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Numerical simulation of styrofoam and rockwool heat transfer flat-plate type solar collector

Parulian Siagian[1,2*], Richard Napitupulu[1], Sibuk Ginting[1], Miduk Tampubolon[1], Soeprapto Manurung[3]

[1]Mechanical Engineering Department, Nommensen HKBP University, Medan Indonesia.
[2]Doctoral Student, Mechanical Engineering Department, Universitas Sumatera Utara Jl. Almamater Kampus USU, Medan 20155 Indonesia
[3]Mechanical Engineering Department, Universitas HKBP Nommensen Pematangsiantar, Indonesia.

*parulian.nommensen@gmail.com

Abstract. In this study a flat plate type 1x1.5m solar collector was studied numerically. The function of styrofoam and rockwool to isolate the existing heat in the solar collector for maximum heat. The purpose of this research is to know better isolator between styrofoam and rockwool in a solar collector. In addition, the process of heat transfer from the absorbent plate to styrofoam and rockwool is examined. The governing equations are developed based on mass conservation, energy efficiency and energy conservation. The developed regression equation was resolved numerically using the dynamic code of the digital computational fluid. The heat transfer rate from the absorbent plate to styrofoam and rockwoll assumes. The results showed that rockwool slower heat transfer process than styrofoam. It is recommended to use rockwool in designing the optimal solar collector.

1. Introduction

The amount of energy producing petroleum derived from fossils will eventually run out, causing some countries in the world to explore renewable energy. Endless energy is energy that comes from the sun [1]. The sun is an energy source that is beneficial to human life [2]. Because the nature of the sun cannot be exhausted, the future is a much-needed energy source. Actually solar energy with the potential of solar radiation in various countries is different. For tropical Indonesia, the radiation potential is quite long. As a result of long irradiation it is possible to be used as an energy source that can be converted through solar collectors, photovoltaics, etc.The function of solar collectors is to utilize solar energy and absorb solar thermal energy through absorbent plates which are limited by insulating material. An efficient solar collector if the insulating material is able to withstand heat not quickly absorbed into the surrounding area during irradiation or the radiation process takes place. Insulation in building design is considered as a simple but very energy efficient technique that can be applied to residential, commercial and industrial sectors. Thermal insulators are prepared by composite materials or materials that have high heat resistance characteristics, which show the ability to reduce the heat flow rate [3]. As a result, building insulation is able to keep heat / cold inside the house and other buildings and prevent heat flux from surrounding [4].Various substances, such as fiberglass, mineral wool, foam and other materials are usually used as insulators. Other main advantages of insulation buildings save costs. This is feasible because building insulation contributes to the balance of positive clean energy through the greater amount of energy stored through the application of isolation rather than energy needed to produce the insulating material itself [5]. Apart from that, the thermal performance of thermal insulation material is also a subdivision or density of material [6]. Mass insulation contains a huge number of tiny water trapped pockets, which reduces conductive heat transfer. These are tiny pockets of trapped air act as barriers for heat flow. Therefore, efforts to reduce mass effectiveness will reduce its effectiveness. [7] There have been many attempts over the past 40 years to improve the efficiency of solar collectors. The latest developments are summarized by Suman [8]. Evaluation of the overall performance of solar collectors is usually carried out by trial and error, according to national or international standards [9].Several experimental studies have been conducted to evaluate the thermal performance of solar collectors. Azad (2018) presented a comparative study of an experimental analysis of two solar heat pipe collectors with different amounts of heat pipes and collector streams.

The three collectors were designed, built, and tested side by side in various environmental conditions and thermal efficiency obtained [10]. He proposed two methods for increasing the efficiency of heat pipe collectors: the first is to increase the number of heat pipes and the second is to increase the effective absorber area. Tagliafico et al. (2014) presents a review of the use of CFD tools for flat plate solar collector studies. Those reported to have reported good agreement with experimental data. It was concluded that numerical simulation of CFD is useful in identifying ways to improve the efficiency of solar collectors. [11].

