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Cortes, Ines Olmedo; Nielsen, Peter V.

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1. Introduction

The “IEA Annex 20 two-dimensional test case” was defined by Nielsen (1990) and was originally considered two-dimensional and steady flow [1]. However, some recent works [2, 3] considering the case as three dimensional have shown different solutions from the 2D case as well as different solutions depending on the turbulence model used in CFD simulations.
The aim of the simulations is to investigate the two dimensional or three dimensional nature of the test, as well as to analyze the results obtained considering the case as steady or unsteady.
The sizes of the Annex 20 room are specified as:
L=9m, H=3m, W/H=1, h=0.168 m, t=0.48m.

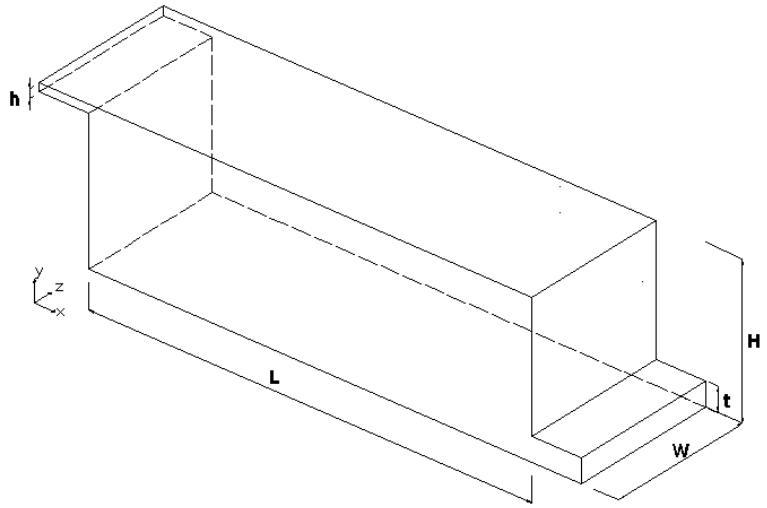

Figure 1 Sketch of the benchmark test

The air is supplied in the room by a slot inlet in the left top of the room with the velocity of 0.455 m/s which corresponds with a Reynolds number of 5000. The exhaust is situated in the right bottom.
In this study a commercial CFD program (FLUENT 6.0) was used with mesh generation from the Gambit 2.6. For the simulations, the k-epsilon turbulence model was used since it produces good quality predictions in indoor airflows.

2. Description of the simulation tests

The isothermal two-dimensional case has been solved numerically as a steady state case. The grid used for the calculation contained 3,586 control volumes.
After looking at the results obtained in the two-dimensional simulations a three-dimensional case was considered in order to study the real nature of the airflow.
The three dimensional simulations were carried out under steady and unsteady conditions. The same grid distribution as in the two-dimensional case was used in the X-Y plane, plus a 60 grid cells division in Z direction. The resulted grid is formed by 215,160 control volumes. The solutions were considered converged when the sum of absolute normalized residuals for all cells in the flow domain becomes less than 10^{-5}.

3. Results and discussion

3.1. Airflow patterns and velocity contours

Figure 2 shows the contours lines of the stream for the three tests simulated. For the three dimensional tests the stream lines are calculated at the plane z/W=0.5 which corresponds with the middle plane of the test room.

