





Investigation on ETC solar water heater using twisted tape inserts

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Abstract

The solar water heaters are finding their application in a number of sectors such as, residential buildings, processing industries, commercial establishments. They can be scaled based on the requirements. Among the different kind of solar water heaters, all-glass evacuated tube type (ETC) solar water heaters are considered to be the better choice for the most applications due to their efficient operations with simple design constraints compared to other type of water heaters. However, there is a large scope to boost-up the performance of the ETC type solar water heaters to the next level with the appropriate modifications in the evacuated tubes, which will help to advance the overall efficiency. The present work proposes the amalgamation of twisted tapes within the evacuated tubes (ET) of the ETC solar water heaters to attain the enhanced performance of the system. The twisted tapes with two different twist ratios of 2 and 3 were used for the investigations. The twisted tapes were made-up of copper tapes of width 15mm. The experimental trials were conducted on a passive flow ETC solar water heater on the days having alike solar insolation and ambient conditions in three different modes namely, ETC water heater without any twisted tapes (ETC-Plain), ETC water heater with twisted tapes comprising twist ratio of 2 (ETC-Twist 2) and the ETC water heater with twisted tapes comprising twist ratio of 3 (ETC-Twist 3). The results evidenced that the twisted tapes helped to improve the evacuated tube temperature and the tank water temperature of the ETC type solar water heater. The efficiency of the ETC type solar water heater was enhanced by 6.8% and 4.6%, respectively using twisted tapes comprising twist ratio of 2 and 3. Furthermore, the twisted tape with smaller twist ratio was determined to be efficient in improving the performance of the ETC type solar water heater.

Introduction

The spread over of the renewable energy based systems are extensively increased in the modern era, due to the awareness and the glitches in conventional systems [1], [2]. Renewable energy based systems are environment friendly and they use the energy from the unconventional sources such as solar power, wind power and so on [3], [4]. Hence, they help us to keep away from massive electricity bills. Water heating is the process which is predominant in variety of needs, right from small residences to huge industries. The household requires hot water for bathing, washing, cleaning purposes, whereas the industrial requirements are boiler preheating, processing heating, and so on [5], [6]. Solar water heaters are proposed to be prominent renewable solution for the aforementioned hot water requirements. It would save a greater amount of conventional energy from the grids and save the environment from the release of

green house gases. The passive flow solar water heaters are very simple systems which doesn't need any external devices for water circulation. The water circulation happens through the thermosyphonic effect driven by the density difference [7], [8].

In recent days, the evacuated tube type (ETC) solar water heaters are diffusing rapidly in global market due to their relative advantages as in passive flow systems [9], [10]. They possess double layered glass tubes, inner glass coated with the solar selective coating for the effective heat transfer to the fluid inside it. A high level of vacuum is maintained between the two glass layers to curb the heat loss to the surrounding. The total effective absorber area depends on the number of ETC tubes in the system [11]. The passive flow systems are mostly having an integrated storage tank for water, from where the circulation of fluid to the tubes is maintained. The efficiency of these kinds of systems can be improved through the modifications in evacuated tubes. Ayompe and Duffy [12] utilized a heat pipe in evacuated tube based water heating system and concluded that the performance was improved with the heat pipe in the water heating system. Abokersh et al. [13] tested the u-pipe within the ETC type solar water heater along with a PCM for enhancing its performance and concluded that the system showed a greater enhancement in its performance. Gang et al. [14] introduced a compound parabolic concentrator along with a u-pipe in an ETC solar water heater. Their experiment revealed that the system efficiency was enhanced above 49% with the incorporation of the aforementioned arrangements. The recent researches focussed on developing the phase changing materials and nano-doped phase changing materials for recuperating the performance of the solar powered systems [15]. Paraffin based PCMs were evidenced to be the effective materials to enhance the efficiency of the solar systems such as solar water heaters [16], solar PV panels [17] and solar stills [18]. On the other hand, they augment the total weight of the system significantly [19].

The major glitch with the evacuated tubes is that the water in the bottom portion of the tube would not get utilized sufficiently due to their large length and hence, the water at the bottom portion remains lagged from the heat transfer to the tank of the solar water heating system [20], [21]. The proper methodology in ETC design would activate this lower portion of the ETC tubes and enhance the system efficiency. The helical twisted tapes were used in different types of solar thermal systems and in some type of heat exchangers to enhance the heat transfer characteristics [22], [23]. Jaisankar et al. [24] piloted an experiment to analyze the presence of twisted tapes with dissimilar twist ratios on the operating effectiveness of the flat plate solar water heater. They proposed that the use of twisted tapes boosted-up the performance of the system by improving turbulence of the fluid through the tubes. The twisted tapes are available in different forms and in different technical details. The twist ratio is the ratio between half the twist pitch to the width of the tape, which is also playing a pivotal role in heat transfer augmentation of the system [25], [26]. They induce the turbulent within the tubes; thereby they ensure thorough mixing of the fluid within the tubes and enhance the heat transfer within the tubes [27], [28], [29]. The available literature shows that the implementation of the twisted tapes in ETC tubes is scarce.

The uniqueness of this work is that it examines the performance of the indigenously fabricated ETC type solar water heater by incorporating the twisted tapes within the evacuated tubes, which is nowhere reported in the previous literature. The work began with the fabrication of the ETC type solar water heater with a straight storage tank of 100L capacity. Then, the twisted tapes were fabricated using copper tapes in two different twist ratios. The performance of the ETC solar water heater was monitored in three modes, namely ETC water heater without any twisted tapes (ETC-Plain), ETC water heater with twisted tapes comprising twist ratio of 2 (ETC-Twist 2) and the ETC water heater with twisted tapes comprising twist ratio of 3 (ETC-Twist 3). The obtained results were analyzed and compared.

Section snippets

Experimental set-up

The ETC type solar water heater was fabricated with ten standard evacuated tubes and a storage tank with a capacity of 100L. Evacuated tubes with the dimension of 5.8cm outside diameter, 4.7cm inside diameter and 180cm length procured from local market and the tank of the solar water heater was manufactured from stainless sheet with the thickness of 0.8mm. The tank is double layered cylindrical tank with ten circular slots to lodge evacuated tubes. The polyurethane foam (PUF) of 5.5cm...

Results and discussion

The experimental trials were accomplished in the month of November 2020 from morning 8.00 a.m. to 6.00 p.m. The readings were observed for every 60min and recorded for further analysis. The three set of experiments were piloted one without any twisted tapes, second set with the twisted tapes comprising twist ratio 2 and the third set with the twist ratio 3. Each set of experiments were organized for minimum of 5 days to ascertain the accuracy and repeatability of the experimental data. Then,...

Conclusions

The ETC type solar water heater was fabricated with ten standard evacuated tubes and the tank capacity of 100L. The twisted tapes were fabricated from the copper tapes of 15mm width and 1 mm thick. There were 20 twisted tapes (ten with the twist ratio 2 and another ten with the twist ratio 3) were prepared. The experimental trials were conducted in three modes of operation namely, ETC solar water heater without any twisted tapes (ETC-Plain), ETC solar water heater with twisted tapes having...

CRedit authorship contribution statement

N. Gunasekaran: Writing - review & editing. **P. Manoj Kumar:** Conceptualization, Methodology, Investigation, Validation, Writing - original draft. **S. Raja:** Data curation, Writing - original draft. **S. Sharavanan:** Writing - review & editing. **K. Avinas:** Writing - review & editing. **P. Aakash Kannan:** Writing - review & editing. **S. Gokul:** Writing - review & editing....

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper....

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