In this discussion Styrofoam and Rockwool insulation materials were analyzed to determine the best insulation power ratio for flat plate solar collectors. In this paper CFD software can help simulation results in predicting heat transfer with Styrofoam and Rockwall insulation materials assuming 80 ^{0}C heat enters flat plate solar collectors. The direction of flow that occurs initially follows the contour of the drying box so that the longer the heat is distributed evenly due to turbulent flow in the middle position of the box. [12] Indonesia has great potential for solar radiation and is very suitable as an energy source for drying agricultural products [13]. For this reason, it is necessary to look for insulation materials that are suitable as a heat barrier for solar collectors so that as much heat as possible is slightly wasted.

2. Methods

This study refers to data on Rockwoll material properties where the value of k = 0.04 W / (mK), type value 140 Kg / m^3, and heat capacity of 840 J / (Kg. K) and Styrofoam material properties k = 0.08 W / (m K), and electrical conductivity (s) 10-16 s / m. Working resistance at low (cold) temperatures: Ugly, Tensile Strength 256 (j / 12): 0.13-0.34, Modulus of elasticity of voltage ASTM D747 (MNm x 10-4): 27.4-41.4, Strong compressive ASTM D696 (MNm): 74.9-110, ASTM 696 thermal expansion (mm C x 10): 6-8, Melting point (soft 0C): 82-103, ASTMd specific gravity 792: 1.04-1, 1, Elastation of ASTM voltage 638 (%): 1.0-2.5, Flexural strength ASTM D790 (mnM): 83.9-118, Electric constant ASTM 150 (10 Hz): 2.4-3.1, Heat type (kph) (Kg): 1,3-1,45.

The data presented is then encoded with the help of CFD oil tools to determine the heat transfer rate and other characteristics. Simulations are assumed to be 2 Dimensions and cut in symmetry to make analysis easier. The boundary conditions are entered according to the nature of material data and solar radiation data to 80 ^{o}C collectors with bright conditions.

2.1. Mathematics and Numerical Methods

Domains are assumed to be a two-dimensional case. The flow in the domain is the flow of incompressible laminer and steady state. The equation of kuntiunitas, momentum and energy can be written [14]

$$\frac{\partial u}{\partial x}+\frac{\partial u}{\partial y}=0 \quad (1)$$

$$u\frac{\partial y}{\partial x}+v\frac{\partial y}{\partial y}=-\frac{1}{\rho}\frac{\partial P}{\partial x}+v\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+g\beta(T-T_\infty)\sin\emptyset \quad (2)$$

$$u\frac{\partial y}{\partial x}+v\frac{\partial y}{\partial y}=-\frac{1}{\rho}\frac{\partial P}{\partial x}+v\left(\frac{\partial^2 u}{\partial x^2}+\frac{\partial^2 u}{\partial y^2}\right)+g\beta(T-T_\infty)\cos\emptyset \quad (3)$$

$$u\frac{\partial T}{\partial x}+v\frac{\partial T}{\partial y}=\alpha\left(\frac{\partial^2 T}{\partial x^2}+\frac{\partial^2 T}{\partial y^2}\right) \quad (4)$$

In the analysis, the non-dimensidized parameter is in the following [3].

$$Ra=\frac{g\,\beta\Delta T H^3}{v^2}Pr \quad (5)$$

Where Pr is the Prandtl number and is calculated by

$$Pr\frac{v}{\alpha} \quad (6)$$

Convection heat transfer coefficient

$$h=\frac{Nu\,x\,k}{H} \quad (7)$$

Where k $[W/\ (m.K)]$ is the conductive heat transfer coefficient of air and H $[m]$ is the distance between the double glass.
Local Nusselt numbers on the bottom and top surfaces are written together

$$Nu_x=\frac{H}{(T_1-T_2)}\frac{\partial T}{\partial y}\bigg|_{y=0}\ Nu_x=\frac{H}{(T_1-T_2)}\frac{\partial T}{\partial y}\bigg|_{y=H} \quad (8)$$

The average Nusselt count is calculated with

$$\bar{N}u\frac{1}{L}\int_{x=0}^{L}Nu_x\,dx \quad (9)$$

System of linear equations for whole field using algorithm in Ansys Fluent.There are several chapters that can be found in the literature, given by Jacob

$$\bar{N}u=0.195\,Ra_H^{0.25}\ for\ 10^4<Ra_H<4\times\ 10^5 \quad (10)$$

$$\bar{N}u=0.068\,Ra_H^{1/3}\ for\ 10^5<Ra_H<4\times\ 10^7 \quad (11)$$

The empirical correlation between the Nusselt number and the average Rayleigh number can be searched with.

