

BOOK REVIEWS

EDITED BY NICHOLAS D. KAZARINOFF

Mathematical Problems from Combustion Theory. By Jerrold Bebernes and David Eberly. Springer-Verlag, New York, 1989. x + 178 pp. \$34.00. ISBN 0-387-97104-1. Applied Mathematical Sciences, Vol. 83.

Mathematical problems involving nonlinear forcing, or source terms, are well exemplified physically by combustion processes, which are usefully modeled as involving strongly temperature-sensitive rates of chemical reaction. Depending on the type of interaction that becomes important under appropriate prevailing conditions, a wide range of interesting problems can be extracted for detailed analysis. In this deceptively thin volume, Bebernes and Eberly start with a sketch of the Navier-Stokes equations augmented by chemical behaviour and show how two basic families of problems (which they describe as *solid fuel models* and *gaseous fuel models*) can be extracted. The behaviour of the resulting systems proves to be very rich and so offers a challenging field for mathematical analysis.

The "solid fuel" models apply in a domain $\bar{x} \in \Omega$ and satisfy the equations

$$\begin{aligned} (1) \quad T_t - \Delta T &= \epsilon \delta y^m \exp\left(\frac{T-1}{\epsilon T}\right), \\ y_t - \beta \Delta y &= -\epsilon \delta \Gamma y^m \exp\left(\frac{T-1}{\epsilon T}\right) \end{aligned}$$

along with suitable boundary and initial conditions. In the limit as $\epsilon \rightarrow 0$, the reduced model

$$(2) \quad \theta_t - \Delta \theta = \delta f(\bar{x}, \theta)$$

is identified and is examined in some depth. The combustion model (1) leads to the form $f(\bar{x}, \theta) = \exp(\theta)$ for the forcing function f

but generalisations such as $f(\bar{x}, \theta) = \theta^p$, for $p > 1$, are also considered. These models are characterised by the absence of any convective or compressible effects, leading the authors to describe them as "solid," even though solids would also normally be associated with the limit $\beta \rightarrow 0$.

In posing their "gaseous fuel" models, compressibility effects are specifically taken into consideration, leading to different models that may be appropriate under different circumstances. The first model arises for relatively weak effects of compressibility and reduces to the equation

$$(3) \quad \begin{aligned} \theta_t - a \Delta \theta &= \delta e^\theta \\ &+ \frac{\gamma-1}{\gamma} \frac{1}{\text{vol}(\Omega)} \int_{\Omega} \theta_t(\bar{x}, t) d\bar{x}, \end{aligned}$$

in which the constant a may be positive or zero. With stronger effects of compressibility, a reduced Euler model becomes

$$\begin{aligned} (4) \quad \gamma \theta_t - (\gamma-1) P_t &= h e^\theta, \\ \gamma \bar{\nabla} \cdot \bar{v} + P_t &= h e^\theta, \\ \gamma \bar{v}_t + b \bar{\nabla} P &= 0 \end{aligned}$$

for $b > 0$. Finally, a full system is considered, involving conduction, diffusion, convection, viscosity, and reaction.

The common thread that links all of these problems is the phenomenon of *self-ignition* or "*blowup*," the analysis of which in recent years has been due, in no small part, to the authors themselves. Indeed, the title of this book would have described its contents more precisely had the words "blowup" or "ignition" been inserted. The existence, location, and nature of any blowup (as well as the associated existence of any possible steady-state solutions) are rigorously and inexorably examined.

Steady-state solutions of the "solid fuel" model (2) (and, equivalently, the steady version of the "gaseous" model (3) for $a > 0$), with the boundary condition $\theta = 0$ on $\bar{x} \in \partial\Omega$, are the first to come under scrutiny in a variety of geometries and number of dimensions n .

Publishers are invited to send books for review to Professor Nicholas D. Kazarinoff, Department of Mathematics, University of New Mexico, Humanities Building, 4th Floor, Albuquerque, New Mexico 87131 (September 1991–November 1991); Abteilung für Mathematik, Mathematik VI, Universität Ulm, Obere Eselsberg, D-7900 Ulm, Germany (December 1991–December 1992).

Mathematical Problems From Combustion Theory

Lei Huang



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