Journal of Advanced Scientific Research

Available online through http://www.sciensage.info

ISSN
0976-9595
Research Article

EXPERIMENTAL STUDY ON THE PERFORMANCE OF SOLAR COLLECTOR WITH NANO SIZED MATERIALS

S. SELVAKUMAR*[1], T. R. RAJASEKARAN[2], V. SABARINATHAN[3], R. V. JEBA RAJASEKHAR[4]

[1]Research Scholar, Reg.No: 12581, Department of Renewable Energy Science, Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, India

[2]Department of Renewable Energy Science, Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, India

[3] Department of Physics, Manonmaniam Sundaranar University, Abishekapatti, Tirunelveli, India

[4]PG & Research Department of Physics, Government Arts College, Melur, Madurai, India

**Corresponding author: kumartvl88@gmail.com*

ABSTRACT

Carbon and metal oxide based coatings are widely used for photo thermal conversion. The collectors collect the sun's energy, transform this radiation into heat, and then transfer this heat into a fluid, water or air, which has many applications in household and industries. In the present investigation, carbon and metal oxide based coatings were prepared and the coatings were affected on metal absorbers. The coatings on the metal absorbers were characterized and it was found that the sizes of constituents in the coatings were in nanoranges. The coated absorbers were integrated in solar collectors and the thermal efficiency of the solar heating collectors was experimentally found. It was found that the thermal enhancements in working fluid varied from 18.4 to 25.5 ^{0}C, 19.0 to 26.9^{0}C and 22.3 and 29.9^{0}C in solar collectors with three different nano-structured absorbers. It was also found that the thermal performances of these solar heating collectors were as per standard specifications. The research revealed that the thermal performances of the solar heating collector with nano-structured absorbers were 1.2%, 1.4% and 1.5% higher than that of the conventional solar heating collector. On the basis of the research outcomes of the present investigation, it could be concluded that the nano-sized carbon and metal oxide coated absorbers would be utilized in solar collectors so as to harvest their enhanced thermal performances.

Keywords: Nano structured absorber, Solar collector, Temperature of fluid, Thermal efficiency, Thermal performance

1. INTRODUCTION

Energy is primary agent for economic development. The absorbed heat transferred to the air as it flows along the channel increases its temperature. Solar energy widely available on the earth is used to convert into thermal energy. World demand for energy is expected to more than double by 2050 and to more than triple by the end of the century. The way to increment in network of producing energy is not sufficient to develop sustainable energy. Finding sufficient supplies of clean energy for the future is challenging [1]. There are many ways to utilize energy but solar air heater have an important role in the energy storage and utilization [2]. Performance improvement can be achieved using nano coating absorber materials with different ratios and layouts [3]. Many researchers have attempted to increase heat transfer rate from absorber plate to flowing air by adding fins on absorber plate.

In this research 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 [4-6].

2. MATERIALS AND METHODS

The conventional solar collector was taken. The solar air heating collector was developed by using plain glass cover, nano carbon and tungsten oxide particle coated absorber and rock wool insulator. The developed solar air heating collector was kept in outdoor conditions and it was tested as per standard specifications [7, 8]. The incident solar radiation, ambient temperature, wind speed, inlet temperature of working fluid and outlet temperature of working fluid were measured during the test tenure. It should be noted that the solar air heating collector was free from fall of dusts, shadows and other influencing materials during the test tenure.

In the present research work, the nano carbon and tungsten oxide were commercially procured. They were blended with solar emulsion in different proportions. The developed emulsion was spray coated on metal plates and the nano-structured solar absorbers were developed. The coatings affected on metal plates were characterized through XRD analysis and the crystallite sizes in the abosorptive coatings were calculated by using Scherrer's formula [9].

The thermal performance of flat plate collector and solar heating device was individually calculated with the formulae such as

$$\eta = m_f C_p (T_o - T_i)/A_g G \text{........................}(1)$$

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

Where η = efficiency (%), m_f = mass flow rate of working fluid (Kg/s), C_p = specific heat capacity (J/kg°C), To = outlet temperature of the working fluid (°C), Ti = 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^2), G = incident solar radiation (W/m^2) and G_I = integrated solar radiation (KJ/m^2 s per day) [8].

3. RESULTS AND DISCUSSION

The present research work was devoted not only for the preparation of the nano-structured absorber but also for the development of solar collector and experimental assessment of the performance characteristics of solar collector with nano-structured absorber configurations. While the crystallite sizes in nano-structured coating on absorber have been presented in Table 1, the thermal enhancement in working fluid in different ratios the solar air heating collector have been presented in Table 2, Table 3 and Table 4.

