GE-International Journal of Engineering Research
ISSN(O): 2321-1717, ISSN(P): 2394-420X
Impact Factor- 5.613, Volume 5, Issue 11, November 2017
Website- www.aarf.asia, **Email** : editor@aarf.asia , editoraarf@gmail.com

NATURAL EXHAUST OF FLUE GASES VERSUS POWERED EXHAUST OF CONTAMINATED AIR IN THE SAME ROOM

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ABSTRACT

The paper deals with common natural exhaust of flue gases from standard gas heating appliances with open flame inside the room/flat, as water heaters etc., and powered exhaust of contaminated air in the same room /flat as kitchen hood. At some circumstances can arise the danger for residents. As integral part of it, the text contains short discussion about principal rules of room ventilating, influence of chimney hood etc. Here are not discussed more sophisticated systems of ventilation, which are more complicated and need higher investment costs, as heat recovery etc.

KEYWORDS - Natural exhaust, Powered exhaust, Chimney, Room ventilation, Flow numerical simulation

1. Introduction

The paper describes the problem of areas, where the heating and water warming is necessary during the winter period and gives suitable procedures of ventilation and exhaust of flue gases.

Using various gas-heated appliances with open flame inside the room/flat, as water heaters etc., some dangers for inhabitants arise, in combination with powered exhaust of contaminated air in the same room/flat, as powered kitchen hood. Next adjoining themes are added and discussed, as the influence of chimney hood on exhausted volume, principal rules of room ventilation etc. They are not discussed more sophisticated systems of ventilation, which are more complicated and need higher investment costs, as for instance [1].

2. Combination of gas heater and kitchen exhaust

Switching on the gas heater simultaneously with powered exhaust of kitchen hood, the exhaust partially reduces the natural exhaust of flues gases from the heater and arises the danger for residents due to their partial backflow in the room. The situation is visible in following figures. In the room A is installed the gas heater with chimney of natural exhaust of flue gases, in the room B is installed powered exhaust of kitchen hood. Both room are connected by the third one (C), used labels A, B, C, see the Fig. 1. The model supposes the openings in walls and open doors between rooms, only, here are not considered nor the necessary exhaust piping (lengths, shapes), either buoyancy of hot flue gases in exhaust. Really, the backflow of flue gases will be lower, when the door is shut, but not tight, flow resistances of piping etc.

During the operation of both devices some open ventilation must be open, to bring enough of air for the combustion. Results of solved cases see the overview below, together with relevant streamlines. Individual streamlines have different colors, so it is possible to track some of them.

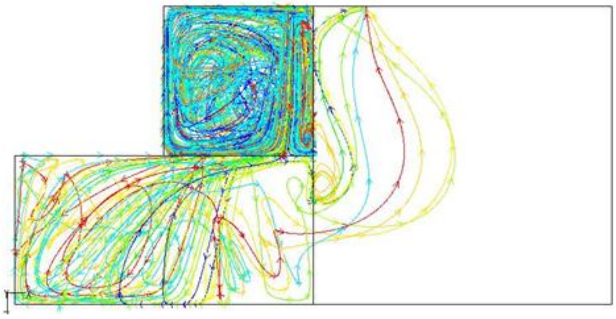

Figure 1: Streamlines of the Case 1

Case 1: Both observed devices are operating, both ventilation openings are shut. The suction of kitchen exhaust is realized through the flue gases chimney. It is dangerous, first in the room A of gas heater.

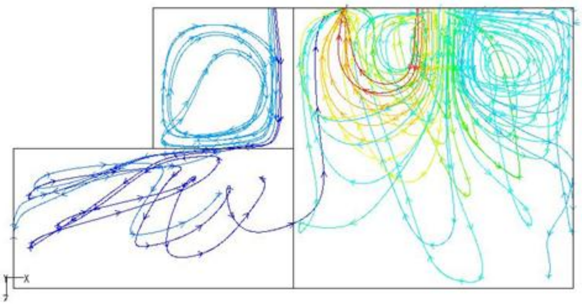

Figure 2: Streamlines of the Case 2

Case 2: Therefore, during the common operation of both devices, some ventilation must be open. Here is tilted the window wing in the room of exhaust (B), near to the exhaust. So arises narrow opening at the ceiling, but some backflow through the chimney remains.

