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RESEARCH ARTICLE

ABSORPTIVE COATING WITH NANO SIZED CARBON AND ALUMINIUM OXIDE: PREPARATION, CHARACTERIZATION AND ESTIMATION OF THERMAL ENHANCEMENT IN SOLAR ABSORBER

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ABSTRACT

Novel absorptive coatings are necessitated so as to have enhanced absorption of solar radiation and also enhanced heat transfer to working fluid in solar collectors. In this connection, the present investigation was devoted for the (i) preparation and deposition of nano-carbon and aluminum oxide mixed coating on absorber (ii) characterization of the prepared coating and (iii) estimation of thermal enhancement not only in solar absorber but also in the working fluid used in the solar collector. While standard methods were adopted for the preparation of nano-carbon and Al_2O_3 based absorptive coatings, the spray coating method was adhered for the deposition. By using Scherrer formula, the size of the particles in coating was calculated and it was found to be 65.90 nm. The micro strain was also calculated and it was found to be 0.526×10^{-6}. It could be concluded that copper absorbers with nano-carbon and aluminium oxide based coatings would be utilized in solar collectors not only to have enhanced absorptance of solar radiation but also to have enhanced thermal performance of solar collectors.

INTRODUCTION

A solar absorber, which is an integral component of any solar collector, is a device designed to absorb incident solar radiation and to transfer the energy by means of conduction to a fluid passing in contact with it [7]. As this is an era of nano-technology, the nano coating based absorbers can be prepared and they can be utilized in solar devices [1]. In the present investigation, a special coatings with carbon, Al_2O_3 and solar selective solution was produced. It was deposited on solar absorber by spray coating method. The characterization with reference to XRD was carried out and the sizes of grains in the coating along with the micro-strain were subsequently calculated. The thermal enhancement in absorber in outdoor atmospheres and thermal enhancement in the working fluid were experimentally estimated. Standard methodology was adopted and the research outcomes have been documented in this research paper for the benefits of manufacturers, researchers and end users worldwide.

MATERIALS AND METHOD

Preparation and deposition of nano-carbon based absorptive solution

Nano-carbon powder was mixed with Al_2O_3 at different proportions. They were stirred thoroughly with solar selective solution. The resultant absorptive solution with different carbon and Al_2O_3 proportions was coated on metal absorbers by conventional spray coating method [2].

Characterization study of absorptive coating

XRD is the most essential technique to investigate the structural aspects of the material. The information on the particle size can be calculated by using the Scherrer formula [2], which has been presented as equation 1.

$$D = x\,\lambda/\beta\cos\theta \qquad \text{-----1}$$

where D is particle size, x is correction factor, λ is wave length of X-ray used and β is the FWHM of the observed peaks. The information in connection with the dislocation density (δ) and micro strain (μ) can also be calculated by using Bragg's formula which has been presented in equation 2 and 3 [3].

$$\delta = 1/D^2 \text{ in } m^2 \qquad \text{-----2}$$

$$\mu = (\beta\cos\theta/4\ ) \times 10^{-3} \qquad \text{-----3}$$

where ε is the effective strain.

Measurements of temperatures of working fluid

The temperatures of working fluid in solar collector with nano carbon and Al_2O_3 coated absorber were record with variations

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in meteorological conditions. It is worth mentioning here that all the measurements, tests and field experiments were carried out by using calibrated instruments.

RESULTS AND DISCUSSION

The present research work was devoted not only for the preparation and deposition of nano sized particles on absorbers but also for the characterization and measurements of enhancement in temperature of the working fluid. While the technical specifications have been presented in Table 1, the diffractogram and measurements of temperatures of working fluid have been presented in figure 1 and table 2 respectively.

