# A Simulation Analysis on Thermal Performance of Air-type PVT Collector with Diversity of Baffles

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**Abstract**

Photovoltaic Thermal (PVT) collector is a type of solar collector that produces electricity and uses heat from the backside of PV simultaneously for space heating. In particular, air type PVT has the benefit of being easily managed and can be used directly for heating in buildings. Baffle is installed in the heat-collecting layer of the PVT collector to increase the velocity and flow path of air inside the collector. As a result, it can be used to improve the performance of the PVT collector. In this study, effect of different baffle types on thermal performance of air type PVT collector was analyzed using NX simulation program. The design variables used for analysis were square, triangle, and bent (using absorb plate) type of baffles of collector. The outlet temperature rose by 3-6°C when the shape of the baffles changed from square to triangular to bent type. Also, the thermal efficiency of the collector with the absorber plate increased by 11.3% compared to the collector without baffle..

*Keywords: Air-type PVT Collector, Thermal efficiency, Baffle design, CFD analysis*

## 1. Introduction

Photovoltaic Thermal (PVT) collector is a type of solar collector that produces electricity and uses heat from the backside of PV for space heating simultaneously. In particular, air type PVT has the benefit of being easily managed and can be used directly for heating in buildings as compared to water-type PVT collector. Baffle is installed in the heat-collecting layer of the PVT collector to increase the velocity and flow path of air inside the collector. As a result, it can be used to improve the performance of the PVT collector.

In this study, effect of baffle on thermal performance of air type PVT collector was analyzed. For this purpose, collectors with different types of baffles were designed and analyzed using NX simulation program.

## 2. Air-type PVT Collector with Baffles

### *2.1. Air-type PVT collector with various baffle types*

Air-type PVT Collector has been developed with lots of space types, materials, and flow path to improve thermal efficiency. The space consists of various types of air space layer such as applying fins, aluminum sheet and steel absorber. Inside structure of air-type PVT collector can highly affect the thermal efficiency and electrical efficiency as well. Especially, Baffles which is installed in surface on air space have merits for air uniformity and heat absorption. Currently, many type of baffles has been developed and analyzed (Fig. 1) [2]. Square baffle design is a basic type and other shapes are analyzed with different baffle sizes and installation positions. Particularly, minimizing vortices and dead zone has been more important and focused on the research field (Fig. 2).


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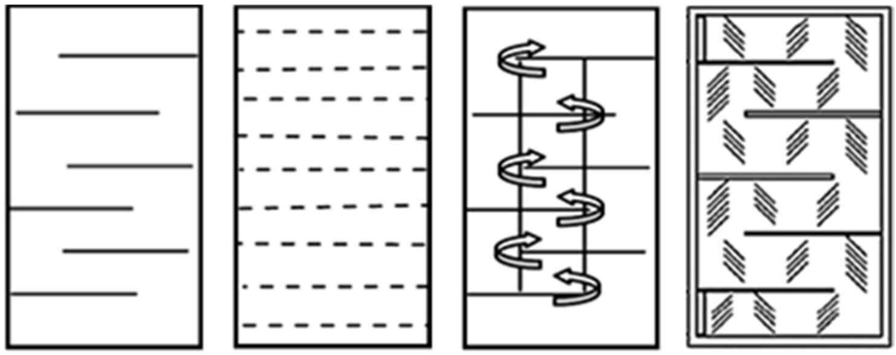

