9th ERCOFTAC/IAHR Workshop on Refined Turbulence Modelling

Case 9.1: Swirling flow in a model combustor with heat release

Description of the case[1]

Schematic of the strongly swirling flow in the combustor chamber geometry investigated experimentally by Roback and Johnson (1983) is given in Fig. 1. Dimensions of the combustor i.e. computational domain (dashed lines) are given in Fig. 2.

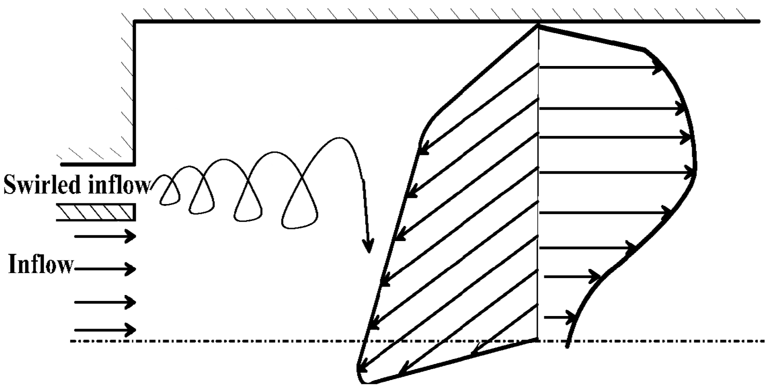

Fig. 1 Schematic of the flow considered

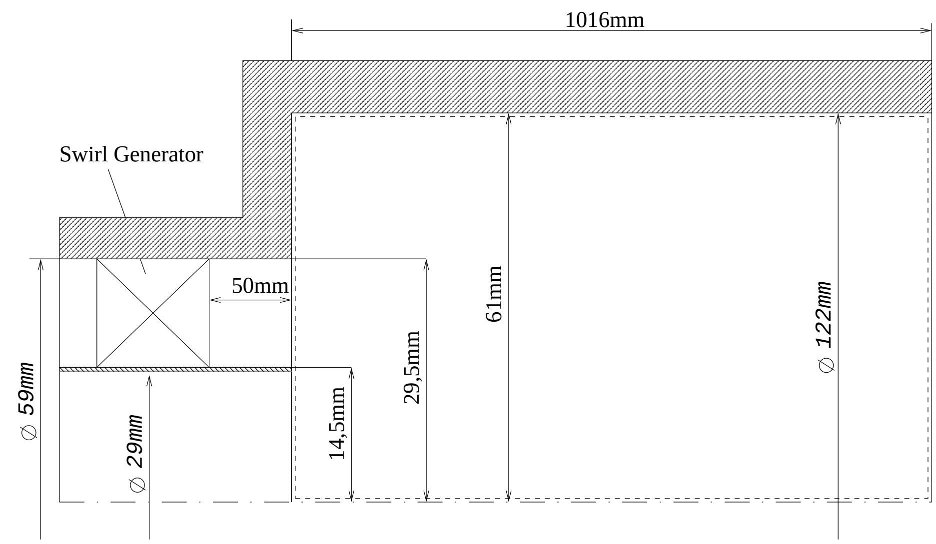

Fig. 2 Description of the combustor geometry

[1] **All details necessary for the computation of the test case with heat release will be given soon**

Flow characteristics

Table 1 Characteristic flow properties

	Primary inflow	Secondary (swirled) inflow
Re_m	15900	47500
Mean axial velocity (m/s)	0.66	1.52
Mass flow rate (kg/s)	0.391	3.331
Swirl number, S	0.0	0.45
Length scale	0.008	0.0045
Density (kg/m^3)	1000	
Viscosity (Pas)	$9.84 \cdot 10^{-4}$	

Inlet conditions

The inlet plane of the solution domain ($x = 0$) is placed at the exit of both pipes (central pipe and annulus), Fig. 2. As there are no experimental data at the location $x = 0$, the results of the measurements taken at the location $x = 5.1mm$ were extrapolated to the inlet plane, satisfying the global mass balance. These extrapolated results, which serve as the inlet data for numerical calculation are given in the file **inlet_dat**. Dissipation rate of the kinetic energy of turbulence was obtained from the experimentally specified length scale (Table 1). This approach was succesfully applied by Wennerberg and Obi (1993) and Wennerberg (1995). Figs. 3 show the inlet profiles ($x = 0$) of all variables (dashed lines). The comparison of the experimental data (symbols) and the computational results obtained by the Jones, Launder and Sharma (JLS, 1972, 1974) low-Reynolds number $k - \varepsilon$ model (solid lines) at location $x = 5.1mm$ is also shown. The numerical grid used consisted of 180x120 cv's. Blended central differencing scheme was applied for discretization of the convective terms.