Table I Technical specifications

Solar absorber	Material/ Dimensions
Material	Copper
Coating	Solar absorptive coating
Coating composition	Carbon, Al_2O_3 and special absorptive solution.
Thickness of material	0.20 mm
Breadth of material	120 mm
Length of material	1950 mm

Table2 Temperature enhancement in collector

Time	Solar radiation W/m^2	Ambient Temperature ^{o} C	Temperature of working fluid (^{o} C)		
			Initial temperature ^{o} C	Final temperature ^{o} C	Enhancement
11:00	784.8	33.7	33.7	74.1	40.4
11:30	800.3	34.8	34.8	76.8	42.0
12:00	813.9	34.9	34.9	76.3	42.4
12:30	821.1	34.6	34.6	77.1	42.5
13:00	810	33.9	33.9	75.9	42.0

The material used for solar absorbers in the present investigation was copper. The choice of this material in solar collector was not only on the basis of the effective heat transfer characteristics but also on the basis of the requirement of temperature elevations of the working fluid for specific applications of the end users [2]. Of course, the metal absorber was coated by using nano-carbon and Al_2O_3 based absorptive solution so as to have effective absorption of incident solar radiation [7]. The thermal test on solar absorber showed that there were neither fading of the coating nor peeling of the deposition.

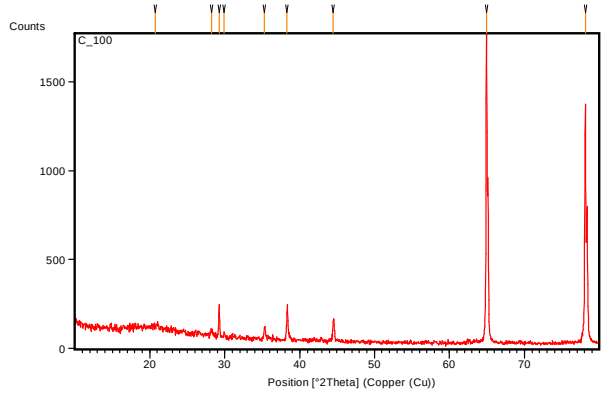

Figure I XRD pattern for nano-carbon based absorptive coating

The thermal test revealed that the same solar absorbers could be utilized not only in stagnant conditions of solar collectors but also in operating conditions of same solar collectors in outdoor atmospheres. The thermal test also revealed that the same solar absorbers could be effectively utilized for effective heat transfer in the working fluid due to the features such as absence of fading and peeling of the coatings in hot conditions [6]. It would be worth mentioning that the utilized solar absorbers had specific dimensions on the basis of the optimized dimensions set by BIS [4].

XRD analysis on coatings of solar absorbers

XRD is a very important experimental technique that has been used to address all issues related to crystal structure. In the present research work, the structural characterization of the solar absorber was performed by XRD measurement by using X-ray diffractometer of make XPERT-PRO operating at 50 KV and 30 mA with a normal θ-2θ scanning.

The peaks were identified to originate from (1,1,3) (2,2,1)(4,0,0) and (4,0,4) reflections (JCPDS-file no 72- 16823) of orthorhombic end-centered crystal with a = 5.760 A^o, b = 8.537 A^o and c = 9.121 A^o. By substituting the required values, it was found that the grain size of the coating was 65.90 nm.

The dislocation density and micro strain was also calculated and they were found to be 2.3026x 10^{14} m^2 and 526 x 10^{-6}respectively.

Thermal enhancement in solar collector

The thermal enhancement of the working fluid in solar collector was measured periodically in varied meteorological conditions.

The thermal enhancement of the working fluid was found experimentally. While the minimum temperature elevation of working fluid was 40.4 ^{o} C, the maximum temperature elevation of the working fluid was 42.5 ^{o} C during the peak hours of incident solar radiation. This temperature elevation of working fluid was observed to be higher than these of the working fluids in solar collectors with absorbers of conventional coatings. The relatively higher absorption of solar radiation and heat transfer to working fluid could be correlated with the presence of more number of absorbing particles in the absorber, presence of carbon particles in the absorbing surface and presence of oxide of metal on the absorber [5].

CONCLUSION

It could be concluded that copper absorbers with nano-carbon and aluminium oxide based coatings would be utilized in solar collectors not only to have enhanced absorptance of solar

radiation but also to have enhanced thermal performance of solar collectors.

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