**Fig. 1: Various baffle designs inside collector**

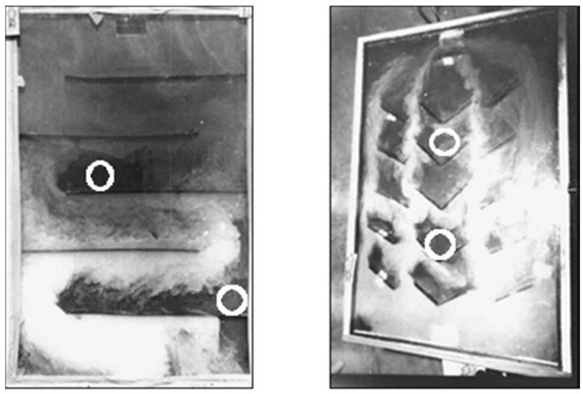

**Fig. 2: Vortices and Dead zone inside collector**

## 3. Methodology

### *3.1. Modelling of Air-type PVT collector with baffle designs*

In this study, general PVT collector without baffle and with different shape of baffles were designed. The shapes of baffle used were square, triangle and bent (using absorber plate) type as shown in Fig. 3. For comparison, a collector without baffle was added, and other variables such as the shape and size of inlet/outlet for each condition were set to be same. The square baffle type was designed in an intercrossed placement with spacing between the baffles to increase the flow rate of the air. The top surface of triangle baffle was made streamlined so that the air passes smoothly through the PV back surface to improve thermal absorption. The bent type baffle was designed with different PV arrangement so that solar radiation directly reaches the absorber plate inside the collector. And the plate was designed to receive more solar radiation with the form of curves. The 3 types of air-type PVT collectors with different baffles were modeled with NX simulation program.

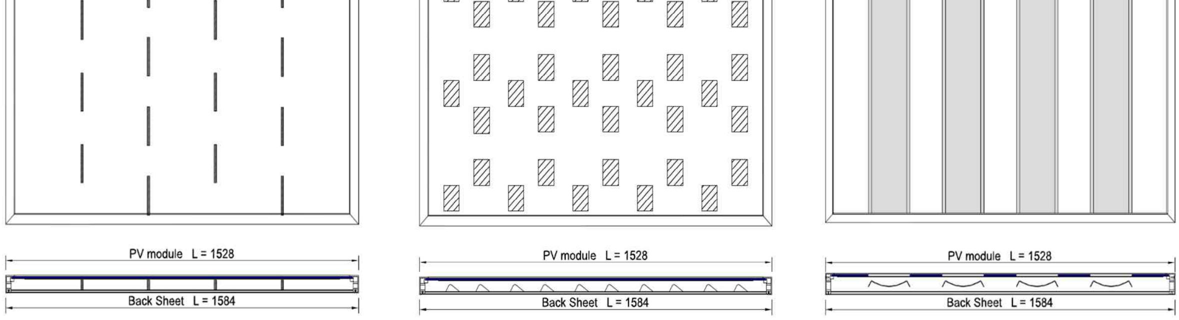


**Fig. 3: Baffle designs inside of the collectors(from left; square, triangle bent types)**

### *3.2. Simulation Properties*

Modelled Air-type PVT collector size is 1.63m$^2$ (height 42.5mm), and supplied thermal energy 780W/m$^2$ that is supposing 15% of solar radiation reached the PV surface. Ambient temperature was 20$^o$C for heat loss calculation, and the air density was decided by each air temperature value such as 1.225kg/m$^3$ when the air temperature was 25$^o$C. K-epsilon model was applied for turbulence expectation, and inlet, outlet and heat flux area of all collector types were equivalent for comparison. Input difference was air flow rate (30, 60, 100 CMH) and baffle designs. The parameters are summarized Table 1.

Table 1: CFD Simulation parameters

| Input | Elements | Unit |
|---|---|---|
| Collector size | 1.6 | m$^2$ |
| Collector height | 42.5 | mm |
| Supplied thermal energy | 780 | w/m$^2$ |
| Ambient temperature | 25 | $^o$C |
| Air density | 1.225(25$^o$C) | kg/m$^3$ |
| Air flow rate | 30, 60, 100 | m$^3$/h(CMH) |
| Turbulence model | K-epsilon | - |

## 4. Results and Discussion

### *4.1. Air uniformity distribution*

As a result, partial congestion of temperature was observed inside the collector depending on the shape of the baffles. Turbulence and dead zone was found in Square type, on back side surface of the installed baffles against air flow pathway (Fig 4). Triangle type was improved compared with square type. However, lots of Dead zone were caused. Unlike the triangle and square baffles, air uniformity and collector temperature of the bent baffle was uniformly distributed. The average flow rate of collector increased to 19% with square baffle. Also, the temperature distribution in the collector was relatively uniform according to the installation of the baffles.

