Journal of Engineering and Applied Sciences 13 (20): 8452-8454, 2018
ISSN: 1816-949X

The V-Groove Solar Collector Performance Using Fresnel Lens and Glass Glazing

Idris Zulkifle, Mohd Hafidz Ruslan, Mohd. Yusof Hj Othman,
Zahari Ibarahim and Kamaruzzaman Sopian
School of Applied Physics, Solar Energy Research Institute,
The National University of Malaysia, 43600 Bangi, Selangor, Malaysia

Abstract: This study presents the performance of solar collector with two type of glazing. Experimental results show that temperature output and thermal efficiency of solar collector using Fresnel lens as glazing is better than the use of glass. The temperature output is inversely proportional to mass flow rate, resulting in an increase of solar collector efficiency. This study carried out the mass flow rate in a range of 0.008-0.036 kg/sec at two different intensities, namely 576 and 755 W/m^2 under solar simulator. The average solar collector efficiency using Fresnel lens as glazing were 8-11% more efficient than glass. The improvement in temperature output and efficiency makes Fresnel lens as an alternative glazing in solar air collector applications.

Key words: Solar collector, Fresnel lens, efficiency, thermal, glazing, Malaysia

INTRODUCTION

Solar energy is the largest source of energy and obtained directly or indirectly. In a year, it is estimated to be 3,400,000 EJ of solar radiation reach the earth, making it the largest renewable resources (Thirugnanasambandam *et al*. 2010). Therefore, solar energy is the best alternative to accommodate the world's energy shortage in the future. Now a days, the main energy generation is from coal, petroleum, natural gas and other fossil sources. Hence, the energy production results in air pollution due to the use of nonrenewable energy (Halabi *et al*., 2015). Solar energy has the potential in drying applications, particularly for agricultural products. This technology is often used in tropical countries due to abundant solar radiation throughout the year and this helps to save time, energy and operation cost (Bal *et al*., 2010). Solar energy is a green technology and has great advantages such as being pollution-free and cost-effective.

The solar radiation is not constant the whole day. Therefore, heat storage needs to be optimized when the solar energy is at the peak (Lingayat *et al*., 2017). So, the use of solar air collector can overcomes this issue.

According to Kalogirou (2004) glazing material, thermal absorber and the collector's housing are the main components in a solar hot air collector. The incident of solar radiation on the collector is mostly shortwave and this increases the thermal absorber plate temperature. Therefore, the plate will emit long wave heat radiation. The long wave is unable to penetrate the transparent glazing, so, it is trapped in the collector, thus, increases the temperature in the collector. Energy in the form of heat stored in the thermal absorber is transferred to the fluid by a fan or air blower, this is known as forced convection while natural convection causing increases fluid's temperature level. The thermal energy will be used in the real applications, in general at low temperature, about 80°C (Kalogirou 2009). The residual energy may disperseinto the collector's glazing, base and frame.

Glazing is beneficial in reducing heat loss from the thermal absorber due to convection and radiation via. long wavelength. It is also used to protect the collector's internal parts from being polluted by dirt and grime. Additionally, glazing materials should either be transparent to short solar radiation wavelength or opaque to long infrared radiation to reduce heat loss (Kenna, 1983). The collector's glazing must be resilient, especially for outdoor use. For some collectors, the thermal energy loss can reach over 150.0 W/m^2 (Soltau, 1992). Therefore, heat loss from the upper part of the collector can significantly affect its performance (Satcunanathan and Deonarine, 1973). The transmittance is inversely proportional to the glazing number (Michalopoulos and Massouros, 1994). This glazing number depends on the application of several factors such as greenhouse walls, space heating or transparent roof in a building. Glazing materials can be in the form of glass, polycarbonate and acrylic. Acrylic is a type of plastic known for its robustness and elasticity but prone to bending at elevated temperatures which deteriorates transmittance performance to 10.0% (Bakar and Othman,

Corresponding Author: Idris Zulkifle, School of Applied Physics, Solar Energy Research Institute,
The National University of Malaysia, 43600 Bangi, Selangor, Malaysia

2013). The application of glass is limited in Third World countries because it is easily breakable and expensive (Jannot and Coulibaly, 1997; Njomo, 1995). Another alternative for glazing is the use of Fresnel lens. Fresnel lens serves as solar concentrator that allows uniform flux on the absorber plate and concentrates low density solar radiation (Leutz and Suzuki, 2001). This indirectly increases the collector's efficiency.

MATERIALS AND METHODS

Design of the solar collector: V-groove solar collector was designed to test under solar simulator in single pass operation. The details of the collector is shown in Table 1.

Performance analysis: Useful energy gained by the collector, based on Hottel-Whillier-Bliss equation (Duffie and Beckman, 2003):

$$Q_u = \dot{m}C_p\left(T_o - T_i\right) \quad (1)$$

Where:

- $\dot{m}$ = The mass flow rate
- C_p = Specific heat capacity of fluid
- T_o and T_i = Temperature output and input, respectively

The collector thermal efficiency, η is given by useful energy gained from the collector, Q_u divided by sum of energy supplied to the collector. Sum of energy supplied is the total solar radiation I exposed to the collector surface times by area of the collector A. The thermal efficiency is calculated by Fig. 1:

$$n_{th} = \frac{\dot{m}C_p\left(T_o - T_i\right)}{AI} \times 100 \quad (2)$$

Table 1: The single pass operation

Specification	Values
Dimension of collector	1×1 m
Height of collector	10 cm
Absorber material	Stainless steel
Sealant	Silicon rubber
Insulation	Rubber (2.54 cm)

