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Research Note

An Effective Parabolic Solar Collector for Evaluation and Testing Experimental Model

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P A P E R I N F O

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A B S T R A C T

The present work demonstrates fabrication and scope of the parabolic solar collector setup with significant temperature rise using concentric copper tubes filled with graphite powder. This paper basically focused on application of alternative energy which is convenient to utilize and maintain. The solar collector's efficiency studies aimed to improvement system performance with respect to energy conversion efficiency. The parabolic collector and the entire setup were fabricated on local workshop. The main objective of the research is to obtain very significant changes in the temperature rise of water from the output gate valve of the collector and to provide a cost efficient method to harvest the solar energy in the most effective way. It also includes comparison of the collector's performance by installing copper tubes and concentric copper tubes filled with graphite. Testing of the entire system was carried out during the month of April 2015 at Noida (28° 57' N and 77° 32'E). This setup found applications such as a solar geyser, thermal power units, steam generation systems etc.

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INTRODUCTION

In present scenario, extensive use of fossil fuels causes global warming. The continuous use of polluting fuels may lead to adverse effect on our environment; resulting ozone layer depletion, acid rain etc. Energy crisis is the biggest issue for many countries. The concern of climate change caused due to air and water pollution is constantly rising. Therefore, it is very necessary to find out the carbon dioxide free energy source to meet the industrial and daily requirements. In order to control the situation and avoid the consequences, there are two alternatives i.e., either to improve the quality of fossil fuels used or to shift towards the usage of renewable sources. Solar energy, being abundant in nature can be produced and utilized effectively, especially in the country like India, where ample amount of solar energy can be accessed for almost seven out of twelve months. Solar thermal energy is a source of renewable energy which is utilized at least concentrations in the world. In United States only two tenth of the total thermal energy is consumed[1]. Solar radiation is a high energy and temperature source for harnessing the thermal energy. It is also a clean source of energy and considered as pollution free resources. Thermal energy from sun is used for various applications such as power productions for industrial purposes [1]. Solar thermal energy is coupled various systems such as concentrators, receivers, collectors, fluid transport, distribution system, control system, Rankine steam turbine or generation system cycle etc [2, 3]. These systems can be assembled in an efficient manner. Various concentrating surfaces are used for solar collectors such as parabolic trough collectors known as point focus concentrators or line focus concentrators and linear Frensel collectors [4]. Parabolic trough collectors are the most efficient setups which are used for harnessing the solar energy by solar steam generation [5]. The flat plate collectors have also been tested for the solar thermal energy concentrations [6]. Flat plate solar collector in air heaters performance parameters for various natures of flows have also been studied [7]. In central Europe, 90 % of the solar collectors used are of flat plate type. The performance of parabolic trough collectors varies with different climate conditions. Various changes in the arrangements along with the use of parabolic trough collectors have

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1. Institute for energy research. (2009, June 18). http://www.instituteforenergyresearch.org/energy-overview/solar/

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been tested to get the optimized concentration of energy. Parabolic trough concentrators with bimetallic Cu-Fe receivers have been tested for solar energy [8]. Aluminium polymer laminated steel reflectors have also been tested along with the optical properties and reflector performance [9]. Fiberglass reinforced parabolic trough concentrations was designed and tested for solar collectors [11]. Fiberglass reinforced plastics trough system could be useful for heating purposes in industrial applications for India due to less cost [10]. A numerical study of heat loss from half insulated annulus between two horizontally concentric cylinders was studied and compared to a conventional receiver [11]. Numerical investigation of the performance of parabolic trough receiver with vacuum shell has also been compared to that of the non evacuated shell type receiver [12]. Investigation on performance and energy consumption efficiency of 15 kW solar receivers for hydrogen production has also been studied [13]. AU type heat circulation pipe system has also been designed and studied for generating medium temperature steam [14]. Also, various solar plants have been setup by the government to concentrate the solar energy while arranging large number of concentrating mirrors in different fashions to heat up the fluid at very high temperatures using solar thermal energy. The mirrors follow the sun's movement throughout the solar cycle to extract the maximum concentration of energy. The heat from the heat transfer fluid is then used by the turbine or generators to generate electricity. Large numbers of mirrors are used for covering commercial sites [15]. The steam generation for electrical appliances can also be replaced by installing an effectively designed solar collector. The scope of the paper is to fabricate and demonstrate an effective parabolic solar collector and its application. The experimental setup was installed at Amity University, Noida, India (28° 57' N and 77° 32'E). The setup has been designed for two cases i.e., for hollow collector tubes and for concentric collector tubes with graphite powder filled inside tubes and the readings have been compared for significant results.