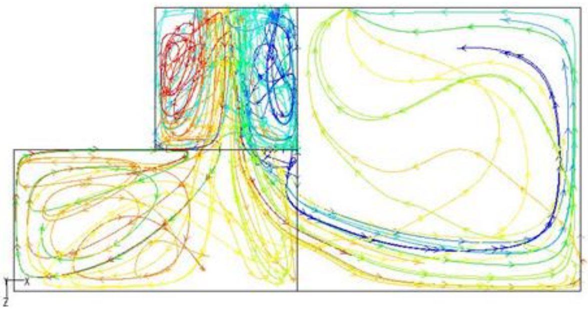

Figure 3: Streamlines of the Case 3

Case 3: Another variant of the same case. Here is tilted the window wing in the room of heater (A), but some backflow through the chimney remains.

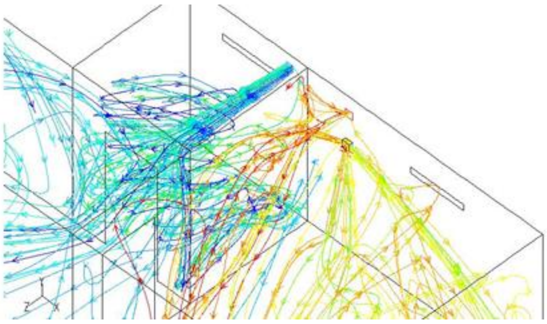

Figure 4: Streamlines of the Case 4

Case 4: Reuse of the former opening for air inlet, near to the kitchen hood, is not suitable, because the orifice cross section is comparable with the cross section for flue gases and so the exhausted volume is divided quite uniformly between both inlets. The influence of added cover, to suppress the short-circuit flow, is negative, it is the next flow resistance in the system.

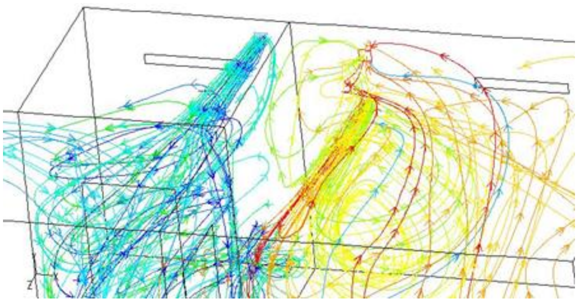

Figure 5: Streamlines of the Case 5

Case 5: The same situation, but without the cover.

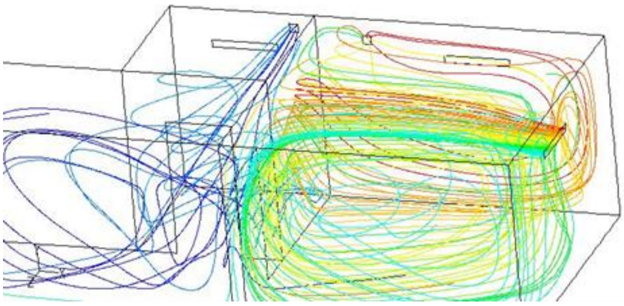

Figure 6: Streamlines of the Case 6

Case 6: Tilted window wing in the distant wall in the room of kitchen exhaust. This case seems to be the most useful, the room is well flushed, and the backflow of flue gases is minimum. At the same time the exhausted volume is lower of 15% approx., compared with cases 2 or 3, therefore the heat loss is lower, too. Better alternative to the case 2.

Figure 7: Streamlines of the Case 7

Case 7: The combination of two open ventilations (cases 3+6). The result is similar to the case 6, inlet flow through both inlets; the backflow in chimney is lower yet. But uncomfortable manipulation with two openings in two different rooms.

