AESMT'20 Alternative Energy Sources, Materials & Technologies, 2020
June 8-9, 2020, Varna, Bulgaria

Experimental and numerical investigation on a multilayer structured PV/T system

Z. G. Fu[1*], Y. Li[1], Y. J. Bao[2], Q. Z. Zhu[1*]
1: College of Energy and Mechanical Engineering, Shanghai University of Electric Power, Shanghai, China
2: Xinjiang oilfield company, Luliang oilfield operation area, Karamay, China.

Motivation

The method of adding phase change materials (PCMs) can be adopted to control the temperature rise of solar panels. The reported electrical and thermal performance deeply depends on the adopted PV/T system and the climate. More results on the performance of practical PV/T system with PCMs are required. The purpose of this study is to propose an effective multilayer structured heat exchanger with PCMs adopted in a practical PV/T system. The performance improvements in typical seasons are validated experimentally. Furthermore, the influence of thickness of PCM layer on the operation performance of the system is investigated numerically.

Equations and Solution

❖ Electrical and Thermal efficiency

$$\eta_e = \eta \cdot a_c \cdot \tau_g \cdot F$$

$$\eta_t = \frac{\dot{m}_w C_w (T_{out} - T_{in})}{A_{pv} \cdot I}$$

❖ Phase Change

If $Q_p < Q_{sol}, T_p = T_{mp} - \frac{Q_{sol} - Q_p}{C_{sol}}$, $\lambda_p = \lambda_{sol}$.

If $Q_{sol} < Q_p < Q_{liq}, T_p = T_{mp}$,

$$\lambda_p = \lambda_{sol} \frac{Q_{sol} - Q_p}{Q_{liq} - Q_{sol}} + \lambda_{liq} \frac{Q_p - Q_{sol}}{Q_{liq} - Q_{sol}} .$$

If $Q_{liq} < Q_p , T_p = T_{mp} + \frac{Q_p - Q_{liq}}{C_{lir}}$, $\lambda_p = \lambda_{liq}$.

❖ Governing Equation

The energy balance of the PV panel can be written as follows.

$$F \cdot \alpha_c \cdot \tau_g \cdot I + U_{gc}(T_g - T_c) = \eta \cdot F \cdot \alpha_c \cdot \tau_g \cdot I + U_{cb}(T_c - T_b)$$

Where, F is packing factor; τ is transmission coefficient; η is photovoltaic efficiency; U is overall heat transfer coefficient.

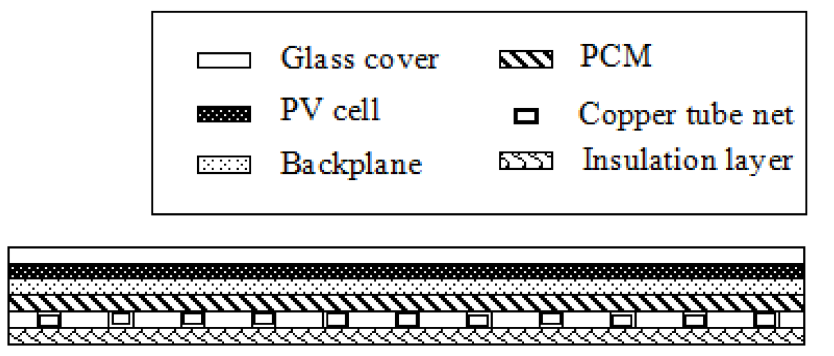
❖ Solution

The overall heat transfer coefficients in the model can be calculated. All equations are solved by a self-made MATLAB procedure to evaluate the temperature of various layers

Table 2. Thermal properties of PCMs

Type	Thermal conductivity	Melting temperature	Latent heat
	W/(m•℃)	℃	kJ/kg
Paraffin	0.20	32.42	124.57
5%EG/Paraffin	3.86	31.98	123.69
10%EG/Paraffin	8.42	31.69	114.95
15%EG/Paraffin	13.00	31.28	101.12

