Simulation with Different Turbulence Models in an Annex 20 Room Benchmark Test Using Ansys CFX 11.0
Rong, Li; Nielsen, Peter Vilhelm

Publication date:
2008

Document Version
Publisher's PDF, also known as Version of record

Link to publication from Aalborg University

Citation for published version (APA):
Simulation with different turbulence models in an annex 20 room benchmark test using Ansys CFX 11.0

Li Rong

Peter V. Nielsen
Simulation with different turbulence models in an annex 20 room benchmark test using Ansys CFX 11.0

by

Li Rong
Peter V. Nielsen

September 2008

© Aalborg University
Scientific Publications at the Department of Civil Engineering

Technical Reports are published for timely dissemination of research results and scientific work carried out at the Department of Civil Engineering (DCE) at Aalborg University. This medium allows publication of more detailed explanations and results than typically allowed in scientific journals.

Technical Memoranda are produced to enable the preliminary dissemination of scientific work by the personnel of the DCE where such release is deemed to be appropriate. Documents of this kind may be incomplete or temporary versions of papers—or part of continuing work. This should be kept in mind when references are given to publications of this kind.

Contract Reports are produced to report scientific work carried out under contract. Publications of this kind contain confidential matter and are reserved for the sponsors and the DCE. Therefore, Contract Reports are generally not available for public circulation.

Lecture Notes contain material produced by the lecturers at the DCE for educational purposes. This may be scientific notes, lecture books, example problems or manuals for laboratory work, or computer programs developed at the DCE.

Theses are monograms or collections of papers published to report the scientific work carried out at the DCE to obtain a degree as either PhD or Doctor of Technology. The thesis is publicly available after the defence of the degree.

Latest News is published to enable rapid communication of information about scientific work carried out at the DCE. This includes the status of research projects, developments in the laboratories, information about collaborative work and recent research results.

Published 2008 by
Aalborg University
Department of Civil Engineering
Sohngaardsholmsvej 57,
DK-9000 Aalborg, Denmark

Printed in Aalborg at Aalborg University

ISSN 1901-726X
DCE Technical Report No. 46
1. Introduction of annex 20 two dimensional isothermal case

The simulations are performed in a well known two dimensional isothermal annex 20 room benchmark test described by Nielsen (1990). The sizes of the annex 20 room are specified as:

\[ L = 9 \text{m}, \quad H = 3 \text{m}, \quad h_1 = 0.168 \text{m}, \quad h_2 = 0.48 \text{m} \]

Figure 1 schematics of annex 20 2-D isothermal case

The air is supplied from left top with velocity in 0.455m/s and exhausted from right bottom. The inlet conditions are listed in the following:

\[ u_0 = 0.455 \text{m/s} \]

\[ k_0 = 1.5(0.04u_0)^2 \]

\[ \varepsilon_0 = k_0^{1.5}/l_0 \]

Where \( l_0 = h/10 \)

According to Nielsen (1990), the inlet conditions correspond to a turbulence intensity of 4%. It is difficult to stipulate \( \varepsilon_0 \) but variation of the length scale \( l_0 \) within a reasonable level shows only a very small influence on the flow in the room.

The inlet condition for the specific dissipation rate \( w_0 \) is adopted the following relation:

\[ w_0 = \varepsilon_0/0.09k_0 \]

The experimental results for the flow are available along the four lines:

\[ x = 3.0, \quad x = 6, \quad y = 0.084 \text{ and } y = 2.916 \]
2. simulation results with $k-\varepsilon$, $k-w$, BSL and SST model

The following simulations are performed in Ansys CFX11.0 with standard $k-\varepsilon$, standard $k-w$, BSL and SST model. The simulations included the following steps:

(1) According to different requirements for $y^+$ with four turbulence models, find out the first grid distance to the wall. $k-\varepsilon$ model require $y^+ > 11.0$ and the other three turbulence models require $y^+ < 1.0$. More details can be referred to Voigt (2000). (2) To do grid independent study. The grid independent study is shown in Appendix. (3) Post simulation results and compare them with measurements.

2.1 Streamlines with using four turbulence models

Figure 2 shows streamlines with using four turbulence models. It is seen that there are two bigger eddy corners with using $k-w$ model and BSL model than $k-\varepsilon$ model. In $k-w$ model and BSL model, the jet flow from the inlet cannot move along the ceiling so far as in $k-\varepsilon$ model and the return flow close to the floor is separated earlier than in $k-\varepsilon$ model. The streamline with using SST model is quite different from the others. Figure 3 shows the streamline in experiment. It is seen that there are two eddy recirculation at the upper right corner and lower left corner, but it is hard to say which turbulence model is better in this case according to Figure 3.

