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Article

Geometry Optimization of PV/T-TEG Collector under Different Operating Conditions Using CFD Simulation and Taguchi Method

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Abstract. PV panel connected within both fins and TEG that is well known as a PV/T-TEG system. The system increases the electrical efficiency affected by the thermal collector and contributes to additional electricity due to the temperature difference of the TEG sides. However, optimizing the thermal performance of the system involved the geometry parameters and operating conditions, it still requires many combinations of factors and levels. In the present study, Taguchi Method with five factors, three levels, and two responses is then implemented to reduce the number of combinations which are related to fin geometry, air mass flow rate and solar irradiation under different operating conditions. Air as a working fluid is applied with the inlet fluid temperature based on the tropical climate in Indonesia. The two responses are needed to be lower in temperature of the PV panel and higher in temperature difference of TEG sides respectively. Furthermore, Computational Fluid Dynamics (CFD) method is applied as an approach to generate the responses numerically. The results revealed that the combinations of the geometric parameters and operating conditions for achieving the optimal PV temperature are found to be the full fin arrangement, fin height of 75 mm, fin thickness of 3 mm, and air mass flow of 0.08 kg/s and heat absorbed of 400 W/m². Thus, the combinations to obtain the optimal TEG temperature difference are staggered fin arrangement, fin height of 25 mm, fin thickness of 1 mm, the mass flow of 0.08 kg/s and heat absorbed of 800 W/m². Additionally, the heat absorbed factor has the biggest impact on PV temperature change with the contribution of 47.57% of the total five factors. Meanwhile, fin arrangement is the factor that has the biggest impact on the temperature difference of TEG sides with a contribution of 33.31%.

Keywords: Optimization, PV/T, TEG, CFD, Taguchi.

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1. Introduction

Fossil fuels are non-renewable energy sources that negatively impact the socio-economic when fossil fuels begin to become scarce [1]. The residual gas from fossil fuel combustion is also one of the main causes of global warming, which causes severe long-term damage [2]. The transition from fossil fuels to renewable energy continues to be developed to minimize the negative impact of using fossil fuels. One of the most abundant sources of energy on earth is solar energy. The sun emits 3.8×10^{23} kW of energy and 1.8×10^{14} kW is captured by the earth in the form of light and heat [3].

A simple method for generating electrical energy from solar radiation, Photovoltaic is the most commonly used system to convert solar energy into electrical energy. Furthermore, another problem with using photovoltaics is that solar energy fluctuates, which can be overcome by storing the electrical energy in the battery [4].

The lack of popularity of solar energy is due to the relatively low efficiency of Photovoltaic (PV) between 10-15% and was predicted maximum efficiency that can be achieved with the development of Photovoltaic materials is only 27% [5]. To accommodate these limitations, an additional system is needed to utilize the residual energy in the form of heat from the Photovoltaic system. Energy in the form of heat stored in Photovoltaics causes an increase in temperature and reduces Photovoltaic efficiency by 6-7.2% if heat is not transferred to the heatsink or converted into other forms of energy [6]. Furthermore, there is 80 % of irradiation energy from the sun is absorbed as heat in the PV module [7].

An advanced technique in the cooling system with PCM material was using an artificial neural network algorithm. The technique has proven its ability to increase the energy output of the system significantly [8-11]. In these studies, the simpler and faster technique was preferred because it focused on the early stage of optimization before the experimental setup was built. Another implementation of PCM material in the cooling system was investigated and developed comprehensively due to energy stored and energy released during the day and the night [12].

Previous research related to PCM applications was also carried out to get the best PCM material. Taguchi Method was used in this study with L9 orthogonal arrays. The result shows that coconut oil is the best PCM material among grease and wax. The best-operating conditions to get optimal performance are 90 minutes of operation, 1525 W/m^2 of Irradiation, and 30 ^{0}C of ambient temperature. Combining with ANOVA, PCM material is the most significant factor affecting PCM base solar collector performance with 82.35 % of contribution [13].

Furthermore, in a PV panel cooling system, experimental research has been carried out on the effect of forced convection and adding a finned heatsink. The result revealed that the system can reduce the PV temperature by 11% compared to PV with a flat plate collector [14]. Additionally, Hosain Nemati proposed a general equation to optimize the use of the fin heat sink. The equation can be used with both natural and forced convection [15]. Irsyad et. al also investigated the use of fin as a heat sink including PCM material in heat exchanger for the cooling process [16-17]. In terms of the heatsink implementation, Amrizal et al. also reported that the performance of the PV/T air collector with the double pass is better than the single pass with a rectangular plate fin absorber [18].

