Thermo-Statistical Investigation of the Solar Air Collector Using Least Angle Regression

Alok Dhaundiyal

Centre for Energy Research, Konkoly Thege M. út 29-33, 1121 Budapest, Hungary

Supplementary Material

The flux absorbed by the absorber (*S*) can be expressed as

$$S = I_b r_b (\tau\alpha)_b + \{I_d r_d + (I_b + I_d) r_r\}(\tau\alpha)_d \quad \text{(S1)}$$

Here, I_b, I_d, r_b, r_d, and r_r represent beam and diffuse radiations, and tilt factors for beam, diffuse and reflected radiations, respectively. The subscripts 'b' and 'd' denote beam and diffuse radiation.

The tilt factors can be obtained from the following relationship.

$$r_b = \frac{\sin\delta \times \sin(\phi-\beta) + \cos\delta \times \cos\omega \times \cos(\phi-\beta)}{\sin\phi \times \sin\delta + \cos\phi \times \cos\delta \times \cos\omega} \quad \text{(S2)}$$

$$r_d = \frac{(1+\cos\beta)}{2} \quad \text{(S3)}$$

$$r_r = \frac{\rho_g(1-\cos\beta)}{2} \quad \text{(S4)}$$

ρ_g denotes the ground reflectivity

The transmissivity–absorptivity product derived from S5

$$(\tau\alpha) = \frac{\tau\alpha}{1-(1-\alpha)\rho} \quad \text{(S5)}$$

Transmittivity(τ) can be derived through arithmetic mean of the polarisation components that are based on the reflectivity (ρ) of these components. The components can be derived by applying Snell's law

$$\rho_I = \frac{\sin^2(\theta_2-\theta_1)}{\sin^2(\theta_2+\theta_1)} \quad \text{(S6)}$$

$$\rho_{II} = \frac{\tan^2(\theta_2-\theta_1)}{\tan^2(\theta_2+\theta_1)} \quad \text{(S7)}$$

$$\tau_{rI} = \left(\frac{1-\rho_I}{1+\rho_I}\right) \quad \text{(S8)}$$

$$\tau_{rII} = \left(\frac{1-\rho_{II}}{1+\rho_{II}}\right) \quad \text{(S9)}$$

$$\tau_r = \frac{(\tau_{rI}+\tau_{rII})}{2} \quad \text{(S10)}$$

From Bourger's law, transmissivity is based on absorption (τ_a) can be deducted

$$\tau_a = e^{-\left(\frac{K\delta_c}{\cos\theta_2}\right)} \quad \text{(S11)}$$

where, K, δ_c and θ_2 represent extinction coefficient, the thickness of the cover plate and the angle of refraction, respectively

The net transmissivity (τ) of the cover plate is obtained by multiplying the transmissivity (τ_r) obtained by considering only reflection and refraction, and transmissivity (τ_a) deduced from absorption only.

$$\tau = \tau_a \times \tau_r \quad \text{(S12)}$$

The fin effectiveness (φ_f) is determined by Eq. S13

$$\varphi_f = \frac{1}{mL_f}\left(\frac{I_1(2m\times L_f)}{I_0(2m\times L_f)}\right)\left(\frac{4\times w\times\left(L_f^2+\left(\frac{\delta_f}{2}\right)^2\right)^{\frac{1}{2}}}{\delta_f\times L_f}\right) \quad \text{(S13)}$$

where,

$m = \left(\frac{2h_{ff}}{k_f \times \delta_f}\right)^{\frac{1}{2}}$ and I_1 and I_0 are the Bessel functions of order one and zero, respectively

In Eq.S13, h_{ff}, k_f, w_i, δ_f and L_f denote the convective heat transfer coefficient between the fin surface and the air stream, and the thermal conductivity of fin material used for manufacturing the fin, the transverse width, thickness, and the height of fin, respectively.