$$Nu=1+1.44\left[1-\frac{1708(\sin 1.8\,\emptyset)^{1.6}}{Ra\times Cos\,\emptyset}\right]\left[1-\frac{1708}{Ra\times Cos\,\emptyset}\right]^{+}+\left[\left(\frac{Ra\times Cos\,\emptyset}{5830}\right)^{\frac{1}{3}}-1\right]^{+} \quad 12)$$

3. Result and Discussion

In this case, CFD simulation was used to determine the rate of heat transfer and other characteristics. The simulation was assumed to be 2 dimensions and cut in the symmetry section. Solar radiation to the collector of 80^0C with sunny conditions.

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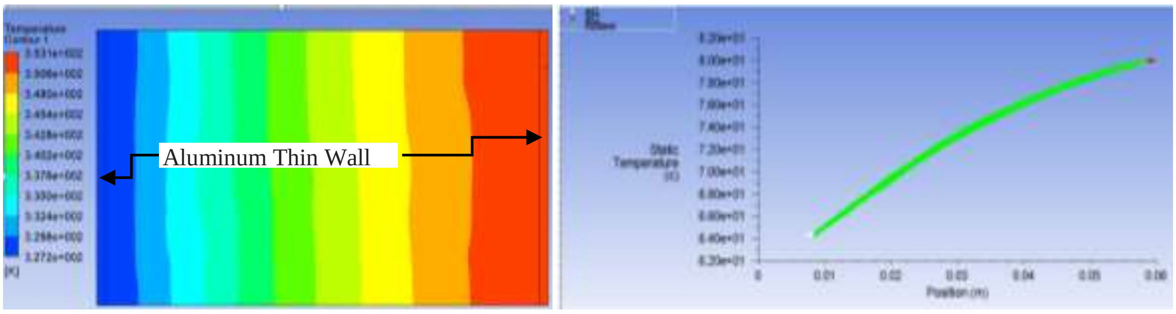

Figure 1. Temperatur distribution of CFD Simulation for Styrofoam insulation

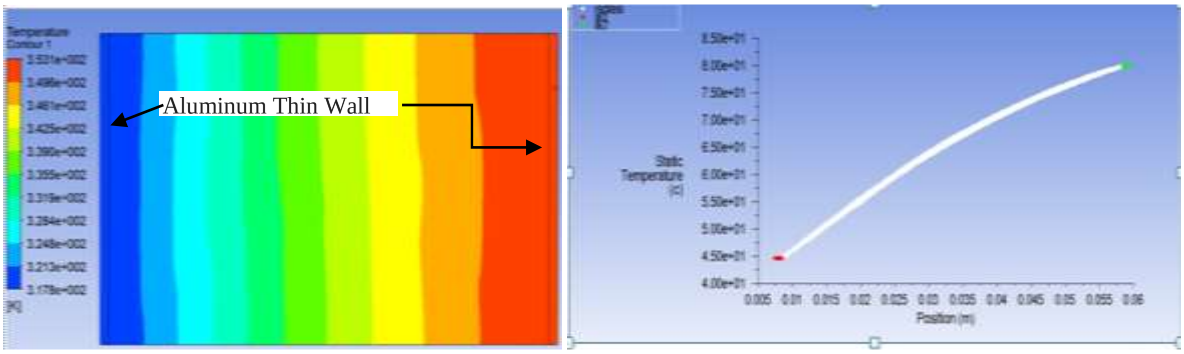

Figure 2. Temperatur distribution of CFD Simulation for Styrofoam insulation

Figure 1 above shows the heat transfer rate that occurs in Styrofoam isolation with a maximum temprature of 353 K equal to zinc plates and a minimum of 327 K. While the material from Rockwall maximum temperature 353 K while the minimum temperatur 317 K (Figure 2). From this result seen the rate of heat transfer faster on Styrofoam than Rockwool. From the picture above shows no significant difference in heat transfer rate in Styrofoam and Rockwall. However it is advisable for good isolation on solar collectors is Rockwool.

4. Conclusions

The best insulation on flat plate solar collectors is Rockwool because it has a low thermal conductivity compared to Styrofoam.

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