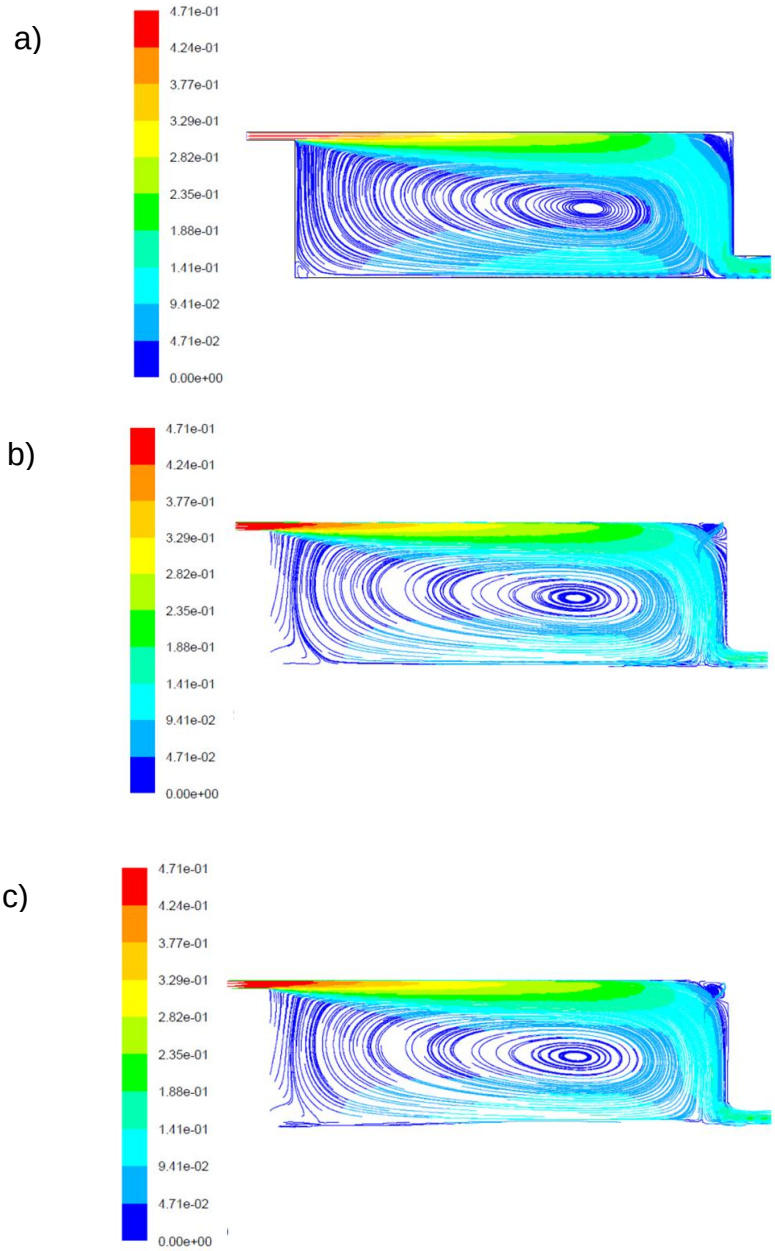

Figure 2 Streamlines calculated using the standard k-ε model for the plane z/W=0.5. a) two dimensional simulation, b) three dimensional steady simulation, c) three dimensional unsteady simulation.

For the three cases considered, the flow is completely developed in the upper part of the room where it is not possible to see larger difference between the cases. However there is an area around x/L= 1 in the lower part of the room when the measurements show large turbulence with both positive and negative instantaneous velocities. In this area is possible to see a slight difference between the path lines in the three predictions.

The x-velocity contours are obtained at the position y=0.028H, in the low part of the room, in order to find any difference in the velocity distribution, see figure 3.

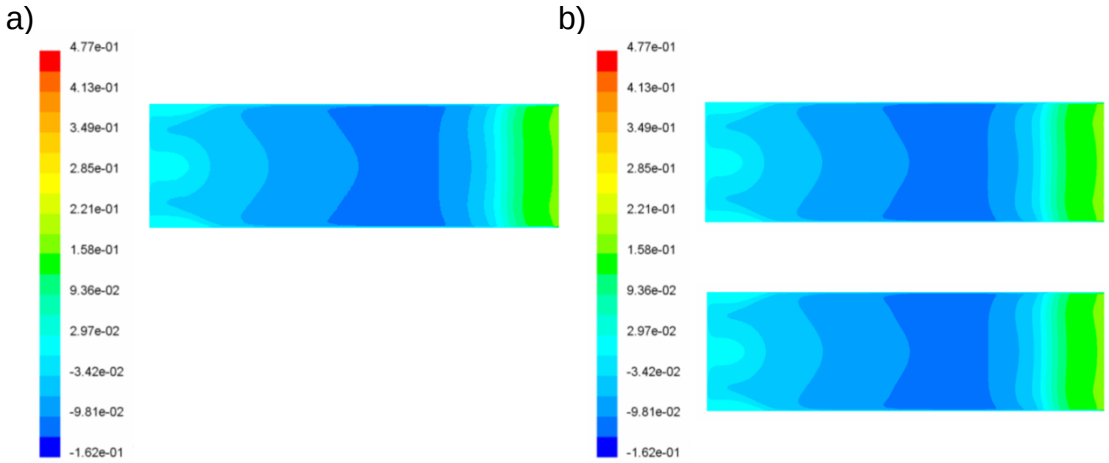

Figure 3 X-velocity contours calculated using the standard k-ε model for the plane y=0.028H. a) three dimensional steady simulation, b) three dimensional unsteady simulation at different instants of time.