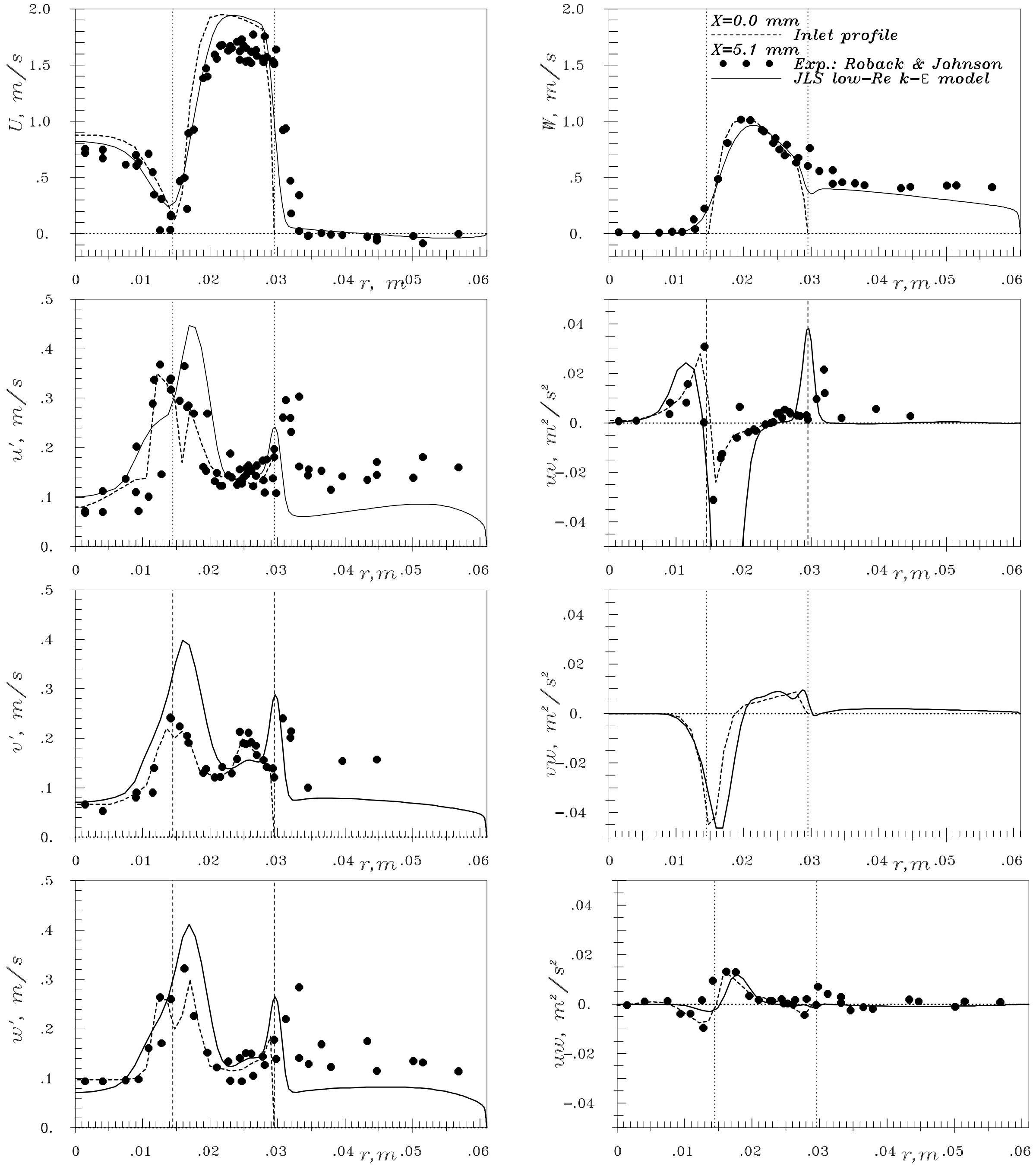

Fig. 3 Inlet ($x = 0$) profiles of all variables compared with the experimental data and the JLS low-Re $k - \varepsilon$ model results at the location $x = 5.1mm$

Some results

The following two figures represent the velocity vector plots and the streamline pattern showing the existence of the large central recirculation zone. These results are obtained by the Jones, Launder and Sharma low-Reynolds number $k-\varepsilon$ model.

