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Improving Solar Central Tower Receiver's Thermal Performance by a New Low Cost Coating Method

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Abstract: Thermal efficiency of solar central receiver's energy systems is considered as an essential topic. Selective coatings in solar application also have other important factors, such as homogeneity, production speed, cycle time, as well as the minimization of the quantity of the needed chemical precursors. In this paper a new coating technique, efficient and low cost is presented for production of selective coatings for solar thermal receivers. The proposed technique had enhanced the central solar receiver thermal performance by 13.97%.
Keywords: Solar tower, receiver, absorbing tubes, Oxidization, Ebonol C.

I. INTRODUCTION

Conversion of solar radiation to thermal energy is an efficient method to offer a suitable way to consider the solar applications in industrial, domestic, and commercial generation of solar power.

An important parameter to achieve the applications is the selective coating for the solar receiver, which is considered as a block body that will increase the receiver absorptivity and decrease its reflectivity which will lead to high gained energy, for applications below 300°C, a wavelength of approximately 2500 nm can be considered as transition point between these two spectral bands. In nature, no materials exist with perfect intrinsic selective properties developed a black selective coating made by sol-gel dip-coating. The characteristic matrices method was used to simulate the designed thin multilayered films. The profile depth of the multilayered three areas coating was confirmed by means of Time of Flight Secondary Ion Mass Spectroscopy (ToF-SIMS) and X-Ray Photoelectron Spectroscopy (XPS). Nanocrystalline particles of (5 to 20) nm in diameter were observed using Transmission Electron Microscopy (TEM). The achieved enhancement in solar absorption had reach more than 0.95 while the thermal emittance was about 0.12. A comparison of corrosion resistance and thermal stability of the presented novel coatings was done with black chrome coatings giving enhanced properties [1].

The coating art had been considered, and investigations of the influence for its application parameters on the durability of coating [2]. Alternative formulations FOR the receiver coatings have also been studied by refs. [3, 4, 5]. The main task is to improve a coating for the solar receivers with a high absorptivity that withstand high temperatures above 600 °C and with lowest coating cost [6, 7]. Coatings is not yet standardized, therefore different test procedures had been conducted by [7, 8, 9].

The improvement of central solar power (CSP) systems efficiency by using selective coatings for the solar receiver that withstand higher temperatures leading to high absorptivity and low emissivity coatings. A thermal coating spray (Pyromark) compositions (Ni-25 graphite, Ni-5Al and WC-20Co) were compared according to the solar emittance and absorptance with other oxidation materials used in coating like NiCo2O4, CuCo2O4, and (NiFe) Co2O5, the results showed that there was an optical improvement using both type of coatings was discussed [10].

Experimental study for the improvement of thermal performance for a flat plate solar collector. The surface radiative properties were modified by testing three types of coating, copper oxidization by using ammonia, graphene, and black matt paint. Results showed that the radiative properties and thermal efficiencies of the absorbers were evaluated, the best performance was observed to be the oxide with a maximum efficiency of 39.5% compared with the black matt paint [11].

An experimental comparison for a flat-plate collector coated using three different materials, black matt paint, black chrome, and carbon-coating. Results showed that the carbon-coated absorber plate had the highest thermal efficiency due to its higher optical absorptivity. Comparing the thermal efficiency of the black-painted absorber collector with other two collectors had showed an increase by approximately 13% for the carbon-coated absorber while a 11.3% increase for the black chrome-coated absorber. Although it is noticed that the coating cost is proportional to the enhancement. The lowest coating cost was for the black matt paint with a thermal efficiency of 56.4% and in second level the black chrome had a thermal efficiency of 67.7% and the carbon coated which is the most highly expensive coating among the mentioned materials but with a thermal efficiency of 69.4%. It is obvious that using selective coatings leads to an enhancement in the thermal efficiency and decreases the heat loss due to higher optical absorptivity and lower emissivity [12].

The main objective for the present study is to find a suitable and cost effective method for coating in concentrated solar applications.

II. MATERIALS AND METHODS SOLAR RECEIVER COATING PROCESS

Copper has a bright shiny surface that causes higher reflectivity which must be decreased as possible to ensure high absorptivity and low reflectivity and emissivity, which is ideal for the maximum gain of solar radiation. For that purpose, several samples had been tested to select the most efficient coating sample for the receiver pipes surface. Oxidation (blacking) the tube surface is recommended as another valid option for coating [13], (Ebonol C) as shown in figure 1 is a chemical material used to oxidize the copper which leads to a cupric oxide for the copper surface producing shiny black surface, and to reduce the reflectivity and emissivity of this surface, black matt spray is used. The coating is considered chemically durable and very stuck, this will give absorptivity and emissivity about 0.84 and 0.07 respectively [14]. Samples were prepared to examine the best coating, the copper pipe samples were closed from both sides with rubber plugs to avoid oxidation on the inner surface of the pipe.

