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An Experimental Investigation of Parabolic Trough Collector using Industrial-grade Multiwall Carbon Nanotube- H_2O Based Nanofluid

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ABSTRACT

Solar thermal systems for heating have a high level of reliability. The usage of parabolic trough collectors (PTC) for domestic applications is still quite limited; furthermore, commercial utilization of nanofluids in these applications is rare. The influence of MWCNT nanofluid as a heat transfer fluid on the efficiency of a locally developed parabolic trough collector was experimentally examined. The effect of surfactant on nanofluid stability was also investigated, and it was revealed that nanoparticles could be evenly suspended in base fluid for at least 10 days and less than one month using Triton X-100. Experiments were also conducted to determine the optimal quantity of Triton X-100 surfactant; it is possible to make nanoparticles stable for 28 days in base fluid with the ratio of Triton X-100 to MWCNT as 0.5:1. At 2.0, 3.0, and 4.0 L/min flow rates, MWCNT/H_2O is used at three-particle concentrations of 0.1, 0.2, and 0.3% by weight. The experiment is carried out under outdoor operating conditions. With 3 L/min at 0.2 wt.%, MWCNT nanofluid achieves a maximum thermal efficiency that is 22% greater than the water. The findings provide important information about the commercialization of a locally developed PTC.

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1. INTRODUCTION

Researchers have been emphasized using sustainable and renewable energy these days. Over the past few years, renewable energy has been widely used, including wind energy, hydrogen energy, and solar energy. Solar energy is the most favorable type of renewable source of energy that can, directly and indirectly, be transformed into various forms of energy. One of the strongest sources of renewable energy with limited environmental effects is solar energy. A well-established technology is the solar parabolic trough collector and it has been proposed for several applications, such as power generation and water heating, but the performance of these collectors is restricted by the working fluid's absorption properties. This technology has recently been combined with the evolving nanofluids and liquid-nanoparticle suspension technologies to create a new class of solar collectors based on nanofluids. The performance increase was seen in the use of nanofluids as the absorption media in solar thermal collectors. In India, over 90% of the country during the summer season a large amount of solar radiation is received in the order of 3.0–6.5 (10.8–23.4 MJ/m^2-day) kWh/m^2-day [1]. Rehan et al. [2] assessed the maximum efficiencies for Al_2O_3 and Fe_2O_3 nano-fluids at 2 L/min and found 13 and 11% increment, respectively compared to water under the same operating conditions. In improving the performance of PTC compared to Fe_2O_3 for domestic applications, Al_2O_3 nanofluids seemed more favorable. Chaudhari et al. [3] found that solar thermal efficiency can be increased by approximately 7% by Al_2O_3 nanofluid and the heat transfer coefficient can be increased by 32 %. Sunil et al. [4] investigated SiO_2-H_2O-based nanofluid is comparatively more efficient at higher volume flow rates and concentrations. Ebrazeh et al. [5] has examined that due to its high energy content, the use of nanofluids increases thermal efficiency. In a wide range of studies, Al_2O_3 nanoparticle has been used because of its lower price. Also, the collector's thermal

