Study the Effect of Wire Mesh Screen on Solar Chimney Assisted Natural Ventilation System

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Abstract

The application of a solar chimney is not restricted to electricity generation; it can also be used for building ventilation. It plays with a mechanism where solar energy is used to enhance the flow rate from the building. Three different face areas (0.56 m^2, 1 m^2, and 2.25 m^2) of solar chimney models are designed and developed in the Mechatronics Engineering Laboratory at the World University of Bangladesh. The solar heating system is replaced with an electric heating system, and the load is fixed from 1 kW to 2.5 kW, depending on the size of the chimneys. The model chimneys are also modified with a wire mesh screen so that the whole solid chimney can be used as a heat source. About 100 sets of experiments were carried out in the modified and traditional chimneys under different solid chimney heights and heat loads. The solid chimney heights are maintained from 0.30 m to 1.20 m with an increment of 0.30 m. The experimental results show that the volumetric flow rate varies from 0.005 m^3/s to 0.014 m^3/s depending on the heat load, solid chimney height, and face areas. The minimum volumetric flow rate of 0.005 m^3/s was observed in the traditional chimney, whereas the maximum volumetric flow rate was 0.014 m^3/s in the modified chimney. Furthermore, the modified chimney also exhibits a higher exit air temperature. Therefore, it can be concluded that the presence of wire mesh in the chimney enhances the flow rate (volumetric), which is approximately 50 to 80 percent higher than the flow rate in the traditional chimney.

Keywords
Solar Chimney, Wire Mesh Screen, Ventilation, Renewable Energy

Introduction
The energy demand serves as a key indicator for assessing the social, structural, and technical progress of a nation. Conventional energy sources, such as petroleum, coal, and natural gas, are deemed essential for the contemporary global economy. Throughout history, traditional energy sources have played a crucial role in fostering economic growth. Given the constraints associated with conventional energy supplies, there is currently a reassessment of their use and a search for alternative solutions for development. Consequently, an increasing number of individuals are seeking "renewable energy sources" as alternatives to traditional energy sources. According to Ostergaard et al. (2020), Zobaa & Bansal (2011), and Gross et al. (2003), renewable energy comes from inexhaustible sources. Throughout the entirety of human existence, individuals have utilized renewable energy sources. It is considered the key energy source for sustaining human life. Upon the initial utilization of fire by mankind, they became the pioneers in harnessing renewable energy. Around 5,500 years ago, wind power powered sail ships. Currently, wind energy is harnessed to generate electrical power. Renewable energy sources are extensively employed, and numerous governments are endeavoring to replicate this practice across various regions of the globe. When it comes to delivering

superior energy, it has no competitors. Despite the existence of other renewable energy sources worldwide (Serensen, 1991; Timmons et al. 2014; Breyer et al. 2022), solar energy is often regarded as a significant and reliable source of energy capable of satisfying future global energy needs. Solar energy has a wide range of applications beyond power generation. One viable choice among them is a ventilation system that utilizes a solar chimney for assistance. A solar chimney comprises a solar radiation absorber and a draft which is also known as a chimney (Chu et al. 2012).

The chimney has been utilized for ventilation and regulating indoor temperatures for many years. It was notably employed by the Romans in Europe as well as by the Persians in the Middle East and North East regions. In 1960, Trombe and Michel first proposed the idea of a solar chimney in France. Solar chimneys were initially employed solely for space heating purposes, but they are now capable of providing both heating and ventilation for buildings. The solar chimney performance depends on the chimney's ability to operate without any loss of draft. The solar chimney draft is greatly reduced because of cold inflow, flow reversal, or the entry of outside air at the chimney's exit. To reduce the foolish losses, it is advisable to employ a wire mesh filter at the outlet of the solar chimney. The airflow rate at the chimney's outlet has been enhanced. Consequently, this work involves the creation and testing of chimney models under two distinct conditions: with and without mesh screens.

Methodology

A robust chimney was positioned atop the electric heater. The solid wall chimney was constructed at heights of 0.3 m, 0.6 m, 0.9 m, and 1.2 m. Wire meshes were affixed to both the lower and upper sections of the chimney's solid wall. The main instruments used were a vane-type anemometer (Airflow LC-430 VA), a differential pressure sensor (Furness Controls FC-0320), a clamp multi-meter, a voltmeter, and twelve Type-K thermocouples.

A vane anemometer with a diameter of 105 mm was mounted at the intake to determine the average mean bulk air velocity across the pipe. To measure differential pressure using the Furness Controls pressure transmitter, the range of the differential pressure measuring meter was first calibrated and set to values near ±5 Pa. To verify the precision of the thermocouple, the measurements were cross-referenced with those of the reference thermocouple to identify any discrepancies. The margin of error for the thermocouple readings is within a range of +3 K to -2 K. Two Cole-Parmer USB Data Acquisition Modules were linked to personal computers (PCs) and thermocouples to directly collect data from the system and transmit it to the PC.