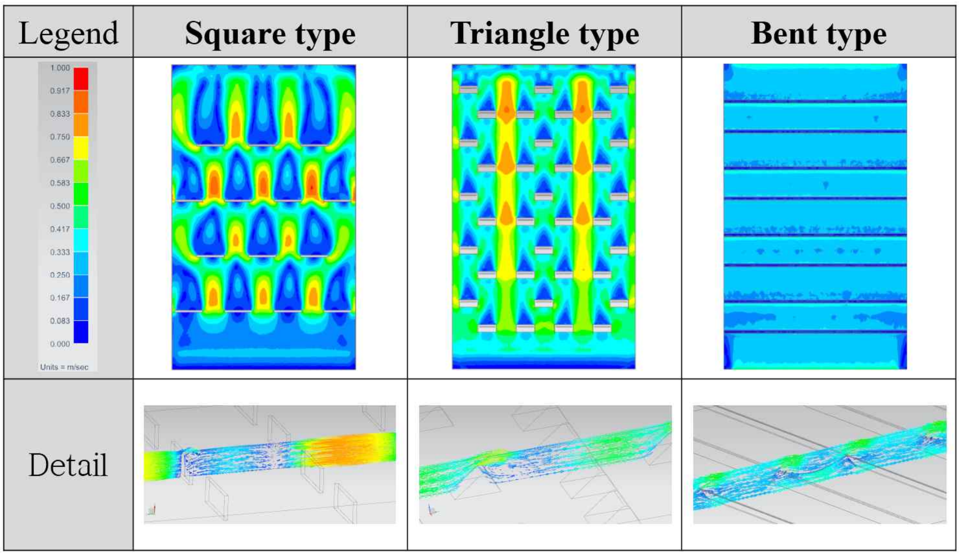


**Fig. 4: air flow pathway with velocity in different baffle types of the collector**

### *4.2. Temperature characterization of the Air-type PVT collector*

Fig. 5 displays the air temperature inside collector according to different baffles. Square type had lots of air stagnant behind baffles against air movement. Triangle type improved the uniformity of the air and velocity especially between baffles. Bent type showed better air uniformity and movement. The air moved to whole surface of the collector and efficiently took heat from the space.

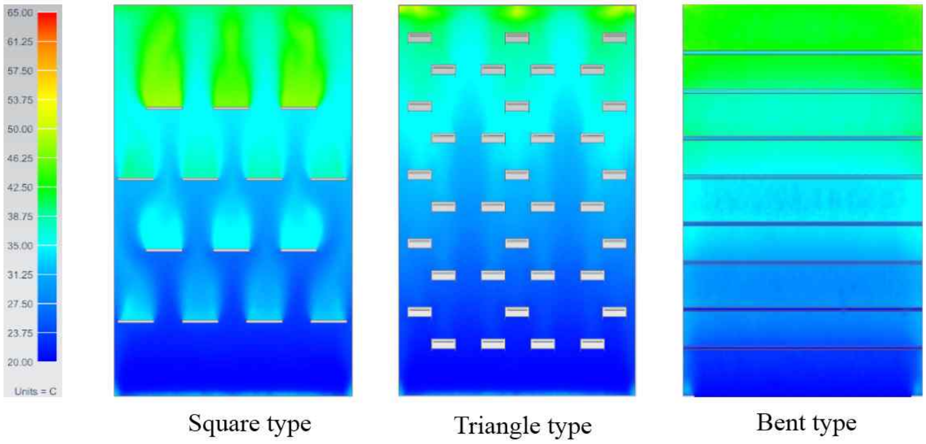


**Fig. 5: air flow pathway with velocity in different baffle types of the collector**

### *4.3. Thermal performance*

Thermal efficiency are presented in Fig. 6. The results were calculated by equation 1.