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efficiency can be improved by raising the working fluid inlet temperature. Among all forms of nanofluids, the use of MWCNTs has the best thermal performance. Verma et al. [6] assessed multiwalled carbon nanotube/water and reported the highest increase in a collector's energy efficiency, which is 23.47%, followed by 16.97, 12.64, 8.28, 5.09, and 4.08%, respectively for graphene/water, Copper oxide/water, aluminium oxide/water, titanium oxide /water, and silicon oxide/water compare to water as the base fluid. The percentage decrease in the area observed in various nanofluids was given as 19.01% as the optimum in MWCNTs/water followed by 14.66, 10.66, 8.78, 4.83 and 3.99%, respectively in graphene, copper, aluminium, titanium, and silicon oxide-based nanofluids. Verma et al. [7] evaluated the use of MgO nanofluid improves the solar collector efficiency by 9.34% for 0.75% of particle volume fraction and volume flow rate at 1.5 L/min compared to water as working fluid. Yousefi et al. [8] found a large improvement in efficiency due to increasing the weight fraction from 0.2 to 0.4%. Using the surfactant also results in an improvement in efficiency. The optimum sonication time was selected to be 30 min. Rastogi et al. [9] proved that Triton X-100 was the best dispersing agent for suspending MWCNTs as a non-ionic surfactant. Maximum dispersion was given by the Triton X-100 among many surfactants like Tween 80, Tween 20, and sodium dodecyl sulfate (SDS). The optimum amount of surfactant required in the case of Triton X-100 is also lower than that of other surfactants. The optimal ratio of Triton X-100-to-CNT was selected to be 1:350. Mishra et al. [10] scrutinized MWCNT nanofluid 0.02 wt% with 160 L/h showed better results for overall thermal efficiency and the use of surfactant Triton X-100 with MWCNT nanofluid was also used to increase the amount of base fluid heat absorption power. Bernard et al. [11] studied that with a mass flow rate of 0.0069 kg/s, 0.0138 kg/s, and 0.0207 kg/s, the heat energy obtained by the MWCNT fluid has increased by 5.2 %, 7.3 %, and 7.2 % compared to water. Hachicha et al. [12] evaluated MWCNT nanoparticles in water results in a 12, 16, and 21% raised in Nusselt number for nanoparticle concentrations of 0.05, 0.1, and 0.3%. The use of low concentrations of nanofluid could improve thermo-hydraulic performance at flow rates below 0.2 L/s, Khanafer et al. [13] surveyed available studies in the literature of solar systems and concluded an increase in thermal conductivity of nanofluid is an important factor for improving the efficiency of nanofluid. Higher volume fractions of nanoparticles do not increase performance regularly. Due to the addition of nanoparticles, the rise in nanofluid viscosity is a major drawback since it is associated with increasing pumping capacity. Thus, the use of low viscosity and high thermal conductivity nanofluids is favorable. Borode et al. [14] described carbon nanomaterials as the most promising for the preparation of nanofluids and the application of heat transfer. This research result showed that carbon-based nanofluids increased the collector performance of flat-plate, evacuated-tube, parabolic trough, and hybrid photovoltaic thermal solar collectors by up to 95.12, 93.43, 74.7, and 97.3%, respectively, with a low concentration of about 0.3 vol.%. Bindu et al. [21] proved improvement in thermophysical characteristics and thermal conductivity of the HTF by nanoparticles such as CuO, Ag, TiO_2, Al_2O_3, SiO_2, MWCNT, CNT, and mixture of the particles forming hybrid nanofluid. The use of nanofluid in PTC improves the system's thermal efficiency. Hussein et al. [15] explained the challenges and difficulties that arise during nanofluid preparation and in an application, (i) A long time is required for the nanofluid to be stable with base fluids. (ii) The toxicity of the nanofluid is high, so it needs to be taken care of during its preparation. (iii) Preparation and testing of the nanofluid are extremely expensive. (iv) The high viscosity of the nanofluid contributes to an increase in the pressure drops and also increases the necessary pumping power. (v) The presence of nanoparticles in the nanofluid can lead to long-term solar collector corrosion and erosion. Olia et al. [16] examined the use of copper nanoparticles led to improve thermal efficiency in metallic nanofluids, followed by CuO, TiO_2, and Al_2O_3, among all the nanoparticles examined, the MWCNT nanoparticle can lead to the highest increase in thermal efficiency for non-metallic nanofluids. Mirabootalebi et al. [20] altering the effective variables, such as increasing milling time, selecting the suitable temperature, utilizing different sizes of balls, and using a special vial, can increase the quality and quantity of MWCNTs. Three essential components of the experiments conducted and described in this article are innovative. (1) With thorough research of such systems, rare relevant literature or experimental data is found for climatic conditions of underdeveloped countries, particularly in South Asia, such as India. Furthermore, different types of nanoparticles are utilized in different climates; however, the experimental examination of industrial-grade MWCNT-H2O is only found in a numerical study. Furthermore, the vast bulk of nano-fluids research is focused on high-temperature applications, particularly for power production, whereas the current effort is mostly focused on low-temperature domestic uses. As a result, the provided findings provide a valuable dataset for the future feasibility of independent PTC applications in off-grid settings. (2) The developed system reported here made use of comprehensive local fabrication capabilities and materials that were readily available locally. The performance rating of entirely local PTC under various atmospheric and operating conditions, as well as nanoparticle amounts, adds great value to these findings, particularly for regional growth. (3) The complete replacement of the PTC's expensive conventional receiver tube with a two-sided open evacuated tube. Finally, parametric variations in nanoparticle weight fractions and flow rates are investigated and reported hereunder local climatic conditions. The provided findings provide insight into the performance of the linear PTC system in terms of product commercialization in similar climatic locations.

2. EXPERIMENTAL SETUP AND PROCEDURE

2. 1. Material The nanoparticles employed in the experimental study were MWCNT of industrial grade. The Nanoparticles with 99% purity were purchased from ‘‘adnano Technologies India’’. To disperse MWCNT nanopowder, laboratory-grade Triton X-100 was utilized as a surfactant. The properties of the nanoparticles used are listed in Table 1, for the manufacture of water-based nanofluids; distilled water was employed as the based fluid. Figure 1 shows the TEM images of industrial-grade MWCNT.

2. 2. Requirement of Surfactant Based on the collected data and the comprehensive survey carried out, Triton X-100 is the best dispersing agent for suspending MWCNT as a non-ionic surfactant. The Triton X-100 is confirmed among different surfactants since the optimum amount of Triton X-100 surfactant required is also lower than that of other surfactants [9]. It is also used to increase the amount of base fluid heat absorption power; Triton X-100 is a colorless viscous fluid. Beaker A represents the Nanofluid without surfactant and Beaker B represents the Nanofluid with surfactant. To avoid agglomeration of nanoparticles magnetic stirrer and sonication were done for 2 and 3 h, respectively with both samples.