(a) streamline with using standard $k-\varepsilon$ model
Figure 2 streamline with using different turbulence model

(b) streamline with using standard $k-w$ model

(c) streamline with using $k-w$ BSL model

(d) streamline with using $k-w$ SST model

Figure 2 streamline with using different turbulence model

Figure 3 streamline in experiment (Peter V. Nielsen PhD thesis, 1974)
2.2 comparison of non-dimensional velocity between simulations and measurements along two horizontal lines

Figure 4 shows four lines location where simulations are compared with measurements. Figure 5 ~ Figure 8 shows comparison of non-dimensional velocity between simulations and measurements along two horizontal lines with four turbulence models. It is seen that the simulations are in good agreements with measurements for $k-\varepsilon$ model and $k-w$ model, but it is in better agreement with measurements at points close to the floor for $k-\varepsilon$ model than $k-w$ model. With BSL model, the simulations along the line of $x=3.0$ is deviated from measurements below $y=0.5m$ because the flow separated from the floor earlier, see Figure 2(c). While in SST model, the simulations are quite different from the measurements except for the points close to the ceiling along the line of $x=3.0$. The simulations above $y=0.5$ is in agreement with measurements along the line of $x=6.0$.

Figure 4 four lines location used to compare simulations with measurements

Figure 5 comparison of non-dimensional velocity between simulations and measurements for $k-\varepsilon$ model
Figure 6 comparison of non-dimensional velocity between simulations and measurements for \( k-w \) model

(a) \( x=3.0 \)  

(b) \( x=6.0 \)

Figure 7 comparison of non-dimensional velocity between simulations and measurements for BSL model

(a) \( x=3.0 \)  

(b) \( x=6.0 \)
2.3 Comparison of non-dimensional velocity between simulations and measurements along two vertical lines

Figure 9 ~ Figure 12 shows the comparison of non-dimensional velocity between simulations and measurements along two vertical lines with four turbulence models. It is seen that there are no models which can predict the upper right corner well among four turbulence models. It is impossible for $k-\varepsilon$ model to predict the eddy recirculation in the upper right corner from Figure 9(b) while other three models underpredict the velocity there. However, $k-\varepsilon$ model can predict the velocity the best on line of $y=2.916$ except for the upper right corner. Along line of $y=0.084$, $k-\varepsilon$ model also is the best one to predict the velocity among the four turbulence models and SST model gets the biggest difference from measurements.
Figure 10 Comparison of non-dimensional velocity between simulations and measurements for $k-w$ model

Figure 11 Comparison of non-dimensional velocity between simulations and measurements for BSL model

Figure 12 Comparison of non-dimensional velocity between simulations and measurements for SST model

3. Conclusion

In this paper, we did simulations in a well known annex 20 room benchmarks with Ansys CFX11.0 to study how different turbulence models predict the velocity distribution in a room ventilation system. The results showed that $k-\varepsilon$ model, $k-w$ model and BSL model can give a reasonable agreement with measurements in the main stream area which is away from the solid wall. For $k-\varepsilon$ model, it is difficult to predict the wall bounded place well while the other three models can predict the eddy recirculation on the upper right corner but underpredict the velocity.
The flow close to the floor is separated earlier with $k-w$ model and BSL model than with $k-\varepsilon$ model from the streamline distribution while the SST model give quite different streamline distribution from the other three models. However, it is difficult to tell which turbulence model is better according to the streamline in experiments.

From the simulations results, we can see that it is important to understand various turbulence models and it is better to have measurements compared with simulations since different turbulence models will give various results in a specific case.

Reference


Appendix grid independent study

The grid number of grid1 is 4736, the grid number of grid2 is 18944 and the grid number of grid3 is 28800.

1. $k-\varepsilon$ model

The simulations with $k-\varepsilon$ model adopted grid1.

Figure 1 Grid independent study with $k-\varepsilon$ model
2. *k–w model*

The simulations with *k–w* model adopt the grid2.

Figure 2 Grid independent study with *k–w* model
3. BSL model

The simulations with BSL model adopted grid2.

![Graphs showing grid independent study with BSL model](image)

(a) $x = 3.0$

(b) $x = 6.0$

(c) $y = 0.084$

(d) $y = 2.916$

Figure 3 Grid independent study with BSL model
4. SST model

The simulations with SST model adopt grid.

Figure 4 Grid independent study with SST model