Temperature measurements were automatically taken at 30-second intervals for five minutes at each location to guarantee precise accuracy. The air input velocity was manually measured 10 times at five-minute intervals after reaching the steady-state temperature. The differential pressure measurement was also obtained on ten occasions, at intervals of five minutes. The clamp multimeter was configured as an ammeter and attached to the positive power input line in order to measure the overall current reading. The ammeter value was recorded ten times, at consistent intervals of five minutes. A voltmeter was employed to gauge the voltage at every terminal of the electric circuit. The voltmeter reading was recorded 10 times at regular five-minute intervals, similar to the van anemometer and furnace controller. To assure accuracy, three repeated values were gathered for each reading, and the average value was recorded in tabular style for subsequent analysis.

Results and Discussion

The overall draft in the model is contingent upon the air velocity and losses. The pressure drop in the diffuser was minimal, hence the differential pressure near the output of the pipe network was regarded as a buoyant pressure for the model. The study involved measuring the differential pressure across various heights of solid wall chimneys and analyzing the impact of chimney height on buoyant pressure. A comparison was conducted both with and without screens placed at the top of the solid wall chimney in order to assess the impact of wire meshes. The models with and without a solid wall chimney were used to measure and illustrate the velocity and pressure drop, as shown in Figure 1. The findings indicated that the chimney with a solid wall considerably increased the rate of flow. This is because there is no cold influx effect at the heat source location. Heat sources are employed as substitutes for the solar collector in the practical solar chimney in this experiment. This graphic also demonstrates that increasing the flow rate down the chimney leads to a corresponding increase in the ventilation rate in real-world conditions. The enhancement in the model chimney is nearly six fold compared to the standard solar-collected or low-height solar chimney. In this study additionally found that the airflow in the solar chimney is to be contingent by factors such as the surface area of the chimney, the amount of heat being generated, the height of the chimney, and the existence of a wire mesh screen.

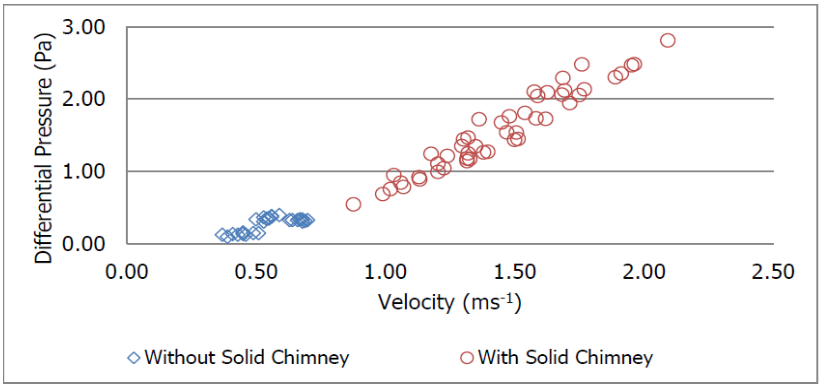

Figure 1. Draft and velocity Relation for two different chimney model.

Figure 2 displays the velocity and draft data, along by trend lines derived from the data. Both trend lines have nearly identical patterns. The magnitudes of both exponential functions are nearly identical, suggesting that the variations in differential pressure are consistent for both maximum and minimum heat loads.

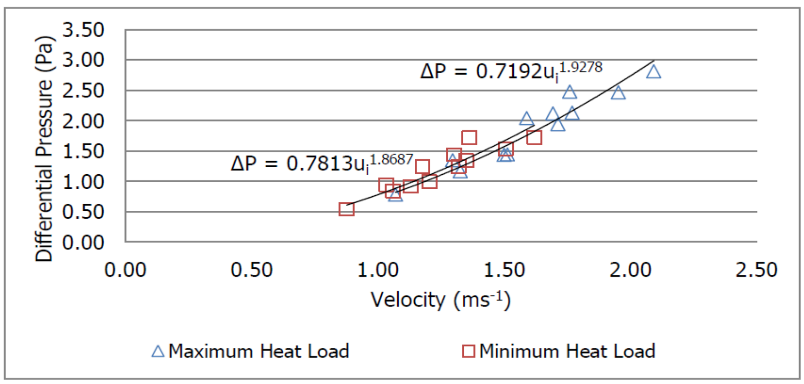

Figure 2. Relation between velocity and differential pressure for different heat load.

Figure 3 compares the draft and velocity of configuration B (solid chimney without wire mesh) with configuration C (solid chimney with wire mesh).