Table 1: Results of crystallite sizes in nano-structured coating on absorber

Parameter	Value
Interplanar spacing(A^0)	3.75
FWAM (2θ)	25.8
Crystallite size (nm)	36.0

The generated diffractogram clearly established the composite nature of the coating that was composed of carbon and Tungsten oxide particles. By using Scherrer's formula, the crystallite sizes were calculated and they were observed to be in nanosizes. In this pattern the diffraction peaks revealed the presence of hexagonal and orthorhombic tungsten oxide nanoparticles. Therefore, the presence of tungsten oxide nanoparticles peaks might lead to the mask the characteristic peak of the nanotubes at 2 θ equal to 25.8 degree. By the by It was found that the thermal enhancements in working fluid different ratios varied from 18.4 to 25.5°C, 19.0 to 26.9°C and 22.3 to 29.9°C in solar collectors with three different nano-structured absorbers. The performance characteristics of the same solar air heating collector showed that the thermal performance of solar air heating collector could satisfy the standard specifications.

Table 2: Recorded parameters and thermal enhancement in working fluid of Carbon and WO_3 (40:60)

Time (Hrs)	Solar Radiation (W/m^2)	Temperature (°C)			
		Ambient temperature	Inlet temperature	Outlet temperature	Temperature elevation
09.00 a.m.	453.1	29.1	28.7	47.1	18.4
09.30	551.1	29.7	29.0	49.5	20.5
10.00	650.0	30.2	29.3	50.2	20.9
10.30	712.2	30.9	29.5	21.4	21.9
11.00	760.4	31.0	29.8	51.6	21.8
11.30	764.5	31.2	30.8	52.5	21.7
12.00 p.m.	809.5	31.4	30.5	53.4	22.9
12.30	833.5	31.9	31.1	54.5	23.4
13.00	842.1	32.5	31.4	55.0	23.6
13.30	870.6	32.9	31.8	56.4	24.6
14.00	881.4	33.2	31.4	56.9	25.5
14.30	740.9	33.8	31.2	55.1	23.9
15.00	685.2	33.3	31.1	54.8	23.7
15.30	584.2	33.1	30.2	54.1	23.9
16.00	465.2	32.5	30.3	54.0	23.7

Table 3: Recorded parameters and thermal enhancement in working fluid of Carbon and WO_3 (50:50)

Time (Hrs)	Solar Radiation (W/m^2)	Temperature (^oC)			
		Ambient temperature	Inlet temperature	Outlet temperature	Temperature elevation
09.00 a.m.	460.5	28.5	27.9	46.9	19
09.30	560.2	28.9	28.1	47.5	19.4
10.00	658.7	29.2	28.5	48.2	19.7
10.30	722.2	29.9	29.0	49.6	20.6
11.00	770.4	30.3	29.5	51.5	22.0
11.30	794.5	30.6	29.8	52.1	22.3
12.00 p.m.	832.7	30.5	30.0	53.6	23.6
12.30	834.5	31.3	30.1	54.6	24.5
13.00	840.1	32.5	30.5	56.2	25.9
13.30	880.6	33.0	31.2	58.1	26.9
14.00	871.4	32.9	31.5	57.5	26.0
14.30	778.9	32.8	31.7	56.2	24.5
15.00	684.2	31.8	30.5	56.3	25.8
15.30	584.2	31.5	30.8	56.0	25.2
16.00	445.2	31.4	30.4	56.2	25.8

Table 4: Recorded parameters and thermal enhancement in working fluid of Carbon and WO_3 (60:40)

Time (Hrs)	Solar Radiation (W/m^2)	Temperature (^oC)			
		Ambient temperature	Inlet temperature	Outlet temperature	Temperature elevation
09.00 a.m.	472.5	29.4	28.0	50.3	22.3
09.30	570.2	29.8	28.3	50.6	22.3
10.00	685.7	29.6	28.9	51.3	22.4
10.30	750.2	30.0	29.1	51.6	22.5
11.00	770.4	30.2	29.3	52.4	23.1
11.30	798.5	30.8	30.1	53.0	22.9
12.00 p.m.	842.7	31.2	30.4	54.9	24.5
12.30	864.5	32.5	31.2	56.5	25.3
13.00	870.1	33.0	31.9	57.9	26.0
13.30	898.6	33.1	32.1	59.5	27.4
14.00	871.1	32.8	31.6	61.5	29.9
14.30	778.1	32.0	31.4	59.1	27.7
15.00	674.2	31.8	31.0	59.4	28.4
15.30	544.2	31.4	30.8	58.5	27.7
16.00	452.2	31.0	30.5	58.6	28.1

The performance characteristics of the solar collector were dependent on the components like glass cover, absorber plate and insulation material [11]. The glass cover was made up of nano-textured materials and it had the transmittance more than 90%. The reflectance was also found experimentally in the two square meter glass cover and it was found to be 8%. The other integral component namely absorber sheet was made up of copper and the existing thickness of the absorber sheet was chosen in order to ensure adequate strength and stability against the pressures to prevent swelling, distortion or ruptures. The collector had absorber sheet with nano-structured absorptive coating, though other coatings have been permitted in specifications. The absorbance of the nano-structured coating on the metal sheet was found to be 84%.