The above Figure 2A depicts that agglomeration of nanoparticles in nanofluid without surfactant would start after 1h and afterward sedimentation of nanoparticles will be observed. Figures 2B, 2C, 2D and 2E show process of agglomeration is quite significant after 2, 3, and 4h. Complete sedimentation can be observed after 5h in Figure 2E.

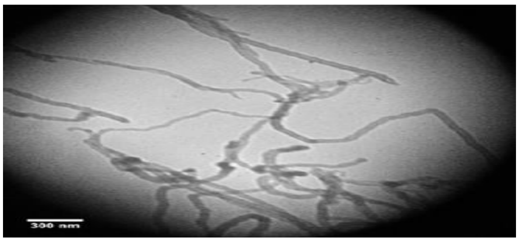

Figure 1. TEM micrograph image of MWCNT nanoparticles at 300 nm [17]

TABLE 1. Properties of Nanoparticles[17]

Multi-Walled Carbon Nanotubes	Description
Purity	~99 %
Outer Diameter	10-30 nm
Inner Diameter	5-10 nm
Length	>10 µm
Surface Area	110 - 350 m^2/g
CNT content	~95-99 %
Bulk Density	0.14 g/cm^3
Color	Black Powder

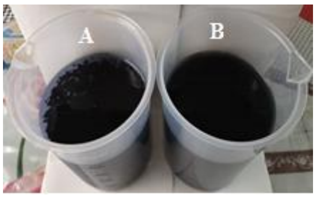

Figure 2A. Condition of Nanofluids after 1h. of preparation

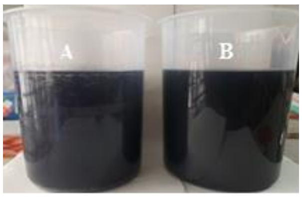

Figure 2B. Condition of Nanofluids after 2h of preparation

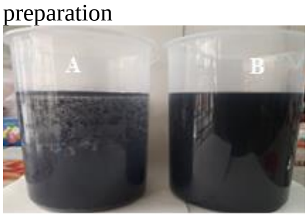

Figure 2C. Condition of Nanofluids after 3h of preparation

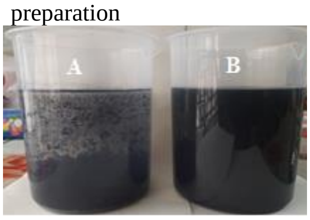

Figure 2D. Condition of Nanofluids after 4h of preparation

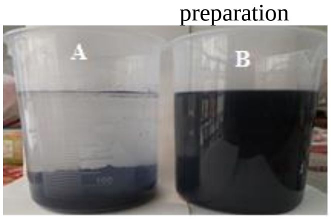

Figure 2E. Condition of Nanofluids after 5h of preparation

While in the case of nanofluid with the surfactant, nanoparticles can be evenly suspended in base fluid for at least 10 days and less than 1 month for Triton.

2. 3. Required Optimum Quantity of Surfactant Based on the extensive literature survey one question need to be addressed, what should be the optimal quantity of surfactant in the particular experimentation. There are different ratios of Triton X-100: MWCNT available in the literature. As far as present research is concern following ratios of Triton X-100: MWCNT have been selected (i) 0.1:1 (ii) 0.25:1 (iii) 0.5:1 [18].

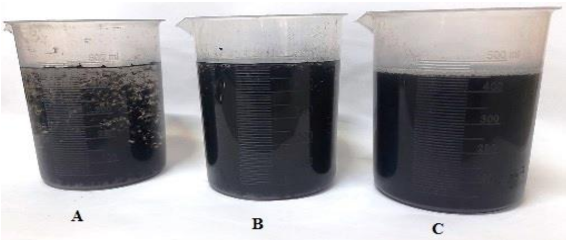

Figure 3. Surfactant: MWCNT ratio, (A) 0.1:1 (B) 0.25:1 (C) 0.5:1

Pilot experimentation was carried out to check the period of stability of nanoparticles in the base fluid. In Figure 3 beakers A, B and C represent the different nanofluids with Triton X-100: MWCNT followed by 0.1:1, 0.25:1, and 0.5:1 ratio. A continuous observation was done for 1 month to observe the sedimentation time taken by the different nanofluid. After 11 days agglomeration was started in nanofluid having surfactant: MWCNT ratio 0.1:1, which can be identified from Beaker A. In the case of Beaker B agglomeration time was 18 days and Beaker C shows maximum stability time for nanoparticles in base fluid as 28 days. To conclude this pilot experiment, one conclusion can be made that Triton X-100 with 0.5 % of MWCNT by weight gives quite enough stability in suspension for a considerable time.

2. 4. Nanofluids Preparation Method MWCNT water-based nanofluids i.e. MWCNT/H_2O is used at three particles concentrations of 0.10, 0.20, and 0.30 % by weight at 2.0, 3.0 and 4.0 L/min flow rates.

