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REVIEW

The Structure of Turbulent Shear Flow, 2nd Edition. By A. A. TOWNSEND. Cambridge University Press, 1976. 429 pp. £15.50.

Most of the fluid flows that man creates or encounters are turbulent; most of those that persist long enough to do much good or much harm are shear flows; and most of the advances in our knowledge of turbulent shear flows that have been made in the last twenty years owe at least something to the first edition of Alan Townsend's book. It was a book for specialists, and though it emphasized ideas rather than data, its direct or indirect influence on both the basic and the applied branches of turbulence research has been great.

However, no scientific text is a possession for all time, and, after what Dr Townsend admits has been a rather long period of incubation, a second edition has now appeared. It is a recognizable development of the first, and the presentation follows the same sequence, but it has been almost completely rewritten and contains an entirely new chapter on heat and pollutant transfer. The book is about 35 % longer than the first edition.

After three introductory chapters on spectra and correlations, the equations of motion, and the basic mechanisms of homogenous turbulence, Dr Townsend outlines his current views about inhomogenous shear flow. As in 1956, the model is that of a large-eddy motion, strongly affected by the spatial variation of the mean strain rate, plus the main quasi-homogenous motion with eddy sizes small compared with the flow width. The large-eddy equilibrium hypothesis is commemorated in the preface, the large eddies are described as "possibly weaker" than the main motion, and their preferred shape is now that of a parallel or conical pair of roller eddies with axes inclined at about 30 ° to the flow direction. This is close to the 'hairpin' or 'horseshoe' vortex favoured by some other workers. Here and elsewhere in the book, statistical properties and correlation shapes are estimated by considering the rapid distortion of (initially isotropic) tubulence by a plane shear with a total strain ratio of about 2–4: this seems to be a very fruitful approach for semi-quantitative purposes, but one would like to know how sensitive the final results are to the initial correlation shapes.

Chapters 5–7 are on duct flows, free shear layers and boundary layers (including wall jets). As before, the emphasis is on self-preserving flows and on results obtainable by simple analytic approximations to velocity-profile shapes, but these are just the vehicles for a masterly discussion of what makes turbulence tick. The several sections on entrainment and on relaxation of slightly perturbed flows are particularly good reading, and there is now some discussion of three-dimensional – though not compressible – boundary layers. Chapter 8, on heat transfer, is an excellent introduction which, unlike some of the other chapters, could be read by someone without much background knowledge. The rapid-distortion arguments show that the turbulent Prandtl number increases with total strain, neatly explaining the low values found near the outer edge of a boundary layer and in free shear layers where the total strain is small. This chapter includes a discussion of buoyancy effects, which leads into chapter 9, on the broadly similar effects of streamline curvature, exemplified as in the first edition by the flow between coaxial rotating cylinders.

One of the reasons why the first edition wore so well is that Dr Townsend totally ignored the rather lamentable methods used in the mid-1950s for calculating non-self-preserving shear layers. This being so, one cannot complain at his almost total neglect of the calculation methods of the mid-1970s! He does discuss the basic eddy-viscosity method and one of the oldest and simplest transport-equation methods, saying that they "are specially relevant to the concepts of turbulent flow developed in previous chapters"; however, those readers who hope for explicit guidance in modelling the Reynolds-stress transport equations, and in choosing an equation for the length scale in rapidly-changing flows, will be largely disappointed. The general Reynolds-stress transport equations are not even quoted, although as before the turbulent energy equation is the main foundation for the discussion of turbulence properties. Dr Townsend has also ignored most of the currently-fashionable problems, like the effects of low Reynolds number on the outer layer or the controversy about 'orderly structure' in free mixing layers. His literature references peak in 1967, with a cut-off, except for two items, at 1972 (only 20 % of the references are pre-1955). This edition, like the first, is not a 'state-of-the-art' survey, but an expression of carefully-formed views which will not date rapidly.

This reviewer's own views owe so much to the first edition that extensive disagreement with the second is not to be expected (though this is not an expression of support for *all* that Dr Townsend says). Those who found the original book difficult will find this one difficult too, though not for any lack of lucidity in Dr Townsend's style. He does tend to use algebraic approximations where most of us these days would fly to our computers, and this adds complication to an analyis which is already complicated by the need for empirical approximations in the turbulence models: however, many readers may prefer approximate analytic results to graphs or tabulations, though there are plenty of these as well. I was disconcerted to find the theory of local isotropy (pp. 88–104) explained without reference to its modification by high-wavenumber intermittency, which appears only at the end of the next chapter and is not to be found under "local isotropy" in the index. It is rather optimistic to state that von Kármán's constant is known to be $0{\cdot}41 \pm 2\,\%$ in the laboratory and in the atmosphere, while the value of the additive constant in the logarithmic law, 5·6, is well above the range 5·0–5·2 usually quoted. The pressure diffusion term in the data quoted for the sublayer energy balance (figure 5.5, reproduced from the first edition) implies that the coefficient of correlation between the fluctuations of pressure and normal-component velocity at $y^* \approx 10$ is about 2, while the diffusion term in the pipe-flow energy balance has the same sign everywhere: both are impossible. There are a number of misprints, but the only ones likely to hold up the average reader are a bold $\boldsymbol{\Phi}$ (3D spectrum) instead of a lower-case one in (3.8.6), and U(D) instead of U(2D) or U_1 in (5.6.2).

However, these are minor quibbles. The only serious criticism this admirable book is likely to encounter is that Dr Townsend has concentrated on the aspects of his subject that he considers important rather than those which some of his potential readers may consider important. They may go elsewhere if they can: Dr Townsend has cultivated his own garden, and it is now open to the public again.

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