#6099

COMPUTATION IN DIFFUSERS AND COMPLEX DUCTS WITH NON-ORTHOGONAL FV PROCEDURE

Researcher: F.S. Lien
Supervisor: M.A. Leschziner
Sponsor: SERC

1. INTRODUCTION

Three-dimensional fluid flow in ducts and passages is of central importance in a wide range of engineering application. Inlet ducts for air-breathing propulsion systems, turbomachine passages, cooling ducts in turbine blades, IC-engine manifolds, rocket-fuel supply lines and ventilation-duct systems are some isolated, randomly chosen relevant examples.

The large majority of the above flows display strongly three-dimensional features. Typically, ducts are strongly curved and their cross-sectional area varies rapidly, giving rise to strong pressure-induced streamwise vorticity. Any turbomachine passage is of that type, and the flow inside it is further complicated by twisting in the passage and compressibility.

In the above condition, curvature-induced secondary motions play a crucial role in the distribution of streamwise momentum, through convective transport processes. The peak value of the secondary velocity is generally very close to the wall, one consequence being a rapid rotation of the wall-parallel velocity vector as the wall is approached. In such circumstances, the detailed resolution of the highly three-dimensional near-wall boundary layer, is important (Iacovides et al (1990)). It is for this reason that a low-Re k-ε model is used here. The particular version used here is formulated by the authors so as to conform with constraints implies by Wolfshtein's (1969) and Norris & Reynolds (1975) one-equation models.

2. APPROACH

The numerical procedure adopted herein is the STREAM algorithm, standing for Simulation of Turbulent Reynolds-averaged Equation for All Mach numbers. The main features of this code can be summarised as follows:

1. applicable to complex geometries by use of a general non-orthogonal, cell-collocated formulation;

2. incorporating accurate (numerically non-diffusive) higher-order approximation for convection;

3. incorporating a range of turbulence closures, among them a Reynolds-stress transport model and a low-Reynolds-number eddy-viscosity variant applicable to the semi-viscous near-wall region;

4. formulated on the basis of a pressure-correction methodology but extended to apply to compressible conditions, including the transonic regime;

5. incorporating convergence-accelerating techniques based on the "Multigrid" approach.

Some of the above characteristics feature in the earlier summaries, and details can be found in Lien (1992).

3. RESULTS

Several three-dimensional flow through complex ducts and diffusers have been computed, among them a 90° circular-sectioned bend, C-shaped and S-shaped diffusers and a square-to-round transition duct. For the case of S-diffuser, examined experimentally by Rojas et al (1983), velocity and turbulence-energy profiles at the exit plane are shown in Fig. 1. As seen, all models give credible predictions in terms of mean-flow quantities. However, in respect of the level of turbulence-energy near the wall, the wall-law approach yields seriously excessive peaks. Reversion to either of the low-Re variants results in a far better level of agreement with experimental data. The second case is the square-to-round transition measured with LDA by Taylor et al (1981). An overall view of the evolution of the secondary motions is given in Fig. 2. While streamwise velocity profiles in the symmetry plane are presented in Fig. 3. Here wall-parallel transverse motion is very small and all k-ε variants return similarly good agreement with experiment.

