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# BOOK REVIEW

**Large Eddy Simulation for Incompressible Flows: An Introduction.** By P. SAGAUT. Springer, 2001. 319 pp. ISBN 3 540 67890 5. DM 119 or £41 or $59.95.

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At first sight, Large Eddy Simulation (LES) offers a bright new prospect for the computation of turbulent flows. By simulating the large scales of turbulent motion explicitly, the need for modelling is confined to the small scales which remain unresolved on the computational grid and are filtered away. Since the small scale motion serves only to drain energy from the large scales, and the behaviour of the small scales is universal, then the modelling task is straightforward and the errors induced by modelling are minimised. All at once, the complexity, unreliability and controversy of traditional Reynolds-Averaged Navier–Stokes (RANS) turbulence modelling is rendered obsolete.

Except that life and nature are not quite that simple. With LES, even more than with most topics in fluid mechanics, the devil is in the detail. LES has a remarkably long history for a new approach, dating back some forty years to some of the early attempts at computational weather forecasting. Ever since then, the technique has been dogged by misunderstandings, numerical difficulties, poor modelling concepts and a wide-eyed belief among many practitioners that the promised land is just across the next (turbulent) river. Greatly to his credit, Pierre Sagaut has written an introduction to the subject that deals with the difficulties head-on and in a scientific manner, and moreover manages to avoid any temptation to evangelise on behalf of either LES itself or any specific modelling approach. The book is an updated version of an original published in French, and its origins in a particular school of turbulence theory are clear without becoming too obtrusive.

Following an entertaining preface by Marcel Lesieur, there is an illuminating Foreword, and then a brief introductory chapter outlining the remarkably simple underlying concept of LES. The simplicity does not survive even into the second chapter, which explains in considerable mathematical detail the theory behind band-pass filtering for LES, including the limitations of standard filters, the issue of commutation error and the extension to inhomogeneous and anisotropic filters. The third chapter deals with the application of filtering to the Navier–Stokes equations. The analysis is carried forward in both physical and Fourier space and allows for a thorough description of the difficulties which arise, mainly in decomposing the nonlinear terms. The physical implications of each of the commonly accepted decompositions are outlined and their conformance with invariance and realisability properties is assessed. By the end of this chapter, the mathematical foundations of LES have been well and truly laid.

The next three chapters are concerned with modelling. Here mathematical rigour is somewhat less applicable and the very French mathematical-textbook style becomes a little strained. Nevertheless the many available models are explained clearly and placed carefully into categories according to their underlying physical concept. Models dealing with the forward energy cascade are dealt with first, then the considerable modelling difficulties posed by the physical existence of backscatter are explained and

available models are presented. Models for anisotropic flows are discussed separately in a short chapter and some valuable physical points are made. Models based on structural concepts of turbulence are also grouped into their own chapter, which provides an opportunity for the reader to compare some of the most advanced ideas in the field. In all cases the advantages and disadvantages of each model are simply stated, and there is no attempt to produce a ranking or to make recommendations.

The remainder of the book looks at the more practical aspects of LES, and does not shrink from pointing out the limitations and inconveniences. There is an interesting chapter devoted to the subtle interaction between LES filtering and the numerical methods commonly used to solve the filtered equations. This is followed by a chapter on analysis and validation of LES data which indicates clearly the need for careful interpretation of the results. Boundary conditions are treated in the next chapter, which deals mainly with the awkwardness introduced by the presence of solid walls. A short chapter is devoted to the implementation of various filters, and there is a final chapter giving examples of applications to various simple flows, such as the round jet, backward-facing step and square-section cylinder, for which there is ample experimental data for comparison. Some general and rather helpful conclusions are drawn regarding the current state of modelling for these flows. There is a general Appendix on the statistical and spectral analysis of turbulence, and a specific Appendix on the EDQNM model.

Falling somewhere between a textbook and a monograph, the book makes a valuable contribution to the literature on LES by collating a vast amount of material in a concise manner and by placing much of it on a sound and uniform mathematical footing. The reasons why LES is not a simple panacea, but instead is a rather challenging area for serious study, are made abundantly clear. Inevitably the book can offer no more than a snapshot of a fast-evolving field. Nevertheless it does so with commendable objectivity, and contains enough reference material to make it a necessary addition to any library on the subject.

STEWART CANT

Editor's Note: since this review was obtained second edition has been published