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REVIEW

Analysis of Turbulent Boundary Layers. By T. CEBECI and A. M. O. SMITH. Academic Press, 1974. 404 pp. $35.00 or £16.80.

A. M. O. Smith and his colleagues at McDonnell Douglas (and earlier, Douglas Aircraft) have made several noteworthy contributions to theoretical aerodynamics, and over the past seven years or so have published a number of papers describing the Cebeci–Smith method of calculating turbulent boundary layers and the Keller box method for solving the boundary-layer equations.

The present book, however, does a good deal more than simply summarize these papers. It described the basic physical structure and behaviour of the turbulent boundary layer, and derives the compressible-flow equations in considerable detail, including the equations governing the transport of turbulence energy and Reynolds stress. A very fair description is given of earlier calculation methods (with at least one exception, discussed below) and of current methods based on the transport equations. This part of the work is covered in the first five chapters. The next chapter deals with the use of transport coefficients in turbulent boundary layers and leads naturally to a specification of the simple eddy-viscosity model used as the basis of the C–S method, which is described in the seventh chapter. The penultimate chapter deals with the Keller box method of computation applied to laminar boundary layers and the last describes the application of the C–S method to a wide range of situations. The only major topic not covered is that of the general three-dimensional boundary layer.

In essentials the C–S method is simplicity itself. By the use of an eddy-viscosity model the turbulent boundary-layer problem is effectively converted to a laminar one, for which a computer solution can readily be obtained without necessarily going to the complication of the Keller box method. (The simplicity and ease of programming claimed for this method are certainly not made evident in the text.) The basic simplicity of the C–S method, as compared with methods based on the transport equations, provokes several questions.

First, of course, is the question, how realistic is the C–S eddy-viscosity model? The answer to this would seem to be 'not very', and although the examples given in the last chapter convincingly demonstrate the versatility of the method, they also show that in the simplest case of two-dimensional incompressible flow on solid surfaces the accuracy is not very high (see, for example, the skin-friction results of figure 9.21); and indeed this would be expected from the results of recent investigations which indicate that, in both the inner and outer regions of the boundary layer, systematic variations of eddy viscosity and mixing length occur which are not represented in the model.

It is also reasonable to ask how the general accuracy of prediction compares with that given by other methods that are currently available, including those based on the transport equations. Unfortunately, this question is not answered, and the only comparisons presented are with predictions of separation given by much earlier methods, and even here the results are not particularly conclusive.

A third question is whether the basic simplicity of the C–S approach is not largely obscured by the detailed exposition of the Keller box method of computation and the variety of assumptions that are introduced to deal with different situations. The answer here may well be in the affirmative, and there is perhaps some danger of confusion arising between, on the one hand, the accuracy of the equations and the numerical technique and, on the other, the very dubious nature of some of these assumptions.

We now come to what the reviewers believe is an important omission from the present volume. It is the lack of any reference to the 'improved entrainment method'. The omission is significant, not only because the method is remarkably accurate in its limited context, but because it draws attention to the importance of departures from two-dimensionality in modifying the entrainment, and hence, by implication, the eddy viscosity. In fact, the use of the Mangler transformation in the C–S method for the calculation of turbulent boundary layers on axisymmetric bodies would seem to imply that the eddy viscosity in absolute terms (like the molecular viscosity) should be independent of flow convergence or divergence, so that, in terms of $\nu_T/U\delta^*$, quite large effects should be apparent. However, so far as can be seen, this point is nowhere discussed, much less explained.

For whom is the book likely to be most useful?

For the student, it would seem to fall far short of the ideal textbook. The derivations given in the earlier chapters are rigorous and general, but these very qualities, combined with the use of density-weighted averages, do not help towards a basic physical understanding. Nor, in the later chapters, does the use of transformed variables, or the detailed description of the Keller box method as the only procedure for solving the equations. Finally, the absence of a critical comparison between the results of different methods cannot lead the uninitiated student to a balanced appreciation of their relative merits.

However, the situation is very different for the reader who already has a fair acquaintance with boundary-layer literature. He will welcome the compact account of basic turbulent boundary-layer theory and the extensive list of references, and will be in a better position to appreciate the significance of the various empirical inputs and to see some of the limitations as well as the virtues of the C–S method. He may well view some of the comparisons with experiment with a rather more critical eye than the authors apparently do, but he will not fail to be impressed with the versatility of the method and will understand the reasons for its widespread popularity.

M. R. Head and L. C. Squire