To make stable nanofluids, a weighted amount of nanoparticles was first dispersed in a base fluid containing a surfactant. Then, using a 40 kHz ultrasonic vibrator, sonication was used to obtain homogenized dispersed nanofluids, as shown in Figure 4. To avoid agglomeration, researchers employed a two-step approach of sonication and magnetic stirrer to prepare MWCNT/H_2O nanofluids [18]. In this experiment, distilled water was mixed with a weighted amount of MWCNT nanopowder and the surfactant Triton X-100. To avoid nanoparticle aggregation, a magnetic stirrer was employed to disperse nanoparticles in distilled water for 2 hours, as illustrated in Figure 5. And then sonication for 3 hours was done to stabilize the nanofluids.

Figure 4. Ultrasonic vibrator

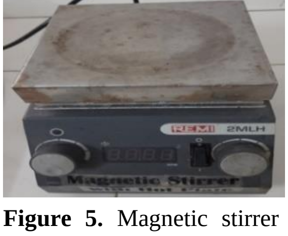

Figure 5. Magnetic stirrer with a hot plate

2. 5. Experimental Line Layout Under actual conditions in Surat, Gujarat, India (21°10'45.8"N, 72°48'47.6"E), the thermal performance of a parabolic trough collector with water and MWCNT/H_2O was compared. The nanofluids were formed utilizing a two-step method in distilled water with the inclusion of Triton X-100 as a surfactant, as well as a sonicator at various nanoparticle mass fractions. In addition to the effects of three different concentrations; 0.1, 0.2 and 0.3 %, by weight, three flow rates; 2, 3 and 4 L/min were also studied. In March near to equinox i.e. 8^{th} to 19^{th} March, experiments were conducted daily from 10:30 a.m. to 2:00 p.m. The experimental setup is depicted in Figure 6. The nanofluid would be re-circulated at any point during the close cycle. The supply pump draws the working fluid from a single nanofluid storage tank and sends it to the parabolic trough receiver. A mechanical stirrer is offered for optimal fluid mixing and equal temperature distribution. The rotameter's control knob can be used to change the working fluid mass flow rate. In addition to controlling the working fluid's mass flow rate, a by-pass arrangement valve is also given. Two temperature sensors are positioned at the intake and outlet sections of the working fluid, respectively, to measure the inlet and outlet temperatures.

Two different sensors will monitor the skin temperature of the receiving tube and the skin temperature of the reflecting sheet, while one individual sensor will measure the ambient temperature. All of these temperature sensors are calibrated with PT-100 kinds before being linked to a computer for analysis.

3. DESIGN OF PTC SYSTEM

Parabolic profile curves, MS pipe struts, and a two-sided evacuated tube with supporting coupling are all

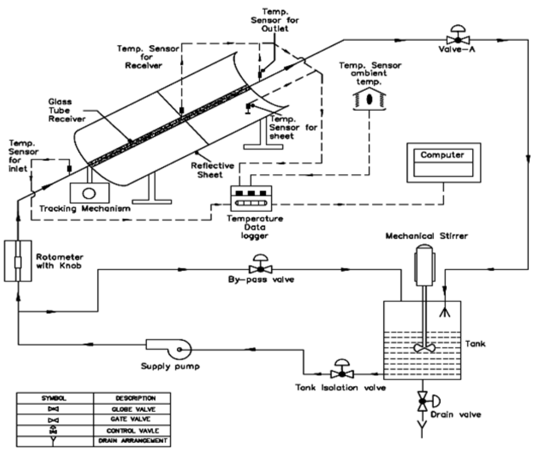

Figure 6. Schematic line layout of the PTC test setup

part of the experimental setup. When incident radiation strikes the PTC's aperture, it forms an angle with the PTC's central plane. The rim angle determines the curvature of a parabola. Equation (1) is the general equation of a parabola in a coordinate system [19]. where f = parabola focal distance (m). W_a = parabolic aperture.

$$y^2 = 4fx \tag{1}$$

The collector concentration ratio C, which is defined as the ratio of the aperture area A_{ap} to the receiver area A_r and is represented by Equation (2), is another significant parameter in PTC. D = Diameter required to intercept the entire solar image.

$$C = \frac{W_a}{\pi D} \tag{2}$$

Equation (3) can be used to calculate the parabolic aperture, where φ_r = Rim angle (°)

$$W_a = 4f \tan\left[\frac{\varphi_r}{2}\right] \tag{3}$$

The acrylic material required for parabolic surface construction is determined by the amount of the rim angle. Equation 4 can be used to compute the length of a reflective surface curve[19].

$$S = \frac{H_p}{2}\left\{\sec\left(\frac{\varphi_r}{2}\right)\tan\left(\frac{\varphi_r}{2}\right) + \ln\left[\sec\left(\frac{\varphi_r}{2}\right) + \tan\left(\frac{\varphi_r}{2}\right)\right]\right\} \tag{4}$$

H_p = Latus rectum of the parabola (m) = 1. In the case of 90° rim angle, it is equal to aperture. $S = 1.147\ \mathrm{m}$, Now the total reflective sheet area required for fabrication is, $A = 2.0\ \mathrm{m}^2$. Table 2 provides a summary of PTC's important characteristics.

