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Assessment of Thermal Characteristics of Solar Thermal Collector with Nano Carbon-MnO_2 Coated Absorber

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Abstract: Assessment of thermal characteristics and performances of solar collector is mandatory due to its probable utilization to match the demand and supply of hot working fluid. In this connection, the present investigation was conducted not only to measure the temperature enhancement of working fluid but also to assess the thermal performance of a novel collector. The research results revealed that the temperature enhancements of working fluid varied from 4.9℃ to 7.2℃. The research results also revealed that the instantaneous thermal performances of solar collector ranged between 53.0% and 67.0%. The observations on research results showed that the overall thermal performance was 67.8% and the heat loss was 3.95W/m^2℃. It could be concluded that the solar collector with nano textured glass cover, nano carbon-MnO_2 coated absorber and novel wool would be used for effective applications in energy-intensive sectors.
Keywords: Solar Collector: Nano based and novel components-Thermal performances

I. INTRODUCTION

A solar thermal collector essentially forms the central unit in solar thermal devices. It absorbs solar energy as heat and then transfers it to the heat transport fluid efficiently. The heat transport fluid delivers the heat to a heat-exchanger or boiler or storage tank [1]. It is pertainant to mention here that the usage of nano textured, nano composite coated and novel components in solar collector can yield enhanced temperatures of working fluid and improved thermal efficiencies of solar devices [2]. In this connection the present research work was devoted (i) to measure the temperature of working fluid (ii) to assess the instantaneous thermal performances of solar collector and (iii) to estimate the overall thermal performance of solar collector. All these objectives were materialized by adhering the standard methodology. The generated research results have been recorded in the research paper for the use of researchers, manufactures and end users of solar devices.

II. MATERIALS AND METHODS

In the present research, a non concentrated solar collector with nano textured glass cover, nano carbon and MnO_2 coated absorber and novel wool was tested in field conditions. The inlet and outlet temperatures of the working fluid were measured [3]. As it is known, the thermal performance of a non-concentrated solar collector operating under steady state conditions could be described as

$$Q/A_g = G\,F_R\,(\tau\alpha)_e - F_R\,U_L\,(T_i - T_a) \qquad (1)$$

The useful energy extracted by the solar collector could be expressed as

$$Q/A_g = m\,C_p/A_g\,(T_o - T_i) \qquad (2)$$

If the thermal performance of a solar collector could be defined as a ratio of the actual useful energy collected to that of the solar energy intercepted by the gross area of solar collector, then the performance of non concentrated collector could be defined as

$$\eta = F_R\,(\tau\alpha)_e - F_R\,[Ti - Ta / G] \qquad (3)$$

The equation (3) could indicate that the thermal performance of a flat plate solar collector would be a linear function of $(T_i - T_a)/G$ assuming that U_L would be constant. So, graphical representation of data could be made in terms of $(T_i – T_a/G)$ verses performance (η) and the overall performance could be found by noting the value of y intercept. The equation (3) could be written in terms of an instantaneous performance as

$$\eta_i = Q / A_g\,G = F_R\,(\tau\alpha) - F_R\,(T_i - T_a)/ G \qquad (4)$$

$$\eta = \dot{m}\,C_p\,(T_0 - T_i)/A_g\,G \qquad (5)$$

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Where $\dot{m}$ = mass flow rate, C_p = specific heat of heat transfer fluid (J/kg °C), F_R = heat removal factor of solar collector (Dimensionless), T_i = inlet fluid temperature (°C), T_o = outlet fluid temperature (°C), T_a = ambient temperature (°C), A_g = collector gross area (m^2), G = solar irradiance on collector plane (W/m^2), Q = rate of useful energy extraction from the solar collector (W), $(\tau\alpha)_e$ = product of absorptance and transmittance (Dimensionless), η = collector performance (%) and U_L = overall heat loss coefficient of solar collector (W/m^2 °C) [4].

By using the above mentioned formulae, the instantaneous thermal performances of solar collector with variations in inlet water temperatures were computed. By the graphical representation, the overall thermal performance was obtained.

III. RESULTS AND DISCUSSION

The assessment of thermal characteristics and performances of non concentrated solar collector is the present research. While the steady state conditions that were maintained during testing of solar collector have been presented in Table 1, the assessed thermal characteristics and performances have been presented from Table 2 to Table 5. At the same time, the graphical representation of the overall thermal performance has been presented in Figure 1.

