

# Energy Collection Efficiency of Solar Collector with Nano Carbon-Cr<sub>2</sub>O<sub>3</sub> Coated Absorber

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**Abstract:** The experimentation on solar absorber and collector is mandatory so as to have their effective utilization in energy intensive sectors. In this connection, experimentation in connection with the characterization of nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated solar absorber was carried out. In addition, experimentation in connection with the estimation of efficiency of solar collector and device was carried out as per BIS specifications. The outcomes of experimentation on solar absorber revealed that the crystallite sizes in the carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coating on absorber were in nano ranges. The outcomes of experimentation on solar collector and device revealed that the instantaneous thermal performances of solar flat plate collector ranged between 66.9% and 68.6% and energy collection efficiency of solar heating device was 51.4%. As the thermal performances of the solar collector and device could distinctively depend on the optical characteristics of the absorbers, it could be concluded that nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated solar absorbers would be effectively used in solar collectors and heating devices.

**Keywords:** Nanostructured absorber, Solar collectors and devices, Improved thermal performances

## I. INTRODUCTION

Solar heating device is one of the technically matured solar thermal devices. It has two major components such as flat plate collector and storage tank [2]. It has been reported that the thermal performance of solar device can be improved by incorporating metal absorbers with relatively higher thermal conductivity. It has also been reported that the thermal performance of solar device can be further improved by incorporating metal absorbers with nanostructured coating on them [3]. In this connection, the present research work was carried out (i) to assess the structural characteristics of the nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated absorber, (ii) to estimate the instantaneous thermal performance of flat plate collector with nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated absorber and (iii) to evaluate the energy collection efficiency of solar heating device. The standard materials, BIS test methods and calibrated test instruments were used for materializing all these objectives. The research outcomes have been recorded in the present research paper for the benefits of researchers, manufacturers and end users of solar thermal devices. As far as the organization of the research paper is concerned, the first section provides the introduction and the second section provides the materials and methods of the present research work. The third and fourth sections provide the results, discussion and conclusion of the present research work.

## II. MATERIALS AND METHODS

The test samples of the present research included (i) nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated absorber (ii) solar flat plate collector with nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated absorber and (iii) solar heating device. While the nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated absorber was characterized through XRD, the flat plate collector was tested as per BIS specifications and the solar heating device was tested as per energy collection efficiency test procedures [1]. It is to be noted that the steady state conditions and test conditions were strictly maintained for testing the flat plate collector and solar heating device. It is also to be noted that the flat plate collector and solar heating device were tested in outdoor conditions and the influencing parameters were recorded. The thermal performance of flat plate collector and solar heating device was individually calculated with the formulae such as

$$\eta = m_f C_p (T_o - T_i) / A_g G \quad \dots(1)$$

$$\eta = m_f C_p (T_{fs} - T_{is}) / A_g G_I \quad \dots(2)$$

Where  $\eta$  = efficiency (%),  $m_f$  = mass flow rate of working fluid (Kg/s),  $C_p$  = specific heat capacity (J/kg°C),  $T_o$  = outlet temperature of the working fluid (°C),  $T_i$  = inlet temperature of the working fluid (°C),  $T_{fs}$  = final temperature of the

working fluid in storage tank (°C),  $T_{is}$  = initial temperature of the working fluid in storage tank (°C),  $A_g$  = gross area of collector (m<sup>2</sup>),  $G$  = incident solar radiation (W/m<sup>2</sup>) and  $G_I$  = integrated solar radiation (KJ/m<sup>2</sup>s per day) [1].

### III. RESULT AND DISCUSSION

The present research work was devoted not only to assess the structural characteristics of solar absorber but also to evaluate the thermal performances of solar flat plate collector and heating device. While the generated diffractogram has been presented in Figure 1, the recorded parameters during the performance tests have been presented in Table 1 and Table 2 respectively.

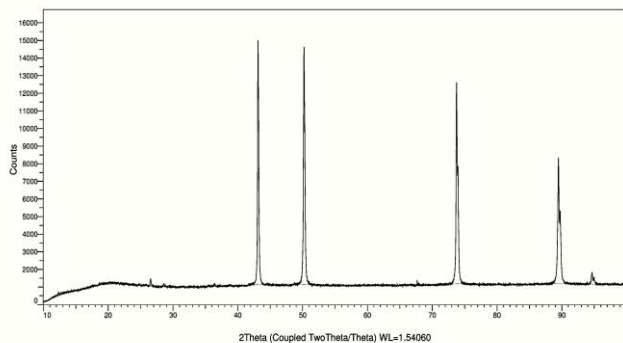


Figure 1. Diffractogram of the nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated absorber.

Table 1 : Recorded parameters and thermal performance of solar flat plate collector

Time (Hr)	Solar radiation (W/m <sup>2</sup> )	Ambient temperature (°C)	Wind speed (m/s)	Temperature of fluid (°C)		Instantaneous performance (%)
				Inlet	Outlet	
11:00	740.2	30.5	0.5	30.0	36.6	68.6
11:30	762.9	30.8	0.6	30.0	36.7	67.8
12:30	787.0	31.0	0.2	30.0	36.9	67.6
13:00	822.0	31.4	0.4	30.0	37.0	66.9

Table 2 : Recorded parameters and thermal performance of solar heating device

Time (s)	Outlet temperature (°C)	Time (s)	Outlet temperature (°C)	Energy collection efficiency (%)
120	70.8	840	75.8	
240	71.2	960	76.2	
360	72.6	1080	76.6	
480	73.5	1200	76.8	
600	74.9	1320	77.0	
720	75.4	1440	77.2	

In the present research, the copper substrates were used. Their sizes were fixed as per BIS specifications. The nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coating was effected on copper substrates and the nano structured absorbers were prepared. Subsequently, the prepared absorbers were characterized through XRD. The crystallite sizes of the constituents of the coating on solar absorbers were calculated from the generated diffractogram and their magnitudes were found

to be in nano ranges. The thermal durability test on the developed solar absorbers was conducted by adopting standard procedure and it was found to be acceptable [5].

In the present research, the temperature enhancements of working fluid were found to vary from 6.6 to 7.0°C for the minimum inlet temperature of the working fluid. The instantaneous thermal performances of solar flat plate collector were found to range between 66.9% and 68.6% with the same minimum inlet temperature of the working fluid. At the same time, the energy collection efficiency of solar heating device was found to be 51.4%. While comparing the thermal enhancements of working fluid, instantaneous thermal performances and energy collection efficiency of the present solar device with those values of the conventional solar devices, it was noted that the thermal profile of working fluid in the present solar collector was better than that of the conventional collector. It was also noted that the performance profile of the present collector was better than that of the conventional collector. The observation on generated database revealed that energy collection efficiency profile of the present solar heating device was better than that of the conventional solar heating device [4]. The improved thermal enhancements of working fluid, thermal performances of solar collector and energy collection efficiency of solar heating device could have been caused due to the usage of nano textured glass cover, nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated solar absorber and novel wool insulation. They could also have been caused due to the improved transmittance of radiation, improved absorbance of radiation and reduced heat losses to the atmospheric environment as a result of the usage of nano textured, nano structured and novel components in solar heating device [5].

### IV. CONCLUSIONS

As the thermal performances of the solar collector and device could distinctively depend on the optical characteristics of the absorbers, it could be concluded that nano carbon and Cr<sub>2</sub>O<sub>3</sub> (60:40) coated solar absorbers would be effectively used in solar collectors and heating devices.

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