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ANALYZE THE PERFORMANCE OF A PARABOLIC TROUGH SOLAR COLLECTOR FOR THE PURPOSE OF GENERATING HOT WATER IN OMAN REGION

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Abstract: This experimental study aims to investigate the influence of several parameters, such as concentration ratio, optical efficiency, and thermal efficiency, on the performance of the trough solar collector. Currently, countries worldwide are collectively concerned about the problem of environmental pollution and its resulting effects. Nevertheless, it is crucial for these nations to ensure sufficient energy supplies to promote the development and expansion of their individual countries. The application of traditional methods, including those utilizing coal, fossil fuels, and organic substances, for energy production results in a substantial amount of air pollution, which acts as the main driver of global warming. The use of alternative approaches for energy generation is considered more advantageous in terms of environmental consequences. Nevertheless, the main obstacle preventing impoverished and growing nations from adopting these non-conventional procedures is the absence of economic feasibility. The geographical conditions play a crucial role in assessing the feasibility of alternative sources like solar energy and wind energy. This study entailed an examination of the operational effectiveness of a solar trough collector, followed by computations to determine its efficiencies.

Keywords: Concentration ratio, nonconventional energy, optical efficiency, solar collector, thermal efficiency

Introduction

The adoption of renewable energy sources has become a necessity for nations in the modern period. Non-renewable sources of energy, because of their limited availability and harmful effects on the environment, impose restrictions and worsen the problem of global warming. Solar energy is widely acknowledged as a sustainable source of energy, which has resulted in its growing acceptance by many countries in recent times [1]. Oman is a country that has a substantial amount of sunlight, which may be efficiently utilised for the generation of solar power. Despite the higher initial costs, technological developments and improved gadget performance will eventually make the use of solar energy more efficient and cost-effective. Oman, with its ample sunlight, especially during the summer season, is an ideal candidate for harnessing solar energy. Nevertheless, several regions in Oman, namely Tamil Nadu, certain southern areas, and Rajasthan, exhibit a consistently abundant supply of solar energy all year round. The Parabolic Trough Collector (PTC) has various benefits, such as its utilisation in industrial steam generating [2] and hot water production [3]. There are already nine solar power plants of considerable commercial size in the United States [4-5]. These installations are noteworthy for their use of the oldest and most well acknowledged solar thermal electric technology worldwide. Prior research has also investigated the efficacy of parabolic trough solar collectors.

Numerical analysis was used by A. Padilha et al. [6] to undertake a performance evaluation of a modified evacuated tube solar collector. An analysis was conducted on a hybrid water heater that combines an evacuated glass tube solar collector with rice husk. Piyanun Charoensawan and colleagues [7] conducted the process of combustion.

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Pei et al. (2018) conducted a study to assess the effectiveness of evacuated tube solar water heater systems. They compared the performance of these systems with and without the utilisation of a mini-compound parabolic concentrating (CPC) reflector (C<1). The work undertaken by J.P. Praene et al. involved simulating a solar power absorption system and dynamically modelling an evacuated tube solar collector. The user submitted a numeric citation. The study conducted by Yadav et al. (10) aimed to examine the usage of evacuated tube solar collectors for heating air in Oman. The study conducted by A. Valan Arasu et al. [11] examined the performance parameters of a parabolic trough solar collector specifically in relation to heat generation. The researchers S.D. Odeh et al. [12] performed a thermal analysis on parabolic trough solar collectors that are utilised for the creation of electric power. Matthew Roesle et al. [13] utilised the direct simulation Monte Carlo technique to analyse the conduction heat loss from a parabolic trough solar receiver with active vacuum. The authors V. Padilla et al. [14] developed a simplified method for designing parabolic trough solar power plants. The study undertaken by N. Naeeni et al. [15] specifically examined the wind flow patterns that surround a parabolic trough solar collector.The present inquiry entailed the creation and construction of a parabolic collector. The experiments were carried out utilising the identical setup, and measurements were subsequently documented. The gathered data underwent computations and analysis to ascertain the optical efficiency and thermal efficiency.