Results of all simulated cases are summarized in the Table 1. They are presented mass flows in (g/s) for the same pressure difference of 100 Pa.

Table 1: Mass flows (g/s) in observed cross sections

case	Chimney A	Vent. B close	Vent. A	Vent. B dist.	Form. open.	exhaust
1	143,5					-143,5
2	25,7	168,4				-194,1
3	26,9		168,8			-195,7
4	91,4				58,7	-150,1
5	78,3				75,4	-153,7
6	22,3			143,3		-165,6
7	12,0		77,3	77,2		-166,5

Conclusion: To prevent the backflow of naturally exhausted flue gases due to operation of powered kitchen exhaust it should be the best to use an automatic device, which blocks the exhaust operation during the heater operation.

3 Chimney Hood

The effect of chimney hood, used with typical gas appliance, as for instance gas heater / boiler, is discussed here as complement to the previous section. More about it see for instance [2], [3].

3.1 Chimney outlet on the horizontal flat roof

Here are solved different chimney caps on horizontal roof. Defined values: chimney diameter of 100 mm, inlet pressure of 10 Pa (given simply as constant, instead the value of gravity circulation as consequence of temperature differences) and temperature 300 K - measured temperatures are higher, therefore real driving pressure difference is higher, too. In the surroundings the crosswind of 0 to 40 Pa (to 8 m/s approx.), 270 K. Turbulence model k-ε, and symmetrical half-model – presented results are valid for one-half of the model. The influence of different caps is summarized in the Table 2 as the relevant flow compared with the initial case.

Free end (cases 1-2-3) – with increased effect of the crosswind the flow is decreasing on 75%.

Conical hood, very closed (cases 4-5-6) – the flow is decreasing on 40% of previous case, only - the designed shape is very close, therefore the cap resistance is very high – the flow bend of 180° under the cap represents very high pressure loss. With increased velocity of the crosswind, the flow is further decreasing.

Coaxial hood (cases 7-8-9-10) – with increased velocity of the crosswind the flow is increased, too. The dynamic pressure on the windward side creates the vertical flow, too, which together with this cap protects the outlet from wind effect. The last case 10 of decreased draught of 2 Pa is similar to the case 7 at zero wind.

Table 2: Summary of results

cap	case	wind press.	chimney press.		flow
		Pa	Pa	m/s	%
	1	**0**	**10**	**4,14**	**100%**
free end	2	10	10	3,06	74%
	3	40	10	3,04	73%
	4	0	10	1,69	41%
conical	5	10	10	1,58	38%
	6	40	10	1,02	25%

	7	0	10	4,12	100%
	8	10	10	4,5	109%
coaxial	9	40	10	5,44	131%
	10	40	2	4,10	99%

As an illustration, the Fig. 8 presents velocity fields of all solved cases 1 to 9.

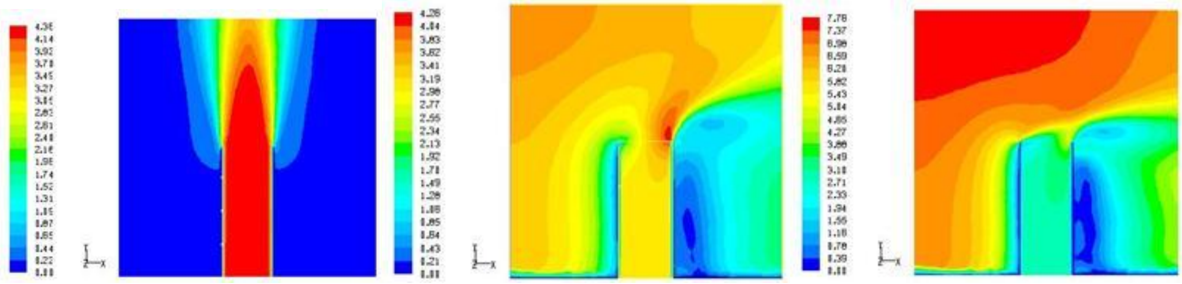

Figure 8a: Velocity Fields free End (draught of 10 Pa, crosswind of 0-10-40 Pa)

