On the influence of the pressure difference on air curtain behavior

Emanuil Georgiev, Detelin Markov, Peter Stankov

On the influence of the pressure difference on air curtain behavior: *The aim of this paper is to present a study on the influence of the pressure differences on a working vertical and horizontal air curtains behavior and sealing efficiency. The study is based on a detailed numerical simulation by means of Computational Fluid Dynamics method - a standard k-ε turbulent model with a pressure based solver at a steady state condition together with a first order upwind discretization scheme were used.*

Key words: *Vertical and horizontal air curtain, CFD, sealing efficiency.*

INTRODUCTION

Air curtains are useful in situations where conventional barriers become unacceptable due to practical, economical or safety reasons. They are used to separate without a physical barrier two adjacent spaces with different indoor environment parameters; an indoor environment from the outdoor environment; warm indoor environment from the cold outdoor environment; cold indoor environment from the hot outdoor environment and to protect the exchange of matter – dust, moisture, pollutants, insects, etc. [1, 2, 3, 4] - *Figure 1* [4]. The aim of the study is to evaluate flow pattern and sealing ability of different air curtains under isothermal conditions and various pressure differences between the outdoor environment and the protected space.

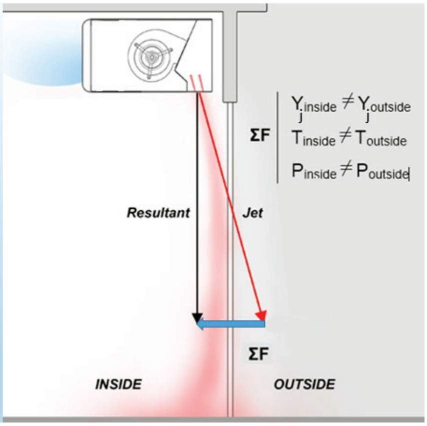


Figure 1. Schematic representation of an air curtain

NUMERICAL DETAILS

In order to simulate a working vertical and horizontal air curtains a computational domain was built in Fluent's preprocessing program Gambit 2.4 – *Figure 2*. The simulated situation was represented by 3 different volumes - 8x8x8 m for the outdoor environment, a volume of 4x4x4 m representing the protected space. The volumes have been connected through a third domain (a door) with dimensions 2x1x0,32 m (HeightxWidthxLength). On the top of the door a box simulating a conventional vertical air curtain with dimensions 0,25x025x2 m (HeightxWidthxLength) was placed. The suction and discharge nozzles of the vertical air curtain were represented by two rectangulars, with dimensions 0,9x0.05 m (LengthxWidth), placed on the top and respectively on the bottom of the box.

The horizontal air curtain was built by a system of nozzles placed on the both sides of the door – four on the right and three on the left side – *Figure 3*.

For the purpose of the numerical simulation a non-uniform block-structured non-conformal grid with 800 000 cells was generated – *Figure 4*.

In order to simulate an outdoor environment the left, right and top side of the domain are set as pressure outlets. The bottom and the front face of the volume, which is in a contact with the door are set as walls – simulating a ground and a wall. Wind with different velocities was generated by setting the back face of the volume as a pressure inlet boundary condition. The discharge and suction nozzles of the vertical air curtain were set as mass flow inlet and outlet. The horizontal air curtain nozzles were set as velocity inlets. On the back wall of the protected zone a square face with dimensions 1x1 m was placed, representing a ventilation shaft with boundary condition – pressure outlet, left on 0 Pa gauge pressure.

For all cases a standard k-ε model with a pressure based solver at a steady state and isothermal conditions of 296,15 K together with a first order upwind discretization scheme were used.