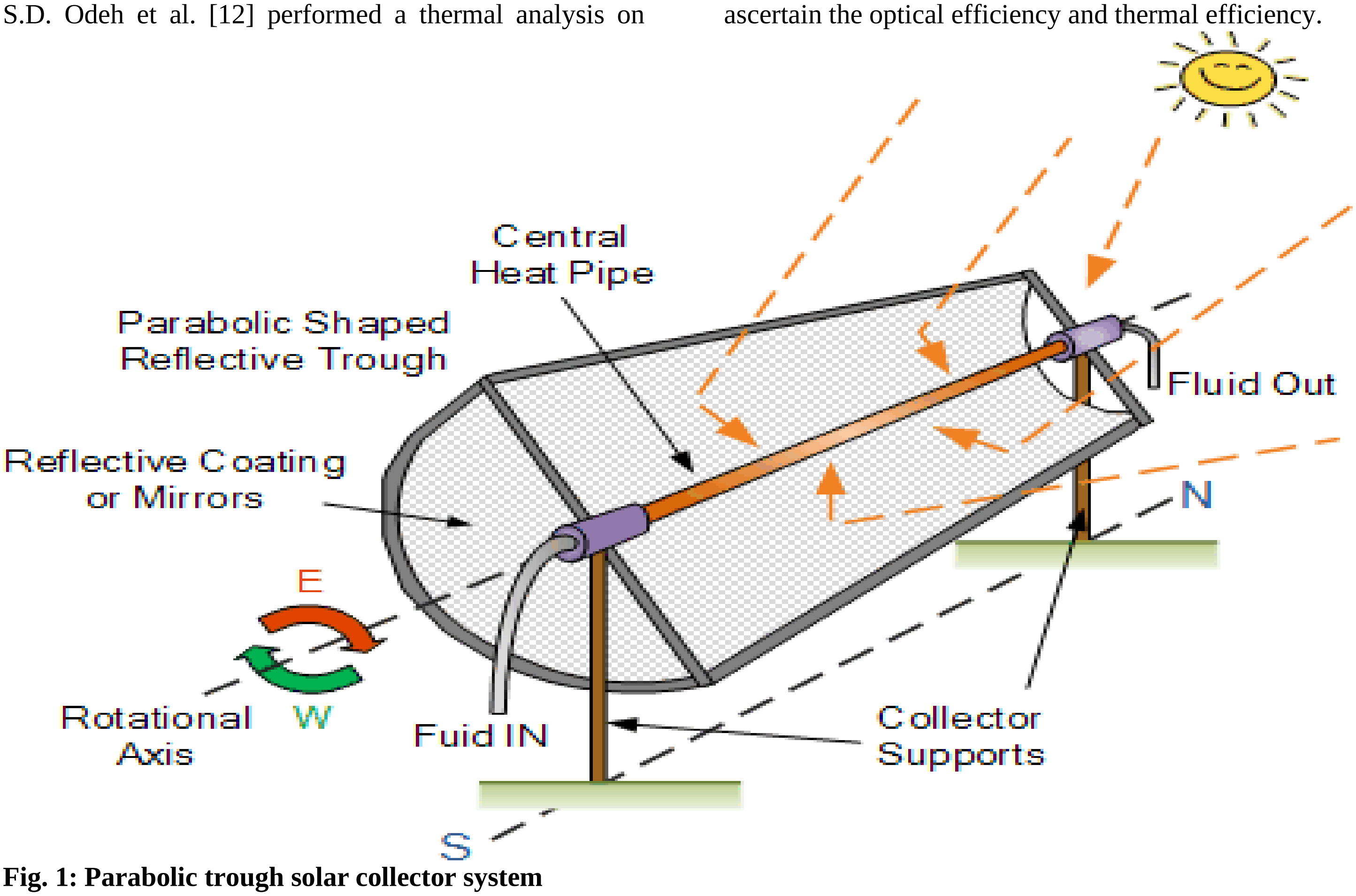

Fig. 1: Parabolic trough solar collector system

Design Parameters

Parabolic trough collectors are unique due to their simple structure. However, in order for them to work effectively,

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they require constant tracking to guarantee that solar energy is concentrated on the absorber tube throughout the day. The accuracy of the PTSC design is vital since it directly affects the optical efficiency of the system. Accurate determination of the dimensions in both the x and y axes is crucial.

Design parameters are the precise criteria and limitations that direct the conception and execution of a design project. The parameters that define the fundamental characteristics of a parabolic trough collector can be divided into two primary categories: geometric and functional. The key geometric properties of a parabolic trough solar collector (PSTC) are its dimensions, such as the width and length of the aperture, the angle of the rim, the focal length, the diameter of the receiver, the diameter of the glass envelope, and the concentration ratio. The functional parameters of photovoltaic solar thermal collectors (PSTC) include optical efficiency, instantaneous thermal efficiency, overall thermal efficiency, and receiver thermal losses. The above parameters are greatly influenced by the absorptivity of the absorber. The observed faults can be ascribed to multiple factors, such as flaws in the reflector material, problems with the support structure, improper positioning of the receiver in relation to the focal plane of the Photovoltaic Solar Thermal Collector (PSTC), and misalignment of the PSTC with the sun caused by tracking errors.

