IMPACT OF OPERATIVE TEMPERATURE OF NANO COMPOSITE COATED ABSORBER ON THERMAL PERFORMANCE OF SOLAR COLLECTOR

N.S.SARAVANAN[1] and R.V.JEBA RAJASEKHAR[2]

[1]Research Scholar, Manonmaniam Sundaranar University, Tirunelveli
Associate Professor & Head, Department of Physics
Arumugam Pillai Seethai Ammal College, Tiruppattur 630 211, Tamil Nadu

[2]Assistant Professor, PG & Research Department of Physics,
Government Arts College, Melur 625 106, Tamil Nadu

Abstract

Thermal investigation on solar absorber and collector is necessitated for optimizing their utilization in application sectors. In this connection, the present research investigation was devoted not only to estimate the operative temperature of nano-composite coated solar absorber but also to assess the thermal performance of solar collector. The research results showed that the operative temperature of nano graphite and nano TiO_2 coated absorber varied from 28.4 ^oC to 39.2 ^oC. The research results also showed that the stagnation temperature of the solar collector was 87.3^oC and the range of increase of temperature of fluid was from 6.4 to 7.1 ^oC. The observation on research results showed that the instantaneous thermal performance of solar collector ranged between 64.6 and 70.2% for the inlet fluid temperature of 30 ^oC. As the thermal performance of the solar collector was diretly proportional to operative temperature of solar absorber, it could be concluded that nanocomposite coated solar absorber would be integraed in solar collector so as to reap improved thermal performances

Keywords : Operative temperature of absorber – Thermal performance of collector – Impact analysis

Introduction

The absorber is the central component of any solar collector. It has been reported that the material, aperture area and characteristics of the absorber determines the thermal performance of solar collector [1]. It has also been reported that the chemical composition, crystallite size and thickness of the coating on absorber also determines the thermal performance of solar collector [2]. In this connection, the present research was devoted (i) to estimate the operative temperature of solar absorber, (ii) to evaluate the stagnation temperature of solar collector and (iii) to assess the instantaneous thermal performances of solar collector. The test samples, materials, methods, instruments and research outcomes of the present research investigation have been documented in this research paper for improving the production, utilization and research avenues of solar thermal gadgets.

Materials and methods

The test samples of the present research investigation included (i) nano structured absorber and (ii) solar collector integrated with the nano-structured absorber. While the physical parameters of absorber were measured, the thermal parameters of the absorber were monitored in outdoor conditions. The solar collector was tested as per BIS specifications [3] and the instantaneous thermal performances of the solar collector were calculated by using the formula $\eta = m_f C_p (T_o - T_i)/A_g G$ where η = efficiency (%), m_f = mass flow rate of working fluid (Kg/s), Cp = specific heat capacity (J/kg°C), T_o = outlet temperature of the working fluid (°C), T_i = inlet temperature of the working fluid (°C), A_g = gross area of collector (m^2) and G = incident solar radiation (W/m^2) [4].

Result and discussion

The present research was conducted not only to study the thermal properties of solar absorber but also to study the thermal performances of solar collector. In this connection, the technical specifications of the nano-structured absorber have been tabulated in Table 1 and thermal properties of the nano-structured absorber in outdoor conditions have been tabulated in Table 2. At the same time, the stagnation temperature, thermal enhancement of working fluid and instantaneous thermal performances of solar collector have been tabulated in Table 3.

Table 1 : Specifications of solar absorber

Parameters	Material, chemicals and sizes
Material	Copper
Coating composition	Nano graphite and nano TiO_2
Thickness	0.5 mm
Size of absorber (Pilot scale)	1000 cm x 2000 cm
Number of risers on absorber	Eight

Table 2 : Thermal properties of solar absorber

Time	Solar radiation (W/m^2)	Temperature (^oC)		Time	Solar radiation (W/m^2)	Temperature (^oC)	
		Operative temperature	Stagnation temperature			Operative temperature	Stagnation temperature
08:30	342.3	28.4	38.0	12:30	720.4	37.0	87.0
09:00	367.8	29.2	41.3	13:00	767.3	38.4	87.3
09:30	397.1	30.5	48.5	13:30	770.4	39.2	87.3
10:00	440.6	31.8	56.0	14:00	664.3	38.0	85.2
10:30	478.4	32.8	67.0	14:30	510.7	36.7	83.8
11:00	547.3	34.0	76.7	15:00	423.9	35.0	81.5
11:30	602.3	34.9	80.4	15:30	347.3	33.5	80.6
12:00	689.3	35.6	82.8	16:00	302.9	31.0	78.0