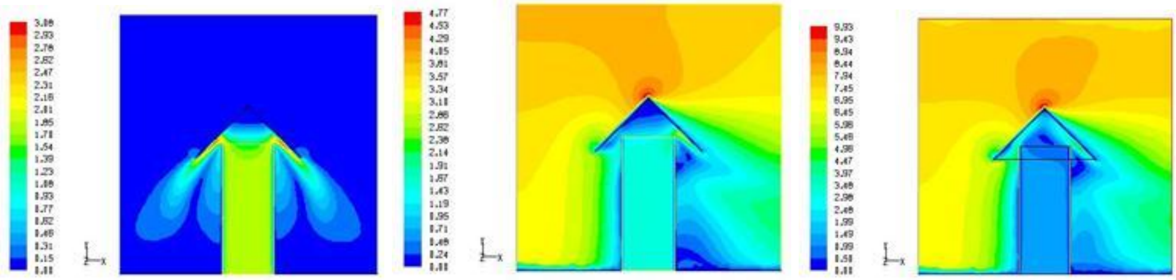

Figure 8b: Velocity Fields for Conical Cap (draught of 10 Pa, crosswind of 0-10-40 Pa)

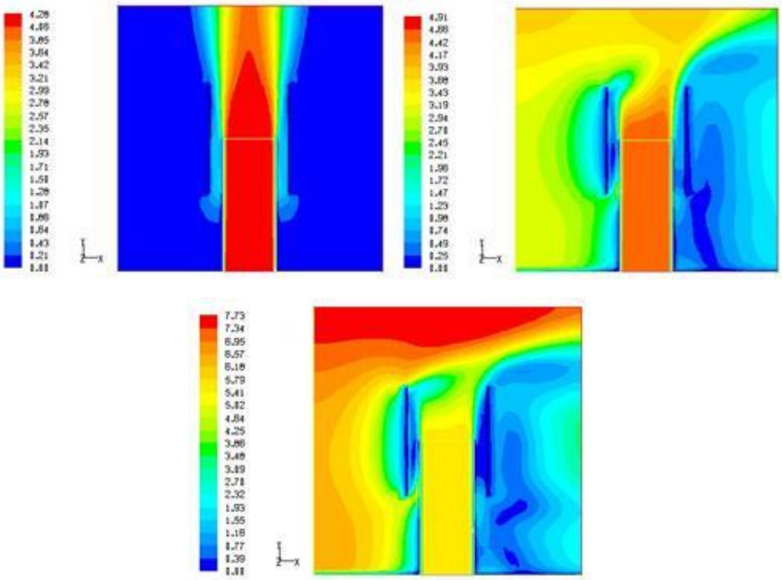

Figure 8c: Velocity Fields for Coaxial Cap (draught of 10 Pa, crosswind of 0-10-40 Pa)

3.2 Chimney outlet on the inclined roof

Next influence on the chimney flow has the wind effect along the inclined roof (here of 45°). For the chimney outlet on such inclined roof, there are solved similar cases for the same boundary conditions as above, but for wind directions from both sides. Due to many solved cases, the summary results are presented as the common graph on the Fig. 9, only. The free end is declared as standard, all other cases have less flow, except the case of coaxial hood.