As looking figure 3(b) is not possible to see any evidence that indicate an time dependent nature of the test since the velocity profiles are the same in two different instant of time. Moreover, it should be noticed that no different patterns have been observed compared to the three dimensional steady case.

3.2. Turbulent intensity

The profiles of the turbulent kinetic energy for the three cases at the position x=H and x=2H are shown in figure 4, where is possible to find slight differences comparing the two dimensional case to the three dimensional cases. However, the same level of turbulence is shown for the steady and unsteady three dimensional simulations.

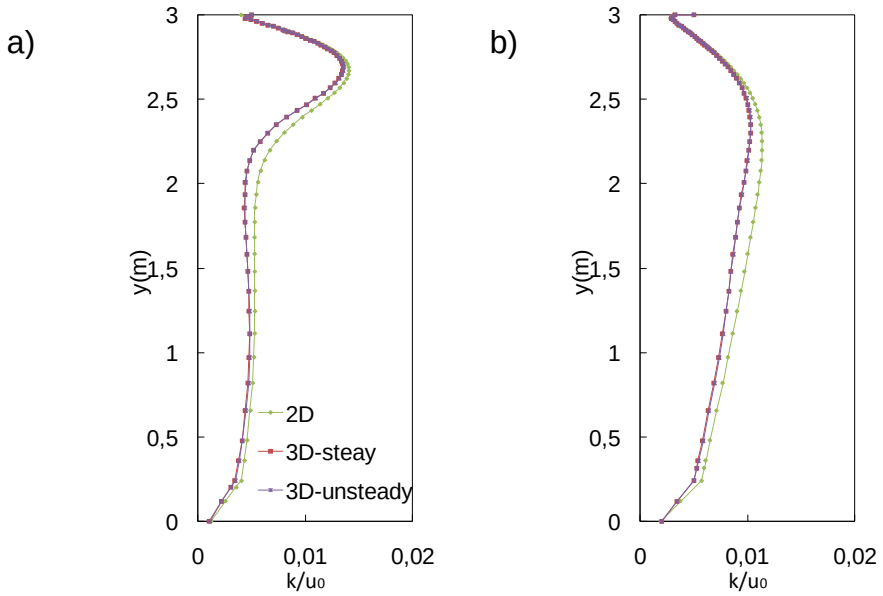

Figure 4 Dimensionless turbulent kinetic energy profiles for x=H and x=2H.

3.3. Velocity comparison

The velocities profiles calculated with the standard k-ε model for four positions of the room, in the middle plane are shown in figure 5.

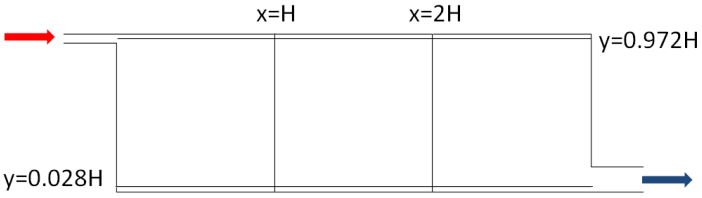

Figure 5 Sketch of the vertical and horizontal lines where the results are shown.