The eight samples were prepared, as listed:

- Sample No. 1: Copper pipe only.
- Sample No. 2: Copper pipe submerged in (Ebonol C) for 20 sec without water bath.
- Sample No. 3: Copper pipe submerged in (Ebonol C) for 20 sec with water bath.
- Sample No. 4: Copper pipe submerged in (Ebonol C) for 30 sec with water bath.
- Sample No. 5: Copper pipe submerged in (Ebonol C) for 30 sec without water bath.
- Sample No. 6: Copper pipe coated with black matt spray only.
- Sample No. 7: Copper pipe submerged in (Ebonol C) for 20 sec with water bath and then coated with black matt spray.
- Sample No. 8: Copper pipe submerged in (Ebonol C) for 30 sec with water bath and then coated with black matt spray.

The coating process for the samples is illustrated in figure 2.

To decide the best sample which gives the highest temperature difference, tests were conducted for samples (2 to 8), and their results were compared with sample no. 1. This was done by fixing thermocouple type K inside the pipe at 10 cm from one side to measure water's bulk temperature at steady state as shown in figure. 3.

Figure 1 Ebonol C oxidization chemical material.

Figure 2 Coating process for the pipe samples.

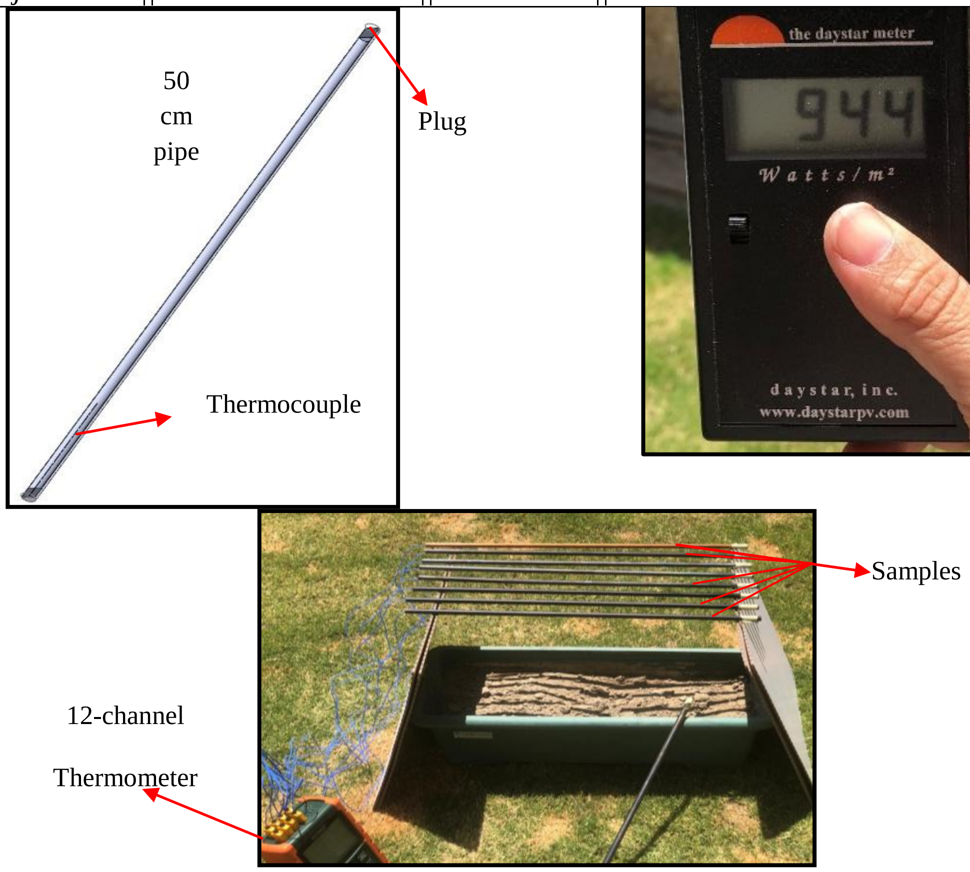

Figure 3 Test procedure for the pipe samples.