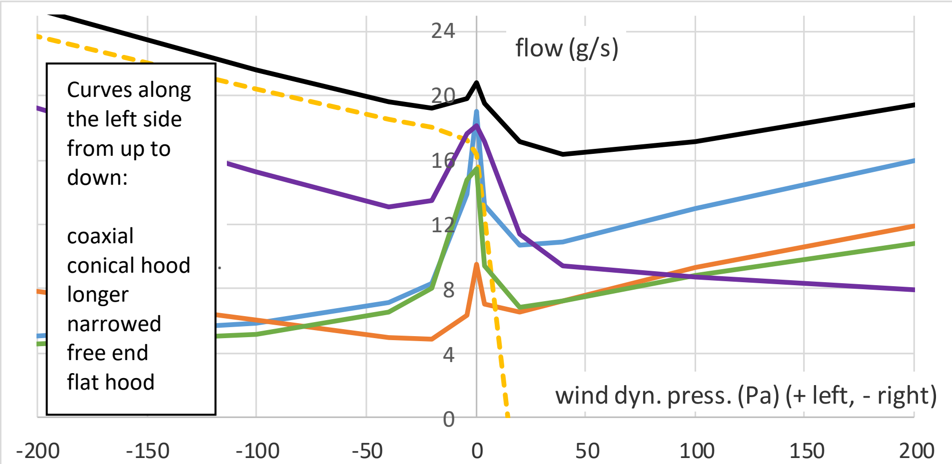

Figure 9: Flow Under Various Conditions – inclined roof, various caps, and various crosswind velocity

Results of the detailed observations for the coaxial hood, only, presents the Fig. 10. The standard case from the Fig. 9 compared with smaller chimney effect and with longer horizontal part. Results are logical and so it is possible to use them as verification of used method of flow numerical simulation.

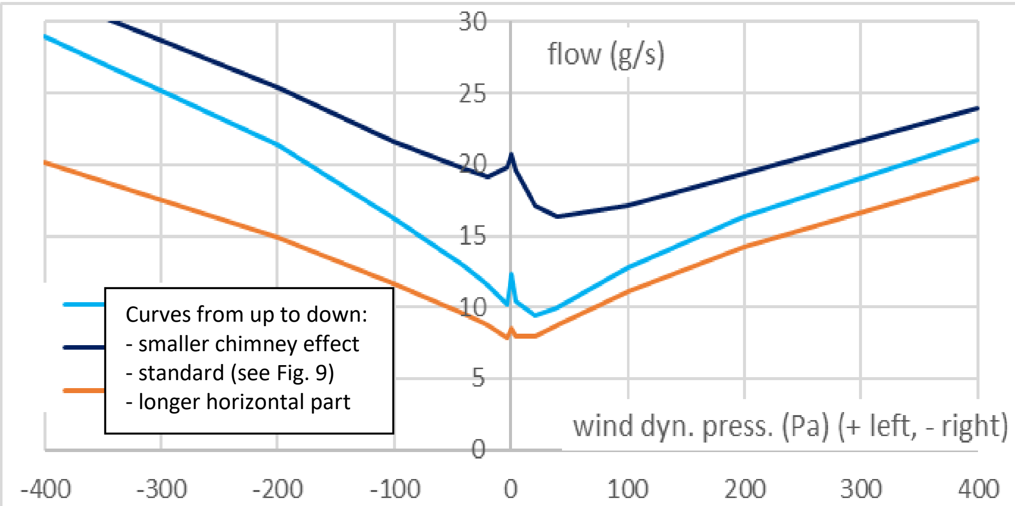

Figure 10: Various Cases for Coaxial Cap

3.3 Unsteady start

Typical for observed gas appliance is the short-time operational mode; therefore the start of the operation is here solved especially. Results of next solved case are for coaxial hood at simple vertical channel and for three values of wind see the Fig. 11.

Wind 0 Pa – flow is starting immediately in the needed direction (they are positive values, only).

Wind 4 Pa with minimum flow – at the beginning, the flow is in opposite direction (negative value) – flue gases are flowing inside, after some time delay the flow is reversed in needed positive direction outside.

Wind 20 Pa with sufficient flow – the undesirable negative pick is not so expressive, but the reversing period is longer.