The effective heat transfer coefficient (h_e) for flat plate (Eq. S14) and finned plate (Eq. S15) solar collectors can be calculated by

$$h_e = h_{fp} + \left(\frac{h_r \times h_{fc}}{h_r + h_{fc}}\right) \quad \text{(S14)}$$

$$h_e = h_{fp}\left(1 + \frac{2L_f \times \varphi_f \times h_{ff}}{W \times h_{fp}}\right) + \left(\frac{h_r \times h_{fc}}{h_r + h_{fc}}\right) \quad \text{(S15)}$$

h_{fp}, h_{fc}, h_r, and h_{ff} are heat transfer coefficients between the absorber plate and airstream, the air stream and the cover plate, radiative heat transfer coefficient, and fin surface and the air stream, respectively.

The useful heat gain (Q_u) for the collector when the air stream is flowing between the cover plate and absorber plate is estimated from the following expression for the Collector-I

$$Q_u = F_R A_p\left[S - U_l(T_{fi} - T_a)\right] \quad \text{(S16)}$$

In Eq. (S16), F_R, A_p, U_l, T_{fi}, and T_a denote the heat removal factor, area of the absorber plate, the equivalent overall heat loss coefficient, the inlet temperature of the air stream and ambient temperature of the air, respectively

Correspondingly, the expression for heat removal (F_R) and the collector efficiency (F') factors are calculated from Eq. (S17) and Eq. (S18),

$$F_R = \left(\frac{\dot{m}_a \times C_p}{U_l \times A_p}\right)\left[1 - exp\left\{-\frac{F' \times U_l \times A_p}{\dot{m}_a \times C_p}\right\}\right] \quad \text{(S17)}$$

where,

$\dot{m}_a$ denotes the mass flow rate of air stream inside the collector

$$F' = \frac{(h_{fc}h_r + h_{fp}U_t + h_{fp}h_r + h_{fc}h_{fp})}{(U_t + h_r + h_{fc})(U_b + h_r + h_{fp}) - h_r^2} \quad \text{(S18)}$$

U_b and U_s are overall heat transfer coefficients for the front and rear surfaces of the absorber plate, respectively.

The equivalent overall heat transfer coefficients for flow between the cover plate and the absorber are estimated by Eq. (S19)

$$U_l = \frac{(U_t + U_b)(h_{fc} \times h_{fp} + h_{fc} \times h_r + h_{fp} \times h_r) + U_t \times U_b(h_{fc} + h_{fp})}{h_{fc} \times h_r + h_{fp} \times U_t + h_{fp} \times h_r + h_{fc} \times h_{fp}} \quad \text{(S19)}$$

Similarly, for the flow behind the absorber plate, the following expressions are used

$$F' = \left(1 + \frac{\left\{U_t + \left(\frac{h_r \times U_b}{h_r + h_{fb} + U_b}\right)\right\}}{h_e}\right)^{-1} \quad \text{(S20)}$$

$$U_l = U_t + \left(\frac{h_r \times U_b}{h_r + h_{fb} + U_b}\right) + \frac{1}{F'}\frac{h_{fb} \times U_b}{(h_r + h_{fb} + U_b)} \quad \text{(S21)}$$

$$h_e = h_{fp} + \left(\frac{(h_r \times h_{fb})}{h_r + h_{fb} + U_b}\right) \quad \text{(S22)}$$

where h_{fb} is the heat transfer coefficient between the air stream and bottom plate.

The uncertainty related to the experimental parameters is given in Table S1

Table S1. Uncertainty in the experimental measurement

Parameters	Collector-I	Collector-II
Global radiation	±16.61 W m^{-2}	±16.61 W m^{-2}
Airstream velocity	±0.10 m s^{-1}	±0.12 m s^{-1}
Absorber plate Temperature	±0.90 K	±0.90 K
Ambient Temperature	±0.34 K	±0.34 K
Inlet temperature for the second pass	±0.57 K	±0.68 K
Inlet temperature for the first pass	±0.31 K	±0.34 K
Outlet temperature for the second pass	±0.76 K	±0.79 K