The current research work is depicted in Figure 7.

3. 1. Thermal Analysis

Equation (5) indicates the available sun irradiation (Q_s) at the aperture can be used to compute the input energy [2]. Where G_b = Direct solar irradiation (W/m^2). $\dot{m}$ = Mass flow rate (kg/s), C_p= Specific heat (Kj/Kg °C), T_i = Inlet water temperature (°C), T_o= Outlet water temperature (°C).

$$Q_s = A_{ap} \times G_b \tag{5}$$

The amount of useful heat gained by the collector's working fluid is determined by Equation (6) [2].

$$Q_u = \dot{m}c_p(T_o - T_i) \tag{6}$$

Equation (7) is used to compute the collector's experimental thermal efficiency.

TABLE 2. The summary of the PTC key features.

PTC key feature	
Collector dimensions	1.00 m ×1.70 m
C	5.5
W_a[m]	1
H_p[m]	1
f[m]	0.250
D[mm]	58
φ_r[deg]	90°
A_{ap}[m^2]	1.70

Figure 7. Experimental setup of PTC with two-sided open evacuated tube receiver

$$\eta_t = \frac{\dot{m}c_p(T_o - T_i)}{A_{ap}G_b} \tag{7}$$

3. 2. The Volume Fraction of Nanoparticles in the Base Fluid

The current study's analysis is based on different amounts of nanoparticles presented as a percentage by weight fraction, which can be converted to volume fraction using the Equation (8) [2] relationship, as shown in Table 3.

$$\varphi \times 100 = \frac{\left[\frac{w_{MWCNT}}{\rho_{MWCNT}}\right]}{\left[\frac{w_{MWCNT}}{\rho_{MWCNT}}\right] + \left[\frac{w_{Base\ fluid}}{\rho_{Base\ fluid}}\right]} \tag{8}$$

4. RESULTS AND DISCUSSION

The thermal efficiency of PTC using water and water-based MWCNT nanofluids was experimentally studied under the actual outdoor operating parameters. The

TABLE 3. Volume fractions of nanoparticles

Sr. No.	Mass fraction of Nanoparticles by weight (%)	Density of nanoparticles ρ_{MWCNT} (kg/m^3)	Mass of Base fluid $W_{base\ fluid}$ (kg)	Density of Base fluid $\rho_{base\ fluid}$ (kg/m^3)	Volume Fraction (%)
1	0.1	140	0.998	999.972	0.007
2	0.2	140	0.998	999.972	0.014
3	0.3	140	0.998	999.972	0.021

influence of varied mass flow rates on the thermal efficiency of water and water-based MWCNT nanofluids with different concentrations by weight is shown. Figure 8 shows the variation in thermal efficiency at 2 L/min distilled water and compared with the nanofluid having different fractions i.e. 0.1, 0.2, and 0.3% by weight of MWCNT. The maximum efficiency achieves by the water is 33.43%. With the same flow rate and at 0.1, 0.2, and 0.3 wt.% obtained maximum efficiencies are 37.81, 39.65, and 38.48%, respectively. It should be mentioned that the thermal efficiency of MWCNT nanofluids is at 0.20 wt.% is higher than water and other nanofluids of various fractions at the same flow rate. Figure 8A depicts the change in thermal efficiency at 3 L/min distilled water when compared to nanofluids containing various fractions of MWCNT, viz. 0.1, 0.2, and 0.3 wt.%. The water achieves an efficiency of 37.09%. The efficiencies were obtained with the same flow rate and at 0.1, 0.2, and 0.3 wt.% are 37.81, 39.65, and 38.48%, respectively. It's worth noting that at 0.20 wt.%, MWCNT nanofluids have greater thermal efficiency than water and the nanofluids of various fractions at the same flow rate. Thermal efficiency at 4 L/min of distilled water and the different fraction of nanoparticles are shown in Figure 8B. The 35.61, 41.04, 42.93, and 41.56% are the maximum efficiencies achieved by the distilled water, 0.1, 0.2 and 0.3 wt %, respectively. It can be noted that again 0.20 wt %, MWCNT nanofluids have better thermal efficiency than water and other nanofluids at the tested flow rate.