MATERIALS AND METHODS

Experimental setup and its Description:

A cost effective model was fabricated. This model is a parabolic type shaped collector made up of copper for desired heat conduction as copper has good thermal conductivity. The specifications of the parabolic collector are summarized in Table 1. The parabola shape increases the surface area in contact with sun radiations allowing the device to heat up a large portion of the total area of the collector regardless of the position of sun and the time variant. Array of concentric copper tubes vertically fitted on the surface of collector. These concentric copper tubes were filled up with graphite power due to its high thermal conductivity and stability while the inner section has been kept empty for the flow of water. Also, array of hollow copper tubes fitted for the normal case to compare the readings taken at normal case, as the readings taken with the concentric tubes filled with graphite powder. Hence, the experimental setup has been designed to be formed for both the cases to obtain the significant outcome from the modified system. The concept of the mechanism was setup in such a way that the collector and tubes heat up by solar radiations and heat transfer takes place into the water flowing inside the vertical tubes.

Figure 1 shows the line diagram of the entire setup. Figure 2 depicts the fabricated parabolic solar collector and the entire setup layout. The experimental setup constitutes of parabolic solar collector, concentric copper tubes filled with graphite powder, hollow copper tubes, acrylic glass cover, RO booster pump 75 GPD, 12V- 7.2A battery, 3W – 6V solar panel, water reservoir, a concentrator setup consisting a series of three convex lenses, a hollow copper pipe and two gate valves. Water from the reservoir flows into the copper tubing of the parabolic collector by RO booster pump and then heated up by the heat transfer unit from the parabolic collector's surface and then flows out through the outlet of the parabolic collector. The heated fluid passes through the copper pipe of the concentrator setup where additional heat is transferred due to the focussing of the solar radiations through the series of convex lenses directly zoomed on the copper pipe. After obtaining the required heat, water regulates with the help of gate valve as per requirements. Taking Uttar Pradesh's geographical location and taking Noida town as reference, located at 28°57' North latitude and 77°32' East longitude, tests were performed for the effectiveness of the collector. RO booster pump was used because of the desired flow rate was less so as to get the significant increment in temperature of the water. An acrylic glass cover was used for covering the parabolic solar collector during the test. The cover has created greenhouse effect for enhancing the effectiveness of heat entrapped inside the collector as it has high visible light transmitting capacity as compared to the normal glass. The collector was painted black in order to increase the heat absorptivity of the parabolic collector.

TABLE 1. Specifications of parabolic solar collector

Height (cm)	40
Base Diameter (cm)	60
Upper Diameter (cm)	20
Tube Diameter (cm)	0.6
Surface area of collector (cm^2)	6848
Weight (kg)	11

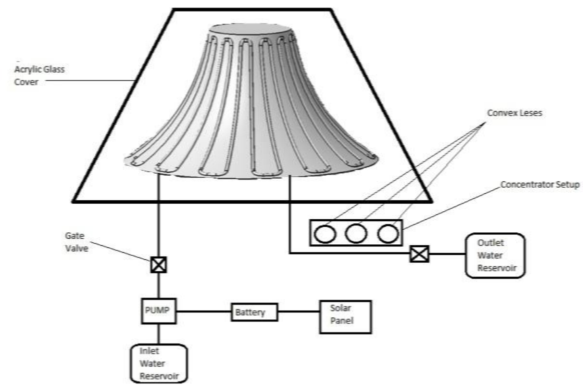
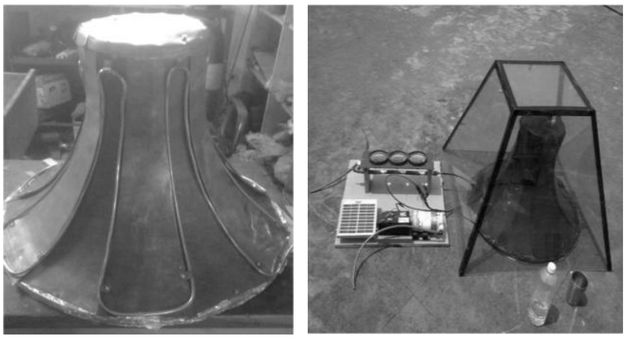


Figure 1. Schematic line diagram of the entire setup



(a) (b)

Figure 2. (a) Parabolic solar collector, **(b)** Experimental setup

RESULT AND DISCUSSION

Experiments were conducted at Amity University, Noida, India (28° 57' N and 77° 32'E) from 17th April 2015 to 20th April 2015 at dry weather condition. This paper deals with the effective use of parabolic collectors for deriving solar energy. Readings for two cases were recorded i.e., when the hollow array of copper tubes was mounted on parabolic collector and for the second case the concentric copper tubes filled with graphite powder were mounted on the collector. Tables 2 to 7 show the experimental readings for both cases. The efficiency of the setup for each set of readings is calculated. Tables 2 and 3 recorded fluid inlet and outlet temperatures with fluid flow rates of 0.01 and 0.0075 kg/s with hollow copper tubes. Tables 5 and 6 stated inlet and outlet fluid flow temperatures with fluid flow rates of 0.01 and 0.0075 kg/s concentric copper tubes filled with graphite powder. Tables 4 and 7 summarized the average efficiency data of different set of readings. Figures 3 to 7 illustrate experimental data collected. It has been found that the device showed up significant increase in the temperature of water when the collector tubes filled with graphite powder inside tubing. Use of graphite powder as effective media for additional heat transfer showed that process efficiency was improved (additional 7%). Hence the proposed parabolic collector setup worked efficiently for the purpose and can be used for a wide range of applications.

