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Book Reviews

EUROSHOCK—Drag Reduction by Passive Shock Control

Edited by E. Stanewsky, J. Délery, J. Fulker, and W. Geißler, Verlag Vieweg, Wiesbaden, Germany, 1997, 414 pp., $141.00

This book gives a comprehensive account of a focused European research effort on drag reduction for transonic airfoils through passive venting. Results are presented from a three-year research effort at five research organizations [DLR (Germany), CIRA (Italy), DERA (UK), NLR (The Netherlands), and ONERA (France)], four universities [Athens (Greece), Cambridge (UK), Karlsruhe (Germany), and Naples (Italy)], and one company [DASA-Airbus (Germany)]. The book is organized as an extensive synopsis of about 80 pages followed by an appendix consisting of 15 technical papers. The advantage of this organization of the book is that one can quite easily get the gist of this research program and its results without having to wade through each technical paper making all of the correlations of the individual contributions for oneself. On the other hand, if the reader has a particular interest in a certain aspect of this topic, he or she can read up on it in the individual contributions that, on average, are quite complete technical reports in themselves.

In the early 1980s, Nagamatsu et al. in the United States and Krogmann, Thiede, and Stanewsky in Europe proposed using porous surface patches on transonic airfoils for reducing wave drag. The basic idea is to generate a bubble of recirculating flow that displaces the boundary-layer flow. The "bump" in the boundary-layer flow causes an isentropic precompression of the locally supersonic flow upstream of a recompression shock that usually terminates the region of supersonic flow over a transonic airfoil. This precompression, in turn, reduces the strength of the transonic recompression shock and thus leads to a reduction in wave drag. As old as this concept is, much research has been spent on porous airfoils to quantify the overall drag reduction and to optimize porosity, i.e., the number of holes, their spacing, spacing patterns, extent and placement of the porous patch, etc. This provokes the obvious question of what this book might add to this technology area. Before attempting to give an answer, a short summary of the book's contents appears to be in order.

One word of caution up front: While published as a volume in the series Notes on Numerical Fluid Mechanics, this book goes well beyond the original scope of the series. About 40% of the book reports on basic experiments and on experimental databases for transonic airfoils with and without passive venting. Thus, if you pick up this book to learn about, for instance, implementation of boundary conditions for modeling passive venting, don't be surprised by the massive body of information about wind-tunnel testing issues, model fabrication, and experimental data. On the other hand, experimentalists are warned not to forgo looking at this book just because it is published in an inappropriate-sounding category.

According to the editors, *EUROSHOCK* was intended to address three major technical issues: 1) modeling of the shock/boundary-layer interaction, 2) validation/calibration of computational fluid dynamics (CFD) performance prediction methods for transonic airfoils, and 3) wind-tunnel experiments for generating an experimental database over a wide range of Reynolds numbers up to flight conditions. The contributions to the first technical topic consist of basic experiments and physical modeling, with three papers that fall in the first category. Bur, Délery, and Corbel conduct a basic study on flow over a porous flat installed in one tunnel wall of an ONERA transonic blowdown tunnel. They provide flowfield surveys and surface pressures. Bohning and Doerffer conduct a similar study in a comparable facility at the University of Karlsruhe; they embellish their research with simultaneous computations. A combined experimental/computational study by Squire, Young, and Faucher (all of Cambridge University) rounds out the set of contributions to this first category. Their twist to the theme is to produce a well-defined shock by way of a wedge.

There are seven entries that primarily contribute to the validation/calibration category. Wolles (NLR) proposes an interactive method that couples a transonic small-disturbance solver with a boundary-layer method. LeBalleur, Girodroux-Lavigne, and Gassot (all of ONERA) modify their interactive method based on a full-potential code coupled with several of LeBalleur's semi-implicit boundary-layer solvers. Dargel (DASA-Airbus) proposes a similar approach. De Matteis and Dima (CIRA) construct an interactive solver using a boundary-layer integral method and an Euler solver. Their approach shows several similarities with a method advanced by de Nicola (University of Naples). Simandirakis, Bouras, and Papailou (University of Athens) compare a similar interactive method with a Navier–Stokes solver. Finally, Geißler (DLR) proposes a Navier–Stokes solver for modeling flows over porous transonic airfoils. Most of these methods appear to have problems with correctly modeling the shock/boundary-layer interaction in the presence of passive venting. On a relative scale, the interactive methods seem to be inferior to the Navier–Stokes solvers, albeit the latter could be improved as well. The sources of mismatch between experiment and CFD are attributed to the very basic turbulence models and to difficulties in specifying transpiration boundary conditions along the porous airfoil walls.

Two papers, by Thiede and Dargel (DASA-Airbus) and by Archambaud and Rodde (ONERA), allow for a facility-to-facility comparison of data for solid and porous versions of the nominally laminar LVA-1A transonic airfoil. Another paper, by Rosemann, Knauer, and Stanewsky (DLR), reports testing of the LVA-1A airfoil in a cryogenic facility to realize Reynolds numbers up to flight conditions. A nominally turbulent airfoil with and without passive venting is tested by Fulker and Simmons (DERA). Finally, Wagner (DLR) presents unsteady or time-accurate flow measurements in an attempt to determine the impact of passive venting on buffet. (The answer is that this effect is negligible.)