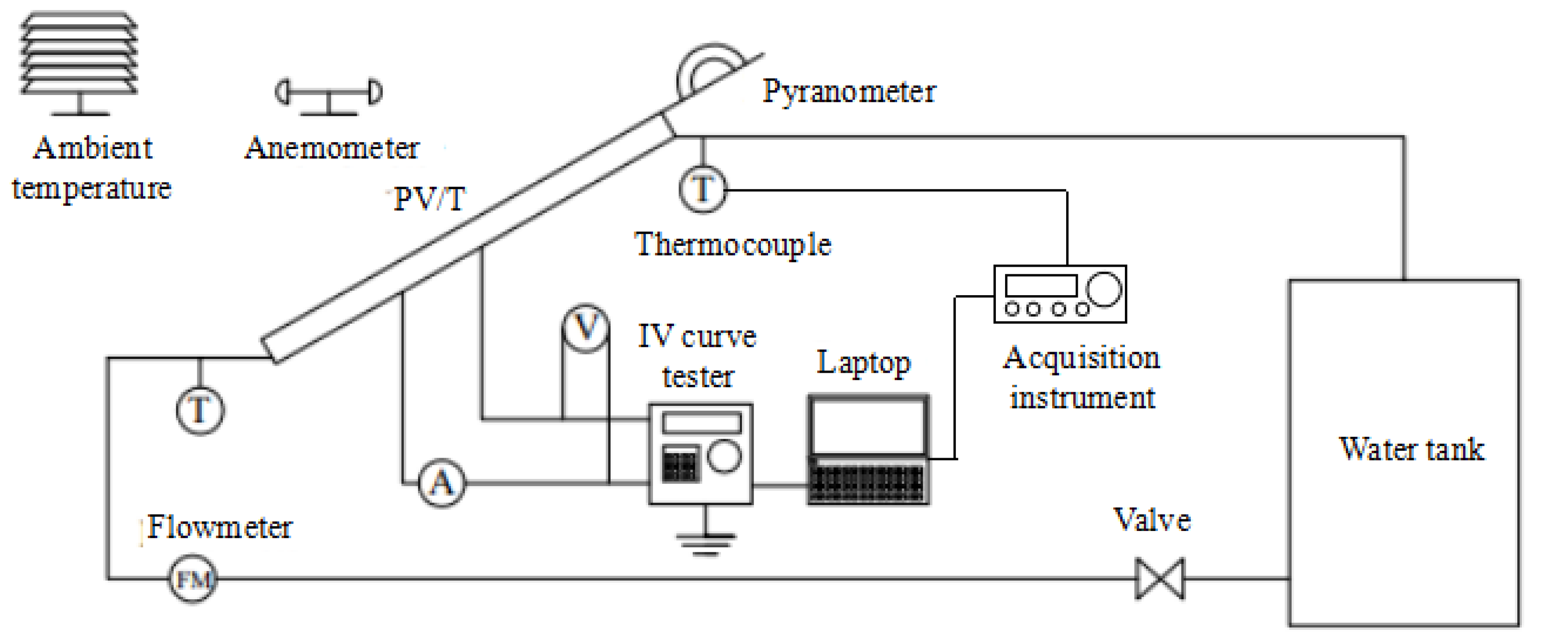
Physical Model



* Multilayer structured heat exchanger

Table 1. Physical and geometric parameters of system

Component	Thermal con.	Transmission	Absorption	Thickness
	W/(m•℃)	-	-	m
Glass	1	0.91	0.05	0.003
PV panel	148	0.09	0.80	0.0003
Backplane	144	0.00039	0.4	0.0005
Air	0.024	-	-	0.01
Insulation	0.035	-	-	0.05
Tube	397	-	-	0.002