Table 1 Steady state conditions

Sl.No	Parameter	Deviation from the mean value during the test period
1	Solar radiation	±50 W/m^2
2	Air temperature	± 1 °C
3	Mass flow rate of fluid	± 1 %
4	Inlet temperature of fluid	± 0.1 °C
5	Temperature difference between collector inlet and outlet	± 0.1 °C

Table 2 Monitored values during testing of solar collector for the inlet water temperature of 30°C

Time (Hr)	Solar radiation (W/m^2)	Ambient temperature (°C)	Wind speed (m/s)	Temperature enhancement (°C)	Instantaneous efficiency (%)
11:00	795.2	30.1	3.1	6.5	67.0
11:30	812.5	31.4	3.2	6.5	66.0
12:30	864.3	32.6	3.0	7.0	67.0
13:00	903.4	33.9	3.2	7.2	66.0

Table 3 Monitored values during testing of solar collector for the inlet water temperature of 40°C

Time (Hr)	Solar radiation (W/m^2)	Ambient temperature (°C)	Wind speed (m/s)	Temperature enhancement (°C)	Instantaneous efficiency (%)
11:00	800.5	29.8	3.1	6.1	63.0
11:30	848.5	30.7	3.2	6.7	65.0
12:30	868.3	32.7	3.1	6.7	64.0
13:00	890.1	34.0	3.4	6.9	64.0

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Table 4 Monitored values during testing of solar collector for the inlet water temperature of 50°C

Time (Hr)	Solar radiation (W/m^2)	Ambient temperature (°C)	Wind speed (m/s)	Temperature enhancement (°C)	Instantaneous efficiency (%)
11:00	798.4	30.2	3.4	5.9	61.0
11:30	812.5	31.9	3.5	5.9	60.0
12:30	882.6	33.4	3.0	6.7	63.0
13:00	937.4	33.9	3.2	7.0	62.0

Table 5 Monitored values during testing of solar collector for the inlet water temperature of 60°C

Time (Hr)	Solar radiation (W/m^2)	Ambient temperature (°C)	Wind speed (m/s)	Temperature enhancement (°C)	Instantaneous efficiency (%)
11:00	777.1	30.0	3.1	4.9	53.0
11:30	835.3	31.9	3.7	5.3	53.0
12:30	890.1	32.7	3.1	5.9	55.0
13:00	918.2	33.6	3.4	5.9	53.0

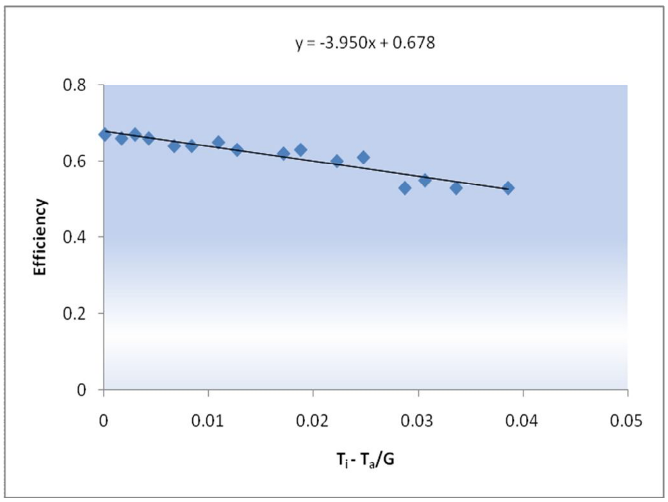

Fig.1 Graph for the estimation of overall thermal performance

In the present research, the temperature enhancements of working fluid were found to vary from 4.9°C to 7.2°C with variations in inlet temperatures of the working fluid. The instantaneous thermal performances of solar collector were found to range between 53.0% and 67.0% with the same variations in inlet temperatures of the working fluid. In addition, the overall thermal performance and heat losses were found to be 67.8% and 3.95W/m^2°C respectively. While comparing the thermal enhancements of working fluid, instantaneous thermal performances and overall thermal performance of the present solar collector with those of the conventional collector, it was noted that the thermal profile of working fluid of the present collector was better than the conventional collector. It was also noted that the performance profile of the present collector was better than the conventional collector [5]. The present desirable characteristics and performances could be caused due to the use of nano textured glass cover, usage of nano carbon-MnO_2 coated absorber and utilization of novel wool insulation [6]. They could also be caused due to the enhanced transmittance of radiation, enhanced absorptance of radiation and reduced heat losses to the surroundings from the solar collector [7].