Table 1: Specification of absorber tube

Reflective material	Stainless steel
Reflectivity of mirror	0.9
Absorber tube material	Glass with copper coating
Inside diameter of Copper tube	35mm
Outside diameter of copper tube	45.4mm

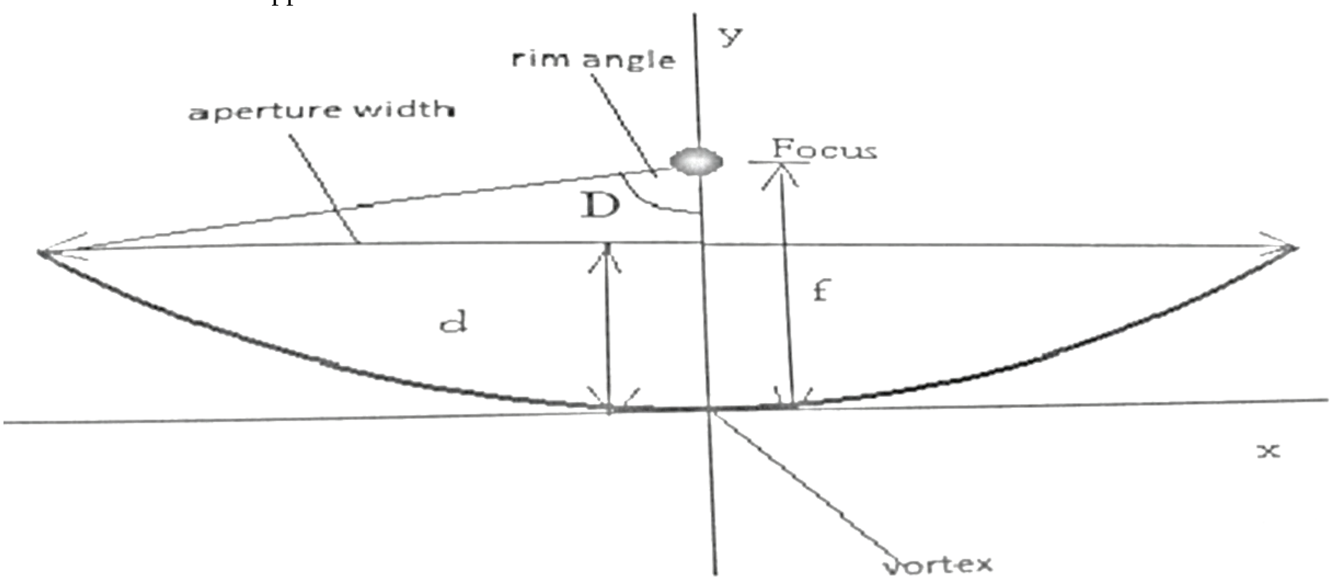

Fig 2: Design specifications of parabolic reflector

Table 2: Different parameters and their values for the fabricated PTSC

Parameter	Value
Collector aperture	1130mm
Collector length	1420mm
Aperture area	1.54m^2
Rim angle	90^0

Focal distance	100mm
Receiver diameter	35mm
Water flow rate	30KJ/hr
Tank material	Stainless steel
Tank insulation material	Glass wool
Water pump	25 W

Formula used for performance testing of hot water generating PTSC

1) Collector efficiency $=\frac{Qu}{AI} = mCp\ (To - Ti)/AI$

Where, Qu = Useful heat gain (KJ/hr)
A = Aperture area (m2)
I = Solar Radiation Intensity (W/m^2)
m = Mass flow rate (Kg/hr)
Cp = Specific heat capacity of water (J/Kg-K)
Ti, T0 = Outlet and inlet temperature of water (^0C)

2) Effective aperture area: (W- Dco) × L;

Where, W = Width of the reflector
Dco = Outside diameter of glass cover tube

Specimen calculation

Flow rate of water = 42 Kg/hr Area of collector = 1.54 m^2
Total heat available = (pyranometer reading × 60 × 4.186 ×104) / (pyranometer constant ×1000)
= (5.2 × 60 × 4.186 × 104) / (5.56 × 1000) = 2349.54 KJ/hr-m^2;
Heat available in collector = Total heat available × area of collector
= 2349.54 × 1.54
= 3618.29 KJ/hr
Heat gained by water = mw × Cpw × Δt
= 42 × 4.187 × (40 - 30)
= 1758.12 KJ/hr
Efficiency = (Heat gained) / (Heat available) × 100 = 48.58%

Result and Discussion

The main utilisation of the parabolic trough solar collector system is in power generation, due to its capacity to attain elevated temperatures in steam. Furthermore, it is also used for the purpose of heating water, air, and other diverse uses.

