Journal of Building Engineering 28 (2020) 101050

Contents lists available at ScienceDirect

Journal of Building Engineering

journal homepage: http://www.elsevier.com/locate/jobe

A numerical study on induced flowrate and thermal efficiency of a solar chimney with horizontal absorber surface for ventilation of buildings

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A R T I C L E I N F O

Keywords:
Solar chimney
Flowrate
Thermal efficiency
Natural ventilation
CFD

A B S T R A C T

Solar chimneys absorb solar radiation heat to create stack effect which induces airflow for natural ventilation of buildings. Solar chimneys have been studied mainly in two forms: vertical air channel and inclined one. In this paper, a solar chimney with a horizontal absorber surface was proposed. Its performance in term of the induced air flowrate through the channel and the thermal efficiency was predicted by a CFD (Computational Fluid Dynamic) model. Examined factors included the heat flux and major dimensions of the chimney: length of the absorber surface, gap of the air channel, and height and width of the inlet and outlet sections. The results show that increasing of all examined factors enhances the flowrate but has minor effect on the thermal efficiency. However, excessive large outlet width results in reduction of the flowrate and thermal efficiency due to appearance of reverse flow at the outlet.

1. Introduction

Ventilation of buildings can be driven by external winds, thermal forces, and/or by the stack effect [1]. Among the methods based on the stack effect, solar chimneys absorb solar radiation to raise air temperature. The main structural element of a solar chimney is a cavity, or air channel, with its walls made of a glazing opposite to an absorber surface [2]. Solar radiation transmitted through the glazing heats the absorber surface thence warming the air inside the channel. The heated air expands, rises up and induces an airflow for ventilating the connected space [2].

Solar chimneys have been widely studied in the literature. In applications to ventilation, induced air flowrate has been the most commonly examined parameter. Previous studies have shown that for solar chimneys with either a vertical air channel [3–11] or an inclined one [3, 12–15], the induced flowrate depends mainly on the applied heat flux at the absorber surface, the gap of the air channel, and the height difference between the inlet and the outlet of the air channel [16]. For both types of solar chimneys, the flowrate is reported to increase with the heat flux, the gap and the chimney height. However, a large gap-to-height ratio may degrade the rate of increase of the induced flowrate due reverse flow at the outlet of the chimney [3,9]. For the inclined chimneys, the induced flowrate also depends on the inclination angle of the air channel to the horizontal direction. As the inclination angle θ varies from 0 to 90°, the flowrate increases, reaches a peak, then decreases [3,12,14,15]. As inclination approaches zero, the induced flow is expected to cease due to the vanishing height difference between the inlet and the outlet of a straight air channel [12,14].

Solar chimneys can be integrated into walls or roofs of buildings [17–19] for natural ventilation or energy saving. Depending on the dimensions of the employed solar chimneys and the tested houses or buildings, the achieved number of air changes per hour (ACH) was between 3.5−15 [19]. Induced air speed was up to 0.49 m/s inside a three-story building in Singapore achieved with roof solar chimneys [18] or between 0.07 – 0.14 m/s in a small test house in Thailand [17]. Compared to typical windows and doors, solar chimneys have helped to reduce heat gain by 11.4% [20] to 50% [21]. The energy consumption of buildings has been reported to decrease by 8.8% for a test room in Qatar [20] and 50% for an office building in Tokyo [22].

A solar chimney with a horizontal air channel has potential advantages. With a horizontal absorber surface, the chimney can receive solar radiation at a wider angle compared to a vertical or inclined one. It is

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https://doi.org/10.1016/j.jobe.2019.101050
Received 22 March 2019; Received in revised form 20 September 2019; Accepted 1 November 2019
Available online 4 November 2019
2352-7102/