#6093

MODELLING SEVERE INHOMOGENEITY IN NEAR-WALL TURBULENCE

Research Worker: D.P. Tselepidakis
Supervisor: B.E. Launder
Sponsor: SERC

1. BACKGROUND AND OBJECTIVE

The 4th Colloquium reported ongoing research in developing a second-moment closure suitable for flow near walls. It had been explicitly designed to satisfy several limiting constraints with which real turbulence conforms in the limit as the wall is approached. Here the completion of that project is reported. Particular attention has been given to accounting for the effect provoked in the model of the very strong spatial variations in mean velocity gradient that arise in the buffer region.

2. THE PROBLEM AND THE PROPOSED MODELLING

The contribution of mean strain to the pressure strain correlation may be expressed

$$\phi_{ij2} = \frac{1}{2\pi}\int_{vol}\left(\frac{\partial U_\ell}{\partial x_m}\right)'\overline{\left(\frac{\partial u_m}{\partial x_\ell}\right)'\left(\frac{\partial u_i}{\partial x_j}+\frac{\partial u_j}{\partial x_i}\right)}\frac{dVol}{r} \tag{1}$$

where primes denote that the quantity in question is evaluated at a point distance r from that where ϕ_{ij2} is evaluated. In devising an approximation for ϕ_{ij2} suitable for use in turbulence modelling, the assumption is made that $(\partial U_\ell/\partial x_m)'$ can be replaced by $(\partial U_\ell/\partial x_m)$ and thus taken through the integral in eq (1). The process is thus represented as

$$\phi_{ij2} = \frac{\partial U_\ell}{\partial x_m}\left(a^{mi}_{\ell j} + a^{mj}_{\ell i}\right) \tag{2}$$

where the fourth-rank tensor $a^{mi}_{\ell j}$ is expressed as a series in ascending powers of a_{ij} [1]. However, Bradshaw et al [2] have shown from examining direct simulations of near-wall turbulence that the replacement of $(\partial U_\ell/\partial x_m)'$ by $\partial U_\ell/\partial x_m$ leads to serious errors in the buffer layer where spatial rates of change of $\partial U_\ell/\partial x_m$ are largest.

The present research has proposed replacing $\partial U_\ell/\partial x_m$ in eq (2) by an *effective* velocity gradient $(\partial U_\ell/\partial x_m)_{eff}$ where

$$\frac{\partial U_\ell}{\partial x_m}\Big|_{eff} = \frac{\partial U_\ell}{\partial x_m} + c_I\,\ell'\,\frac{\partial \ell'}{\partial x_k}\,\frac{\partial^2 U_\ell}{\partial x_k \partial x_m} \tag{3}$$

where $\ell' = (k/\varepsilon)(\overline{u_p u_q}\,n_p n_q)^{1/2}$ is a representative length scale normal to the wall.

Equation (3) has been used to replace $\partial U_\ell/\partial x_m$ in eq (2) in conjunction with UMIST's cubic model of $a^{mi}_{\ell j}$. This replacement with $c_I = 0.3$ greatly reduces the strength required of the traditional 'wall-reflection' process in the pressure-strain term. Indeed with $c_I = 0.4$ the wall reflection process can be entirely discarded, at least in a parallel shear flow.

3. RESULTS

Computations have been made of fully developed flow in an infinite plane channel in both stationary and rotating conditions [1,3] and the results compared with direct simulations. The normal stress profiles arising in these cases are presented in Figures 1 and 2. For a stationary channel agreement with the direct simulation data is extremely close including the faster decay of u_2 to zero as the wall is approached. Agreement in the case of a rotating channel is also good - clearly superior to that obtained with the earlier and widely used Launder-Shima model [4].

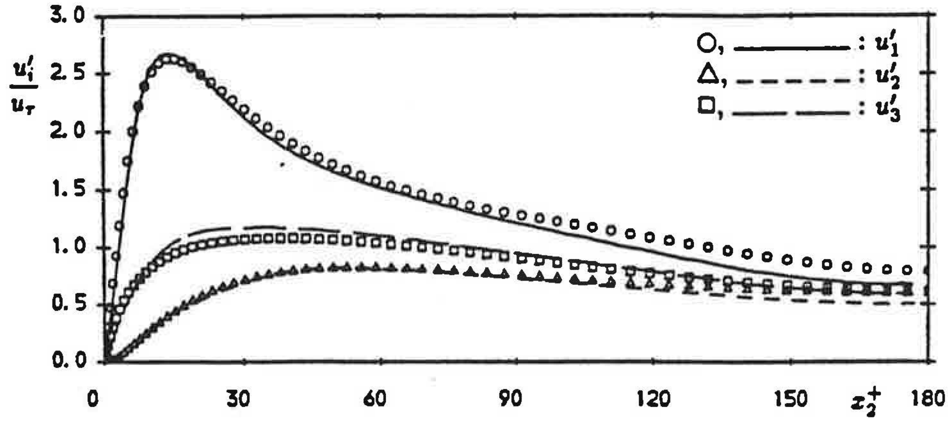

Fig 1 Turbulence intensity profiles in plane channel at Re = 5600. Symbols: DNS data; Lines: present computations. c_1 = 0.3

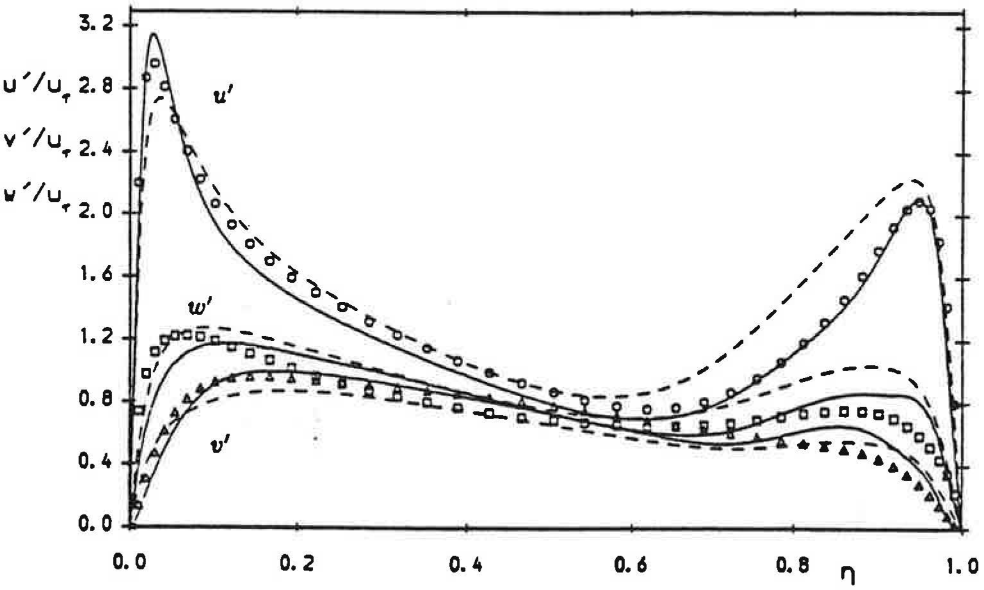

Fig 2 Turbulence kinetic energy (a) and turbulent intensity (b) profiles at Ro = 0.05. Symbols: DNS data; ------: LS model; ____: present computations. c_1 = 0.3

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