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Experimental investigations on solar chimney for room ventilation

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Abstract

Experimental investigations on a small size solar chimney show that the rate of ventilation increases with increase of the ratio between height of absorber and gap between glass and absorber. This finding is in agreement with results of the steady-state mathematical model developed for analysis of such systems. Nine different combination of absorber height and air gap have been investigated on the experimental set-up. Highest rate of ventilation induced with the help of solar energy was found to be 5.6 air change per hour in a room of 27 m^3, at solar radiation 700 W/m^2 on vertical surface with the stack height-air gap ratio of 2.83 for a 1 m high chimney.

Keywords: Solar chimney; Natural ventilation; Air movement; Stack effect

1. Introduction

Ventilation in residential buildings can be achieved using solar chimney as an integral part of any building. One or more walls of a vertical solar chimney are made transparent by providing glazed wall(s) for allowing the solar radiation to accumulate enough heat to induce the chimney effect. Various theoretical and experimental studies conducted for determining the size of a solar chimney, have established that the velocity of air flow and temperature of different parts are functions of the gap between absorber and glazed walls, ambient air temperature, insolation rate, and the elevation of air exit above the inlet duct. Akbarzadeh et al. (1982) analyzed a 2.66 m high Trombe wall with air gaps varying from 0.10 to 0.35 m with help of flow visualization studies to conclude that the mode of heat transfer is of purely convection between two single plates. Bansal et al. (1993) developed a steady-state mathematical model for a solar

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Nomenclature

Δw_{ins}	thickness of insulation behind absorber (0.05 m)
A_i, A_o	cross sectional area of inlet and outlet to air flow channel (m^2)
A_r	ratio of A_o to A_i
A_g	area of glass (m^2)
A_w	area of wall (m^2)
C_d	coefficient of discharge of air channel inlet (0.57)
C_{fl}	specific heat of air (J/kg K)
d	gap between absorber wall and glass (m)
H	incident solar radiation on south facing vertical surface (W/m^2)
h_c	conductive heat transfer coefficient for glass (W/m^2 K)
h_g	convective heat transfer coefficient between glass cover and air channel (W/m^2 K)
h_{rs}	radiative heat transfer coefficient between wall and air channel (W/m^2 K)
h_{rwg}	radiative heat transfer coefficient between wall and glass cover (W/m^2 K)
h_w	convective heat transfer coefficient between vertical wall and air channel (W/m^2 K)
h_{wind}	convective heat transfer coefficient due to wind over glass cover (W/m^2 K)
k_f	thermal conductivity of air (W/m K)
k_{ins}	thermal conductivity of wall insulation (W/m K)
L_s	stack height (m)
L_g	height of glass (m)
L_w	height of absorber wall (m)
$\dot{m}$	mass flow rate (kg/s)
$\dot{V}$	ventilation rate (m^3/s)
ACH	no. of air changes per hour
v	volume of room
q	heat transfer to air stream (W/m^2)
S_1	solar radiation heat flux absorbed by glass cover (W/m^2)
S_2	solar radiation heat flux absorbed by vertical absorber (W/m^2)
T_a	ambient temperature (K)
T_r	room temperature (K)
T_f	mean temperature of air in channel (K)
$T_{f,i}$	air temperature at inlet of channel (K)
$T_{f,o}$	air temperature at outlet of channel (K)
T_g	mean glass temperature (K)
T_{sky}	sky temperature (K)
T_w	mean temperature of vertical wall (K)
u_o	air velocity at outlet of flow channel (m/s)
U_b	overall heat transfer coefficient between vertical wall and room (W/m^2 K)
U_t	overall heat transfer coefficient from top of glass cover (W/m^2 K)
V	wind velocity (m/s)
z	height of bottom opening (m)

Greek symbols

σ	Stefan–Boltzmann constant (5.67×10^{-8} W/m^2 K^4)
γ	constant for mean temperature approximation (0.74)
ι	transmittance of glass (0.84)
α_1	absorptance of glass (0.06)
α_2	absorptance of absorber wall (0.95)
ε_g	emittance of top of glass cover (0.90)
ε_w	emittance of black absorber surface (0.95)
ρ_{fl}	density of air in flow channel (kg/m^3)

chimney system consisting of a solar air heater connected to a conventional chimney. Anderson (1995) presented a mathematical approach to predict natural ventilation in a room with small openings. Afonso and Oliveira (2000) presented a thermal model and validated it with the help of tracer gas technique for a solar chimney attached to a room of 12 m^2 floor area having brick walls and concrete roof. Theoretical and experimental studies on the natural ventilation of buildings were also carried out by Hirunlabh et al. (1999) for four different combinations of height and air gap. Ong (2003) has presented a mathematical model of solar chimney using matrix method for solving simultaneous equation for heat transfer. Further Ong and Chow (2003) have presented experimental results on a 2 m high solar chimney.

The work presented in this paper is based upon the theoretical modeling and experimental validation studies conducted on small size solar chimney