Table 3 : Thermal performances of solar collector

Time	Solar radiation (W/m^2)	Ambient temperature (^oC)	Temperature of fluid (^oC)		Instantaneous thermal performance (%)
			Inlet	outlet	
11:00	756.8	31.2	30.0	36.5	64.6 to 70.2
11:30	740.6	31.5	30.0	36.4	
12:30	880.4	31.9	30.0	37.0	
13:00	849.0	32.0	30.0	37.1	

The nano graphite and nano TiO_2 coated absorber was characterised. By using the characterisation results and Debye Scherrer formula, the crystallite size was calcuated. The calculated crystallite size was 42.8nm. As the crystallite size was in nano range, the number of crystallites in coating that had been effected on aperture area of absorber would be enormous. This would have caused enhanced absorption of solar radiation and so there would be increased operative temperature of solar absorber, improved stagnation temperature of solar collector and improved fluid temperature in solar collector [5].

The nano graphite and nano TiO_2 coated absorber was tested. It was tested at equal intervals of time with variations in meteorological conditions. The operative temperature of solar absorber was observed to vary from 28.4 ^oC to 39.2 ^oC. The developed solar collector with nano graphite and nano TiO_2 coated absorber was also tested in stagnant and working conditions during sunshine hours. The stagnation temperature of the solar collector was observed to be 87.3^oC and the increase in temperature of fluid was observed to vary from 6.4 to 7.1 ^oC. All these operative, stagnant and fluid temperatures were found to be higher than those of the conventional solar absorbers and collectors. In continuation, the instantaneous thermal efficiency of solar collector was calculated. It was observed to range between 64.6 and 70.2% for the inlet fluid temperature of 30 ^oC. The observed operative temperature, obtained stagnation temperature and obtained fluid temperature could be correlated with increased absorption of incident radiation, improved radiation to heat conversion and improved efficacy of components [6]. They could also be attributed with chemical constituents in absorptive coating, sizes of crystallites in absorptive coating and efficacy of absorptive coating effected on solar absorber used in solar collector [7]. As the thermal performance of the solar collector was diretly proportional to operative temperature of solar absorber, it could be concluded that nanocomposite coated solar absorber would be integraed in solar collector so as to reap improved thermal performances

References

1. Jeba Rajasekhar, R.V., 2018, Experimental investigations on components, heating systems and test set-ups in photothermal applications, Ph.D. thesis., Madurai Kamaraj University, Madurai, India.

2. Vasantha Malliga, T., Jeba Rajasekhar, R.V., 2017, Preparation and characterization of nanographite –CuO based absorber and performance evaluation of solar air heating collector. Journal of Thermal analysis and Calorimetry, Springer Publications, 129(1):233-240.

3. John A.Duffe and William A.Beckman, 1980, Solar engineering of thermal processes, A Wiley Interscience Publications, New York, U.S.A.

4. Jeba Rajasekhar, R.V., 2007, Solar thermal devices, Daisy & Daerin Publishing House, Madurai, India.

5. Uma Maheswari, K., and Jeba Rajasekhar, R.V., 2015, Absorptive coating with nano sized carbon and aluminum oxide: Preparation, characterization and estimation of thermal enhancement in solar absorber, International Journal of Recent Scientific Research, 6(3): 3226-3228.

6. Selvakumar, S., Rajasekaran, T.R., Sabarinathan, V., Jeba Rajasekhar, R.V., 2018, Energy collection efficiency of solar collector with nano carbon – Cr_2O_3 coated absorber, International Journal of Scientific Research in Physics and Applied Sciences, 6(6):127-128.

7. Jeyasankar, P., Jeba Rajasekhar, R.V., 2018, Preparation, characterization and evaluation of thermal efficacy of nanocarbon-MnO_2 coated solar absorber, International Journal of Scientific Research in Physics and Applied Sciences 6(2):52-54 .