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

| | |
|---|---|
| $\eta_{th}$ | thermal efficiency [-] |
| $A_{pvt}$ | collector area [$m^2$] |
| $T_o$ | collector outlet air temperature [°C] |
| $T_i$ | collector inlet air temperature [°C] |
| $\dot{m}$ | air flow rate [$m^3\ h^{-1}$] |
| $C_p$ | specific heat [$J\ kg^{-1}\ K^{-1}$] |
| $G$ | irradiance on the collector surface [$W\ m^{-2}$] |

According to the shape of the baffle, the outlet temperatures were varied by 3-6 degrees. With the outlet temperature difference, thermal efficiency of the air-type PVT collector without baffles was 31.3%. The collector with square and triangle type showed improved thermal efficiency of 32.5% and 33.1% respectably. Bent type had 35.3% with minimized turbulence and dead zone inside collector. Consequently the thermal efficiency of PVT collector with baffle increased by 11.3% than the collector without baffle.

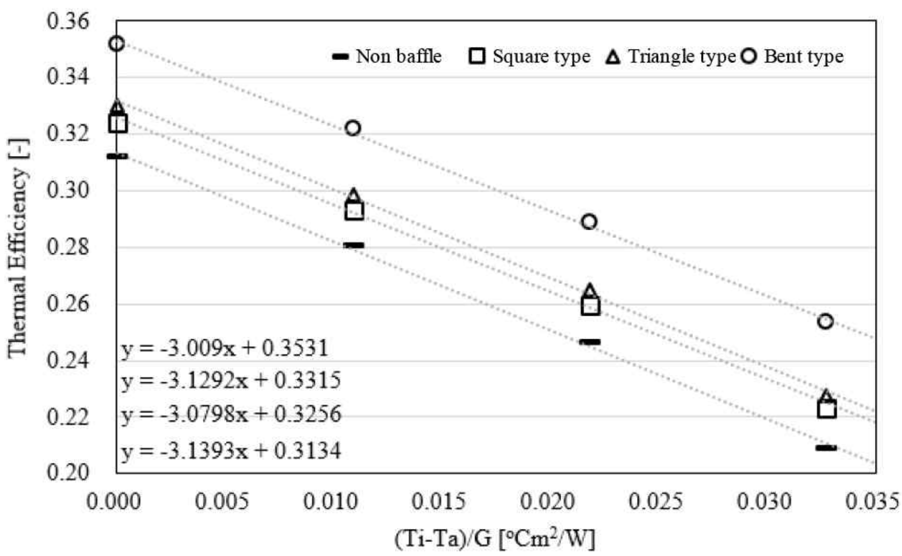


**Fig. 6: Thermal efficiency graph of the different baffle type collectors**

## 5. Conclusion

In this research, Air-type PVT Collector with various baffle types was analyzed with CFD simulation. Results showed that partial air statement was caused with baffle types except for bent type. Also, air uniformity of bent type was improved compared with square and triangular baffles. Outlet air temperature varied by 3-6ºC according to baffle type. Air flow velocity of square type baffle improved 19% compared with basic baffle type. Dead zone was minimized for bent baffle type than square and triangular types by baffle shapes. Furthermore, thermal efficiency of the air-type PVT Collector with bent type improved 11.3% compared with basic (Non baffle) type.

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**Nomenclature**

| | | |
|---|---|---|
| $A_{pvt}$ | Surface area of the collector | $m^2$ |
| $C_p$ | Specific heat of air at a constant pressure | $J\ kg^{-1} \cdot K^{-1}$ |
| G | Solar radiation | $W\ m^{-2}$ |
| $\dot{m}$ | Mass flow rate | $m^3\ h^{-1}$ |
| $T_a$ | Ambient air temperature | °C |
| $T_o$ | Outlet air temperature of PVT | °C |
| $T_i$ | Inlet air temperature of PVT | °C |
| $\eta_{th}$ | Thermal efficiency | - |

## 6. Reference

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