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Thermodynamic investigation on an innovative unglazed transpired solar collector

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Abstract

Renewable energy represents an attractive solution to fulfil two requirements: indoor air quality and energy efficiency. Passive solar systems are easy to implement and effective in areas with high solar potential. The Unglazed Transpired Solar Collector (UTSC) is made of metal cladding with perforations, installed at several centimetres from a building wall, creating thus a cavity, allowing to preheat the fresh air. Several measurements were performed on an innovative perforated solar wall model. This study is a preliminary approach of an analysis on the importance of the orifice shape of the perforated panel as a heat transfer influencing parameter. Both the fluid dynamics and thermal behaviours were investigated. The more complex dynamics of the lobed flows results in a better heat transfer rate. Changing the geometry of the perforations will increase on one hand the orifice's perimeter and it would generate complex fluid dynamics, resulting in higher mixing between the primary flow and the ambient and thus a higher efficiency of heat recovery of these devices. The comparison of a conventional UTSC with a new geometry with innovative perforation leads to interesting results, with almost 40% increase in thermal efficiency.

Keywords: Unglazed transpired solar collector; Ventilated facade; Energy saving

1. Introduction

The building sector remains an important player on the international economy dynamics, at it integrates significant resources which can be translated in energy consumption. In this context, European Directives (Directive on the energy performance of buildings 2002/91/EC) require, for example, a high energy performance of buildings for significant reduction of the energy consumption (Energy, 2002). Different countries have already adopted drastic regulations in order to achieve high building performance. In the same time, the environmental quality is an important parameter requested for residential or tertiary buildings.

Indoor air quality and energy consumption go hand in hand in urban environment which is developing faster in the latest decades. Buildings are the largest energy consuming sector in the world, and account for over one-third of total final energy consumption and an equally important

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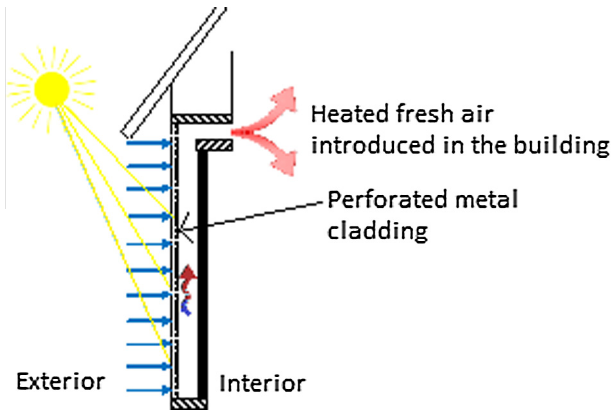

Fig. 1. Unglazed transpired solar collector principle: Sun's radiation heats the perforated metal cladding, heat which will be transferred to passing airflow.

source of carbon dioxide (CO_2) emissions (IEA, 2013). Given that many nations are actively pursuing carbon reduction plans, achieving significant energy and emissions reduction in the buildings sector is a challenging but achievable policy goal. The built environment offers also some opportunities to save energy through the use of innovative systems or through advanced management systems (Kumar and Morawska, 2013).

In the same time indoor air quality has become a critical parameter when considering health of the occupants and the importance of fresh air inside buildings. Further complexity is added by the changing climatic conditions and the human expectations of comfortable indoor environments, both of which increase building energy requirements for heating, cooling or lighting. Local climate conditions directly influence the energy consumption of buildings through HVAC systems, whether there is a heating or a cooling load. During the cold season in cold countries, the heat demand of the building represents the highest percentage from the total amount of energy demand, while during the summer, air treatment or ventilation is a major consumer of electrical energy. For example, in United Kingdom, the energy used for interior heat demand was about 50% of the total energy consumption in 2004 (UNEP, 2007). On the other hand, air cooling systems use more than 40% of peak load in a hot summer in Shanghai(Al-Shaalan, 2012). All these energy consumptions, whether it's heating or cooling demand, can be translated in terms of CO_2 emissions (IEA, 2007a,b, 2008). The renewable sources can provide low-cost energy consumption when using passive systems. Among these renewable energies, the use solar systems are easy to implement and efficient from the accessibility point of view in the zones with solar potential (IEA, 2005). These systems can have a significant contribution to achieve high envelope performances and in the same time to save energy for winter heating or/and summer cooling. The multitude of solutions for using thermal energy from the Sun has important advantages but also disadvantages that maintains the research in this area. Among them, thermal walls can be split in several categories (i.e. Trombe walls, solar eutectic walls, other systems that store energy with water) (Hami et al., 2012). Solar Air Collectors have some interesting potential benefits (no danger of frost, no health and environmental dangers due to leakages) in comparison to Liquid Heating Collectors (Reichl et al., 2015) and are potentially cheaper in acquisition and maintenance. One of the most interesting solution is from our point of view the solar collector walls or Unglazed Transpired Solar Collector (UTSC).

An UTSC is made of metal cladding with perforations, installed at a certain distance from a building wall, thus creating a cavity through which the air is circulating. The metal cladding is heated by the solar radiation from the sun and ventilation fans create negative pressure in the cavity, extracting the solar heated air through the perforated panel. The air is generally taken off at the top of the wall (due to air temperature gradients in the cavity) ensuring that all of the produced solar heat is collected and then distributed in the building via the ventilation system. The heat transfer between the fluid and the metal is intensified depending on the flow's characteristics and other external parameters.

A quick survey allows us to be aware of the huge possibilities of such devices in energy recovery. For instance, the CFD study of Arulanadam et al. (Arulanandam et al., 1999) concludes that not only metal cladding could be used for the perforated absorber but even low conductivity materials can lead to acceptable thermal efficiency of the system, for low porosity of the transpired plate absorbers and for low velocity flow situations. But studies such as

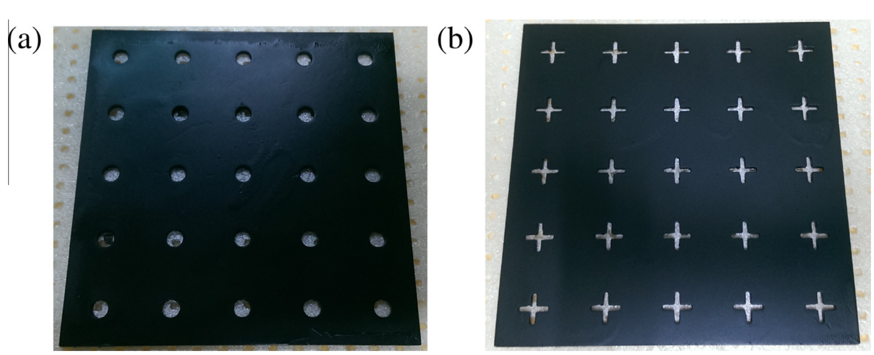

Fig. 2. Evaluated perforated claddings: (a) Round perforation; (b) Lobed cross perforation.