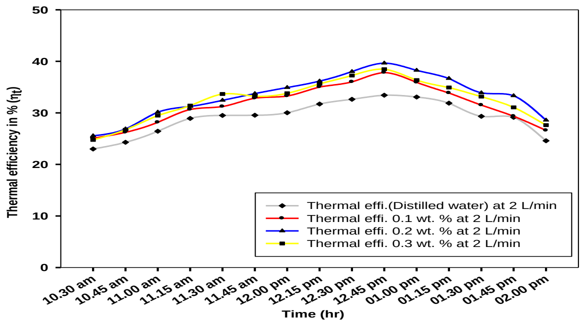

Figure 8. Variation of efficiency with distilled water and different weight concentration at 2 L/min

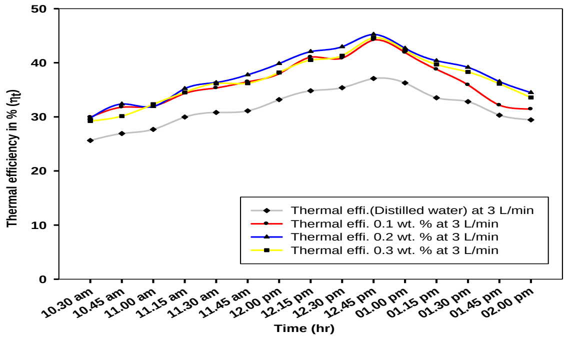

Figure 8A. Variation of efficiency with distilled water and different weight concentration at 3 L/min

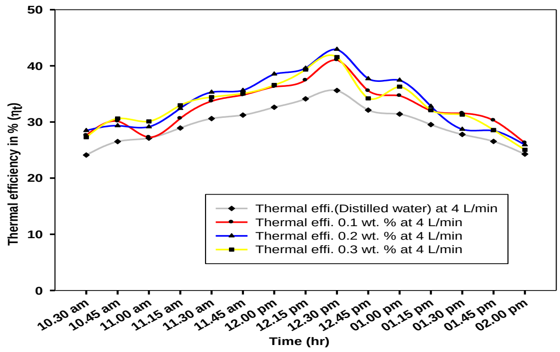

Figure 8B. Variation of efficiency with distilled water and different weight concentration at 4 L/min

It was observed that maximum efficiency conditions occur near solar noontime. Figure 9 shows the percentage gain in thermal efficiency at 2 L/min. The maximum gain was observed at 0.2 wt.% followed by a 19 % increment compared to base fluid efficiency, and the all-over average gain was 14.0%. In the case of 0.1 wt.% fraction average and maximum improvement were 8 and 13% respectively. 11 and 15 % were the values of average and maximum efficiency gain with 0.3 wt. %. Figure 9A depicts the percentage gain in thermal efficiency at 3.0 L/min with different concentrations of Nanoparticles. The highest gain was observed at 0.2 wt.% as 22% and average improvement was 19%. This was the highest efficiency achieved during the complete experimentation. 14 and 19% were the averages and maximum efficiency increment noted at 0.1 wt.%. The maximum gain was 20% and the average gain was 16% at 0.3 wt.%. The percentage gain in thermal efficiency at 4.0 L/min with different concentrations of Nanoparticles was shown in Figure 9B. The performance of fraction 0.2 wt.% was highest at 21% and the average value of efficiency gain was 13%. The maximum and average gains of efficiencies were 15 and 11% at 0.1 wt.% respectively. The performance at 0.3 wt.% is worthy as compared to 0.1 wt.% but it is less than 0.2 wt. %.17 and 12% are the values of maximum

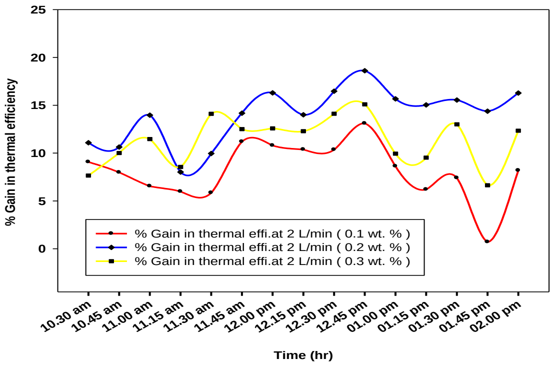

Figure 9. Percentage gain in efficiency w.r.t distilled water at 2 L/min

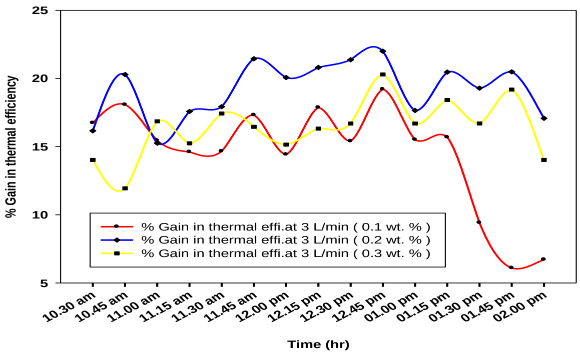

Figure 9A. Percentage gain in efficiency w.r.t distilled water at 3 L/min.

