Numerical study of the airflow during aeration with windows and doors opening

Martin Ivanov, Sergey Mijorski, Detelin Markov

"Числено изследване на движението на въздуха при проветряване чрез отваряне на врати и прозорци": *В представената публикация са разгледани получените резултати от проведено числено изследване на механизма на проветряване и движението на въздуха в жилищни помещения, без организирана вентилационна система в тях, и при опростен вариант на различните дейности по проветряване, извършвани от обитателите. За целите на изследването е разработен числен модел на жилищно помещение, с помощта на комерсиалният софтуерен пакет FLUENT, който представлява мощен инструмент за предсказване и анализ на системи, включващи флуидни течения, топло и масообменни процеси, както и на множество други прости и сложни химически реакции. Разработеният модел, граничните и начални условия, както и особеностите на геометрията и на изчислителната мрежа са представени в: „Иванов М., Мижорски С., Марков Д., „Моделиране на движението на въздуха при проветряване чрез отваряне на врати и прозорци", Сборник доклади на „Научна конференция на Русенски университет и Съюза на учените – Русе, 28-29.10.2011г.", том 50, серия 1.2, стр. 66 – 70, 2011г". Към този момент са обработени и анализирани почти всички получени резултати от проведените числени изследвания. В настоящата публикация са представени скоростните полета в характерни равнини от изследваното помещение, при различните симулирани режими. Въпреки множеството констатирани несъвършенства на създадения модел, резултатите онагледяват механизма на проветряване на жилищни помещения без организирана вентилационна система в тях, и при опростен вариант на различните дейности по проветряване, извършвани от обитателите*.

Key words: *Computational Fluid Dynamics, Indoor Air Quality, Indoor Environment, Aeration, Occupant Behavior*

INTRODUCTION

This paper presents the results from numerical study on the aeration mechanism in non-ventilated residence areas, with respect to windows and doors opening behaviour of the occupants. For the purpose of the study a numerical model has been developed with the commercial Computational Fluid Dynamics (CFD) software package FLUENT. Nowadays the CFD is a very powerful tool for prediction and analyses of different systems, including fluid flows, heat and mass transfer processes, as well as chemical reactions with different reaction mechanisms. The developed model, the boundary and initial conditions, as well as the specifics of the geometry and the computational grid, has been previously presented in "Ivanov M., Mijorski S., Markov D.," Airflow modeling during aeration with windows and doors opening", proceedings of "Scientific conference at University of Ruse – 2011", vol. 50, series 1.2, p-p 66-70, Ruse, 2011" [3]. Up till now, almost all results has been processed and analysed. In the current paper, results about the velocity fields in the investigated room are presented, with respect to the different simulated regimes. Nevertheless that the developed numerical model has many disadvantages, it is able to visualise the aeration mechanism in non-ventilated residence areas, with respect to windows and doors opening behaviour of the occupants.

ROOM GEOMETRY, COMPUTATIONAL GRID AND INITIAL CONDITIONS

Opening of windows and doors is very often the only way for conscious aerating of residence room without any means of ventilation system installed. In most of the cases, it means that the occupant itself is the only responsible for that act. But in practice, the occupant decision, whether to open a window or not, is a complex task with lots of objective and subjective prerequisites [2]. Taking this consideration, in the paper stated above, a numerical study of the airflow during aeration was suggested and described. This

attempt was made in order to demonstrate the mechanism of aeration and to help the occupants in their everyday aeration behavior by means of windows and doors opening.

As it was mentioned, the room geometry, model characteristics, boundary and initial conditions are described in details in the previous paper. It should be noted that, in this study, the position of the open window determines the different investigated cases. Because of that, for each studied positioning different computational grid was developed. Figure 1 shows the room geometry and the computational grid for the cases with the considered position of 12.5% and 75% of window opening. Those two cases were selected in this publication in order to demonstrate the achieved results. The room area is approximately 14 m2 and the height of the ceiling is 2.7 m, which corresponds to 37.8 m3 volume. When it is fully opened, the window dimensions are 59.5 cm width and 121.5 cm height. The outside area was modeled as a room with five times bigger volume than the residence room. That consideration was observed to ensure undisturbed flow between the outside and inside areas.

The initial and boundary conditions for the two cases are presented in Table 1.