TABLE 2: Readings at flow rate 0.01 kg/s with hollow copper tubes

Ambient temp. (˚C)	Time	Initial water temp. (˚C)	Final water temp. (˚C)
36	12:30 PM	29	70 (Still water) 58 50
35	2:15PM	30	69 (Still water) 55 50
32	3:30PM	28	58 (Still water) 49 42

TABLE 3: Readings at flow rate 0.0075 kg/s with hollow copper tubes

Ambient temp. (˚C)	Time	Initial water temp. (˚C)	Final water temp. (˚C)
38	12:30 PM	29	72 (Still water) 60 54.5
37	2:15PM	30	71 (Still water) 57 52
36	3:30PM	29	65 (Still water) 56 51

TABLE 4: Average Efficiency with hollow copper tubes

Ambient temp. (˚C)	Time	Initial water temp. (˚C)	Final water temp. (˚C)
38	12:30 PM	29	79 (Still water) 65 57
36	2:15PM	30	75 (Still water) 61 54
34	3:30PM	28	69 (Still water) 55 47

TABLE 5: Readings at flow rate 0.01 kg/s with graphite filled concentric copper tubes

Experiment no.	Avg. inlet temp.	Avg. outlet temp.	Efficiency (%)	Avg. η (%)
1.	29 30 28	54 52.5 45.5	28.2 25.3 20	24.5
2.	29 30 29	57.25 54.5 53.5	23.9 20.7 20.7	21.7

Table 6: Readings at flow rate 0.0075 kg/s with graphite filled concentric copper tubes

Ambient temp. (˚C)	Time	Initial water temp. (˚C)	Final water temp. (˚C)
37	12:30 PM	30	81 (Still water)
			68
			61
36	2:15PM	30	80 (Still water)
			66
			59
34	3:30PM	29	75 (Still water)
			65
			57

TABLE 7: Average Efficiency with graphite filled concentric copper tubes

Experiment No..	Avg. inlet temp.	Avg. outlet temp.	Efficiency (%)	Avg. Ƞ (%)
	29	61	36.1	31
3.	30	57.5	31	
	28	51	26	
	30	64.5	29	27.83
4.	30	62.5	27.5	
	29	61	27	

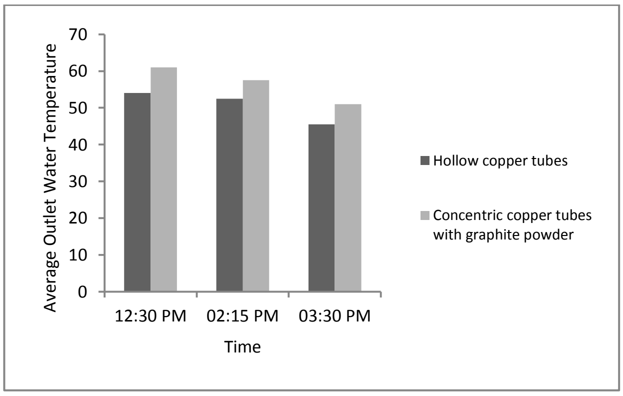


Figure 3. Average outlet water temperature vs time at 0.01kg/s

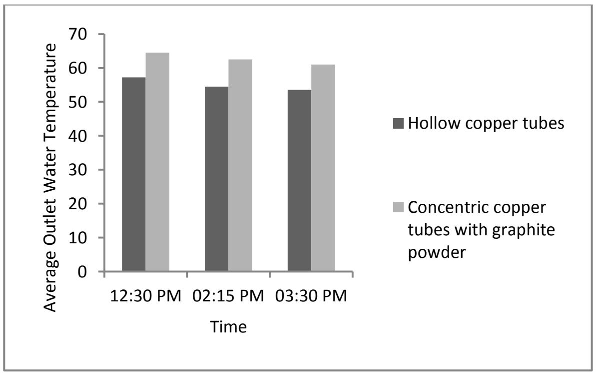


Figure 4. Average outlet water temperature vs time at 0.0075kg/s

CONCLUSION

The results of the research show up with the efficient setup of the parabolic solar collector. The test was