There are several ways to view this book. First, one can approach it as a final contract report published in archival and publicly available form. This by itself would warrant its place on the shelves of technical libraries. Second, one could use it to compare research in the United States and in Europe on passive venting for reducing drag on transonic airfoils. Taken this way, *EUROSHOCK* is judged to be an extensive exercise in rediscovering lessons learned a while back in the United States. Passive venting using porous surface patches with cavities underneath generally increases overall drag for transonic airfoils over most of the relevant performance range. The off-design flight conditions where benefits due to passive venting are seen are usually too far off the design points to be practically relevant, particularly in view of the added costs and complexity, e.g., maintenance, of passive venting. All of this was recognized in the United States years ago.

Another way to view *EUROSHOCK* is as a thorough study of issues that were left somewhat unresolved in previous research efforts. In particular, this concerns modeling issues such as supplanting the commonplace use of Darcy's law to correlate transpiration velocities with pressure difference across porous surfaces with possibly better empirical relations like that by Poll et al. Also, the question of the impact of porosity on buffet was previously left unanswered. Finally, former experimental verifications of the passive venting concept were conducted at Reynolds numbers well below flight conditions. Not that anything contradictory to previous analyses and tests was found, but at least one could claim to know this for sure now.

Finally, the summary of results of the *EUROSHOCK* program point to alternate applications of porosity, for instance, to achieve self-adaptive airfoils and to improve stability and control characteristics, e.g., inlet flows. Taken this way, *EUROSHOCK* might make a good foundation on which to base future research in these areas. Whatever the preferred tack is in judging this book, it should be read by anybody who wants to explore the possibilities of passive venting in aerodynamics, if only to avoid reinventing the proverbial wheel.

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Nonlinear Dynamics and Chaotic Phenomena

Bhimsen K. Shivamoggi, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1997, 404 pp., $190.00

This is a nice, complete, thorough introduction to dynamical systems theory, starting with nonlinear differential equations and continuing through bifurcation theory, Hamiltonian dynamics, and integrable systems to chaos in conservative and dissipative systems, fractals and multifractals in turbulence, and singularity analysis and the Painlevé property. Although the book appears in the series Fluid Mechanics and Its Applications, there is virtually no fluid mechanics in it. The discussion of fractals and multifractals deals exclusively with the probability density of homogeneous turbulence.

The central goal in turbulence research is to understand turbulence well enough to make useful calculations in real situations. In principle, any contribution could prove to be useful. Perhaps I may be forgiven for feeling that statistical models for the probability density in homogeneous situations, while intellectually interesting, will not help much toward our goal. Of course, turbulence is a very small part of the author's concerns in this book.

The author is a member of the Departments of Mathematics and Physics at the University of Central Florida. The orientation of the book is approximately what one might expect from a mathematician/physicist. That is to say, the book is short on the kind of physics that might be appreciated by an engineer. For example, on page 11, in a footnote, the author says (referring to critical phenomena, but indirectly to turbulence) that a correlation function having a power-law decay suggests the absence of a characteristic scale in the system. I assume him to mean that such a correlation function has an infinite integral and hence has no integral scale. However, everyone in turbulence knows that a power-law correlation cannot be valid at large or small scales and that such scales always exist in real flows. I am perhaps reading too much into this remark, but it seems to me characteristic of a tendency to believe too much in idealizations, both mathematical and physical. The academy has suffered from this since the days of the Greeks. Progress is made by finding simple, universal structures; however, these are usually models of parts of reality, and there is a tendency to mistake them for the whole of reality itself and to fall in love with them. In another instance, on page 13, the author states "…fluid turbulence…cannot be studied via smooth solutions of differential equations." Now, in fact, so far as anyone knows, all variables in a real turbulent flow have smooth derivatives of all orders (defined by suitable averages over molecular motions). [Even if they did not, real measuring devices (requiring the acceleration of mass, however small) would produce outputs having smooth derivatives of all orders.] The author probably has in mind certain models of parts of turbulence, for which it is convenient to assume that certain variables are not smooth. However, that is quite a different thing.

This tendency (to jump into bed with abstraction) may even be a cultural phenomenon: After all, as long as we talk about abstract things (the more, the better), no one can mistake us for engineers. I believe it is an ancient principle of philosophy that people who think about thinking are of a higher order than people who think about things.

There are other examples of slightly nonphysical points of view in this book. On page 324, for example, the author says that "…the energy dissipation ε may be distributed in a rather spotty way, at every scale of motion." I have no quarrel with the spottiness, but what does he mean by "every scale of motion," since the dissipation takes place only at the smallest scales of motion? In footnote 6, on page 326, the author quotes Kraichnan regarding the use of the dissipation in inertial range scaling, saying that the dissipation is not an inertial range quantity. However, as we pointed out in *A First Course in Turbulence* (Tennekes and Lumley, MIT Press, 1972), in a turbulence in equilibrium the rate at which energy enters the spectral pipeline, the spectral energy transfer rate, and the rate at which energy is dissipated are all equal, and the scaling of the inertial range is properly done in terms of the spectral energy transfer rate, which is an inertial-range property.

I have some minor quibbles. The author's notation when he talks about turbulence is vector/dyadic. Everyone in turbulence uses Cartesian tensor notation. The author's notation is subject to ambiguity when representing certain tensor forms, but that is an academic quibble—my objection is mostly cultural. Students should learn the common language of the field. The book is not carefully proofread; for example, on page 11, the author refers to a "…power law dacy…," which must have been meant to be "decay." My final quibble is the price: $190.00 places the book beyond the reach of nearly everybody. This is surely not the author's fault, but the publisher's. This works out to 47 cents a page. Xerox is a lot cheaper. Because the manuscript was presumably delivered camera-ready, it is hard to imagine how this figure can be justified.

However, this is minor carping. The book is a good introduction to nonlinear dynamics and is charmingly written. The author has included many apposite quotations that make reading it a pleasure.

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