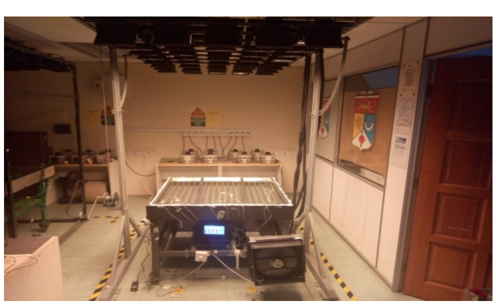

Fig. 1: Experimental setup under solar simulation

Experimental investigation: V-groove solar collector with 12 inch fan was put under solar simulator. The solar simulator consists of 45 halogen lamps while the solar radiation source was set at 576 and 755 W/m^2, controlled by regulator. The experiment was conducted using four mass flow rates in the range between 0.0085-0.036 kg/sec. The output, input and ambient temperature were measured using K type thermocouples, connected to data acquisition (ADAM view). The thermocouples and data collection system were calibrated prior to the experiment.

RESULTS AND DISCUSSION

Figure 2 and 3 show the effect of mass flow rate and intensity on the thermal performance. At 576 W/m^2, the maximum and minimum T_o using Fresnel lens as glazing was 59.62 and 40.12°C, respectively, whereas the values were 54.5 and 38.09°C when glass was used as glazing. Meanwhile, at the intensity of 755W/m^2, maximum T_o was 69.5°C and minimum was 44.63°C for Fresnel lens and for glass, the values were 48.52 and 41.25°C, respectively. The output temperature difference for Fresnel lens was around 2-5°C higher than glass for the varies mass flow rate. This shows that using Fresnel lens as glazing will increase output temperature.

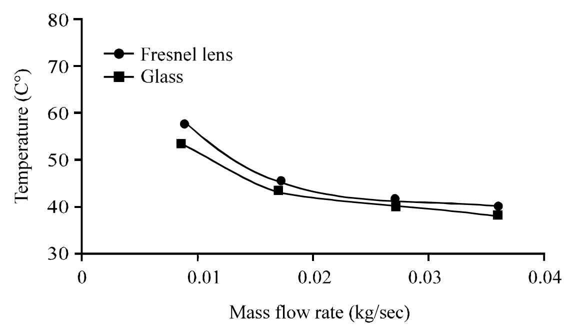

Fig. 2: Output temperature variation over mass flow rate at intensity of 576 W/m^2

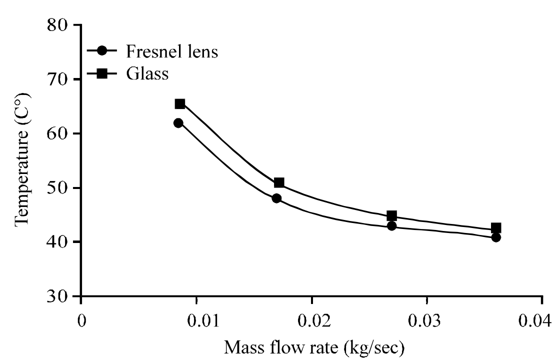

Fig. 3: Output temperature variation over mass flow rate at intensity of 755 W/m^2

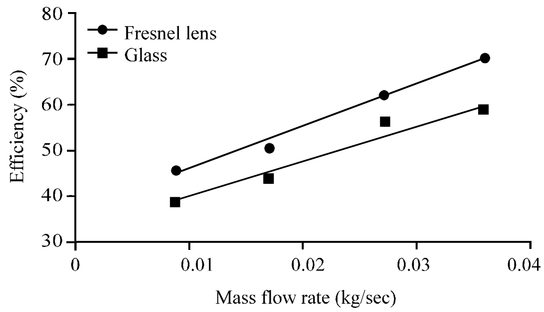

Fig. 4: The effect of mass flow rate on solar collector efficiency at intensity of 576 W/m^2

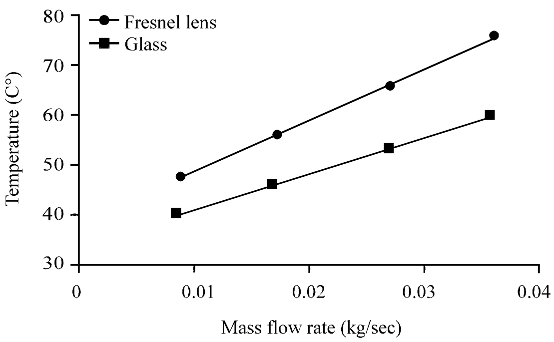

Fig. 5: The effect of mass flow rate on solar collector efficiency at intensity of 755 W/m^2

Figure 4 and 5 illustrate the thermal efficiency as a function of mass flow rate. It was demonstrated that, the average solar collector efficiency was 57.62% for Fresnel zens and 49.28% for the glass at 576 W/m^2. Whereas at 755 W/m^2, the average efficiency were 61.19% for Fresnel lens and 49.58% for the glass. The light source is concentrated by Fresnel lens, thus, increases the absorber plate temperature. This increases the heat transfer coefficient due to increased heat removal, resulting in a more efficient system. The efficiency is directly proportional to mass flow rate.

CONCLUSION

In this study, the solar collector performance with different glazing was obtained. It was found that Fresnel lens as glazing is 8-11% more efficient than glass. This has further increased the performance of the collector. Introduction of Fresnel lens as glazing increases solar radiation concentration to the absorber. Hence, the thermal performance is higher than the use of glass as glazing.

ACKNOWLEDGEMENTS

The researchers would like to thanks The Ministry Of Higher Education of Malaysia for sponsoring this project under Grant TRGS/1/2014/UKM/01/11/4 and School of Applied Physics, Universiti Kebangsaan Malaysia for support this project.

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