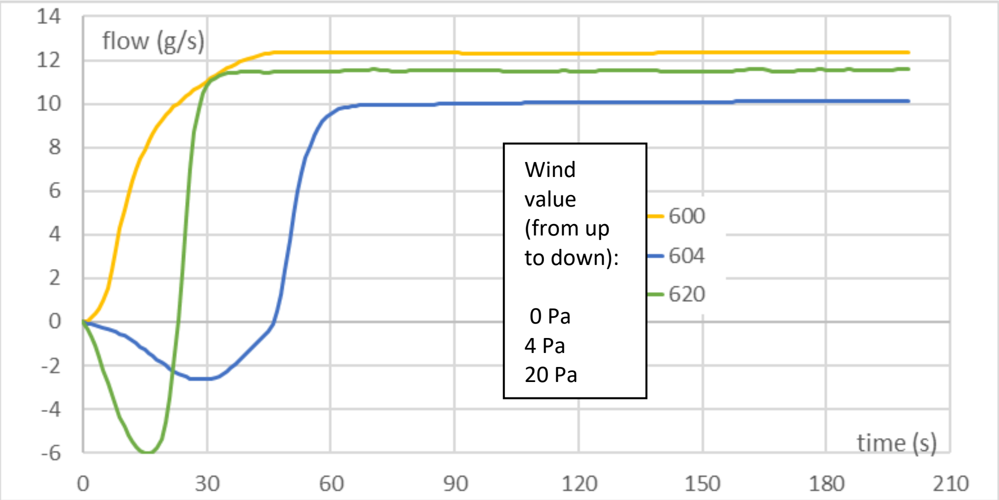

Figure 11: Flow Starting after Burner Ignition – short vertical channel

Results are presented for short vertical channel after the Fig. 8a, only. Using longer horizontal inlet part, i.e. without next effective pressure difference, but with pressure losses, only, the time period of negative flow is longer than here on the Fig. 11 – without next details. From such summary graph above it is possible to evaluate three important time points:

- the point of maximum negative flow
- the end of negative flow
- the fully developed steady flow in needed positive direction.

Due to the typical short-time operation of the heater, such relative long period of negative flow at the start of operation is undesirable. Calculating the volume flowing inside during this starting period it is possible to evaluate the time for full exhaust of flue gases outside again.

The best solution seems to be the coaxial protective hood, protecting the chimney flow from wind influences etc. Various hoods against rain etc. decrease flow and cause undesirable backflow. Some problems arise at the start of the operation – period of backflow before the satisfactory chimney effect is created by filling of the channel with hot effluents.

4 Room Ventilation

The conditions in living rooms must be comfortable enough – to take out various contaminants, as higher humidity, increased fraction of CO_2 or other contaminants etc. More about it see for instance in [4], [5], here a simple overview, only, is given for two solved cases, as amendment for above-mentioned problems. Generally said, after many solved cases, the ventilation at fully open window is the most effective, the effect of the narrow tilting of the window is very low.

4.1 Window fully open

Very simple ventilation by open window – short and intensive. The air exchange is sufficient and walls do not cold too much. As an example see following Fig. 12 to Fig. 15 for temperatures out/in = +22°/0°C, including changes of air density with temperature, air draught of 0,1 to 1,0 Pa, only. Without the effect of heater under the window.

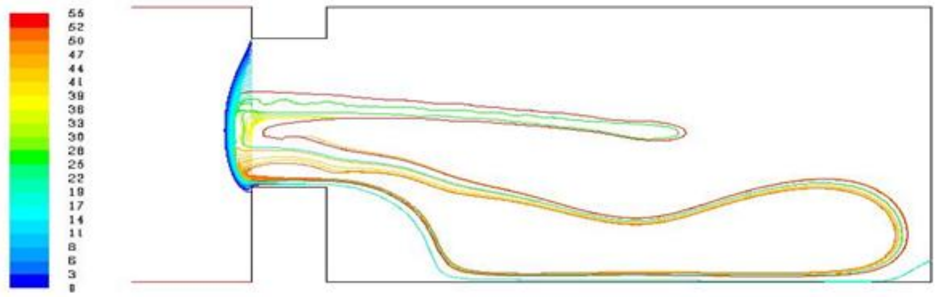

Figure 12: Streamlines from Fully Open Window in the Room (surroundings = left)

