THE EXPERIMENTAL PERFORMANCE COMPARISON OF TWO DIFFERENT TYPES OF UNGLAZED PVT COLLECTOR

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1. Introduction

A photovoltaic/thermal (PVT) collector, which is also known as a photovoltaic-thermal system, generates both thermal and electrical energy simultaneously. A photovoltaic/thermal (PVT) collector is a combination of photovoltaic module with a solar thermal collector, forming one device that converts solar energy into electricity and heat simultaneously(Kim and Kim, 2008). The excess heat that is generated from PV modules can be removed and converted into useful thermal energy. As a result, PVT collectors can generate more solar energy per unit surface area than side by side photovoltaic modules and solar thermal collectors(Kim, et al., 2009).

In general, two types of the PVT collector can be distinguished: Glazed PVT collector with covered glass, which produces more heat but has a slightly lower electrical yield, and unglazed PVT collector with no covered glass, which produces relatively less thermal energy, but has a somewhat higher electrical performance. Unglazed PVT collectors are more similar to regular PV panels, and consist of PV-module and thermal absorber with no additional glass cover. Unglazed one has lower thermal efficiencies: The collector delivers relatively lower thermal energy with higher electrical efficiency due to the cooling effect of PV module. The electrical efficiency of Unglazed PVT collector is higher than that of glazed PVT collector, and even higher than that of regular PV module due to the cooling effect. But the thermal efficiency of the unglazed is lower than that of the glazed collector due to higher heat loss from the collector surface of the former(Kim, et al., 2010).

On the other hand, two types of the PVT collector can be distinguished according to absorber attached into PV module: the sheet-and-tube absorber PVT collector (Fig.1) and the fully wetted absorber PVT collector (Fig. 2).

The aim of this study is to compare the electrical and thermal performance of the sheet-and-tube absorber and the fully wetted absorber PVT collectors, both categorized as unglazed. For this paper, the PVT collectors with two different types of thermal absorber were made, and both the thermal and electrical performance of them were measured in outdoor, and the results were compared.

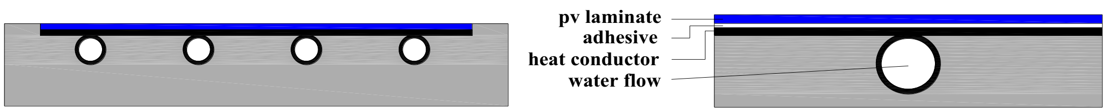

Fig. 1 Sectional view of sheet-and-tube absorber PVT Collector

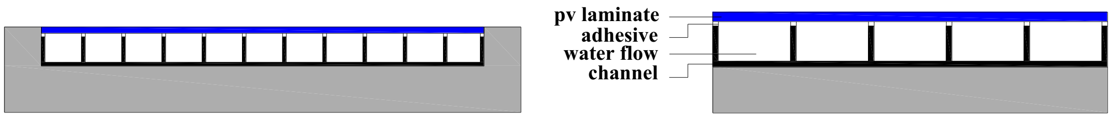

Fig. 2 Sectional view of fully wetted absorber PVT Collector

2. PVT Collector Design and Manufacture

The liquid-type unglazed PVT collectors of two absorber types, the sheet-and-tube and fully wetted absorber, were designed and made for this study. The sheet-and-tube absorber was the well-known technology for solar thermal collector and commercially available. For the case of a fully wetted absorber, the fully wetted absorber of rectangular shape as water flow channel can reduce thermal resistance between PV module and the collector fluid(Affolter, 2007). The fully wetted absorber is no absorber sheet which is attached at PV module back side like the sheet-and-tube absorber

The PVT collectors consist of PV modules in combination with water heat extraction units made from aluminum of sheet-and-tube and fully wetted type. Also, PVT collectors consist of a PV-covered absorber with no additional glass cover, and are thermally protected with 50mm glass-wool insulation.

For the sheet-and-tube absorber PVT collector, the aluminum sheet-and-tube absorber was attached at the PV module back side by thermal conduction adhesives. The PV modules used for the collectors were $240W_p$ mono-si PV modules and had the electrical efficiency of 14.5% in the standard test conditions (STC). The specifications are shown in Table 1.