The initial and final water temperatures were recorded for each sample according to the conditions, date (5 July 2019), time (11:00 AM), duration (90) minutes, and average solar intensity was (952 W/m2). The test results and comparison among the samples are listed in Table 1.

III. RESULTS AND DISCUSSION

From Table 1 observations, sample no. 7 gives the highest temperature difference compared with the other samples, and its coating process was selected to coat the entire receiver as shown in figure 4.

The results showed that sample no. 7, Copper pipe submerged in (Ebonol C) for 20 sec with water bath and then coated with black matt spray is the best choice for coating due to the 7.1oC temperature difference between inlet and outlet sections of the test section (pipe).

The first step of coating method (oxidization) had led to decrease in reflectivity while the second step (matt spray) which caused an increase in absorptivity, this method had been conducted with minimal cost using available materials and using this technique had enhanced the central solar receiver thermal performance by 13.97%.

Table 1 Sample coating selection matrix.

ΔT (^{o}C)		Sample number							
		1	2	3	4	5	6	7	8
Sample number	1	-							
	2	-0.25	-						
	3	-0.31	-0.15	-					
	4	-0.24	-0.21	-0.17	-				
	5	-0.23	-0.20	-0.15	-0.15	-			
	6	-0.33	-0.40	-0.19	-0.26	-0.18	-		
	7	7.10	2.70	2.85	2.31	2.35	2.51	-	
	8	6.30	1.90	2.05	2.16	2.23	2.42	1.1	-

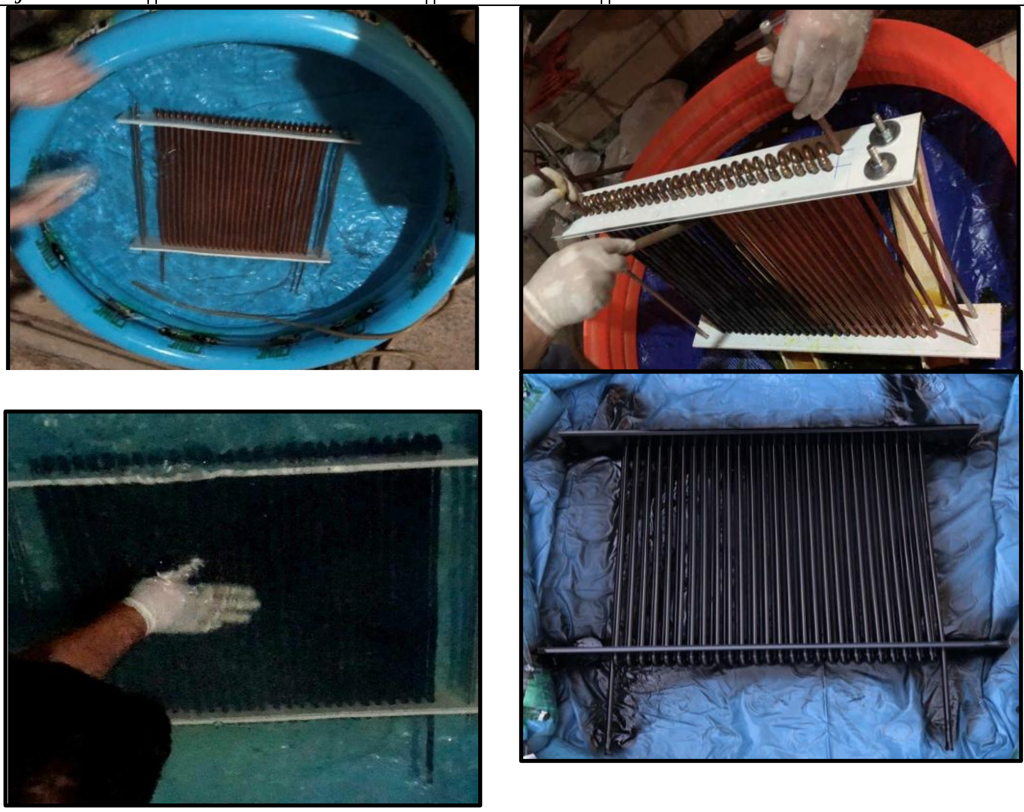

Fig. 4 Coating process for the receiver.

IV. CONCLUSION

The receiver copper pipes were oxidized using (Ebonol C) and then it was coated with black matt paint to reduce the reflectivity and emissivity with increase in the receiver absorptivity, this coating process had enhanced the pipe thermal efficiency by 13.97% compared with that for copper pipes.

This technique is considered costly effective compared with other coating methods, taking into consideration the temperature limits for the solar receiver.

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