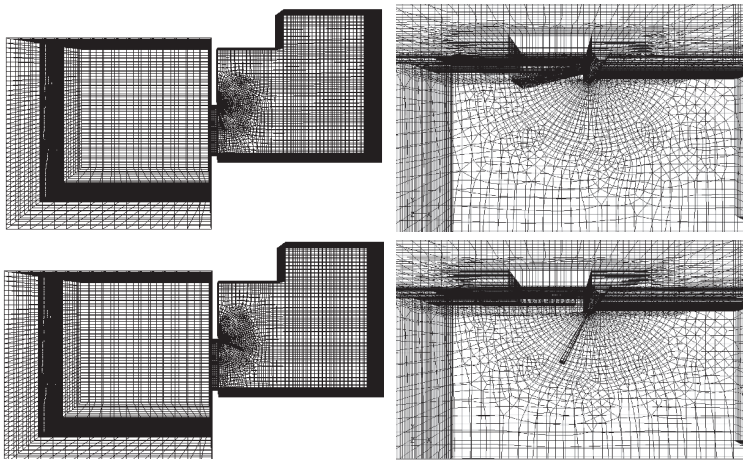

Figure 1. Computational grid for the investigated cases with 12.5% and 75% of the window opening position

Table 1. Initial conditions for the two investigated cases

Case 1 – 12.5% of window opening, 11.25° angle of opening

	T, °C:	RH, %:	B, Pa:		CO2	H2O	O2	I
Room:	21.41	50.36	94920	**ppm**	2041.5	13523.7	206265.7	778169.1
				kg/kg	0.0031150	0.0084470	0.2288358	0.7596022
Outside conditions:	-2.16	72.32	94920	**ppm**	390	3956.1	208616.4	787037.5
				kg/kg	0.0005934	0.0024642	0.2308047	0.766138
	Time for flow development: 600 seconds (10 minutes)							

Case 4 – 75% of window opening, 67.5° angle of opening

	T, °C:	RH, %:	B, Pa:		CO2	H2O	O2	I
Room:	20.42	45.15	95270	**ppm**	1930.5	11366.1	206741.0	779962.4
				kg/kg	0.0029434	0.0070939	0.2291888	0.7607739
Outside conditions:	-8.53	76.99	95270	**ppm**	390	2578.8	208905.0	788126.3
				kg/kg	0.0005931	0.0016054	0.2310036	0.766798
	Time for flow development: 600 seconds (10 minutes)							

RESULTS AND DISCUSSION

Figure 2 illustrates the velocity contours at 30, 90 and 180 seconds from the beginning of the aeration for the cases with 12.5% and 75% of window opening. For the case with 12.5% open window, there are fewer zones with higher velocity compared to the case with 75% open window. These zones are concentrated in the areas near the simulated warm radiator which also adds convection flow. It is also shown that when the window is widely open, the aeration is more intense, followed by higher flow velocity in the investigated room.

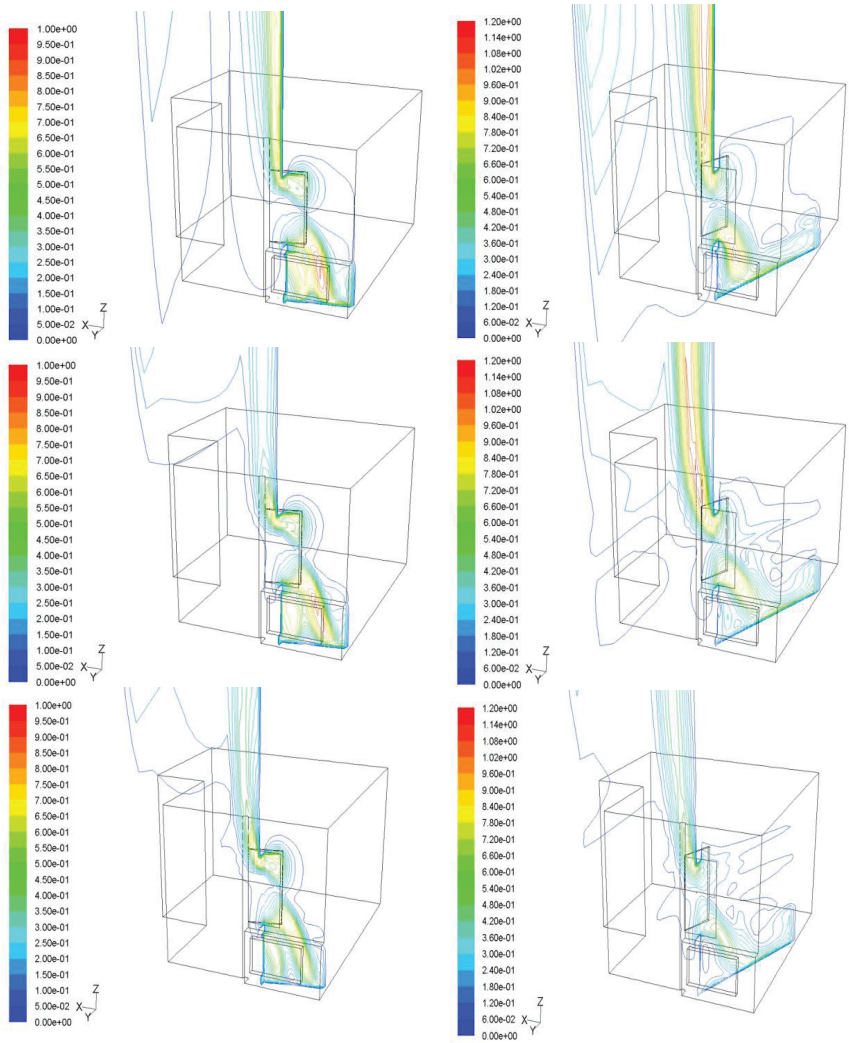

Figure 2. Velocity contours at 30, 90 and 180 seconds from the beginning of the aeration for the cases with 12.5% and 75% of window opening

