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Thermal performance of double pass packed bed solar air heaters – A comprehensive review

Satyender Singh*, Prashant Dhiman

Department of Mechanical Engineering, National Institute of Technology, Hamirpur, H.P. 177005, India

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ABSTRACT

The present work intended to conduct a comprehensive review on the thermal performance of double pass packed bed solar air heaters. Various aspects that govern the thermal performance of such solar air heaters has been highlighted and discussed in detail. A comprehensive review of reported studies indicate that the use of porous packed bed material in the upper channel of double pass solar air heaters significantly increases the thermal performance as compared to solar air heaters without packed bed and with packed bed when porous material is provided in the lower channel. Moreover, studies revealed that employment of parallel, counter and recyclic double air pass increases the thermal performance of the packed bed solar air heater as well by increasing the heat extraction rate of the flowing air through the packed bed duct. Although, it has been obtained that sufficient work using parallel and counter double air pass has been reported on packed bed solar air heaters, only few studies were reported using recyclic double air pass. However, results show that employment of recycle operation to the double pass packed bed solar air heaters momentously increases the thermal performance and can be used as an alternative thermal performance enhancement technique. Therefore, more investigations are required to be conducted using recyclic double pass packed bed solar air heaters.

Contents

* Corresponding author. Tel.: +91 9418662007; fax: +91 1972 254736.
E-mail address: satusingh.vicky@gmail.com (S. Singh).

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1. Introduction

The concept of solar air heating has been in use from many years. Heat from the sun stored in iron was utilized to heat a home in 1877 [1]. First design of solar air heater comes into light in 1881 which was a wall hung wooden framed cabinet consisting of a blackened metallic sheet covered with a transparent glass. Thereafter, many attentions have been paid to make solar air heaters more efficient, reliable and cost effective for industries and house hold uses. In 1968, the concept of Vee-grove absorber plate and packed bed storage has been enlightened. Since, 1970 experimental techniques for solar air heaters were developed and their performance was measured. After that several experimental and theoretical studies expressing way of modelization and optimization of solar air heaters were reported every year. A comprehensive literature review of double-duct double-pass solar air heater has been presented in the current work with an aim to emphasize the relevance of double duct double pass packed bed solar air heaters. The literature review is classified into following extensive topics.

2. Air flow patterns

The mode of air flowing in the ducts of a solar air heater is one of the most significant aspects concerned with solar air heater which dominantly affect its thermal performance. From many years, single pass of air has been used to extract the heat from the absorber of a solar air heater, but with the rapid increase in the research related to air flow patterns. It has been proved that single pass of air flow cannot effectively extract heat from the absorber, whereas a low convective heat transfer exists between absorber and air, therefore some more flow patterns were suggested by many researchers in order to enhance the heat extraction rate between the air and the absorber. On the basis of air flow pattern double duct double pass solar air heaters are classified as shown in Fig. 1.

2.1. Parallel flow

In order to increase the heat extraction rate and lower the heat losses, parallel air flow pattern has been used in double duct solar air heaters. Sodha et al. [2] in 1982 reported a theoretical study on parallel flow solar air heater design. Design consists of two air flow channels/ducts, one was formed between the glass cover and the absorber plate and other was formed between the absorber plate and the back plate as show in Fig. 2(a). Likewise, Biondi et al. [3] in 1988 proposed another model of parallel flow double duct solar air heater. Design was nearly similar to that of soon after reported by Jha et al. [4] in 1992, Pawer et al. [5] in 1994 and Ong et al. [6] in 1995 except that the single glass cover was used in these designs as presented in Fig. 2(b). After that, various designs of parallel flow double duct solar air heater were reported in the literature. Based on experimental [4,10,11,14–17] and theoretical [2–10,12–17] investigations, it is obtained that the thermal performance of parallel flow solar air heaters, in which air is flowing simultaneously over and under the absorbing plate, is more effective than that of the devices with only single flow over or under the absorbing plate because the heat-transfer area in parallel flow systems is almost double [14,15]. Moreover, the effect of the fraction of mass flow rate in the upper or lower flow channels of the parallel flow double-duct device on collector efficiency has also been investigated theoretically and experimentally. Considerable improvement in collector performance is obtained by employing a parallel double-flow type solar air heater, instead of using a single flow device, if the mass flow rates in both flow channels are kept the same [14,15].

2.2. Counter flow

Solar air heater using counter flow arrangement is one of the attractive designs to enhance thermal performance of a double duct solar air heater by increasing the heat extraction rate of the air in the heater ducts. Generally, counter flow of air is generated in solar air heaters by first introducing the air between the two glass covers and then by providing a divergence at the end of the duct, the air is guided to flow through the duct formed between the absorber and the glass cover as shown in Fig. 3(a) [9,18,19,21,22,26,32]. In order to increase thermal performance of double duct solar air heaters employing counter air flow pattern, some advancements in the heater designs have been reported in the literature as presented in Fig. 3(b) [9,13,20,27–31,33] and (c) [16,18,23–25]. Heater designs with double glazing as well as two air flow ducts where one was provided between the glass cover and the absorber plate, and second was made between absorber and back plates is one of the important designs in order to increase thermal performance as shown in Fig. 3(c). Air flow in the first and then through the second duct increases the convective heat transfer coefficient between the air and heat elements, resulting increment in the thermal performance. Whereas, Use of double glazing lower the heat losses by decreasing the radiative and