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Absorber Tube with Internal Hinged Blades for Solar Parabolic Trough Collector

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Abstract

Solar parabolic collectors exploit solar energy for both thermal and power generation applications. But, they demand long arrays of reflective concentrating surfaces with receiver tube throughout the length of axis of the concentrators. For one and half meter long parabolic trough with aluminium sheet as reflective surface, experimental analysis was done attempting to increase the energy transfer rate and reduce the length of arrays. Two absorber tubes were fabricated and distilled water was used as the working fluid in the tubes. The modified absorber tube with hinged blades delivered an average efficiency of 69.33% compared to 60.82% obtained for simple conventional absorber tube. Plots for performance results of the tubes with varying direct normal irradiance and mass flow rates were obtained. Slope and intercept values of 70.887 and -0.419 respectively were obtained for the collector equation of absorber tubes hinged blades compared to slope and intercept values of 61.571 and -0.401 respectively. The present work delivers better performance compared to earlier works Thus, the proposal present its scope for both domestic and industrial applications.

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Keywords: absorber tube; parabolic trough; aluminium reflective sheet; hinged blades; solar thermal

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1. Introduction

Solar energy presents itself as a highly potential source of energy for sustainable progress. But, high investment, requirement of large area for installation of solar energy devices and wavering availability of radiations has restrained its development. Solar parabolic trough collector (SPTC) provides an effective way to harness solar energy providing "one-axis concentration" such that distilled water flowing through the absorber tube, gains the concentrated energy and accomplish the work as per required application. Since years, researchers and scientists have been trying to optimize the performance of SPTC so that rapid heat transfer can take place and overall length of the trough collector can be reduced.

Tao et al. [1] introduced design method and working principle for new type of trough collector with efficient performance of SPTC by introducing widely opened concentrating collectors. However, increase in the width of concentrating apparatus may result to unbalanced design and higher probability of back reflection with spillage loses of the incident solar radiations. To avoid such hindrances, requirement of precise design and tracking will be needed, that adds some more minuses to the proposed design. Cobalt electrode position on absorber tubes by Barrera et al. [2] and effort on solar selective coatings by Farooq and Raja [3] resulted in enhancement of the efficiency for operation of solar apparatuses. But with increase in coating temperature, radiation thermal losses may increase, thus high thermal stresses may develop in the receiver tube.

The implementation and development of recirculation operation mode for SPTC by Valenzuela et al. [4] showed increase in output temperature and performance of the apparatus. But, the system possesses minor drawbacks concerning the use of steam at high pressures, risk for steam leakage and higher stresses on tube. An innovative numerical model evaluation of heat transfer characteristics for porous disc receiver by Ravi Kumar and Reddy [5] presents an efficient design of absorber tube, but flow across the tube is very high and also the system will require only pure fluid to avoid accumulation of particles on the tube walls and porous disc, than can be caused by highly interrupted flow through the receiver tube. Selectively coated receiver with U-tube was analyzed by Ma et al. [6] that demonstrated better performance, but with very mass flow rate of fluid flowing through the tube.

Although ample research and development have been done to improve performance efficiency of parabolic trough concentrators, the authors presents innovative design of absorber tube with internal hinged blades. The experimental analysis and fabrication procedure for the modifications done in the receiver tube are presented. The proposed absorber tube is well suitable for application in various solar energy devices, linear and line focus concentration systems with various advantages as well. Experimentation was performed at VIT University, Vellore (12.92 °N, 79.13 °E) twice, once on October 24th, 2014 and on October 26th, 2014, to verify the consistency of the obtained results.

2. Materials and Methods

Copper tubes with 1 mm thickness and 1.5 cm outer diameter were used to fabricate the absorber tubes. The specifications of cylindrical axis trough collector, absorber tubes and the apparatus are given in Table 1. All the tubes were made of 1.5 m long copper tubes. Parabolic trough with rim angle of 120° and focal length 26.25 cm, was used which has reflective surface of aluminium alloy and reflectivity of about 85%. Details for fabrication processes of the tubes have been included.

The enclosed volume in the glass tube was evacuated to develop a low pressure vacuum, thus reducing the heat transfer losses. Absorber tube with internal hinged blades had 2 mm drill holes along a straight line with pitch distance of 50 mm. Galvanized iron sheets of 49 mm^2 (7 mm * 7 mm) were made to hinge internally from the drilled holes, such that the blades don't make contact with tube's inner surface. This ensured the continuous flow of distilled water. The drill holes were welded using gas welding to make the tube leak proof. With flow of distilled water, the blades provide hindrance to flow along the tube, creating turbulence in the flow. Increase in turbulence increased the contact time between distilled water and absorber tube's inner surface, hence the heat transfer increased. The experimental setup and design of hinged blades is presented in Figure 1.

Initially, absorber tube was fixed on SPTC's axis and the trough was adjusted such that axis of focus and the absorber tube accords. Then the tube was connected to the pump through a hose and distilled water, used as working fluid, was collected in tank. The pump was switched on, leaving the system for 10 minutes with specified volume