Figure 3 demonstrates the turbulent intensity contours at 30, 90 and 180 seconds

from the beginning of the aeration for the cases with 12.5% and 75% of window opening. This parameter indirectly gives more understanding about the mixing processes between the indoor air (potentially polluted) and the outdoor air (assumed as clean). It is shown that for the case with 75% open window, the total mixing is more intense and for the simulated time it covers wider areas from the occupied space in the room. At the beginning of the aeration, there are more intensive mixing zones inside the simulated space, compared to the situation after 180 seconds from the aeration beginning. At that time, the convective flow from the warm radiator again intensifies the mixing process but in that case outside the occupied space.

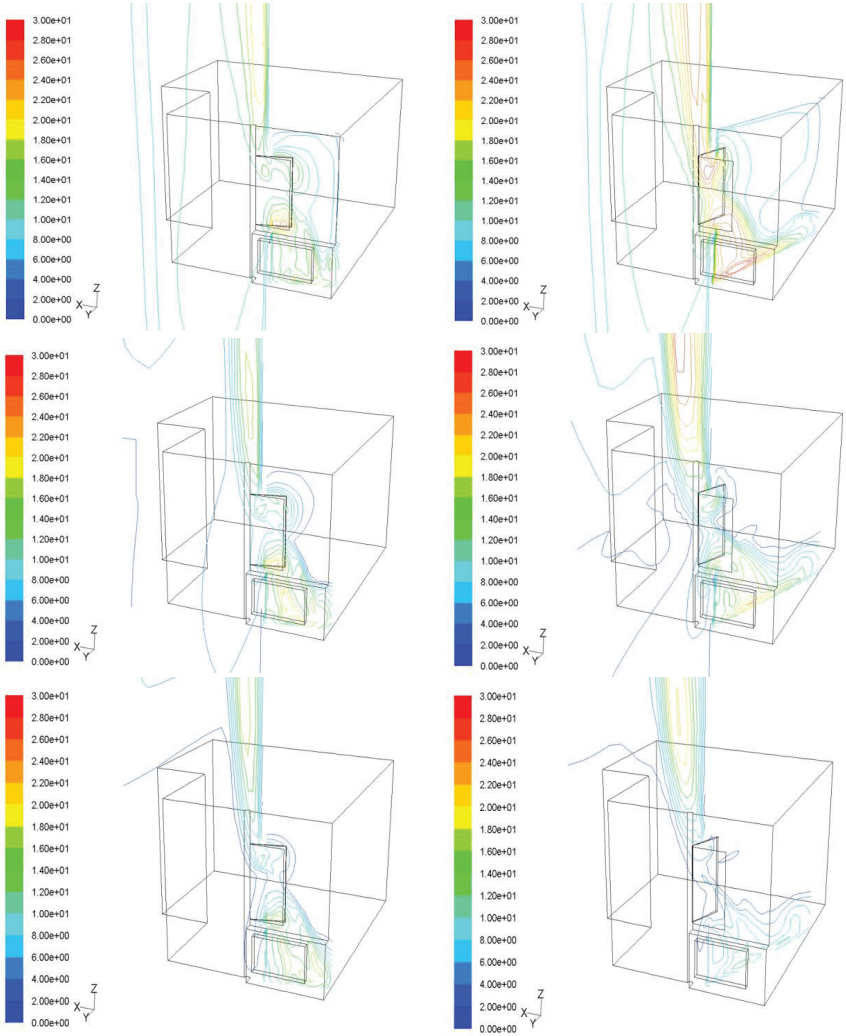

Figure 3. Turbulent intensity contours at 30, 90 and 180 seconds from the beginning of the aeration for the cases with 12.5% and 75% of window opening

CONCLUSION

Numerical simulation is carried out of the aeration process in a bedroom without mechanical ventilation at various levels of window opening. In such spaces indoor air replacement by outdoor fresh air is driven by the gradient between temperature of the indoor and outdoor air as it is shown by the results presented.

Nevertheless that the developed model has certain disadvantages, the numerical results visualize with good accuracy the mechanisms of aeration by opening of windows and doors through the time variation of the basic flow parameters and flow pattern variation.

The developed numerical procedure could be used for simulation of aeration process in any kind of spaces. Based on this procedure recommendations could be prepared in any practical situations about the length of the aeration period and the level of window opening under different temperature differences.

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The paper is reviewed.