Concerning the cooling system of the PV/T-TEG collector, a method to increase the electrical efficiency of the Photovoltaic panel is carried out by extracting unused heat by using a working fluid and a heatsink. The fin absorber is attached with TEG material which transfers the unused heat from the Photovoltaic to the environment both passively and actively. In this case, the TEG material provides the hot and cold sides that are attached to the PV surface and the fin absorber respectively. The TEG absorbs the heat from the hot side and then transfers it to the cold side by the conduction method. The temperature difference between the two sides generates additional electricity.

Another study reported that the temperature difference TEG has been used to convert waste heat from engine exhaust into electricity [19]. In terms of PV/T application, TEG with 1.6 mm of length and 1.4mm of width generates 0.0357 W with 4.9% of efficiency from total heat absorbed on the hot side as reported by Wei et.al [20]. Theoretically, the addition of TEG to a Photovoltaic panel with natural convection cooling system can generate additional energy by 5% and increase the efficiency of the PV-TEG hybrid system by 6% [21]. This value can still be increased by optimizing the temperature difference between the hot and cold sides of the TEG. Increasing the temperature on the hot side of TEG cannot be done because it has an impact on decreasing PV efficiency, but on the contrary, decreasing the temperature on the cold side of TEG can increase the energy produced and the efficiency of the whole system. Based on these studies, it can be concluded that the addition of TEG and finned absorber with air as a working fluid is the potential to improve the PV panel performance.

Furthermore, the PV/T-TEG air collector has advantages in comparison with other cooling systems since it is simple and easier to operate. Additionally, the material needed may not be costly in comparison with other cooling materials. The working fluid implemented also can be forced or natural convection and no leakage problem. However, the disadvantage of air as a working fluid is related to the low heat capacity in the heat transfer convection process.

Concerning the difficulties in the experimental processes, therefore, numerical software can be used to characterize the thermal effect on geometric and operating conditions variations of heatsink [22]. In this context, computer programming languages are importantly used to solve several types of equations [23]. Additionally, Taguchi Method is also can be one method to reduce the number of combinations of parameters in doing research.

In terms of the Taguchi Method, it is used to obtain the optimal combination with a smaller number of combinations. Finned PV/T optimization research has been carried out with controlled factors of fin material, PV temperature, and airflow velocity with 3 levels on each of the factors. Combining with the Analysis of Variance, the most significant factor affecting PVT performance is fin material with a contribution of 88.14 % [24].

Besides being used in optimization with the data from the experimental study, the Taguchi Method can also be used in the optimization process with the data from the numerical study [25]. Previous research has been conducted to obtain the optimal geometry TEG system and operating conditions with heat sources from solar radiation. A robust result was achieved using the integrated Taguchi Method and Computational Fluid Dynamics to get optimal geometry and operating conditions of finned PV/T-TEG.

Based on previous research, the combination of the CFD process with numerical software and the Taguchi Method is feasible to use in this interesting study to obtain the optimal combination of geometric and operating conditions of the PV/T-TEG system. Meanwhile, the references on PV/T-TEG collectors available are very limited related to the use of various fin geometry, TEG material and operating conditions, especially in tropical clime conditions. As reported by Amrizal et.al, the implementation of finned PV/T-TEG collectors under tropical climates has potentially improved PV panel performance [26].

For that reason, Taguchi Method with five factors, three levels, and two responses is then introduced to reduce the number of combinations in this work. Therefore, the present study aims to simulate and optimize the effect of geometry and operating conditions on the thermal performance of PV/T-TEG systems using the Taguchi Method. Several factors are combined in this work such as fin arrangement, fin height, fin thickness, air mass flow, and heat absorbed with two responses in the form of PV temperature and TEG temperature difference. In addition, air as a working fluid is circulated through the collector based on the tropical climate of Indonesia.

2. Methods

2.1. Procedures of Simulation and Optimization Method

Numerical simulation conducted in this study is to create and solve the model study, meshing, setup boundary conditions and the numerical equation. Additionally, the statistical analysis of this work is also assisted by Minitab using Taguchi Method. The flow process of this study is described in Fig. 1.