* Schematic diagram of the experimental facility

Results & Discussions

❖ Validation

Temperature of system

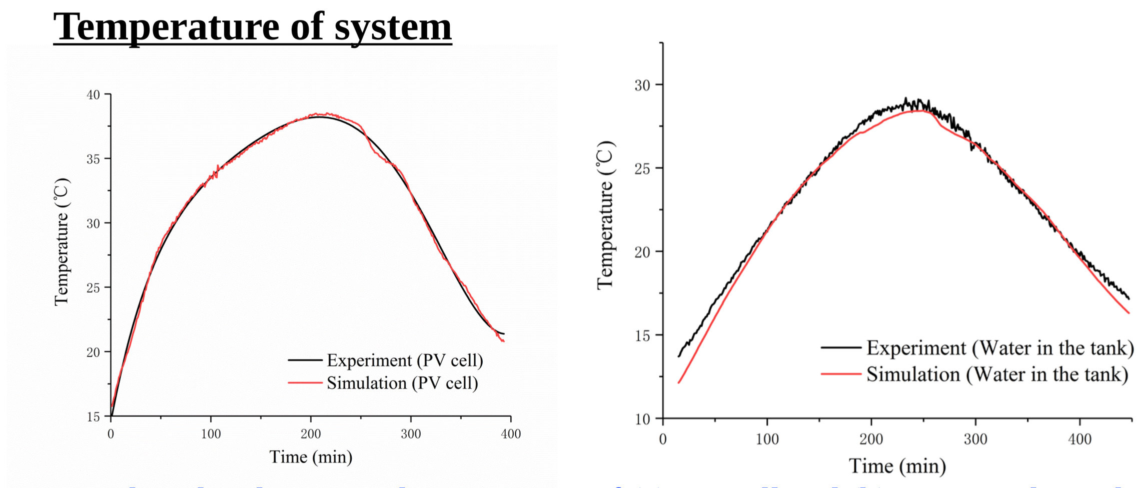


Fig. 1. Predicted and measured temperature of (a) PV cell and (b) water in the tank.

✦ Therefore, the numerical model established is reliable and the results are in good agreement with the experimental results whether it considers PCM layer or not. It can be used to simulate the operation performance of PV/T system based on the multilayer structured heat exchanger.

❖ Improved Efficiencies

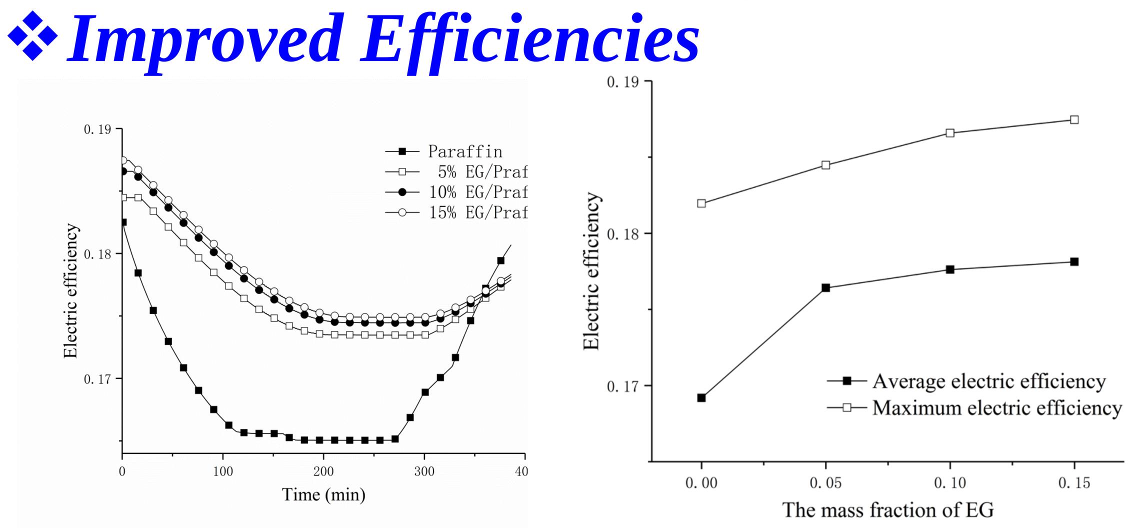


Fig. 2. Electrical efficiency of different composite PCMs, (a) instantaneous and (b) mean value

