinitely fast mixing of the reactants and the combustion products, such that uniform temperature and concentration fields exist within the reactor. The effects of particle diameter and the Damkohler number on ignition and extinction of gas-droplet/particle mixtures in adiabatic and non-adiabatic reactors are described in detail. The final chapter is devoted to a discussion of displacement reactors, with additional consideration of the stability of the combustion process. In this case, the rate of mixing of the initial reactants and combustion products is negligible, such that non-uniform temperature and concentration distributions exist within the reactor volume, and heat and mass transfer must be considered between the reactants and products.

Professors Yarin and Hetsronis' book contains a wealth of references to related works in the literature, and it is sure to be a very valuable resource to researchers wishing to delve deeper into the field. The analysis methods are presented in a lucid and well organized format, and the simplifying assumptions that are made are very classical. The results also illustrate the power of analysis to provide insights about very complex problems, including the present problem of combustion in two-phase flows. In view of the fact that most practical combustion systems involve multiphase flows, in my opinion *Combustion of Two-phase Reactive Media* is a valuable addition to the combustion literature.

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