Before doing the simulation process with various combinations of several factors and levels, it is necessary to validate the CFD simulation program to be a suitable software for further step procedures. The purpose of the validation process is to ensure that the CFD simulation with several setting parameters can represent the real conditions and agree with the experimental data. Furthermore, the next step after doing the validation process is to simulate a model. Finally, the performance optimization process is carried out and analyzed under different operating conditions and the Taguchi method.

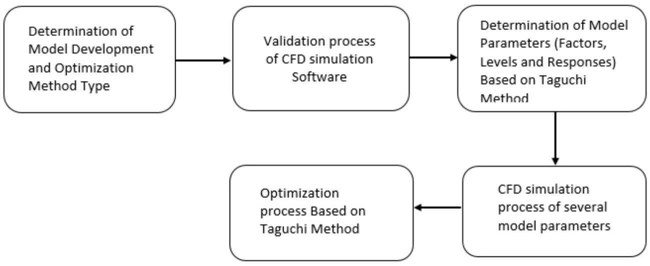

Fig. 1. Basic flowchart for simulation and optimization process.

2.2. Design of Experiment

In this study five control factors at three levels each were considered. The first factor determined is the TEG configuration which is also well known as the fin arrangement in this work since they are joined together as seen in Fig. 2. The previous research investigated the effect of straight and staggered fin configuration and the result revealed that the fin configuration affects PV cooling in natural convection but has not been tested on PV panel with additional TEG and forced air flow [27].

The second control factor used in this work is fin height. Based on the research conducted by Kasaeian et al., the height of the PV/T channel affects the thermal performance of the PV/T. The results of this study indicate that the channel height of 50 mm is better than the channel height of 100 mm and 150 mm [28]. In the present study, the fin height was varied by 25 mm, 50 mm, and 75 mm.

The third control factor is fin thickness. There is not much literature discussing fin thickness's effect on PV/T thermal performance. The thickness of the fin affects heat transfer by conduction, where the thicker the fin, the more the heat that flows through the fins. However, further analysis of the effect of fin thickness on the thermal performance of PV/T-TEG is needed conduct. The level chosen is the standard size of the available fin thickness those are 1mm, 2 mm and 3 mm. Apart from being able to be tested numerically, it can also be tested experimentally.

The fourth control factor is air mass flow which affects the convection heat transfer coefficient. The greater the air mass flow, the bigger the heat transfer coefficient. In this study, the level values to be varied are 40 gr/s, 60 gr/s, and 80 gr/s. Furthermore, the fifth control factor is the amount of heat absorbed by the PV panel. Heat absorbed affects the thermal performance of the PV/T-TEG collector. The more heat absorbed by the PV panel, the higher the temperature of the PV panel. It makes the electrical performance of the PV panel decrease because of overheating case. The specified level values are 400 W/m², 600 W/m², and 800 W/m² because the average peak radiation by the sun is 1000 W/m² while only 80% is absorbed as heat by PV/T in the form of heat. Based on these statements, 5 factors with three levels each are shown in Table 1.

Table 1. Factors and value of each level.

Code	Factor	Level 1	Level 2	Level 3
A	Fin arrangement	Straight	Staggered	Full
B	Fin height	25 mm	50 mm	75 mm
C	Fin thickness	1 mm	2 mm	3 mm
D	Air mass flow rate	40 gr/s	60 gr/s	80 gr/s
E	Heat absorbed	400 W/m²	600 W/m²	800 W/m²

The responses of the simulation process used in this study are PV surface temperature (R1) and the temperature difference between the hot and cold sides of TEG (R2). The PV surface temperature response has the bigger is the better condition, while the TEG temperature difference response has the smaller is better condition. Because of the two different conditions, the two responses could not be analyzed simultaneously but had to be examined separately. Based on Taguchi's experimental design with five factors and three levels, each has a degree of freedom value of 10. The L9 orthogonal array could not be selected because the number of tests was smaller than the degrees of freedom [29]. Thus, an orthogonal array larger than L9, namely L27 fulfils the requirement of an orthogonal array that must be greater than the degrees of freedom. Combinations for orthogonal array and statistical analysis of the Taguchi Method in this study are calculated using Minitab software.

2.3. Model Geometry

A model of PV/T-TEG is created using CAD software with a width of 510 mm and a length of 700 mm. Figure 2 shows the cross-section of PV/T-TEG. Additionally, a working fluid used in this work is air due to the simplicity and easier of operation. To enable the air to circulate through the PV/T-TEG collectors, the structure of the collector is enclosed by the rectangular channel and also acts as insulation as shown in Fig. 2.

