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Absorber with Triangular Cavity for a Linear Fresnel Collector investigated numerically

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Abstract

The performance of a solar collector with Fresnel type, consists absorber with a triangular cavity is tested. In order to create a Fresnel collector, it contains an absorber through many rows of tube, a mirror reflector by flat cover glass with 4mm in thickness. The transient method was considered in the present article to test the thermal performance. The solar parameters that had been analyzed here numerically can be considered are coefficients for no-load, loosed heat, and thermal efficiency for the collector, respectively. The loss heat of 110W/m and the efficiency of 36.6 percent are the results.

Keywords : Triangular Cavity, investigated numerically

Introduction

Heat source of middle temperature for industrial processes can be produced by using the technology of Fresnel linear focus, 1960 was first planned. The cost for Fresnel collector compared with the trough linear focus technology, around 50 to 60 percent less than the latter per square foot. Trough collectors, on the other hand, can reach 70-80% efficiency, while Fresnel collectors only reach 50-60%. As a result, compared to that collectors of type trough, Fresnel collectors entail a greater surface area.

Fresnel collector in figure 1 is composed of mirrors in multiple rows that track the sun at different angles and reflect sun-rays to the absorber. The collector converts low-density solar energy into high-density solar energy because of the concentrated ratio which can be defined as the ratio of areas for reflection and absorption that always is greater than unity.

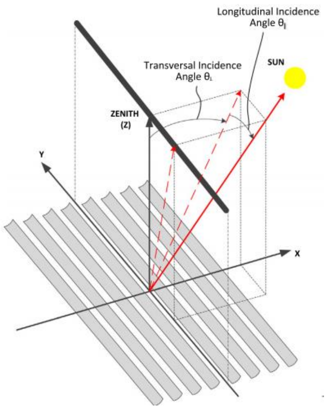


Fig. 1 3D schematic for LFR

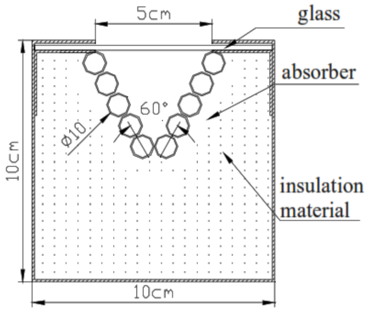


Fig.2 Triangle cavity absorber

As part of this research, a triangular cavity Fresnel collector was constructed and tested (Fig.2). According to design theory, the design of collector, eliminating the arrangement of mirrors, size and tracking technique, had been established in the first place. On wards with the no-load performance test as well as the transient efficiency test. The efficiency of Fresnel collector is nearby 10% lesser than that for a trough collector, but it's still better than nothing. Because of the low cost, easy operation and maintenance, and ease of production, Fresnel collectors are still used in solar energy utilization at intermediate temperatures.

According to Zhang Liying's [2] calculations, the Fresnel collector's concentration ratio is among 40 and 50, which is sufficient to encounter the supplies. According to calculations it is 48.

Referring to Zhai Hui's study, it picked absorber with a cavity of triangular in place of a evacuated tube used in trough collection. Considering that the employed working fluid is not inadequate to HTF oil, but can choose water, in order to endure high pressure, it chose an absorber tube with rows as shown in Fig.2). The the structure of absorber tubes with triangular cavity precludes the use of secondary concentration forms. The absorbed consists primarily of copper tubes, a stainless steel cover, a glass cover, and a lagging layer. On table 1, it can see the physical parameters of the components.

Table 1 Physical parameters of the cavity

Materials	ρ/kg·m^{-3}	λ/W·m^{-1}·K^{-1}	C_p/J·kg^{-1}·K^{-1}	ε
Copper (selective coating)	8978	387.6	381	0.5
Aluminum	2710	236	902	0.1
Stainless steel	7830	14.7	460	0.1
Glass	2719	0.65	871	0.85
Insulation material	41	0.035	35	-

There is no secondary heat exchanger in the absorber and the lamp entrance is 5cm wide, so the reflector should be 30cm wide or more. Because of its curvature, the mirror can reflect light into the absorber's entrance. The width of mirrors ca be set around 240 cm in order to maintain the concentration ratio.