The configuration of fully wetted absorber PVT collector was the same as the sheet-and-tube absorber PVT collector except the absorber.

Tab. 1 PV module Specifications

cell type	Mono crystalline silicon
maximum power	240W
maximum voltage	29.93V
maximum current	8.15A
shot current	8.56A
open voltage	37.55V
size	1656*997*50mm

3. Experiments

3.1 Experimental Methods

Two different types of the PVT collector were tested under irradiance above 790W/㎡, flow rate 0.02kg/s ㎡, based on ASHRAE Standard 93-77(ASHRAE, 1991) and PVT performance measurement guidelines of ECN (Zondag, et al., 2005). The electricity and thermal performance measurements were carried out under quasi-stationary condition in outdoor(fig. 3). For the electrical performance measurements of the PVT collectors, such DC current-voltage and power, electrical loading resistors and a power meter were installed.

Fig. 3: Experiment view of sheet-and-tube and fully wetted absorber PVT collector

3.2 Analysis of the Experimental Results

With the results of the outdoor testing of the PVT collectors, the thermal and electrical performances were analyzed: The experimental results for the two different types of PVT collector were compared.

(1) Thermal performance

The thermal efficiency is determined as a function of the irradiance (G), the input fluid temperature (T_i) and the ambient temperature (T_a). The steady state efficiency is calculated by:

$$\eta_{th} = \dot{m}\, C_p\, (T_o - T_i) / A_{pvt}\, G \qquad \text{(eq. 1)}$$

Where,

η_{th} : thermal efficiency

A_{pvt}: collector area (㎡)

T_o: collector outlet temperature (℃)

T_i: collector inlet temperature (℃)

$\dot{m}$: mass flow rate(kg/hr)

C_p: specific heat (kJ/kg℃)

G: irradiance (W/㎡)

The thermal efficiency η_{th} of a PVT collector is conventionally shown as a function of reduced temperature, which is defined as $\Delta T/G$, where $\Delta T = T_m - T_a$

Where, T_m is collector mean fluid temperature, and is defined as the average of inflow and exit point temperatures. T_a is ambient temperature, and G is the irradiance in the collector plane. Hence, ΔT is a measurement of the temperature difference between the collector fluid and its surroundings, relative to the irradiance. The thermal efficiency η_{th} is then expressed as

$\eta_{th} = \eta_0 - \alpha_1(\Delta T/G)$

Where η_0 is the thermal efficiency at zero reduced temperature, and α_1 is the heat loss coefficient.

With the measurement results of the PVT collectors of two different types, the thermal performance can be expressed with Fig. 4. Thermal efficiencies of the sheet-and-tube absorber and the fully wetted absorber PVT collector can be expressed with relational expression η_{th} = 0.66-14.29(ΔT /G) and η_{th} = 0.70-13.29(ΔT /G) respectively. Thus, the thermal efficiencies (η_0) at zero reduced temperature are 0.66 and 0.70 respectively, and the fully wetted absorber PVT collector efficiency was about 4% higher than that of sheet and tube absorber PVT collector. Also, the heat loss coefficients (α_1) are -14.29W/m^{2}K and -13.29W/m^{2}K, respectively: The fully wetted absorber PVT collector had better thermal performance than the sheet-and-tube absorber PVT collector, but their heat losses are similar.

Therefore, the thermal performance difference by absorber type was concluded as relatively small. The average thermal efficiency of the sheet-and-tube absorber and the fully wetted absorber PVT collector is about 48% and 51% respectively, at the same outdoor condition.