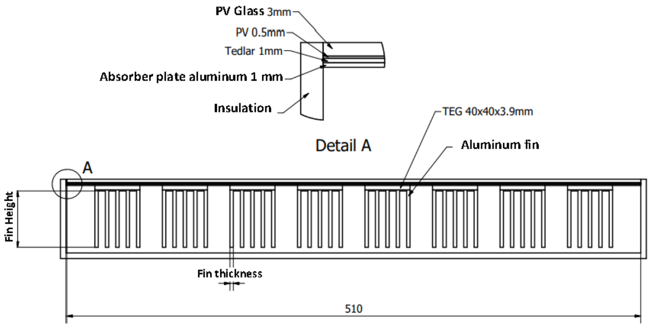

Fig. 2. Cross-section of PV/T-TEG system.

The finned PV/T-TEG consists of PV with a cooling system in the form of finned TEG in which the heat is transferred by forced airflow through the rectangular channels. PV module consists of 3 layers of materials, those are glass, PV cells, and Tedlar which have thermal properties shown in Table 2.

Table 2. PV module materials [30].

Material	Thick-ness (mm)	c_p (J/kg.K)	k (W/m.K)	Density (kg/m3)
Glass	3	500	1.8	3000
PV Cell	0.5	677	148	2330
Tedlar	1	1250	0.2	1200

An aluminium plate is placed underneath the PV system as a heat-absorbing plate and TEG base. Aluminium was chosen because it has a high conductive heat transfer coefficient and is relatively cheaper than other materials with a high conductivity [31]. Furthermore, TEG material was also then placed underneath the absorber plate with 40 mm square dimension and 4mm thickness. TEG material is bismuth telluride with a density of 7740 kg/m³, a heat capacity of 159 J/kg.K and a conductive heat transfer coefficient of 1.52 W/m.K [32]. To obtain the optimal TEG temperature difference, aluminium fins placed on the cold side of the TEG were varied in thickness and height. The fins are cooled by forced airflow with varying mass flow. Fin arrangement is also varied to obtain the optimal configuration varying in straight, staggered, and full arrangement, as shown in Fig. 3.

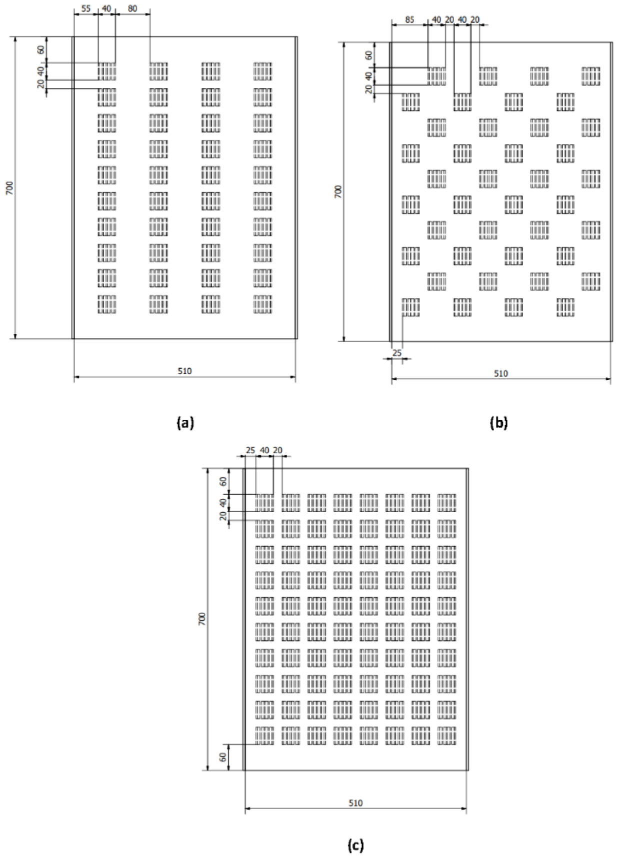

Fig. 3. Fin arrangement (a) straight, (b) staggered, and (c) full.

There are 40 TEGs in 4 column configuration in the straight arrangement with 10 TEGs each. Each row has a horizontal spacing of 60 mm and a vertical spacing of 20 mm. In the staggered arrangement, there are 40 TEGs in an 8-line configuration, each consisting of 5 TEGs and arranged in a zig-zag. There are 80 TEGs in an 8-line arrangement with 10 TEGs each in the full arrangement. Each row has a horizontal spacing of 20 mm and a vertical distance of 20 mm.

