Natural Ventilated Building Thermal Simulations

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Abstract

Ventilation is mainly used to control indoor air quality and for the purpose of thermal comfort by diluting and displacing pollutants. Because of the effects it has on health, comfort, and serviceability, indoor air quality in our homes is becoming of increasing concern to many people. Many countries even push citizens to opt for energy conservation , energy savings buildings based on natural ventilation. The design of kitchen ventilation or exhaust hoods are gaining significance in this modern world due to buildings with air tight spaces and due to effluents or smokes generated.

In this, a comparative simulation study between the natural and forced ventilation in kitchen is considered using **COMSOL software**. As per the Ventilation rate standards, ventilation rate is expressed in terms of volumetric flow rate of outside air introduced into the building Typical units used are cubic feet per minute (CFM) or litres per second(L/s).

Keywords: Natural ventilation of buildings, Buoyancy based Kitchen ventilation, Flow/CFD , Chimney design,Multiphysics CAE

1. Introduction

Natural ventilation is the means of air flown into and out of indoor space by natural phenomenon, without the use of mechanical systems. In view of raising concerns with regard to cost, energy consumption and its effect on environmental impact, the trend of opting for natural ventilation is gaining high significance from all over the world. Natural ventilation will ensure better healthy and comfortable conditions for occupants in living space, along with energy saving. In this paper, a brief review of natural ventilation mechanisms is given. Critical mechanisms are discussed in detail. A COMSOL based model of a representative building component such as a kitchen is considered. The wind driven and buoyancy type ventilation are considered in simulations. The energy saving potential is estimated and highlighted. This study has wider implication on overall natural ventilated building , climate control in automobiles and data center Thermal management.

2. Natural Ventilated Simulations using COMSOL MULTIPHYSICS®

Focus of this work is to evaluate the difference in performances between natural and forced ventilation and thereby illustrate the potential energy savings by eliminating the usage of mechanical forced systems. In **COMSOL Multiphysics software**, Turbulent flow, Heat Transfer in Fluids and Nonisothermal flows are selected. Three cases are considered, Case 01: Natural ventilation based simulation, Case 02: Forced ventilation based simulation and Case 03: Parametric study on chimney height using natural ventilation, so as to equalize the performance with that of forced ventilation. The boundary conditions, for example, Velocity of air at the inlet is taken as 0.27 m/s and at the outlet opening, pressure boundary condition is applied. Inlet opening temperature of air is considered as 303.15 K. Time-dependent study was performed for performance evaluation.

2.1. Mechanisms and governing/ empirical Equations of Natural Ventilation

2.1.1.Wind driven ventilation:

Wind driven ventilation depends on wind behaviour and openings such as inlets.when natural ventilation is driven only by wind, pressure difference is created by wind speed and direction of the wind. A basic knowledge about the pressure distribution around a building structure will assist in understanding the airflow inside.

$$\Delta P_{wind} = \Delta C_p . \tfrac{1}{2} . \rho \; . v_{ref}^2 \qquad \text{---------} \qquad (01)$$

Airflow rate due to wind,

$$Q_V = \pm C_D . A . \sqrt{\frac{2.|(\Delta P_{wind})|}{\rho}} \qquad \text{-------} \qquad (02)$$

Where

c_P – pressure coefficient, dependent on shape of building,wind direction

ΔP - the pressure difference on the surface relative to the pressure at some reference point.[Pa]

v_{ref} - Reference mean velocity of wind, velocity at roof height [m/s]

ρ – Outdoor air density [kg/m3]

Q_V - Wind-driven ventilation airflow rate, m³/s

A - cross-sectional area of opening, m²

C_D - Discharge coefficient for opening (typical value is 0,65)

2.1.2. Buoyancy driven ventilation:

Buoyancy driven ventilation arise due to difference in temperature. When there is temperature difference between adjoining volumes of air, the warmer air has lower density and thus rise above cold air creating an upward air stream.

