Using a deforming domain to study fluid flow

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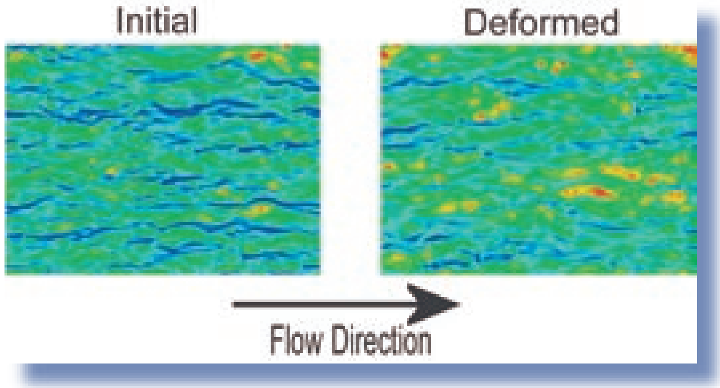

Fig. 1: Initial and deformed domain of time-developing strained-channel flow.

For many years now engineers have been using computers in order to investigate the behaviour of turbulent fluid flows. Originally, empirical models were used as the exact calculations were far beyond the computer power available at the time. As the power of computers has increased a near exact solution to flows has become possible though the use of Direct Numerical Simulation (DNS). This method solves all the scales of the turbulence rather than modelling them (see Fig. 2). Even with today's super computers such as HPCX, the range of situations to which DNS can be applied is limited. This fact leads engineers to design novel geometries which maintain simplicity, yet hold useful analogies to actual flows. The deforming channel is one such geometry.

Fig. 1 outlines the geometry of the flow which is currently being studied. The domain is deformed in time with a constant strain rate while the channel walls are gradually accelerated to reduce the relative bulk velocity. This strategy was designed to have many of the properties which are exhibited in a turbulent boundary layer which is exposed to an adverse pressure gradient (a flow travelling from a low pressure to a higher pressure).

Previous work has been carried out using this geometry using an initial bulk Reynolds number of 13,750. The current work sets out to increase the Reynolds number by 50% and to look at the flow's response to the removal of the deformation. This recovery process is well known to be complicated and long, yet there is little understanding of the processes which take place. Study of the information resulting from these DNS calculations will, it is hoped, lead to a better understanding of these processes and help the development of improved models for such flows.

To illustrate the size of the problem being solved here it should be noted that in order to gain useful statistics from the high Reynolds number problem 60,000 HPCX CPU hours were required. This generated a five sample ensemble over which the statistical quantities were averaged.

Fig. 3 illustrates the quality of data which can be obtained from the DNS. It highlights the areas which play an important part in the flow's behaviour. When data from different locations in time are compared responses to the deformation and recovery can be noted and compared to the behaviour of existing turbulence models. It is hoped this detailed knowledge will lead to an improvement in the performance of these simple turbulence models.

This project is funded by EPSRC and managed through the UK Turbulence Consortium. Further information on this project can be found in the following publications:

G.N. Coleman, J. Kim, P.R. Spalart, Direct numerical simulation of a decelerated wall-bounded turbulent shear flow, J. Fluid Mech. (2003) 495 pp. 1-18

C.P. Yorke, & G.N. Coleman, Assessment of common turbulence models for an idealized adverse pressure gradient flow, Eur. J. Mech. B/Fluids (2004) 23 pp. 319-337

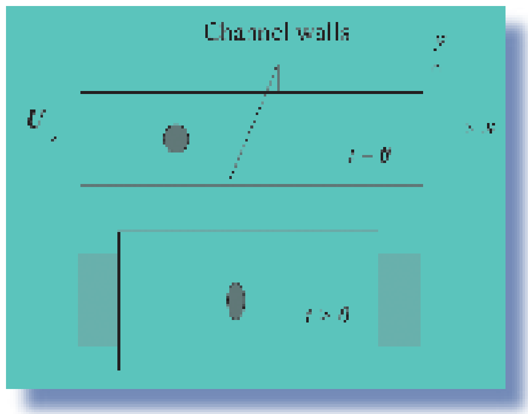

Fig. 2 (above): Slices of the flow a small distance from the wall showing the changes in the flow structure as the domain is deformed. Contours show the variation in the streamwise velocity.

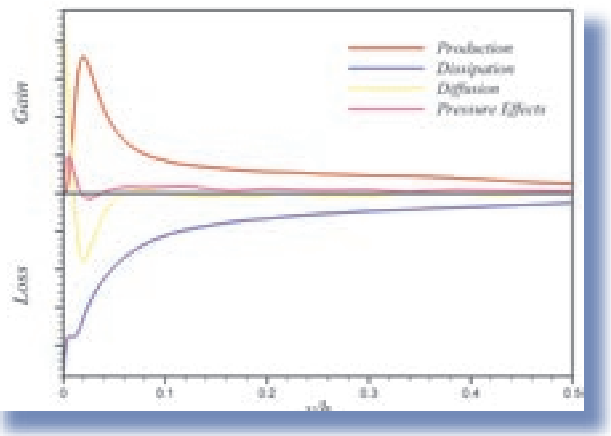

Fig. 3 (right): Turbulent Kinetic Energy Budget for strained flow. Loss/Gain against distance from wall/channel half width.