Concerning the performance of PV/T-TEG, it is divided into electrical and thermal efficiency. The electrical performance is contributed by PV panel and TEG material conditions as given by Eq. (2-3). Meanwhile, the thermal performance is related to the temperature difference between the inlet and outlet of the working fluid which affects the PV panel temperature as presented in Eq. (1). The thermal performance is presented by the following equation:

$$\eta_{th} = \frac{\dot{m}\, c_p (T_{fo} - T_{fi})}{A\, G} \quad (1)$$

where η_{th} is the thermal efficiency (%), c_p is the air-specific heat (W/m^2 ^{o}C). $T_{f,in}$ is the inlet fluid temperature (^{o}C) $T_{f,out}$ is the outlet fluid temperature (^{o}C), A is the absorber area including fin and TEG material (m^2), G is the solar irradiation (W/m^2), while the electrical performance is presented through the following formula:

$$\eta_{el} = \frac{I\, V}{A\, G} \quad (2)$$

where I is the current generated by the PV panel (A), V is the voltage of the PV panel (V), A is the PV collector area including fin and TEG material (m^2) and G is the solar irradiation (W/m^2). The electrical efficiency is obtained through the following equation:

$$\eta_{el} = \frac{\textit{Power of PV panel} + \textit{Power of TEG}}{A\, G} \quad (3)$$

In the present study, the performance of the PV/T-TEG is only analyzed in terms of the thermal part such as PV temperature and temperature difference of TEG sides. This is because the thermal energy stored in the Photovoltaics panel reduces the electrical performance as reported by Sajjad et al. [6]. Furthermore, the CFD software used in this work only provides the thermal analysis available.

2.4. Numerical Simulation

Numerical simulation is carried out using Ansys AIM Software. Meanwhile, the grid-independent test should be done earlier to ensure that the simulation results do not change to different mesh settings. In this test, grid-independent is found to be 1.17 x 10^6. Furthermore, the grid numbers of the model used in the present study are 1.2 × 10^6 elements for 25 mm fin height, 2.4 × 10^6 elements for 50 mm fin height, 3.6 × 10^6 elements for 75 mm fin height respectively. The calculation is conducted until target convergence 1 × 10^{-5} is satisfied. Boundary conditions applied are inlet, outlet, isolation wall, solar irradiation approached by heat flux absorbed, and natural convection from PV glass to the environment. Furthermore, in the post-processing process, average PV surface temperature and temperature difference between the hot side and the cold side of TEG are used as response values.

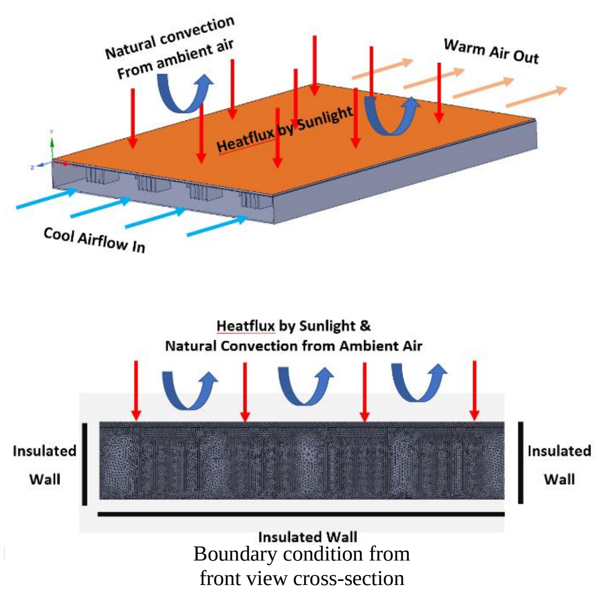

Fig. 4. Boundary condition of PV/T-TEG model.

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3. Results and Discussion

3.1. Validation

The validation process is carried out by comparing the results obtained from numerical simulation with the experimental result from the previous research [33] under the same model dimensions and operating conditions. The validation process is necessary to ensure the CFD software used can represent the real conditions.