$$(\Delta p)_{Buoyancy} = \rho \; .g.(H_U - H_L). \frac{(T_i - T_o)}{T_o} \qquad \text{--------} \qquad (03)$$

Airflow rate due to buoyancy,

$$Q_V = \pm C_D . A . \sqrt{\frac{2.|((\Delta p)_{Buoyancy})|}{\rho}} \qquad \text{--------} \qquad (04)$$

Where

g - gravitational acceleration, around 9.81 m/s² on Earth

$H_U - H_L$ - Height from midpoint of lower opening to midpoint of upper opening, m

T_i - Average indoor temperature between the inlet and outlet, K

T_o - Outdoor temperature, K

Q_V - Wind-driven ventilation airflow rate, m³/s

A - cross-sectional area of opening, m²

C_D - Discharge coefficient for opening (typical value is 0,65)

2.2 kitchen with chimney

2.2.1. Natural vs Forced Ventilation

Several factors normally considered comparing natural to forced ventilation are i) Fan power savings ii) temperature control iii) Occupant comfort zone.

Natural ventilation may not able to provide thermal comfort in unavoidable environment conditions.In order to overcome this, mechanical systems (such as fan) may be installed at the exit opening. Infiltration of air into indoors happens through leaks or cracks.The motivation behind this paper is to evaluate the difference in performances between natural and forced ventilation and thereby illustrate the potential energy savings by eliminating the usage of exhaust fan.

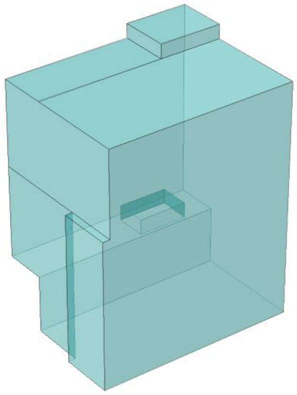
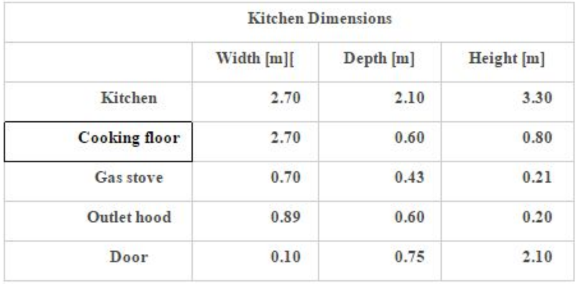


Figure 1: Parametric CAD model



Kitchen Dimensions			
	Width [m][	Depth [m]	Height [m]
Kitchen	2.70	2.10	3.30
Cooking floor	2.70	0.60	0.80
Gas stove	0.70	0.43	0.21
Outlet hood	0.89	0.60	0.20
Door	0.10	0.75	2.10

Table 1: Kitchen dimensions

4. Results and Discussions

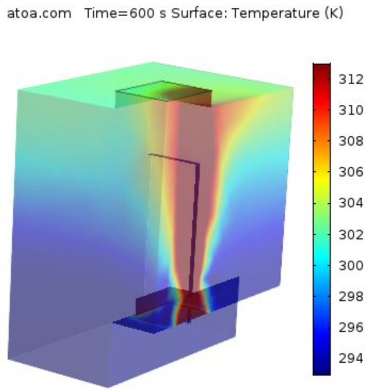


Figure 2. Temperature Profile based on Natural Ventilation (case 01)

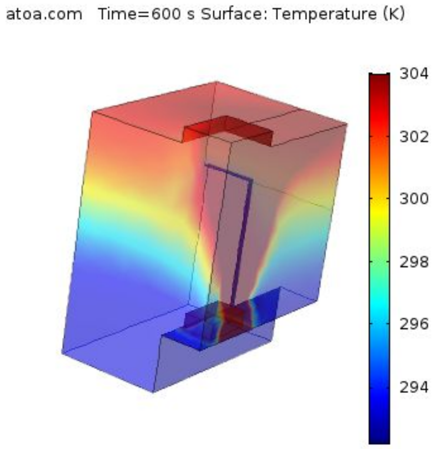


Figure 3. Temperature Profile based on Forced Ventilation (case 02)

