CC/NUMBER 50
DECEMBER 10, 1984

This Week's Citation Classic™

Launder B E, Reece G J & Rodi W. Progress in the development of a Reynolds-stress turbulence closure. *J. Fluid Mech.* 68:537-66, 1975.
[Dept. Mechanical Engineering, Imperial College, London, England]

The paper develops a second-moment closure for approximating the additional effective stresses due to turbulence that appear in the averaged equations of motion. Extensive applications are reported showing the width of applicability of the model. [The *SCI*® indicates that this paper has been cited in over 155 publications since 1975.]

Brian E. Launder
Department of Mechanical Engineering
University of Manchester
Institute of Science and Technology
Manchester M60 1QD
England

July 3, 1984

"The research that created the base for the work reported in this paper was undertaken in the late 1960s by colleagues S.V. Patankar and D.B. Spalding at Imperial College.[1] Their finite-difference procedure for solving the thin-shear-flow equations far outdistanced competing schemes in its computational economy and in its generality of conception. Although only a rudimentary model of turbulent transport was included in their original code, this underlying generality made the method an admirable vehicle for developing more widely applicable models.

"The next three years saw intense activity in turbulence modelling by Spalding's group, with students and faculty working in friendly competition with one another. The new approaches characterized turbulence through certain scalar properties, e.g., its kinetic energy, which were obtained by solving transport equations similar to those governing the mean velocity or temperature. Several two- and three-equation turbulence models were evolved in this period,[2] achieving significant successes. As the dust of this effort began to settle, however, Wolfgang Rodi (doing a year's postdoc with me) and I both felt that a full second-moment closure was the most sensible level at which to try to devise turbulence models of general applicability. With models of this type, one abandons the notion of an effective turbulent viscosity and instead focuses directly on the equations for the turbulent stresses themselves. Rodi took responsibility for calculating free-shear flows. My research student, Gordon Reece, considered various wall flows, while my own efforts went toward the physical modelling and overall coordination.

"A preliminary version of the paper was prepared for airing at a fluids engineering conference in 1973. To our surprise, it was tossed out by what is still the most abusive review I have received in 20 years of publishing. 'Reads like a rejected *Journal of Fluid Mechanics* manuscript!' the referee fumed (which from his tone was even marginally worse than an *accepted Journal of Fluid Mechanics* manuscript). So, we polished up the text a bit and followed our critic's unwitting advice.

"The popularity of the paper probably stems from two factors: the large number of test flows against which the model was compared, and the fact that it gives a simple derivation for what has become a standard model for the linear part of the 'pressure-strain' correlation. (I had worked out the form in 1971 in trying unsuccessfully to devise a tensor-based model to fit Hanjalic's largely correct but *ad hoc* representation of the process.[3] Before that could be used, however, knock-on adjustments were required to models of other processes, but there had been no opportunity for making these in that study.)

"All the authors left Imperial College shortly after completing the work. Rodi is now professor of computational fluid mechanics at the University of Karlsruhe. Reece is lecturer in engineering mathematics at Bristol University. After four years at the University of California, Davis, I moved to the University of Manchester Institute of Technology in 1980."

1. **Patankar S V & Spalding D B.** *Heat and mass transfer in boundary layers.* London: Morgan Grampian, 1967. 138 p. (Cited 355 times.)
2. **Launder B E & Spalding D B.** *Lectures in mathematical models of turbulence.* London: Academic Press, 1972. 169 p. (Cited 310 times.)
3. **Hanjalic K & Launder B E.** A Reynolds stress model of turbulence and its application in thin shear flows. *J. Fluid Mech.* 52:609-38, 1972. (Cited 130 times.)