The potential of PTSC technology in water heating applications is substantial, as long as the system cost is efficiently reduced.

Figure 1 illustrates the graphical depiction of the correlation between solar intensity, quantified in kilojoules per hour per square metre (KJ/hr-m^2), and time, measured in hours. The sun irradiance was quantified throughout a duration of 15 minutes, precisely from 10:15 to 14:15. Graphs were created to illustrate the correlation between sun intensity and various flow rates, specifically 30 kg/h, 42 kg/h, and 60 kg/h. The solar irradiation was measured at different flow rates.

Figure 4 illustrates the correlation between collector efficiency, measured as a percentage, and the duration of time, measured in hours. The collector's efficiency was assessed at different flow rates, and a graph was created to demonstrate the correlation between these variables.

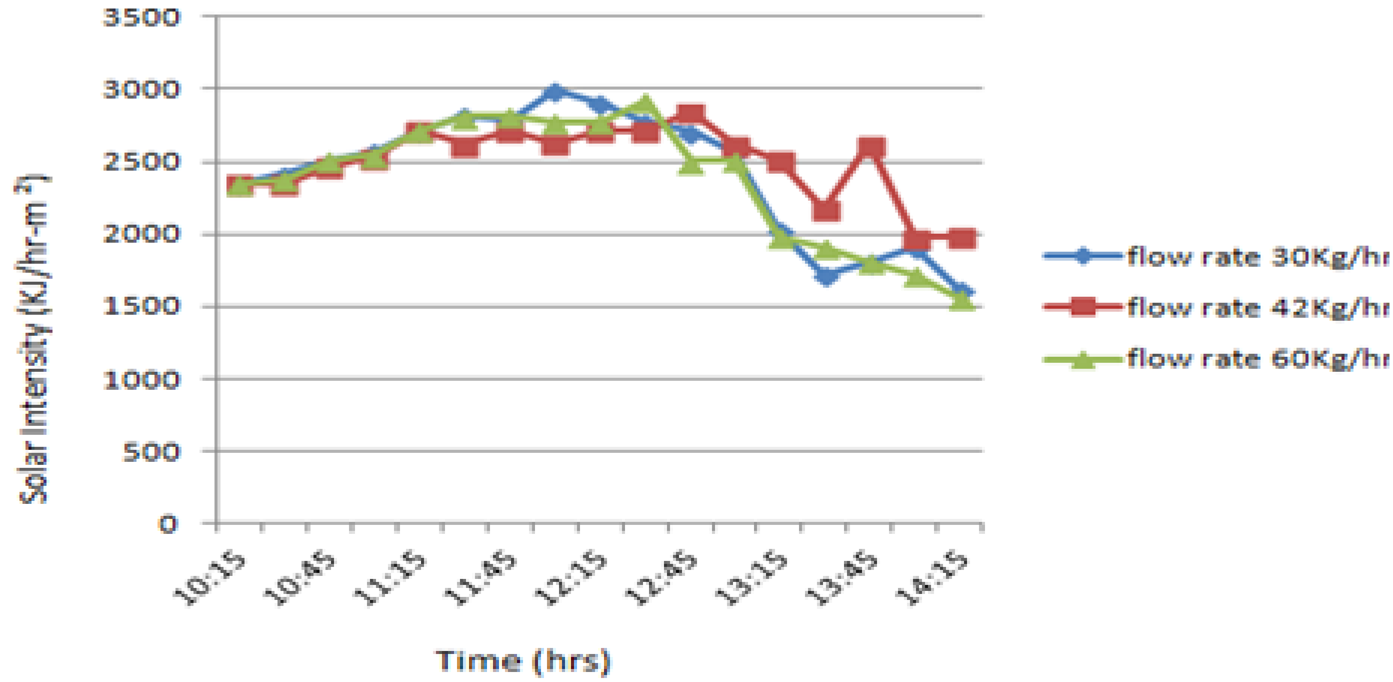

Fig. 3: Graph between Solar Intensity and Time

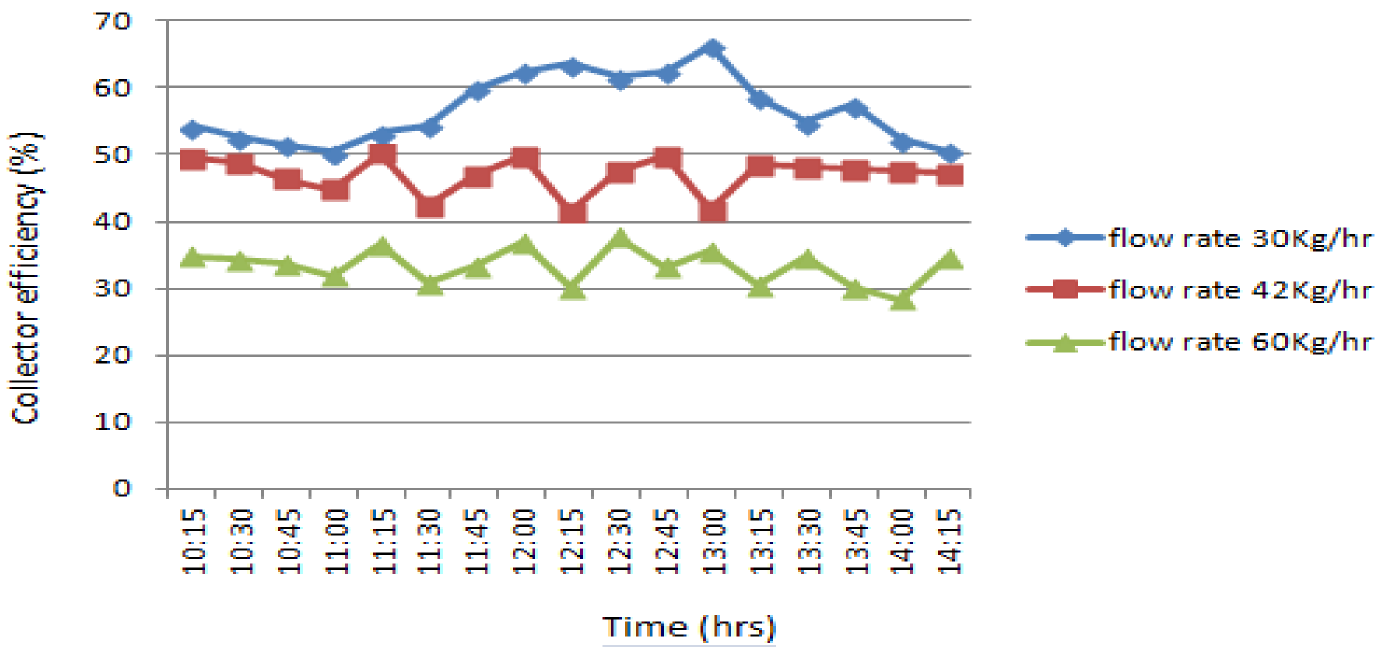

Fig. 4: Graph between collector efficiency and Time

Figure 3 presents a graph that showcases the correlation between time and solar intensity. It is noted that the solar intensity first increases over time. Nevertheless, throughout time, the sun intensity undergoes a persistent decrease. The graph in Figure 4 demonstrates a direct relationship between collector thermal efficiency and time. As time passes, the thermal efficiency of the collector improves in direct correlation with the increase in solar intensity. This results in a rise in temperature, eventually reaching its maximum level. However, as the temperature reaches its highest point, the collector's thermal efficiency starts to decrease as the temperature decreases.

A calculation was conducted to ascertain the overall heat availability, heat available at the collector, heat received by water, and thermal efficiency at a flow rate of 42 kg/hr. The determined values are as follows: 2349.54 KJ/hr-m^2, 3618.29 KJ/hr,

Conclusion

Parabolic trough solar collectors utilise materials that undergo a phase change from liquid to gaseous in order to enhance the efficiency of heat transmission. The solar collectors are characterised by the presence of heat pipes, which are very efficient conductors of thermal energy. These heat pipes are enclosed in tightly sealed tubes to ensure that no air can escape. The heat pipes are made of copper and have absorption plates, which are copper fins plated onto them. The width of the fins matches the inner diameter of the pipe. Each heat pipe is equipped with a metal condenser tip extending from its top.

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