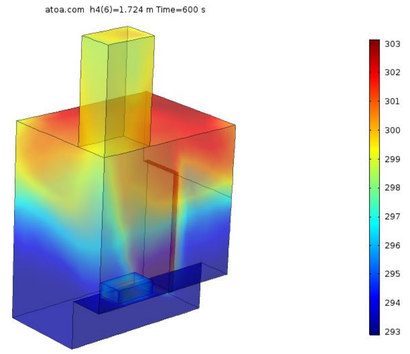


Figure 4. Temperature Profile to replace forced ventilation with increase in chimney heights (case 03)

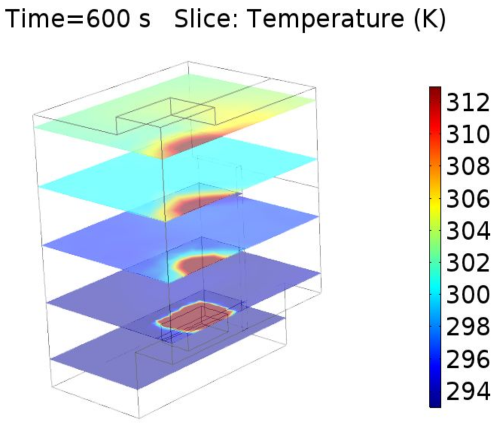


Figure 5. Slice plane Temperature Profile based on Natural Ventilation (case 01)

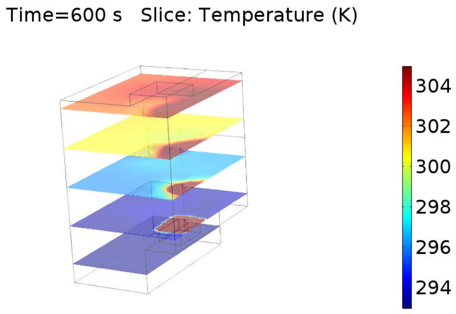


Figure 6. Slice plane Temperature Profile based on Forced ventilation (case 02)

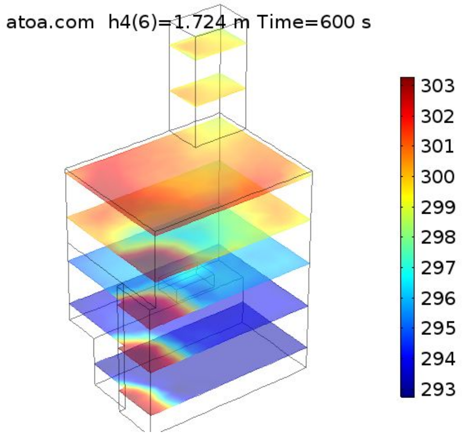


Figure 7. Slice plane Temperature Profile to replace forced ventilation with increase in chimney height case 3

Kitchen ventilation simulation study results are shown in figure 2-7. Temperature and slice plane temperature profiles are depicted using COMSOl Multiphysics software. Outflow temperatures for natural ventilation are in the range of 293 K -315 K [Fig.02.]. When an exhaust fan (forced ventilation) is used , temperature ranges between 293 K -304 K [Fig.03]. Parametric studies on chimney heights were conducted in incremented steps of 0.304799 m (=1 ft) from 0.2 m to 2 m. At 1.7432 m (=5 ft), the temperature ranges observed between 293 K -303 K [Fig.04]. Comparison of simulation results, shows that, usage of exhaust fan can be replaced by extending the height of chimney further by 1.7432 m (= 5 ft).

5. Conclusions

Increase in chimney height has equalized the effect of forced mechanical system, resulting in energy and cost savings. This cost savings are for small component such as exhaust fan. If energy and cost savings are considered for entire large buildings, cost savings will be much higher.

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