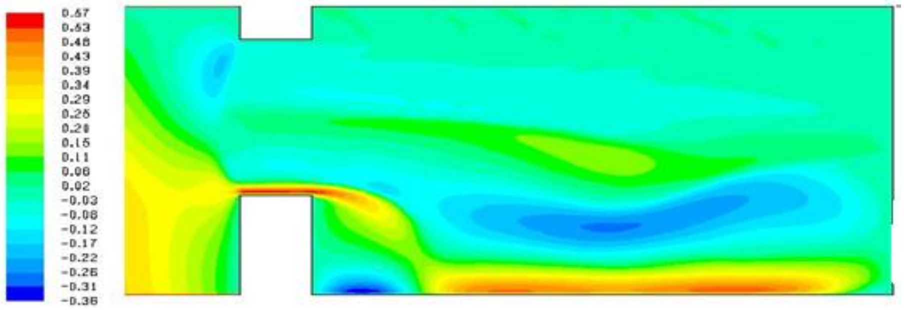

Figure 13: The Same Situation, Presented as Isolines of Horizontal Velocity Component (wx)

The main flow of exchanged air is flowing along the floor to the opposite wall, than is moving back along the ceiling.

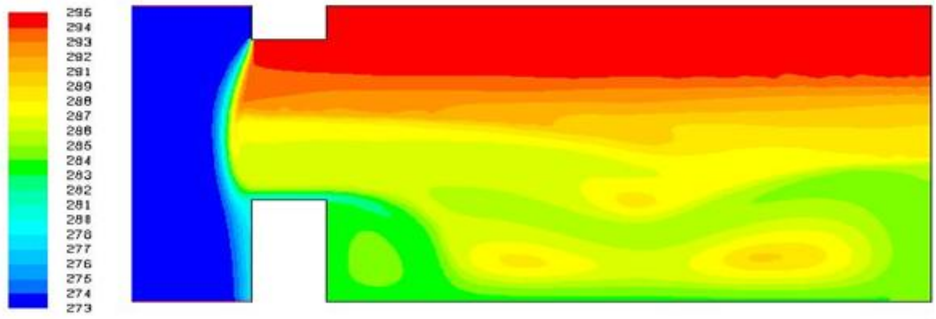

Figure 14: Corresponding Stratification of Temperature – cold at the floor, hot at the ceiling

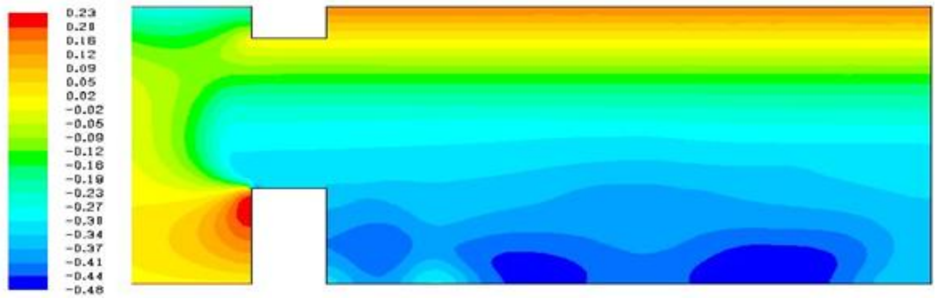

Figure 15: Corresponding Pressure Stratification – driving force of the observed ventilation

4.2 Tilted window

Frequently used ventilation mode – the simulation results in the Fig. 16 to Fig. 18 show its ineffectivity. The exchanged volume is low, but wall near the opening is cold and humidity condensation can arise there.