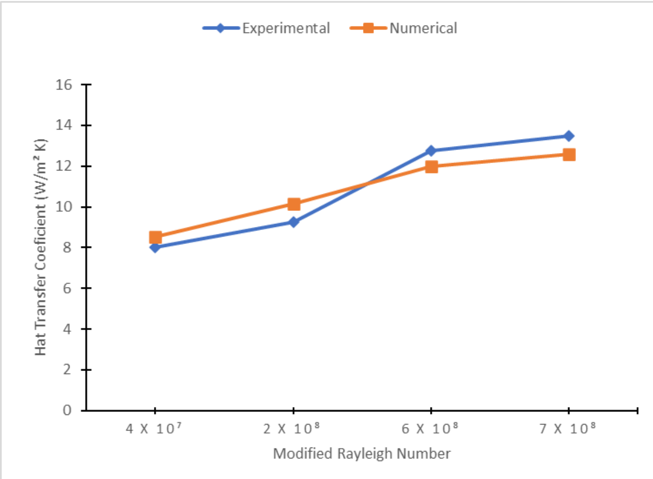

Fig. 5. Comparison between the experimental and numerical value.

Based on the chart in Fig. 5, the experimental and numerical results have no significant difference in heat transfer coefficient with modified Rayleigh Number. The difference occurs because the numerical simulation is carried out by assuming the system conditions are ideal. However, in the experimental study, several conditions are difficult to control. However, as both graphs show the same trendline and there is no significant difference in value, therefore the CFD simulation software is feasible to use.

3.2. Taguchi Analysis

An orthogonal array consisting of 27 combinations is determined and each of the combinations is modelled and numerically simulated. Average PV temperature (R1) and temperature difference of hot side and cold side (R2) of TEG are achieved from post-processing of numerical simulation as shown in Fig 6.

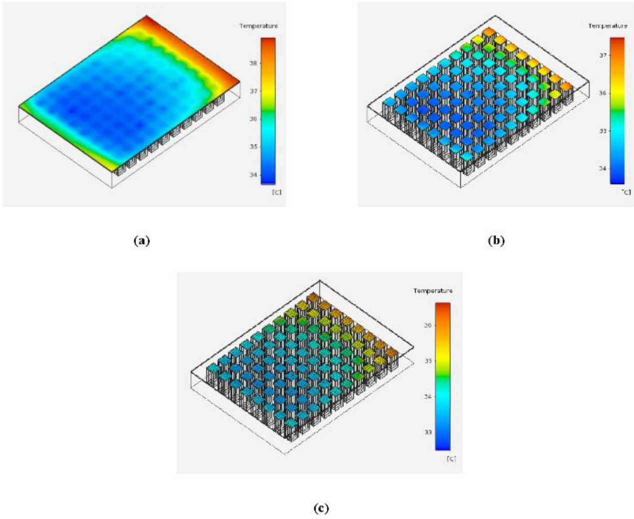

Fig. 6. Temperature contour generated in post-processing process (a) PV temperature, (b) TEG hot side temperature, and (c) TEG cold side temperature.

The average value of temperature contour is used as response values of Taguchi analysis. The orthogonal array with response values is shown in Table 4.

Table 3. Orthogonal array with response values.

No	A	B	C	D	E	R1 (°C)	R2 (°C)
1	1	1	1	1	1	43.4	2.68
2	1	1	1	1	2	50.09	4.18
3	1	1	1	1	3	56.78	5.63
4	1	2	2	2	1	41.07	1.92
5	1	2	2	2	2	46.61	2.96
6	1	2	2	2	3	52.18	3.97
7	1	3	3	3	1	37.56	1.84
8	1	3	3	3	2	44.83	2.76
9	1	3	3	3	3	49.01	3.68
10	2	1	2	3	1	38.28	2.92
11	2	1	2	3	2	42.42	4.37
12	2	1	2	3	3	46.55	5.83
13	2	2	3	1	1	39.1	1.82
14	2	2	3	1	2	43.15	2.76
15	2	2	3	1	3	48.19	3.61
16	2	3	1	2	1	38.7	2.36

No	A	B	C	D	E	R1 (°C)	R2 (°C)
17	2	3	1	2	2	43.54	3.38
18	2	3	1	2	3	47.37	4.28
19	3	1	3	2	1	35.77	2.32
20	3	1	3	2	2	38.51	1.78
21	3	1	3	2	3	41.72	2.41
22	3	2	1	3	1	36.32	2.22
23	3	2	1	3	2	38.6	1.9
24	3	2	1	3	3	41.48	2.55
25	3	3	2	1	1	35.95	1
26	3	3	2	1	2	39.42	1.35
27	3	3	2	1	3	41.89	1.91

Using Minitab software, the data were analyzed separately based on the PV temperature response and the TEG temperature difference response. The lower PV temperature is the better condition, while the higher TEG temperature difference leads to the better condition.