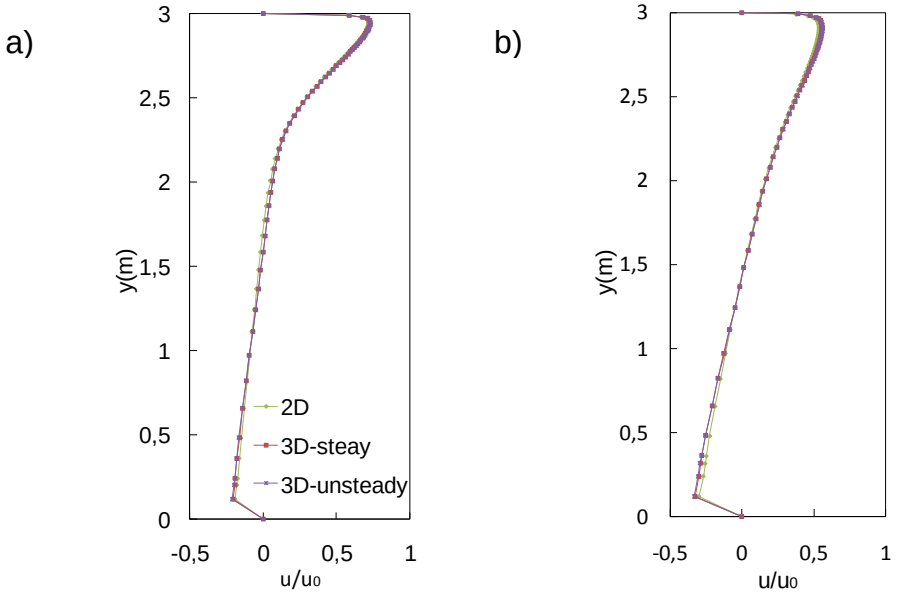

Figure 6 Dimensionless x velocity profiles predicted at a) x=H and b) x=2H.

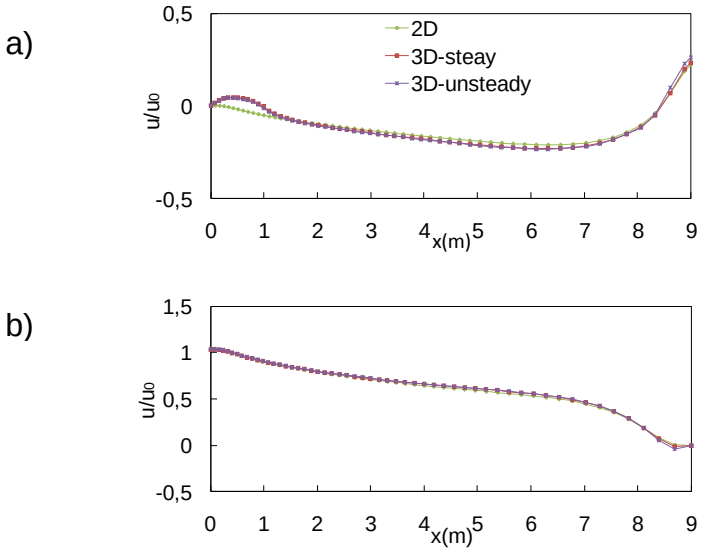

Figure 7 Dimensionless x velocity profiles predicted at a) y=0.028H and b) y=0.972H.

4. Conclusions and suggestions

It has been shown that the IEA Annex 20 case solved with time dependent equations and k-epsilon model gives a solution similar to the solution obtained with steady state three dimensional and the two dimensional equations.
By analyzing the results of the three tests it has been observed that the streamlines are the same in the major part of the domain, which means the flow may in practice be considered two-dimensional.
Moreover, the predictions show no evidence of unsteady nature of the flow. Time dependent equations give the same solution as steady state equations.
In general the most significant differences between the cases were obtained in the level of turbulence comparing the two dimensional case to the three dimensional cases. However, the test can be considered as a steady two dimensional case in the major part of the domain since it is no possible to find huge differences with the three dimensional, steady or unsteady, cases.

5. References

[1] www.cfd-benchmarks.com, IEA Annex 20 2D test case.

[2] Peter V. Nielsen, Li Rong and Inés Olmedo, The IEA Annex 20 Two-Dimensional Benchmark Test for CFD Predictions, Clima 2010, Turkey, 2010.

[3] Roberto Mathias Susin, Guilherme Anrain Lindner, Viviana Cocco Mariani and Kátia Codeiro Mendoza. (2009) Evaluating the influence of the width of inlet slot on the prediction of indoor airflow: Comparison with experimental data, *Building and Environment*, 44, 971-986.