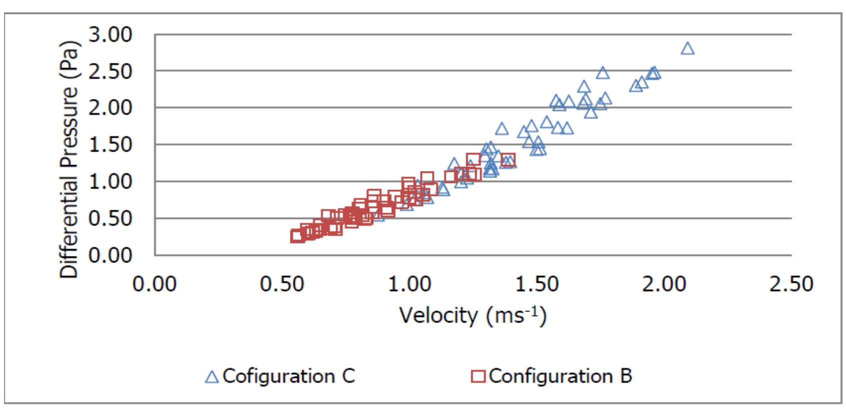

Figure 3. Wire mesh effect on Draft and Velocity

An investigation demonstrated that the screen substantially enhances both the rate of air flow and the occurrence of drafts. The presence of a mesh screen reduces draft losses by mitigating the impact of cold temperatures on airflow, hence improving the rate of air flow or ventilation. The model study demonstrated a ventilation improvement of over 90 percent when wire mesh screens were inserted in the solid chimney model, and a ventilation improvement of around 300 percent compared to a solid wall chimney.

Conclusions

A chimney model is tested with and without a solid-walled chimney under different heat loads. The model is also tested with and without a wire mesh screen. The maximum draft loss is observed at the model chimney when there is no solid wall chimney or wire mesh screen. In this condition, the air flow rate is also found to be very low compared to other conditions. Although the solid wall chimney enhanced the air flow rate significantly, the maximum air flow rate was observed when the model was introduced with a solid wall chimney and wire mesh screen. The outcome of the model indicates that the solar chimney with a mesh screen and a solid wall chimney has significantly enhanced the flow rate.

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Biographies

Md. Mizanur Rahman presently holds the position of a professor at the World University of Bangladesh. Furthermore, he has contributed to the Renewable Energy Technology in Asia (RETs in Asia) project at KUET and AIT from January 1999 to December 2004 in various roles such as a research assistant, research engineer, and consultant. Subsequently, he joined BRAC Bangladesh, an NGO, in the capacity of a program support professional. He his employment at Rural Power Company Ltd. (RPCL) in February 2006 and held the position of assistant manager until July 2007. He commenced his PhD studies in Natural Draft Chimney at Universiti Malaysia Sabah in July 2007. Dr. Rahman assumed the position of lecturer at the TAS Institute of Oil and Gas in July 2009 and held this position till August 2012. Subsequently, he transitioned into the role of a senior lecturer at Universiti Malaysia Sabah prior to his admission to the World University of Bangladesh. Furthermore, he possesses a life fellowship in the Institutes of Engineers Bangladesh and maintains professional membership in the IEOM.

Naheen Ibn Akbar is currently working as a lecturer in the Department of Mechatronics Engineering at the World University of Bangladesh (WUB). He received his B.Sc. degree in mechanical engineering from the Military Institute of Science and Technology (MIST), Dhaka, Bangladesh. He has experience leading research projects for premium robotics competitions like the University Rover Challenge (URC) and Anatolian Rover Challenge (ARC). He also has research experience in machining technology. He is the author of two peer-reviewed publications in international journals and conferences. His research interests include advanced manufacturing, additive manufacturing, and robotics.

Mr. Rezwan us Saleheen is an assistant professor at the Department of Mechatronics Engineering, World University of Bangladesh. Mr. Saleheen received his Master of Science in Biomedical Physics and Technology from the University of Dhaka, Dhaka, Bangladesh, in 2015. He also earned a Bachelor of Science in Electrical and Electronics Engineering from American International University-Bangladesh (AIUB), Dhaka, Bangladesh, in 2012. Mr. Saleheen started his career as a lecturer at the World University of Bangladesh, Dhaka, Bangladesh, in 2012. His research interests are biomedical instrumentation, electronics, and automation. He is also experienced in designing and reviewing the curriculum regularly and also overlooks the activities and professional development of faculty members. He also served as a member of the Program Self-Assessment Committee, Department of Mechatronics Engineering, under the HEQEP Project of UGC. He has published a number of papers in international journals and has also published several book chapters.

Ms. Rumana Tasnim is currently working as an assistant professor in the Department of Mechatronics Engineering at the World University of Bangladesh. She graduated with a B.Sc. in Electrical and Electronic Engineering (EEE) from the International University of Business, Agriculture, and Technology, Bangladesh, and an M.Sc. in Electronics Engineering (MSEE) from the International Islamic University of Malaysia (IIUM). She has published in over 50 books, conferences, and peer-reviewed international journals. Throughout her academic career, she has reviewed several international journals. She serves as the WUB Chapter advisor for the IEOM Society. Smart sensing, automation, robotics, IOT, computer vision, instrumentation and measurement, and renewable energy are some of the topics she is interested in studying.

Dr. Mohammad Mashud is a research fellow at the Aerospace Center at UTEP, USA, and a professor in the mechanical engineering department at Khulna University of Engineering & Technology, Bangladesh. In 1975, he was born in Dhaka, Bangladesh. He graduated with a doctorate in aerospace engineering. In 2006, I received my degree from Nagoya University in Japan. In 2003, he graduated with a Master of Engineering from the same department and Japanese university. At Bangladesh's Khulna University of Engineering and Technology (KUET), he earned a Bachelor of Science in Engineering (Mechanical). He began working as a lecturer in the KUET Mechanical Engineering Department in 1999.