3.2.1. PV Temperature Response

The data shown in Table 3 generate the main effect plot based on the signal-to-noise ratio as shown in Fig. 7.

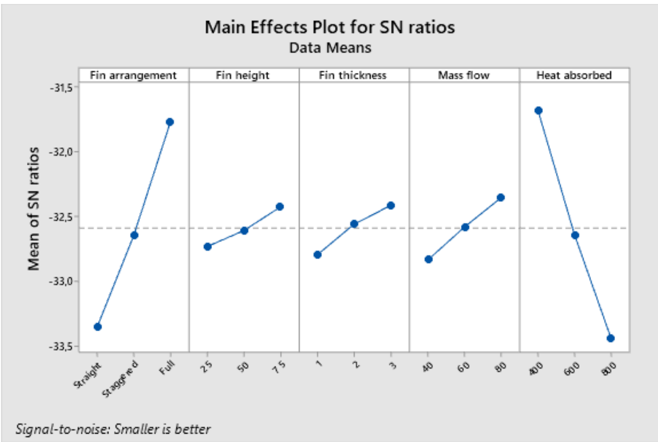

Fig. 7. Main effect plot based on SN ratio for PV temperature response.

SNR (Signal to Noise Ratio) analysis describes the ratio between signal to noise. The advantage of analysis using the Taguchi method is that noise, or invalid data signals are taken into account so that the experimental design becomes robust. Based on the data in Fig. 7, the optimal value is the level with the highest value in the plot with the smaller condition is better.

The optimal combination to get the optimal response are full fin arrangement, 75mm fin height, 3mm fin thickness, 80 gr/s air mass flow rate, and 400 W/m² of heat absorbed. Figure 7 shows the plot of the SNR analysis. Heat absorbed and fin arrangement have a much larger range of values than the other three factors such as fin height, fin thickness and mass flow.

3.2.2. TEG Temperature Difference Response

As shown in Fig. 8, it is described the Taguchi analysis using Minitab software with the data shown in Table 3.

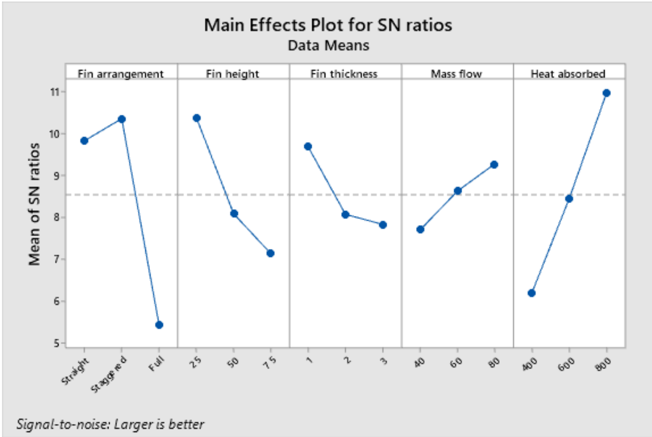

Fig. 8. Main effect plot based on SN ratio for TEG temperature difference response.

Based on the SNR analysis in Fig. 8, the optimal combination to obtain the optimal TEG temperature difference is the staggered TEG arrangement, 25mm fin height, 1 mm fin thickness, 80 gr/s air mass flow rate, and 800 W/m² heat absorbed. It can be seen that the plot of the SNR analysis shows that heat absorbed, fin height, and fin arrangement have a larger range of values than fin thickness and mass flow. Thus, heat absorbed, fin height, and fin arrangement have a greater influence than the other two factors.

3.3. Analysis of Variance

Analysis of Variance (ANOVA) was used to determine the significance of the factors on the observed responses. ANOVA was carried out using Minitab software based on the data generated using the Taguchi method. ANOVA was carried out in two separate parts. Those are the response of the PV temperature and the response of the temperature difference between the hot and cold sides of TEG.

3.3.1. PV Temperature Response

Analysis of Variation with fin configuration, fin height, fin thickness, air mass flow, and heat absorbed as factors and the response in the form of PV surface temperature generate values as shown in Table 4.