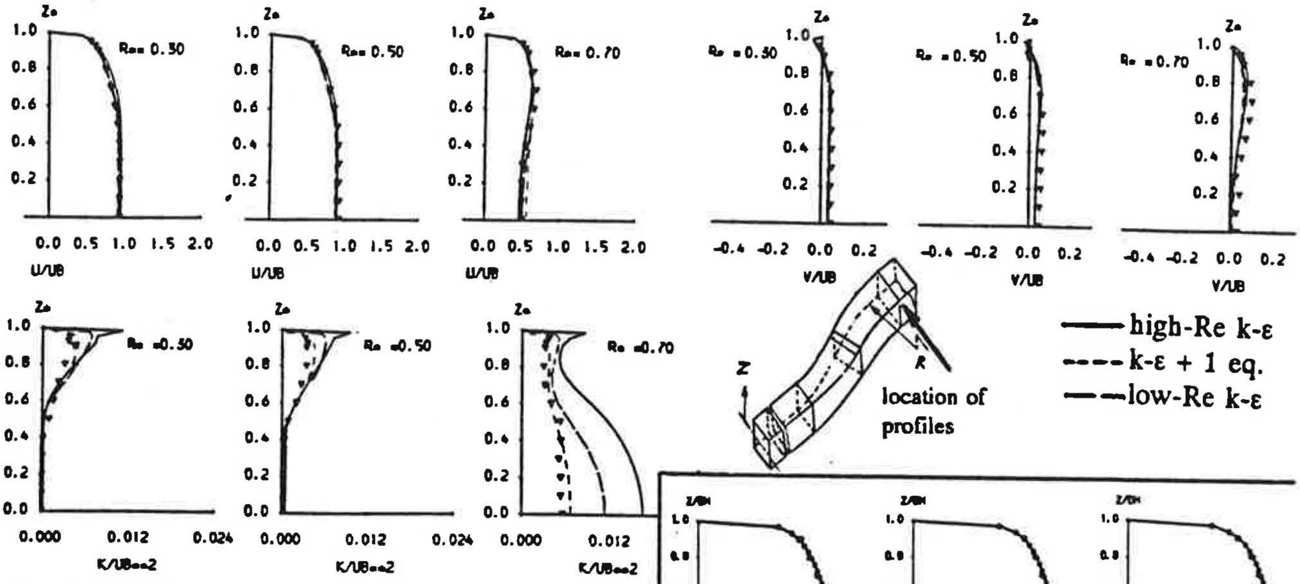

Fig. 1: Velocity and turbulence-energy profiles at the exit of S-shaped diffuser

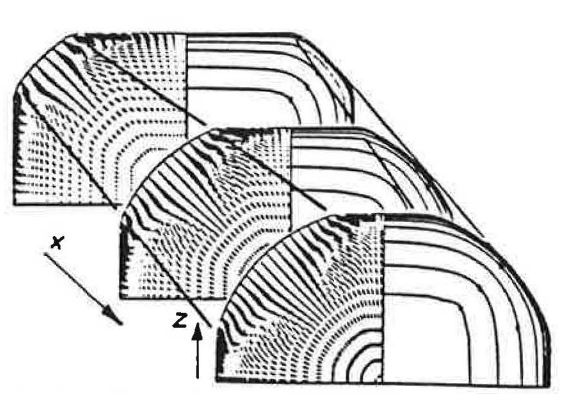

Fig. 2: Evolution of the secondary motions in a square-to-round transition duct

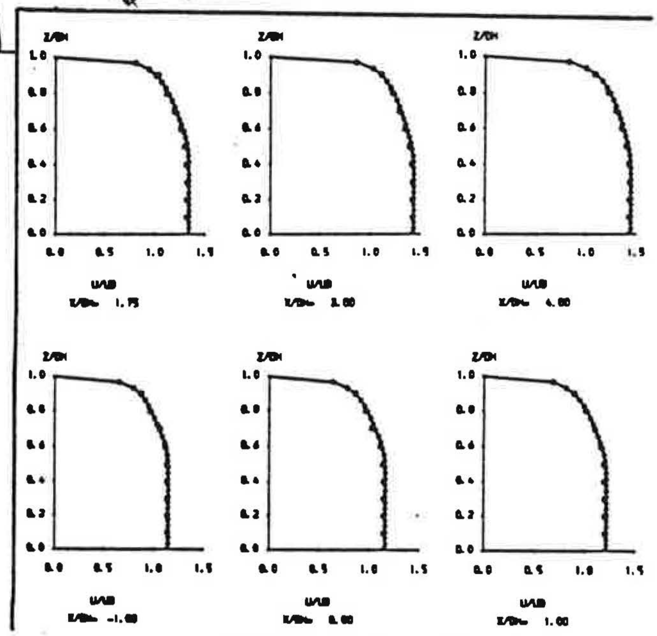

Fig. 3: Streamwise velocity profiles in the symmetry plane of transition duct

REFERENCES

1. Iacovides, H., Launder, B.E., Loizou, P.A. and Zhao, H.H. (1990), ASME J. Fluids Engrg., Vol. 112, p. 409.
2. Lien, F.S. (1992), "Computational Modelling of 3D Flow in Complex Ducts and Passages", Ph.D Thesis, University of Manchester.
3. Norris, L.H. and Reynolds, W.C. (1975), Rep. FM-10, Dept. of Mech. Engrg., Stanford University.
4. Rojas, J., Whitelaw, J.H. and Yianneskis, M. (1983), Rep. FS/83/12, Fluids Section, Dept.of Mech. Engrg., Imperial College.
5. Taylor, A.M.K.P., Whitelaw, J.H. and Yianneskis, M. (1981), NASA CR-3447.