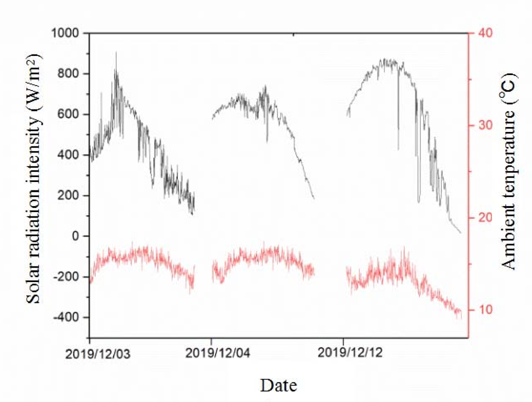


Fig.3. Typical solar radiation intensity and ambient temperature in winter

❖ Effects of Thickness of PCM Layer

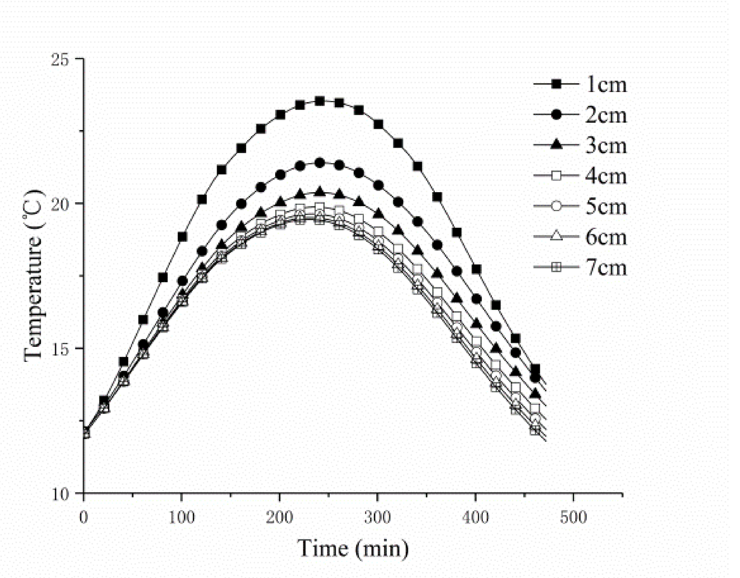


Fig.4. Variation of water temperature with PCM thickness

✦ The water temperature in the heat storage tank with a thickness of 1cm is the highest, which is 24.5 ℃. The water temperature of the heat storage tank with a thickness of 7cm is the lowest, which is 19.4 ℃. When the water temperature of reaches the maximum temperature, it begins to decline due to the weakened solar radiation. At the end of the final time, the corresponding maximum and minimum water temperature are 13.8 ℃ and 11.8 ℃, respectively, corresponding to the use of PCMs with thickness of 1cm and 7cm.