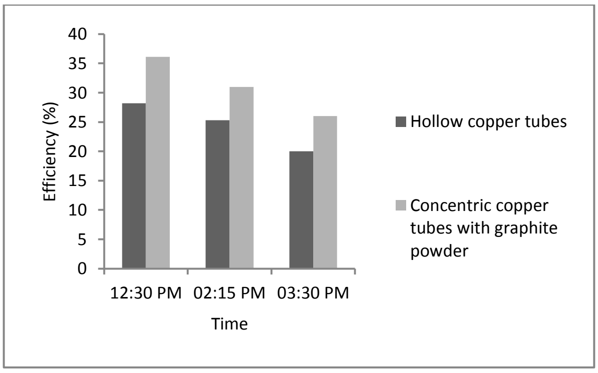


Figure 5.Efficiency vs time at 0.01kg/s

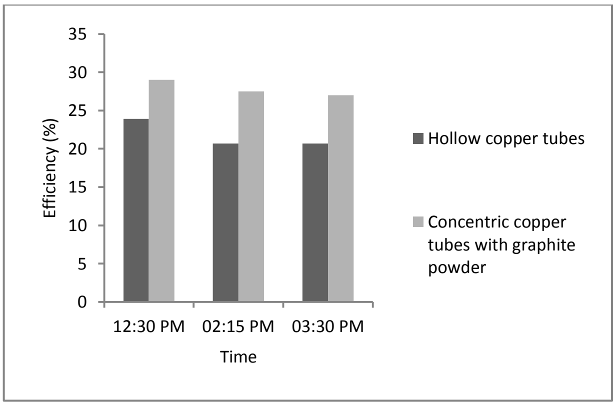


Figure 6. Efficiency vs time at 0.0075kg/s

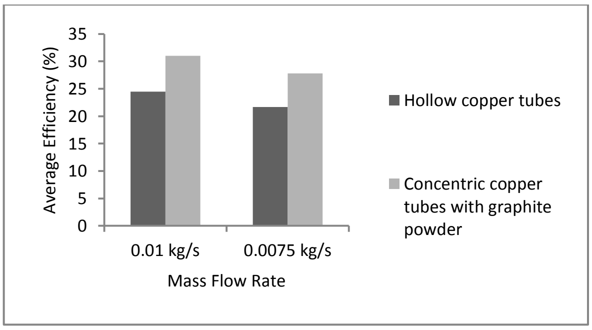


Fig. 7. Average efficiency vs mass flow rate for both the cases

carried out using water as the working fluid. The parabolic shape of the collector increases the surface area in contact with sun radiations allowing the device to heat up a large portion of the total area of the collector regardless of position of sun and the time variant. Readings were taken for two different cases and for different sets of time. The result for the different cases indicates that the setup copper collector tubes filled with graphite powder showed significant increase in heat transfer efficiency as compared to the hollow copper tube collector tube setup. The illustrated graphs clearly showed that by installing graphite powder filled copper collector tube in the parabolic collector's setup increases its efficiency by 6-7 % for a mass flow rate of around 0.075-0.01 kg/s which is a great margin in terms of energy harvesting. A very significant change in the temperature rise of water was obtained from the output gate valve of the collector outlet and provides cost efficient way to harvest the solar energy in the most effective way. This also leads to conclude that, larger the mass flow rate more will be the conversion efficiency of the setup. Hence, the setup will be very useful for the applications where the harvesting of solar energy is required in substantial amount. The setup can be easily implemented and gives an accurate approach. This setup finds applications such as a solar geyser, in paper industries, thermal power units, steam generation systems, household purposes, desalination etc.

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Persian Abstract

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چکیده

کار حاضر، ساخت و راه اندازی کلکتور خورشیدی سهموی با افزایش قابل توجه درجه حرارت با استفاده از لوله های مسی متحدالمرکز پر شده با پودر گرافیت را نشان می دهد. این مقاله اساسا روی کاربرد انرژی های جایگزین که از لحاظ استفاده و بقا مناسب هستند، متمرکز شده است. کلکتور سهموی و نصب و راه اندازی کلی آن در کارگاه محلی ساخته شد. هدف اصلی این تحقیق به دست آوردن تغییرات قابل ملاحظه در افزایش درجه حرارت آب از شیر دروازه خروجی از کلکتور و ارائه یک روش مقرون به صرفه برای برداشت انرژی خورشیدی با موثر ترین روش است. این تحقیق همچنین شامل مقایسه عملکرد کلکتور بوسیله نصب لوله های مسی و لوله های مسی متحدالمرکز پر شده با گرافیت، است. تست کردن کل سیستم در طول ماه آوریل در نویدا (Noida) (28° 57' N and 77° 32'E) انجام شد. این مجموعه کاربردهایی مثل چشمه های آب گرم خورشیدی، واحدهای برق حرارتی، سیستم های تولید بخار یافته است.