and average efficiency gain respectively. Variation in the efficiency of PTC using MWCNT/H_2O with 0.1 wt. % at different flow rates are plotted in Figure 10. It can be observed that nanofluids with 3 L/min and 0.1 wt. % sustain its maximum value during the whole experimentation period. The maximum efficiency was 44.22% observed with 3 L/min at 12.45 pm. The efficiency of PTC utilizing water-based MWCNT with 0.2 concentrations by weight at varied flow rates is depicted in Figure 10A. When comparing the efficiency of MWCNT/H_2O nanofluids with 3 L/min and 0.2 wt.% to other flow rates at the same concentration, it is worth noting that the efficiency of MWCNT/H_2O nanofluids with 3 L/min and 0.2 wt.% is the highest at 45.25%. Figure 10B shows the efficiency of PTC using water-based MWCNT with 0.3 wt.% at various flow rates. When comparing the efficiency of MWCNT/H_2O nanofluids with 3 L/min and 0.3 wt.% to other flow rates at the same concentration, the efficiency of nanofluids with 3 L/min and 0.3 wt.% comes highest as 44.62%. The highest thermal efficiency for PTC was achieved at a 3 L/min flow rate with 0.2 wt.% across the whole experiment. Figure 11 shows the average values of direct normal irradiation on that particular day. Direct solar radiations were recorded using a handy Solarimeter (MECO-936) with 20 reading storing facilities.

The variations in ambient temperature and wind speed of the environment data for 3 L/min with 0.2 wt. % during the test day is given in Figure 12. Data were measured and recorded by using PT-100 type thermometer and digital AVM-03 anemometer, respectively.

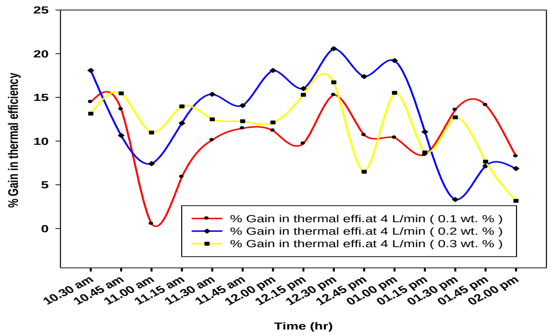

Figure 9B. Percentage gain in efficiency w.r.t distilled water at 4 L/min

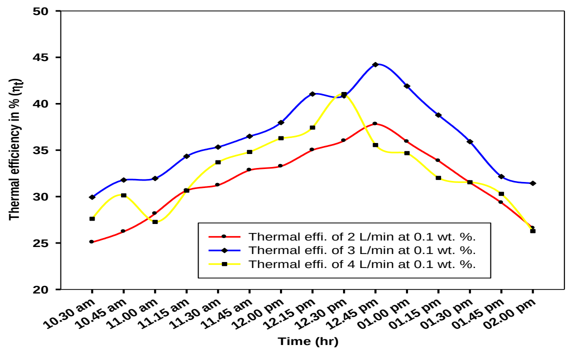

Figure 10. Variation in efficiency with 0.1 wt.% with different flow rates (L/min)

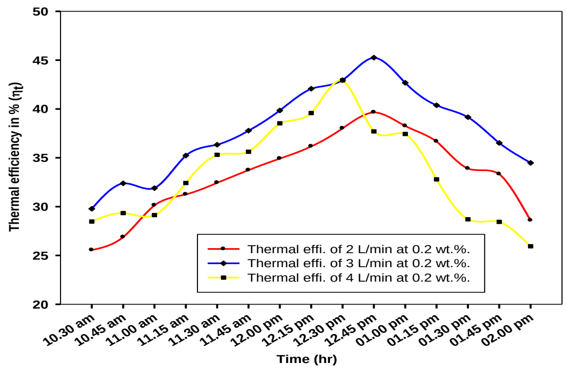

Figure 10A. Variation in efficiency with 0.2 wt.% with different flow rates (L/min)

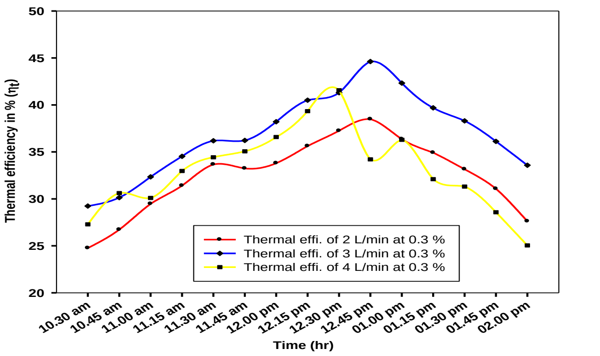

Figure 10B. Variation in efficiency with 0.3 wt.% with different flow rates (L/min)