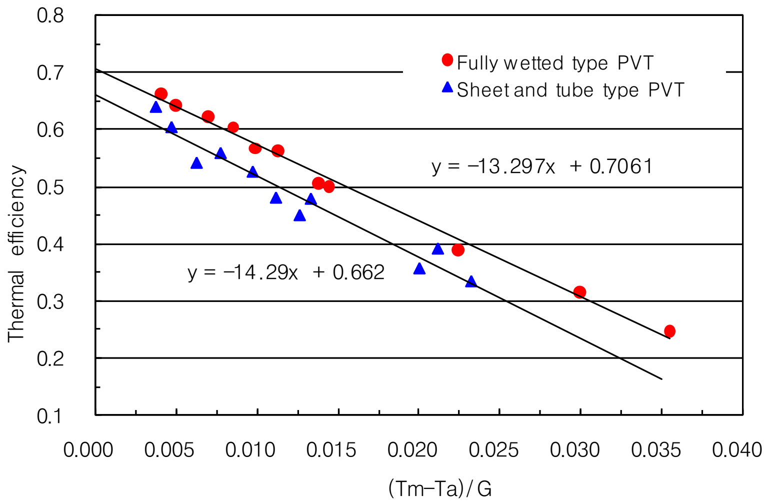

Fig. 4: Sheet-and-tube and fully wetted absorber PVT collector thermal efficiency

(2) Electrical performance

The electrical efficiency depends mainly on the incoming irradiance and the PV module temperature, and is calculated with the following equation:

$$\eta_{el} = I_m V_m / A_{pvt}\, G \qquad \text{(eq. 2)}$$

I_m and V_m are the current and the voltage of the PV module operating at maximum power.

The electrical efficiencies of the sheet-and-tube absorber and the fully wetted absorber PVT collector at the outdoor condition are shown in Fig. 5. The performance of the sheet-and-tube and fully wetted absorber PVT collector can be expressed with relational expression, η_{el} = 0.14-1.56 (ΔT /G) and η_{el} = 0.15-1.33 (ΔT /G), respectively. Thus, the electricity efficiency (η_0) at zero reduced temperature is 0.14 and 0.15, respectively, and the electricity loss coefficient is -1.56 and -1.33, respectively. From these results, it was analyzed that the fully wetted absorber PVT collector presents about 10% higher electrical efficiency, compared to the sheet-and-tube absorber PVT collector. This difference seems to be significant as this means about 1% difference of the PV module's electrical efficiency.

It was found that the fully wetted absorber PVT collector had the better electricity performance as well as better thermal performance. The average electrical efficiencies of the sheet-and-tube and the fully wetted absorber PVT collector are about 12.6% and 14%, respectively.

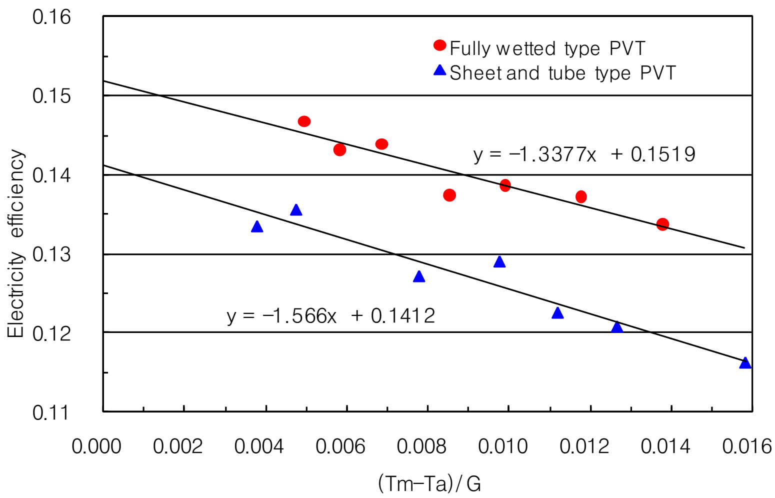

Fig. 5: Sheet-and-tube and fully wetted absorber PVT collector electrical efficiency

The PV module temperature depends on the cooling effects of PV module by the fluid into the PVT collectors. The electrical performance was analyzed as function of PVT mean fluid temperature. The PV module electricity efficiency of the collectors as the function of mean fluid temperature is shown in Fig. 6, 7.

For the sheet-and-tube absorber PVT collector, the electricity efficiency was decreased according to mean fluid temperature increase. This result indicates that the mean fluid temperature of PVT collector had an effect on PV module temperature.

In the case of fully wetted absorber PVT collector, it also found that the electricity efficiency was decreased according to mean fluid temperature increase, although its mean fluid temperature is lower compared to that of the sheet-and-tube absorber PVT collector.