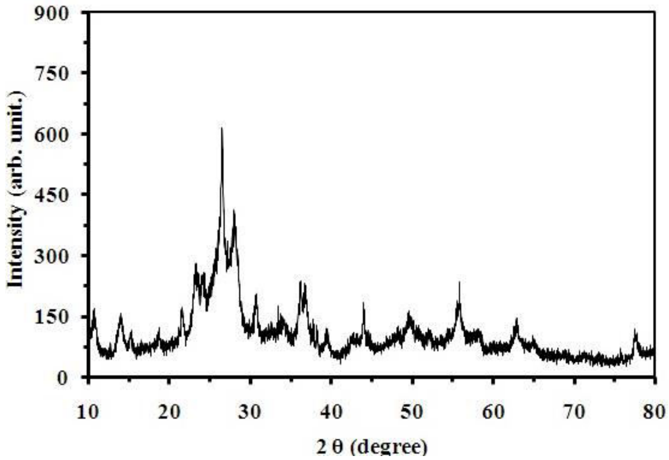

Fig. 1: Diffractogram of the nano Carbon and WO_3 coated absorber

The rock wool was used insulation material and it was found that the bulk density of the rock wool used in solar collector was ±15%. While the sulphur content was 0.015%, the chloride content was 0.0010% in the insulation material. The thermal insulation of insulation material was 0.95 m^2 °C/W. As per the specification of Bureau of Indian Standards, the thermal resistance and conductance of rock wool were found to be satisfactory [10]. As far as workmanship and finishing were concerned, all the components and supporting structure were found to be smooth. They were also free from all other surface defects. The solar air heating collector was constructed in such a way that replaceable components could be accessible for repair or replacement at sites.

The performance characteristics of the solar air heating collector were also dependent on the parameters like incident solar radiation, ambient temperature and initial air temperature of the collector. The incident solar radiation was considerable during sunshine hours. Subsequently, the heat absorbed by the flat plate collector would have been transferred to the working fluid totally due to the favorable inlet air temperature and ambient temperature. Hence, there was elevated temperature of air in the present solar air heating collector [10]. Eventually, the performance characteristics of the solar air heating collector could be correlated with enhanced transmittance of the cover plates due to the usage of nano-textured glass cover, increased absorbance of the absorber sheets due to the utilization of copper based nano-structured absorber plate, improved heat transfer between absorber sheets and baffles due to the laser welding, and reduced heat losses due the presence of rock wool with suitable thicknesses, reduced heat losses to the surroundings due to the presence of opt gaskets and favorable meteorological conditions [10, 11].

4. CONCLUSION

In the present study, the solar air heating collectors were tested and a comparison is made among them on the performance. The improved thermal enhancements of working fluid, thermal performances of solar air heating collector could have been caused due to the usage of nano textured glass cover, nano carbon and WO_3 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 air heater system. As the thermal performances of the solar devices could distinctively depend on the optical characteristics of the absorbers, it could be concluded that nano carbon and WO_3 (60:40) coated solar absorbers would effectively be used in solar air heating collectors. The research revealed that the thermal performances of the solar air heating collector with nano-structured absorbers are 1.5% higher than that of the conventional solar heating collector.

5. REFERENCES

1. Dharam Singh, Bartaria VN. *Int. J. Engineering Trends and Technology*, 2013; **4(10)**:4434-4436.
2. Brij Bhushan, Ranjit Singh. *Energy,* 2010; **35(1)**:202-212.
3. Ebru Kavak Akpinar, Fatih Koçyiğit. *Int. Communications in Heat and Mass Transfer,* 2010; **37(4)**:416-421.
4. Nwachukwu P, Nwosu. *Energy*, 2010; **35(2)**:571-575.
5. Aharwal KR, Gandhi BK, Saini JS. *Int. J. Heat and Mass Transfer,* 2009; **52(25-26)**:5970-5977.
6. Jaurker AR, Saini JS, Gandhi BK. *Solar Energy,* 2006; **80(8)**:895-907.
7. Ozgen F, Esen M, Esen H. *Renewable Energy Science,* 2009; **34(11)**:2391-2398.
8. IS 12933 (Part 1, 2, 3 & 5: 2003 together with amendment No.1 of June 2005), Bureau of Indian Standards, India.
9. Uma Maheswari K, Jeba Rajasekhar RV. *Int. J. Applied Research,* 2016; **2(11):**459-461.
10. Jeba Rajasekhar RV. *Experimental investigations on solar gadgets*, *Daisy and Daerin Publications*, *Madurai,* India, 2010.
11. Jeba Rajasekhar RV, Vasu V, Lalitha S. *Journal of Research in Science*, 2017; **3(1)**:37-40.