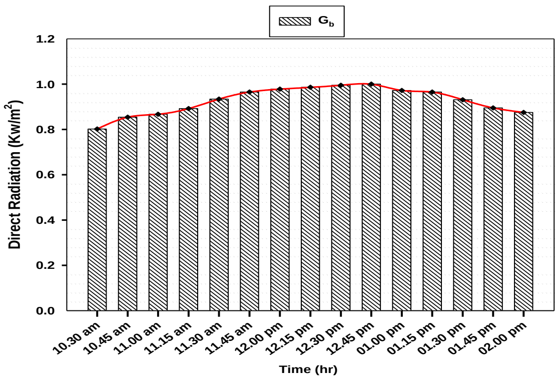

Figure 11. The average value of G_b for 3 L/min with 0.2 wt.%

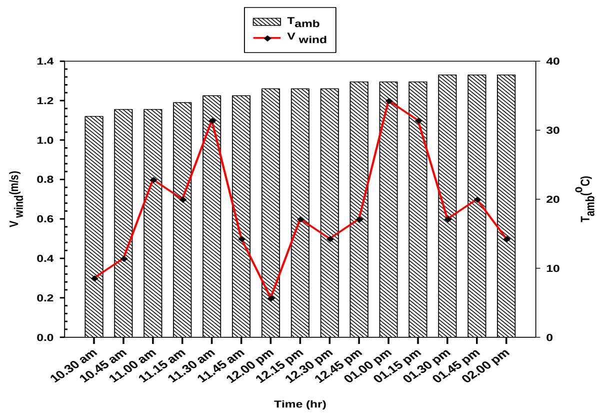

Figure 12. The ambient temperature and wind speed for 3 L/min with 0.2 wt.%

5. CONCLUSION

(i) In the present work, the impact of surfactant on nanofluid stability was experimentally studied and found that for Triton X-100, nanoparticles can be evenly suspended in base fluid for at least 10 days and less than one month. Surfactant is the safest and most environmentally friendly way to obtain nanofluid stability.

(ii) The optimal quantity of Triton X-100 surfactant was also evaluated experimentally, there were three ratios of Triton X-100: MWCNT selected i.e. (i) 0.1:1 (ii) 0.25:1 and (iii) 0.5:1. Based on the stability of the nanoparticles in nanofluid 0.5:1 has been selected, it can make nanoparticles stable for 28 days in the base fluid.

(iii) The effect of mass flow rate and particle weight fraction on the PTC's efficiency is investigated in this study. The results show that using MWCNT nanofluid as a working fluid boosts solar collector efficiency. The optical and heat transfer properties of HTF are improved by suspending nanoparticles in a base fluid with a higher relative surface area.

(iv) The maximum thermal efficiency achieved by MWCNT nanofluid with 3 L/min at 0.2 wt. % is 22 % higher than the base fluid.

(v) The higher concentration of nanoparticles in the base fluid may lead to deterioration of thermal properties and a rise in viscosity value, which would increase the power consumption of the working fluid supply pump.

(vi) Demonstrating that the use of nanofluids makes a solar collector system more compact and efficient at converting available solar energy into various forms of energy for beneficial use. Making a solar collector more compact and using MWCNT/H_2O nanofluid instead of traditional fluid water can make it more cost-effective.

(vii) There are still several stumbling barriers that need to be removed before commercializing the applications of nanofluid, i.e. Cost of mass production, instability, agglomeration, increased pump power, and corrosion.

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Persian Abstract

چکیده

سیستم های حرارتی خورشیدی برای گرمایش دارای قابلیت اطمینان بالایی هستند. استفاده از کولکتورهای سهمی (PTC) برای کاربردهای داخلی هنوز کاملاً محدود است. علاوه بر این ، استفاده تجاری از نانوسیالات در این برنامه ها نادر است. تاثیر نانوسیال MWCNT به عنوان یک سیال انتقال حرارت بر بازده یک کولکتور سهموی محلی توسعه یافته به صورت تجربی مورد بررسی قرار گرفت. تأثیر سورفاکتانت بر پایداری نانوسیالات نیز مورد بررسی قرار گرفت و مشخص شد که نانوذرات را می توان با استفاده از تریتون X-100 به مدت ۱۰ روز و کمتر از یک ماه به طور همگن در مایع پایه معلق کرد. آزمایشاتی نیز برای تعیین مقدار بهینه سورفکتانت تریتون X-100 انجام شد. می توان نانوذرات را به مدت ۲۸ روز در سیال پایه با نسبت Triton X-100 به MWCNT 0.5: 1 پایدار کرد. در سرعت جریان ۲.۰ ، ۳.۰ و ۴.۰ لیتر در دقیقه ، MWCNT/H_2O در سه غلظت های ذره ای ۰.۱ درصد ، ۰.۲ درصد و ۰.۳ درصد وزنی استفاده می شود. این آزمایش در شرایط عملیاتی در فضای باز انجام می شود. با ۳ لیتر در دقیقه در ۰.۲ وزنی. ٪ ، نانوسیال MWCNT حداکثر بازده حرارتی را بدست می آورد که ۲۲ درصد بیشتر از آب است. یافته ها اطلاعات مهمی در مورد تجاری سازی PTC توسعه یافته محلی ارائه می دهد.