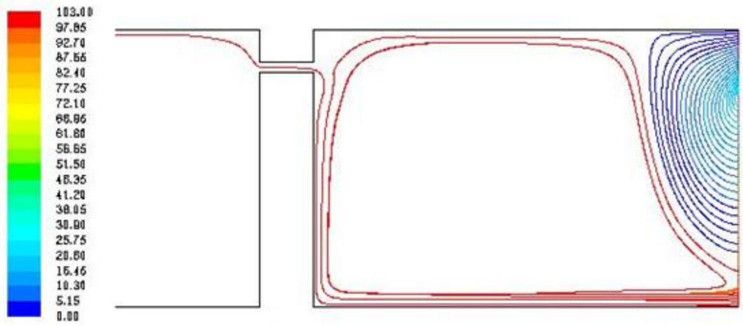

Figure 16: Streamlines at Tilted Window – the room volume is hardly ventilated

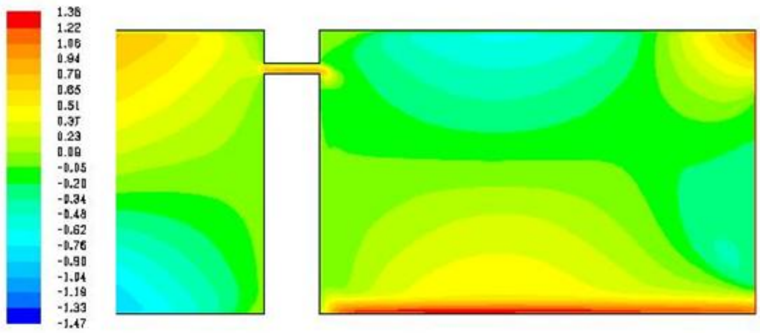

Figure 17: The Same, Presented as Isolines of Horizontal Velocity Component (wx)

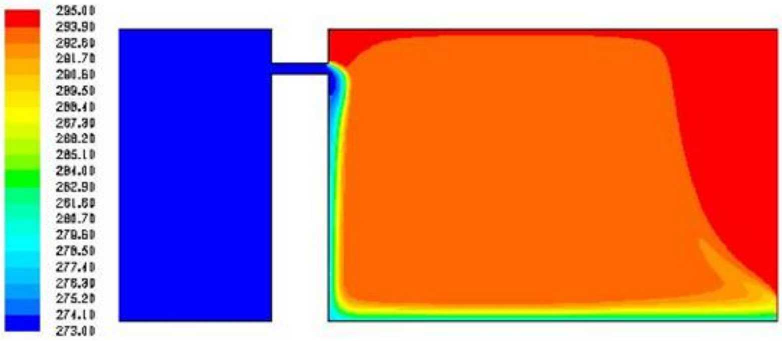

Figure 18: Temperature Field at Tilted Window – ventilating effect is feeble

Another simple ventilation devices are presented in [1], [6] etc., operate without any external power source and assume some minimum air exchange.

5. Summary and conclusion

The main conclusion for individual solved themes are just in relevant Par. 2, 3, 4, where simple and standard realization of chimney for flue gases, exhaust flue gases, room ventilation etc. are discussed. Of course, exist more sophisticated systems [1], [6] etc., need higher investment costs.

1. To prevent the backflow of naturally exhausted flue gases due to operation of powered kitchen exhaust it should be the best to use an automatic device, which blocks the exhaust operation during the heater operation. Among several tested cases, the best is the tilting of the window wing in distant wall of the room.

2. As to the chimney cap, the best prevention against the blocking effect of the crosswind is the coaxial hood around the chimney end. The crosswind is blocked and more, some positive additional draught arises here.

3. Such coaxial chimney cap gives the best suppression of the wind effect along inclined roof on the exhausted volume.

4. At the burner start arises in chimney short time of negative flow; the simulation presents the extreme value and the time of such unsuitable operation. The volume of negative flow must be exhausted again during next operation; its time can be calculated from simulation results.

5. As to the room ventilation the most effective is the short-time opening of the whole window wing. Tilted wing creates narrow ventilating orifices, only, and is not effective.

Acknowledgment

Our acknowledgment is given to VUTS Liberec – Center for Development in Machinery Research for the support in the framework of the grant NPU-LO1213 "National program of sustainability, granted by the Ministry of education, youth and sports.

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