IV. CONCLUSION

It could be concluded that the solar collector with nano textured glass cover, nano carbon-MnO_2 coated absorber and novel wool would be used for effective applications in energy-intensive sectors.

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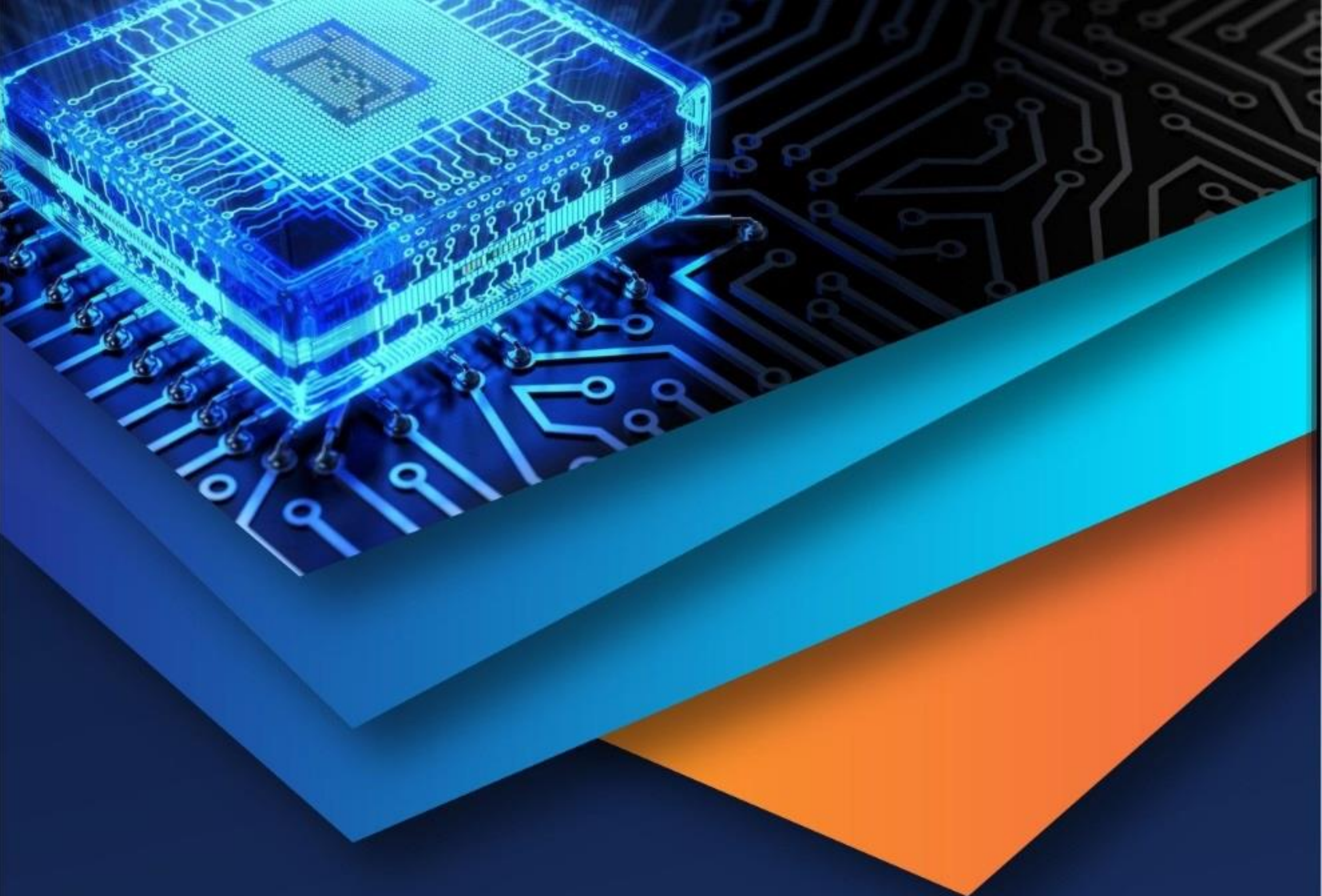

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