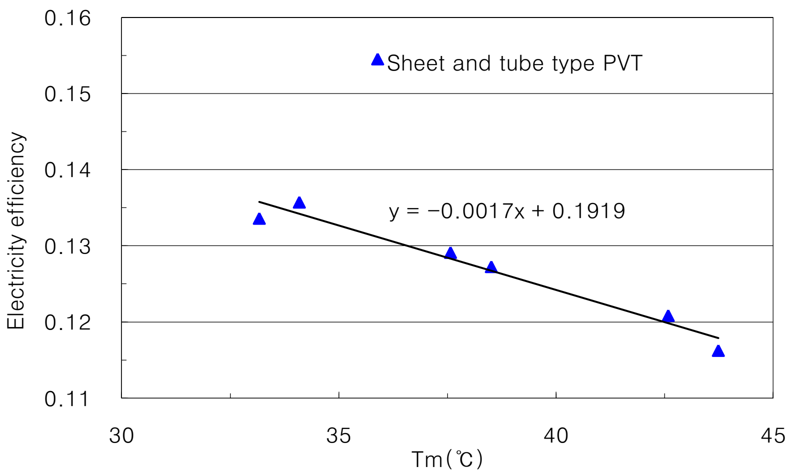

Fig. 6: Sheet-and-tube absorber PVT collector electricity efficiency as a function of mean fluid temperature

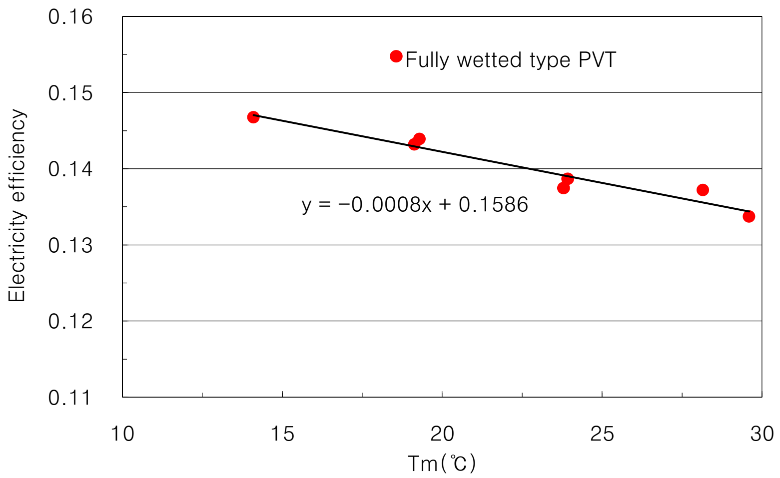

Fig. 7: Fully wetted absorber PVT collector electricity efficiency as a function of mean fluid temperature

4. Conclusion

This study analyzed the experimental results for the thermal and electrical performance of liquid PVT collector of two absorber types, a sheet-and-tube absorber type and a fully wetted absorber type.

The thermal and electricity efficiency curves were calculated and it was shown that for zero reduced temperature, the thermal and electricity efficiency of the sheet-and-tube absorber PVT collector are 66% and 14%, respectively, and for the fully wetted absorber PVT collector they are 70% and 15%, respectively.

The experimental results were analyzed that the thermal efficiency of the fully wetted absorber PVT collector is about 4% higher than the sheet-and-tube absorber PVT collector, and for the electrical efficiency, the fully wetted absorber PVT collector had about 1% higher than the sheet-and-tube absorber PVT collector. Therefore, the fully wetted absorber PVT collector had better thermal and electricity performance.

Through these study results, it was found that both the unglazed PVT collector of two absorber types could keep their electrical performance by similar level to electricity efficiency in STC. In particular, it is obvious that the fully wetted absorber PVT collector had the better thermal performance at zero reduced temperature, and performs better in generating electricity as well.

However, it is very difficult to say that the fully wetted absorber PVT collector has a priority against the sheet-and-tube absorber PVT collector. This is due to that the fully wetted absorber could require more difficult bonding technique than the sheet-and-tube absorber.

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