Testing of commercial black painted for flat plate solar collector applications

J Simalango\textsuperscript{2}, H Ambarita\textsuperscript{1,2}, F Napitupulu\textsuperscript{2}, and H V Sihombing\textsuperscript{2}

\textsuperscript{1}Sustainable Energy and Biomaterial Centre of Excellent, Universitas Sumatera Utara, Jl. Almamater Kampus USU, Medan 20155, Indonesia
\textsuperscript{2}Mechanical Engineering Department, Faculty of Engineering, Universitas Sumatera Utara, Jl. Almamater, Kampus USU, Medan, 20155, Indonesia

\textsuperscript{*}Email: simalango_jeffri@yahoo.com, himsar@usu.ac.id

Abstract. High absorption of absorber makes improve the performance of the collector. Solar coating should be safe from chemically, and structurally stable for the variable range of the temperatures. The high cost of coating collectors made an option to utilize commercial black paint to be a coating absorber. Commercial black painted for solar collector absorber surface was discussed. These are four commercial coatings were laboratory tested and compare to get the performance. Identify of properties commercial black painting was used to explore the utility of the coating surface. To improve the absorptance solar commercial coating have been used by the researchers. This would allow the use of the low-cost coating in the solar collectors.

1. Introduction

Many researchers are finding alternative sources because fossil fuel resources will end soon and rate of population increasing. Nowadays, many researchers are concentrating more on renewable energy resources such as solar, wind, hydropower, geothermal, and biomass energy. Solar energy, among other renewable sources of energy, is promising and freely available energy source for managing long term (sustainable) issues in energy crisis. Solar power is classified into two methods such as thermal and Photovoltaics to generate power. These two methods have their advantage and disadvantage [1]. Indonesia is blessed with a very wide solar power. Each of the places of Indonesia receive the sunlight. Direct Normal Irradiance value of the sunshine is 4.8 kWh/m\textsuperscript{2}/day. There are many ways to utilize solar thermal energy, they are flat plate collector applications for dryers, water heaters, desalination, etc [2].

Flat plate solar collector (FPSC) systems are used in many regions which receive sunlight. The solar collection method comprises of glass covered steel boxes encompassing insulation, steel tube, plat absorber painted with commercial black paint. Many researchers have focused on how to improve already existing FPSC, an increase of thermal on collectors by improving the absorber materials. Nowadays, the coating on absorber become a concern of researches. One of the critical components on solar collector is plat absorber. High absorption of absorber makes improve the performance of the collector. Also, the choice of the coating has a significant impact on the unit production cost of a solar collector and determine its competitiveness in the market [3,4].

The solar coating should be safe from chemically, and structurally stable for the variable range of the temperatures. The solar coating should have passed with the rules of the local administration. In this study, we investigate a variety of commercial black painted. Individually, most of commercial black paint have similar properties. A commercial black coating material have high solar absorptance than other [5]. Madhukeshwara and Prakash [6] investigated the characteristics of solar flat plate collector with different selective surface coating. There three variances of coating used, black chrome, matt black, and sol chrome. It showed that black chrome has higher temperature than others. Xiaodong et al [7] analysed absorber coating on thermal performance of the solar flat plate collector. This paper compared some coating of plate absorbers such as anodic coating, chromium coating, and blue
coating. It showed that the efficiency of blue core coating has a higher 5\% than others. The absorptance of aluminum solar receiver was improved by C/NiO coating has been deposited by the spray coating technique. Result show that absorptance has been increased up to 90\% [8].

This work the commercial black paint was investigated. The collector uses a flat plate collector. Type to choose the best black paint for coating absorber collector. In this case, four the flat plate solar collector was tested, and these four commercial black paints tested in the laboratory to identify the specifications of the black coating. These four commercial black paintings are used for comparing their effect on the performance (solar heat absorption).

2. Experimental procedure
In the section, the specification of the flat plate solar collector and the measurement tools that were used in the test are presented. The experimental test of flat plate solar collector was design with an area 1 m\(^2\). Figure 1 shows the experimental setup and the schematic diagram of it. The experiments were performed at University of Sumatera Utara, Medan, Indonesia (latitude 3°33'43.3"N 98°39'11.9"E.).

![Figure 1. The schematic diagram of flat plate collector](image)

In the Table 1 specifications of the fabricated flat plate collector are shown.

| Description            | Specification        |
|------------------------|----------------------|
| Dimension              | 1 m x 1 m x 0.3 m    |
| Collector Type         | Flat plate collector |
| Number of glass covers | 2                    |
| Cover material         | Low iron glass       |
| Cover Thickness        | 5 mm                 |
Cover Transmission 94 %
Absorber
Material Zinc sheet
Absorber area 0.45 m²
Thermal Insulation
Insulation Material Rockwool (K=0.035 W/m °C)
Insulation Thickness 0.15 m
Casing
Frame Aluminum

2.1. Experimental setup
The collector uses a flat plate collector type. These four commercial black paintings are used for comparing their effect on the performance (solar heat absorption) of flat plate collectors. The experimental setup is shown in Figure 2. The temperature of each part has record for every one hour from 08.00 am to 04.00 pm.