Table 4. ANOVA for PV temperature response.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Fin arrangement	2	287,18	143,588	68,27	0,000
Fin height	2	12,97	6,484	3,08	0,074
Fin thickness	2	19,43	9,713	4,62	0,026
Air mass flow rate	2	29,26	14,632	6,96	0,007
Heat absorbed	2	347,07	173,533	82,51	0,000
Error	16	33,65	2,103		
Total	26	729,55			

It can be seen in Table 4, that fin configuration, fin thickness, air mass flow, and heat absorbed have a significant effect on PV temperature. The most contributing factor to changes in PV temperature is the heat absorbed with a contribution of 47.57%. Meanwhile, the fin configuration, air mass flow rate and fin thickness contribute to the PV temperature change by 39.36%, 4.01% and 2.66% respectively.

Heat absorbed and fin arrangement have much more influence on the change in PV temperature than other factors because heat absorbed by PV is directly converted into temperature increment while fin configuration is responsible for fluid flow pattern and the effective area of heat transfer in the channel. The more turbulence the flow, the bigger the heat transfer occurs. Air mass flow has a significant effect but not as much as heat absorbed and fin arrangement. It occurs because mass flow affects the convective heat transfer coefficient linearly, not drastically as the fin arrangement effect. Fin thickness also has a significant effect but not as much as the two dominant factors because fin thickness only slightly affects the conductive heat transfer. Fin thickness has no significant effect because the higher the fins, the bigger the cross-sectional area of fluid flow. While constant mass flow was applied, the velocity reduced as the cross-sectional area increased.

3.3.2. TEG Temperature Difference Response

The factors as presented in Table 5 such as fin arrangement, fin height, fin thickness, and heat absorbed have a significant effect on TEG temperatures difference. Furthermore, fin arrangement with a contribution of 33.31% is the most contributing factor to change in PV temperature. Furthermore, heat absorbed, mass flow, and fin thickness affects the PV temperature of 31.96%, 15.82% and 5.58% respectively.

Table 5. ANOVA for TEG temperature difference response.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Fin arrangement	2	12,7485	6,3742	22,86	0,000
Fin height	2	6,0535	3,0267	10,85	0,001
Fin thickness	2	2,1372	1,0686	3,83	0,044
Air mass flow rate	2	0,6380	0,3190	1,14	0,343
Heat absorbed	2	12,2318	6,1159	21,93	0,000
Error	16	4,4620	0,2789		
Total	26	38,2710			

The factors as presented in Table 5 such as fin arrangement, fin height, fin thickness, and heat absorbed have a significant effect on TEG temperatures difference. Furthermore, fin arrangement with a contribution of 33.31% is the most contributing factor to change in PV temperature. Furthermore, heat absorbed mass flow, and fin thickness affects the PV temperature of 31.96%, 15.82% and 5.58% respectively.

Contrary to the PV temperature case, fin height has a significant effect on the TEG temperature difference response because it affects the conductive and convective heat transfer on the cold side of the TEG. The higher the fin dimension, the lower the temperature of the cold side of TEG. Fin thickness also has a significant effect but it is smaller than the effect of fin height. This is because fin thickness only affects the conductive heat transfer of the cold side of TEG. Air mass flow has no significant effect on the TEG temperature difference because it affects the heat transfer rate from the whole system. The change of mass flow affects both the hot side of TEG and the cool side of TEG, resulting in no change in the temperature difference between the hot side and the cold side of the TEG.

4. Conclusion

Optimization of PV/T-TEG collector performance based on the geometric parameters and operating conditions has been analyzed. The factors proposed in the present study are fin arrangement of (Straight, Staggered, Full), fin height of (25-75) mm, fin thickness of (1-3) mm, air mass flow rate of (40-80) gr/s and heat absorbed of (400-800) W/m^2 respectively.

Based on the combination of factors and levels analyzed by the Taguchi Method, the optimal PV temperature as the first response is obtained from full fin arrangement, fin height of 75 mm, fin thickness of 3 mm, air mass flow rate of 80 g/s, and heat absorbed of 400 W/m². Meanwhile, the optimal TEG temperature difference as the second response is affected by the staggered fin arrangement, fin height of 25 mm, fin thickness of 1 mm, air mass flow rate of 80 g/s and heat absorbed of 800 W/m². The use of numerical simulation and the Taguchi Method to reduce the number of combinations in the present study leads to an easier and simple way of optimizing and improving the PV/T-TEG performance. Therefore, the optimal geometry and operating conditions of the PV/T-TEG collector should be potentially investigated using an experimental process, especially in the tropical climate.

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