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Effects of Aluminum Fin Thickness Coated with a Solar Paint on the Thermal Performance of Evacuated Tube Collector

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Abstract

In commercial evacuated tube collector (ETC) with double layers evacuated tube, a solar absorber is coated on the outer surface of the inner glass vacuum tube. In order to reduce cost of production and maintenance, our previous research work has been successfully initiated to place an aluminum fin inside the ETC to be a solar receiver together with clear double layers evacuated tube. Therefore, the objective of this present research is focused on the effect of aluminum (Al) fin thickness coated with solar paint on the thermal performance of ETC. Commercial Al fins with three different thicknesses (11, 13, and 24 µm) were considered in this study. An available solar paint (Thurmolax 250 selective black solar collector coating) was coated on the Al fin solar absorber using an air spray deposition technique with three different coating thicknesses. Spectral reflectance and thickness of the coatings were characterized using Ultraviolet-visible-near infrared (UV-Vis-NIR) spectrophotometer at the wavelengths 300-2500 nm and a Mini Test 730 equipment respectively. The solar absorptance (α) was calculated based on the relationship of observed reflectivity (R), and the solar spectral irradiance of AM 1.5 in the whole wavelength range of the solar spectrum. The collector thermal efficiency (η) of ETC with different thicknesses of Al fin coated with solar paint as solar receiver was evaluated, following a standard ISO 9806-1. As a result, it is found that the α of all the thicknesses of solar paints considered was identical (α=0.94), indicating that the thickness of solar paint was an insignificant effect on the α. The η, heat removal factor (F_R), and overall heat loss coefficient (U_L) were calculated for different Al fin thicknesses with 1x solar paint coating thickness and were found to be increasing with decreased Al fin solar absorber thickness. The results revealed that the F_R was predominant for the increase in the η with the reduction of Al fin solar absorber thickness. It can be concluded that the thinner Al fin (11µm) with single layer solar paint coating is suggested to be used in ETC due to its relatively higher η and F_R, including light weight and low cost.

Keywords: Evacuated tube collector (ETC); aluminum; solar paint; thermal efficiency; solar absorptance.

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1. Introduction

As the need of thermal energy worldwide increases from time to time, improving thermal efficiency of solar collector become very crucial and indispensable. Efficiency of a system is improved mainly by increasing the efficiency of its components. Solar paint, selective solar absorber, and absorber geometry have great influence on the thermal performance of solar absorber. Introduction of polymers and nanofluids in the solar thermal application also improves the performance of the collector [1-3].

Nomenclature

c_p	specific heat at constant pressure, J/kg·°C
F_R	heat removal factor
U_L	overall heat loss coefficient, W/m^2·°C
T_i	collector inlet temperature, °C
T_o	collector outlet temperature, °C
T_a	ambient air temperature, °C
G_t	global solar radiance at the collector plane, W/m^2
c_o	intercept efficiency
c_1	first order coefficient of the collector efficiency, W/m^2·°C
c_2	second order coefficient of the collector efficiency, W/m^2· °C^2
$\dot{m}$	mass flow rate of water, kg/s
A_a	absorber area, m^2
η	thermal collector efficiency
R	reflectance
τ	transmittance
α	solar absorptance
I_s	solar spectral irradiance at AM 1.5, W/m^2·μm
λ	wavelength, m

Basically, evacuated tube collector (ETC) uses copper heat pipe and heat transfer fin enclosed in double sealed evacuated glass. Application of ETC ranges from small scale heating of water for personal consumption to large-scale production of hot water for industrial use [4]. ETC is preferred to another collector due to its higher thermal efficiency and convenience [6], however, the commercial available ETC requires highly developed technique to apply the coating, as the coating is in the inner part of the glass tube as shown in Fig. 1a. Once the glass tube is broken the whole glass tube with coating should be replaced which increases the maintenance cost. One of the most important and critical parts of the collector is the solar absorber. Absorbers with spectrally selective solar coating have more efficiency than without [5]. An ideal spectrally selective surface should have a reflectance of zero in the solar wavelength range and unity in the thermal infrared (IR). The most common solar absorber type is the absorber-reflector tandem, which is obtained by combining two surfaces, one surface which is highly absorbing in the solar region and another highly reflecting in the infrared. Selective solar coatings can be applied to a surface using a large number of techniques such as electroplating, chemical conversion, spray pyrolysis, vacuum deposition, and chemical vapor deposition [7].

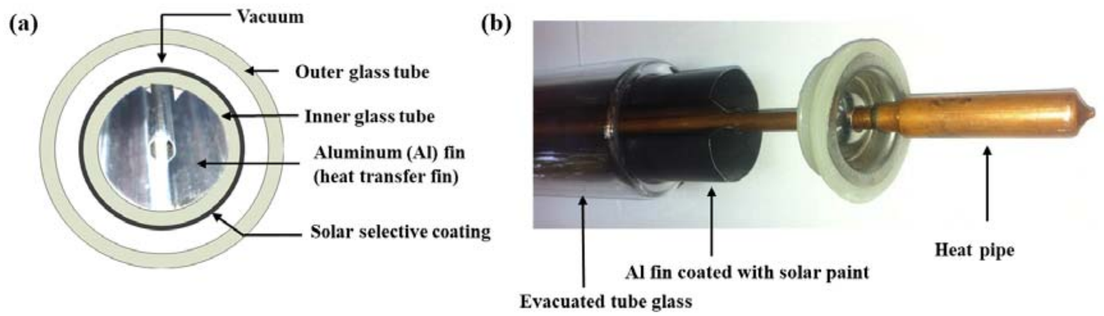

Fig. 1. (a) Cross section of commercial ETC showing original coating and (b) solar paint coating on Al fin.