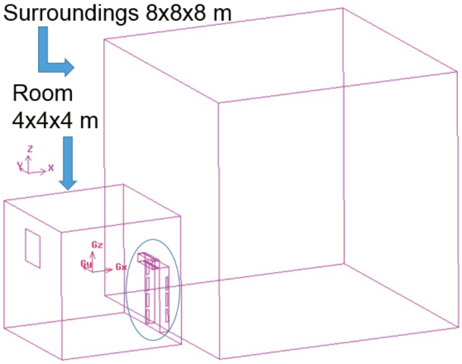


Figure 2. Geometry of the computational domain

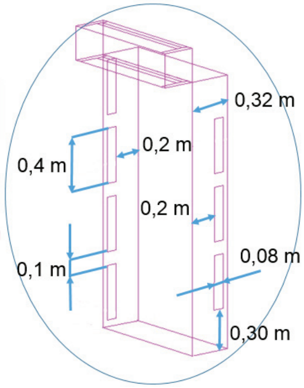


Figure 3. Geometry of a vertical air curtain unit and nozzles

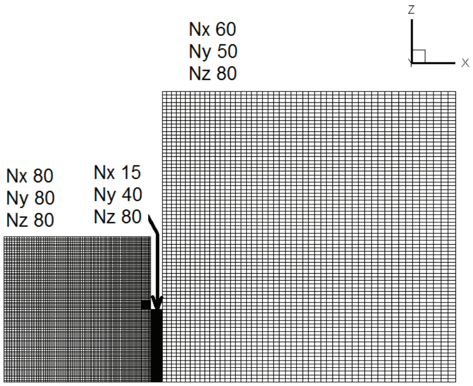


Fig. 4. Computational grid

RESULTS AND DISCUSSION

The presented numerical results describe the air curtains in operating mode. All performed cases are shown in *Table 1* together with *Table 2* where the mass flow rate is given according to the relevant discharge velocity.

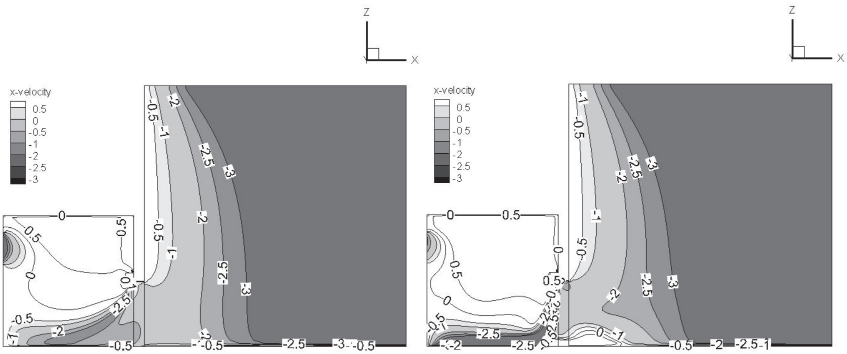
Table 1. Tested conditions

	Air curtain unit (ACU) - isothermal cases									
	NO ACU	Vertical ACU			Horizontal ACU					
ΔP, Pa	-	10m/s	20 m/s	30 m/s	2 m/s	4 m/s	6 m/s	8 m/s	10 m/s	15 m/s
5	+	+			+	+	+	+		
10	+	+			+	+	+	+		
15	+	+	+	+	+	+	+	+	+	+

Table 2. Discharge velocity, m/s and mass flow rate, kg/s, of an air curtain unit at different tested conditions

Type ACU	Discharge velocity m/s	Mass flow rate kg/s
Vertical	10	0,53
	20	1,06
	30	1,59
Horizontal	2	0,53
	4	1,05
	6	1,61
	8	2,17
	10	2,66
	15	3,99

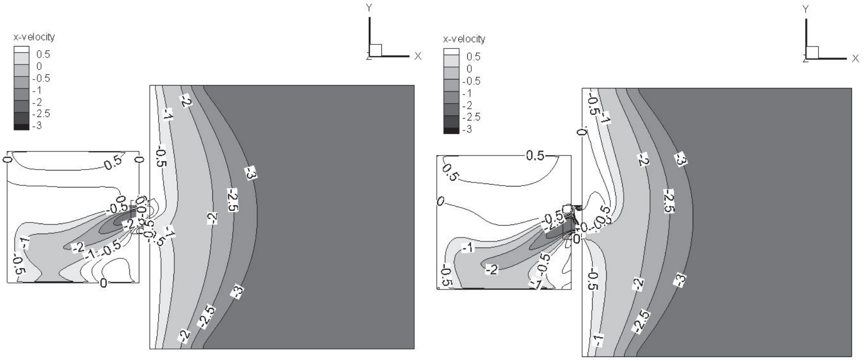
On *Figure 5* the X velocity component (u, m/s) contours in a plane passing through the middle of the door and the vertical air curtain at 10 m/s and ΔP 15 Pa - *Figure 5 (a)* and 15 m/s and ΔP 15 – *Figure 5 (b)* Pa are shown. The negative value of the X velocity component is caused by the movement of the air stream in an opposite direction to the coordinate system. As it can be seen a discharge vertical velocity of 10 m/s is not enough to stop the flow from the outdoor environment. A vertical air curtain with a discharge velocity of 30 m/s at the same pressure difference level of 15 Pa performs much better. Part of the air curtain's jet after reaching and hitting the floor spreads and leaves the protected zone.