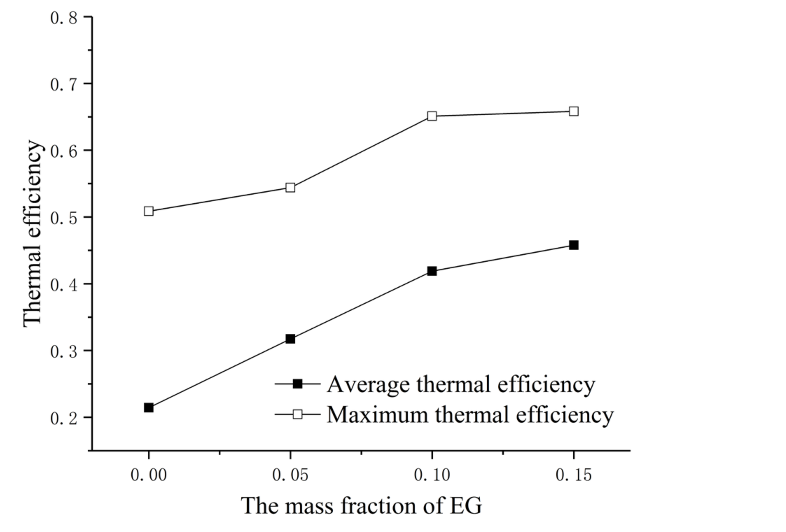


Fig.5. Mean thermal efficiency of different composite PCMs

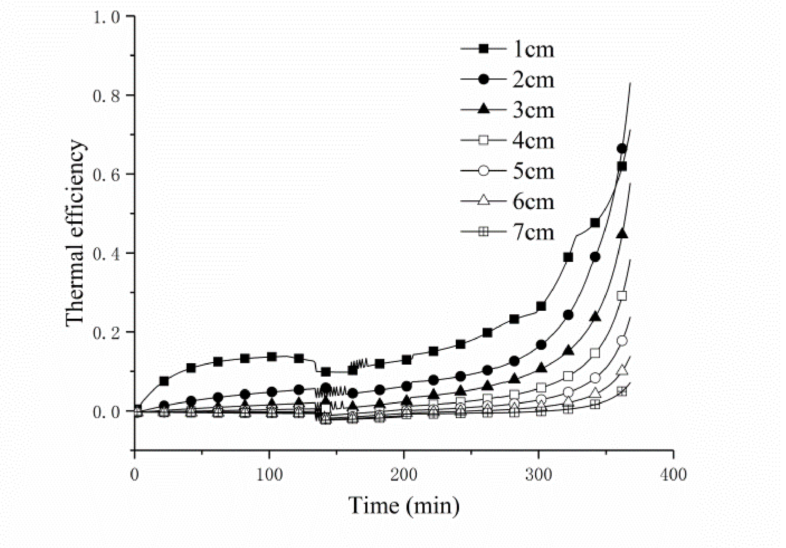


Fig.6. Thermal efficiency under different thickness of PCM layer

✦ The thermal efficiency of the system mainly depends on the temperature difference between the inlet and outlet of the heat exchange system and the solar radiation intensity. From the beginning of the system to 260min, the PCM layer and the water absorb heat at the same time, resulting in only part of the absorbed solar radiation heating the water with the increasing solar radiation intensity. Thus, the thermal efficiency of the system is maintained at about 10%. When the system runs to 360 min, the solar radiation intensity decreases obviously and the heat is released from the PCM layer, which improves the thermal efficiency of the system.

Conclusions

- Under the condition of typical weather, for the closed-cycle PV/T system, the temperature difference between the water tank and the ambient temperature at the end of operation can be increased without affecting the electrical efficiency by using the PCM between the backplane of PV panel and the heat exchange passageway.
- Under the condition of typical weather days in winter, for the composite PCM used in the experiment, the greater the mass fraction of expanded graphite in the composite PCM, the greater the improvement of the system operation performance. The maximum electrical efficiency and thermal efficiency of the system can be increased by 0.9% and 14.9% respectively when 15% expanded graphite paraffin composite phase change material is used.
- Under the meteorological conditions of typical weather days in winter, the influence of the thickness of phase change materials on the operation performance of the system is obvious. The PCM layer with a thickness of 1 cm has the highest system electrical efficiency and thermal efficiency, which are 17.8% and 51.5% respectively.

The supports by the National Science Foundation of China (No.51606114) and Science and Technology Commission of Shanghai Municipality (STCSM NO.18020501000) to this study are acknowledged and highly appreciated.