![Figure 2. Experimental of flat plate collector](image)

2.2. Laboratory measurements
Black paint has tested to identify the properties of commercial black paint. There are parameters testing of black paint, these are Lead (Pb), Cadmium (Cd), Chromium Hexavalent (Cr6+), and Mercury (Hg).

2.3. Collector plate energy balance
The useful energy harvested by solar collector is determined by the ability of the surface to absorb incident radiation as well as the capacity of the body to limit long wavelength radiation from the surface. Further, the convection losses from the collector plate to the ambient air limit the overall useful energy gain. Equation 1. Shows the available useful energy \( Q_u \) harvested by a solar thermal collector plate.

\[
Q_u = q_u A_c = (\tau \alpha) q_s A_c - \overline{U} A_e (T_e - T_a) - \varepsilon \sigma A_e \left( T_e^4 - T_a^4 \right)
\] (1)
Equation 1 the overall balance as essentially: useful energy harvested = energy absorbed - convection losses - radiation losses. Where, the energy absorbed depends on the transmissivity-absorptivity product ($\tau \alpha$), the area of the collector $A_c$, and the incident solar radiation intensity $q_s$. The radiation loss from the surface of the collector plate is directly proportional to the emissivity ($\varepsilon$) of the surface. Further, since the sides of the collector as well as the top and bottom surfaces are subject to convection and conduction losses, the overall heat transfer coefficient $U$ is critical in determining the amount of loss from the collector.

3. Results and Discussions
Solar energy is the source of heat in a solar collector and the input power is usually the irradiation ($E$) received on the surface of the collector, absorb, and transferred to the working fluid. These are four of commercial black paint separate to collector 1, collector 2, collector 3 (coating A), and collector 4 (coating B). In figure 3, the curves show that the energy use values for all coating. Different commercial black paint has varied energy and it shows total energy uses from collector 3 has highest than others. As can be seen in Figure 3, the energy value inside follow the same trend in radiation, an increase in the value of radiation makes the energy used higher.

![Figure 3. Total energy uses flat plate solar collector](image)

Some parameters became concerned in this research, like chromium Hexavalent and Lead (Pb). Addition chromium to black coating making increases the thermal absorption of the collector. But high lead had negative impact for plate absorber. Because lead is a heavy metal that it is denser than most common material. The result showed that coating with high lead where it contains in coating B has an effect for low absorption on the collector. It showed at figure 3, the energy use for collector 3 is higher than collectors 1, collector 2, and collector 4. Heat transfer increase parallel with the enhancement of radiation value. The highest energy is shown at 13.01. when it shows the highest radiation value of 660.6 W/m².

4. Conclusions
Various experiments were conducted to characterize the overall performance of solar collectors of four different selective absorber coatings. When the inner structure of the collectors and the environment is the same, Collector 3 (coating A) with higher energy use. Compared to other three kinds of selective absorber coatings, collector 3 (coating A) has a higher spectral absorptivity. Addition chromium at collector 3 (coating A) to black coating making increases the thermal absorption of the collector. But high lead (collector 4) where it contains in coating B has an effect for low absorption on the collector.
Results show that it can remarkably improve the efficiency of solar collector and is with outstanding energy-saving performance and practical value.

References
[1] Mohtasham J 2015 *Energy Procedia* **74** 1289–1297.
[2] Ambarita H and Sihombing H V 2018 *IOP Conf. Series: Journal of Physics: Conf. Series* **978** 012098.
[3] Alshamaileh E 2010 *Solar Energy* **84** 1637–1643.
[4] Mar H Y B, Peterson R E and Zimmer P B 1976 *Thin Solid Films* **39** 95–103
[5] Prakash B J, Vishnuprasad B and Ramana V V 2013 *International Journal of Mechanical Engineering and Robotics Research* ISSN **2278–0149**.
[6] Madhukehwara N and Prakash E S 2012 *International Journal of Energy and Environment* Vol 3 Issue 1 99–108.
[7] Han X, Zhang S, Chen C and Tang Y 2013 *Advanced Materials Research* Vols **690-693**.
[8] Polizos G, Winter K, Lance M J, Meyer H M, Armstrong, Schaeffer D A, Simpson J T, Hunter S R and Datskos P G 2014 *Applied Surface Science* **292** 563-569.
[9] Tyagi H, Argwal A.K, Chakraborty P.R, Powar S 2019 Advance in Solar Energy Research. Energy, Environment, and Sustainability. Springer. India.
[10] Incropera F P, Bergman T L, Lavine A S, Dewitt D P. Fundamental of Heat and Transfer 7th edition. John Willey and Son.
[11] Sidabutar R, Trisakti B, Husin A, Irvan 2020 *IOP Conf. Ser: Mater. Sci. Eng.* **801(1)** 012053
[12] Haryani N, Harahap H, Taslim, Irvan 2020 *IOP Conf. Ser: Mater. Sci. Eng.* **801(1)** 012051