a) b)

Fig. 5. Contours of the X velocity component (u, m/s) in a plane passing through the air curtain, vertical air curtain 10 m/s and ΔP 15 Pa (a), 15 m/s and ΔP 15 Pa (b)

The X velocity component contours in a plane 0.9 m above the ground for a horizontal air curtain at 10 m/s and ΔP 15 Pa and 15 m/s at ΔP 15 Pa are shown on *Figure 6 (a)* and *(b)*. The generated impulse of the horizontal air curtain having a discharge velocity of 10 m/s is not high enough to seal the premise well. It seems that the horizontal air curtain working on 15 m/s at ΔP 15 Pa seals the door.



a) b)

Fig. 6. Contours of the X velocity component (u, m/s) in a plane 0.9 m above the ground, horizontal air curtain 10 m/s and ΔP 15 Pa (a), 15 m/s and 15 Pa (b)

For all studied cases the mass flow rate on the door is presented as a function of the pressure differences - *Figure 7*. As it can be seen all cases have sealing effect on the door. The best case for the highest pressure difference at *ΔP* 15 Pa is with a horizontal air curtain with discharge velocity of 15 m/s.

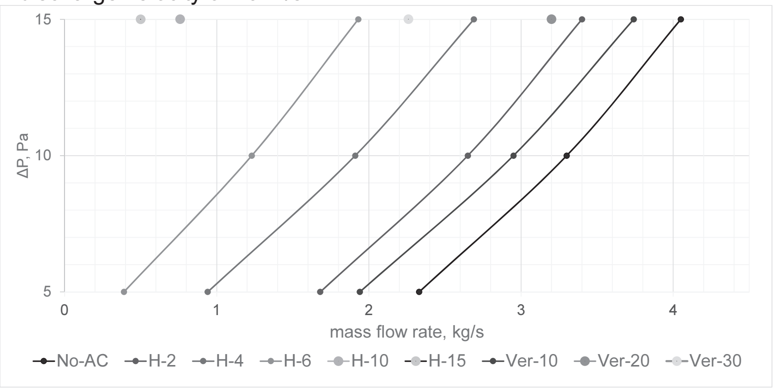


Fig. 7. Mass flow rate, kg/s, on the door at different pressure levels

CONCLUSION

The obtained results show that a conventional vertical air curtain with discharge velocity of 10 m/s is unable to seal well a protected area under pressure difference of 15 Pa.

The horizontal air curtains with a discharge velocity of 2 and 4 m/s have a better sealing ability compared to the vertical ones at 10 and respectively 20 m/s.

The length of the vertical air curtain’s nozzle should equal the width of the door.

In order to evaluate reliably the sealing ability of an air curtain the transport of a tracer gas must be simulated together with the flow and temperature field. The tracer gas source must be located in front of the inlet of the protected premise.

REFERENCES

[1] Georgiev Emanuil, Air curtains – present status and perspectives, Ninth International Course for Young Researchers, Pamporovo, 2013, 119-120.

[2] Georgiev Emanuil, Stankov Peter, Markov Detelin, On the numerical study of air curtains, XVIII International scientific conference FPEPM, Sozopol, 2013, 55-61.

[3] Leading Edge a Marley Engineered Products Brand, Design&Application Guide, 2008.

[4] Simper J.I., New uses for air curtains, BSE 43, 1975, A16–A18.

For contacts:

MSc. Eng. Emanuil Georgiev – “Department of Hydroaerodynamics and Hydraulic machines”, Technical University – Sofia, tel.: +35929653305, e-mail: emanuilg@tu-sofia.bg;

Assistant Prof. Detelin Markov – “Department of Hydroaerodynamics and Hydraulic machines”, Technical University – Sofia, tel.: +35929653305, e-mail: detmar@tu-sofia.bg;

Prof. DSc. PhD Peter Stankov – “Department of Hydroaerodynamics and Hydraulic machines”, Technical University – Sofia, tel.: +35929652326; +35929653305, e-mail: peter.stankov@abv.bg

This paper has been reviewed.