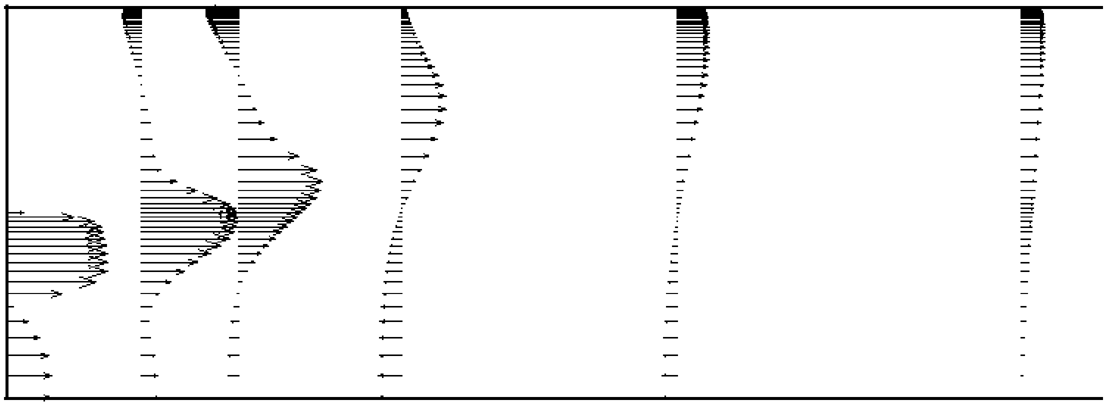

Fig. 3 Velocity vectors plots

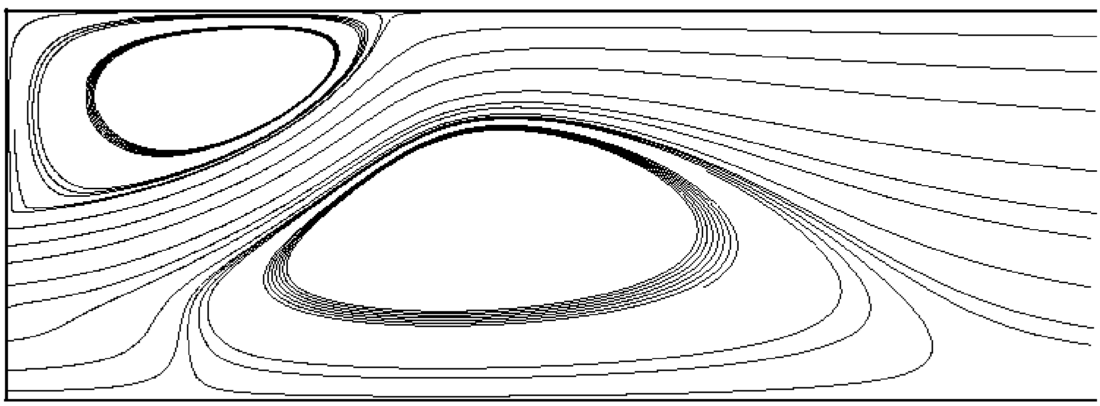

Fig. 4 Typical streamline pattern

Reference data

The experimental data serving for comparison with computational results are given for all variables (mean velocities and Reynolds-stress components) at the following locations: $x = 5.1, 25, 51, 102, 152, 203$ and $406mm$ (the file **roback_and_johnson_dat**). The work of Wennerberg and Obi (1993)[2] comprises very detailed results obtained by applying the standard high-Reynolds number $k - \varepsilon$ model and the basic second-moment closure model (Gibson and Launder, 1978), using the wall function concept for the near-wall treatment.

References

Roback R., and Johnson B.V. (1983): Mass and Momentum Turbulent Transport Experiments with Confined Swirling Coaxial Jets, *NASA CR-168252*

Pierce, C.D., and Moin, P. (1998): LES of a confined coaxial jet with swirl and heat release, AIAA Paper 98-2892

Other relevant references

Lin, C.A. (1998): Modeling a Confined Swirling Coaxial Jet, *Ann. Research Briefs*, Center for Turbulence Research, Stanford University, Stanford, pp. 211-219 (downloadable from http://ctr.stanford.edu)

Pierce, C.D., and Moin, P. (1998): Method for Generating Equilibrium Swirling Inflow Conditions, *AIAA Journal*, Vol. 36, No. 7, 1998, pp. 1325-1327

Wennerberg, D., and Obi, S. (1993): Prediction of Strongly Swirling Flows in Quarl Expansions with a Non-Orthogonal Finite-Volume Method and a Second-Moment Turbulence Closure, *Engineering Turbulence Modelling and Experiments*, edited by W. Rodi and F. Martelli, Vol. 2, 1993, pp. 197-206

Wennerberg, D. (1995): Entwicklung eines vorhersagefähigen Berechnungsmodel für stark verdrallte Strömungen mit Verbrennung, PhD Thesis, University of Erlangen-Nuremberg, Germany, p. 152

[2] **A pdf file of this article could be obtained per e-mail on request**