We chose a single row of independent driven mirrors with small step motor tracking because the mirrors with multi-row tracked sun rays simultaneously. Table 2 summarizes the final design parameters for Fresnel collectors.

Table 2 Basic design parameter of the Fresnel collector

Events	Parameters	Events	Parameters
Work temperature	100 ~ 250°C	Type of the mirror	Slightly curved pattern
Concentration ratio	48	Total width of mirrors	240cm
Type of absorber	Triangle-cavity absorber	Numbers of mirrors	8
Size of absorber	Referring to Fig. 2	tracking form	Homotaxial tracking

Numerical analysis

The effect of operating variables such as flow rate and inlet temperature of the heat transfer fluid (HTF) on the thermal performance of the LFR was studied using the simulation model. During the first half of the year, weather conditions were similar to those experienced in the second half of the year, and the results were satisfactory. It was decided to include as fixed parameters the receiver tube's outer and inner diameters as well as the mirror's curvature and focal length. According to Table I, the optical parameters of the mirror and receiver tube were also taken into account when creating the model.

The following formula was used to calculate the incident solar energy insight on the receiver tube:

$$\dot{q}_{\text{input}} = A_{\text{net}} * DNI * \eta_{\text{otp, }p} * \text{IAM}(\theta) * ELF$$

The DNI is the direct normal irradiance (w/m2). To determine the maximum optical efficiency (opt,p), consider the glass cover (g), mirror reflection (mi) and selective surface absorption (co) of an absorber tube, respectively.

$$\eta_{\text{otp, }p} = \rho_{mi} * \tau_g * \alpha_{co}$$

<u>Testing the performance of a Fresnel line</u>

Test with no load

A no-load performance test was carried out to verify the collector's maximum operating temperature. Heat transferred by convection type between the inside air and outside surface for absorber tube which can affect the test results, so the import and export of the absorber are sealed. It is recorded every minute how much solar irradiance is present at the measuring points. Figure 3 shows the test results from 9:40 to 17:00 on a sunny, breezy day. For analysis, select the following data: total irradiation intensity, direct radiation intensity, ambient temperature, temperature of the cover glass, and surface temperature of the absorber. There is a 664.0w/m average direct radiation intensity, and the average ambient temperature is 18.6 C. There is also a 260.3 C increase in temperature of the absorber's surface as the collecting time increases, and a 60 C increase in temperature of the glass cover. In the later period, the amplitudes of both changes decrease sequentially.

Transient test

Test results are shown in Figure 4 after selecting at least 8 measuring points. The following formula can be used to calculate the collector's transient thermal efficiency:

$$\boldsymbol{h}_t = \frac{\dot{m}c_{p,w}(T_{out} - T_{in})}{AI_b}$$

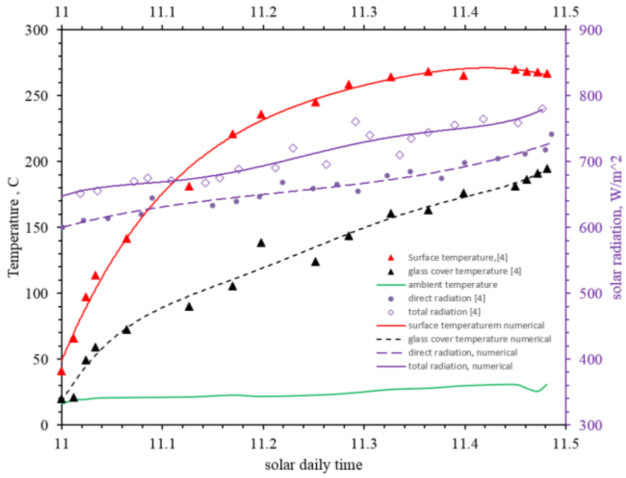


Fig. 3 test with no-load

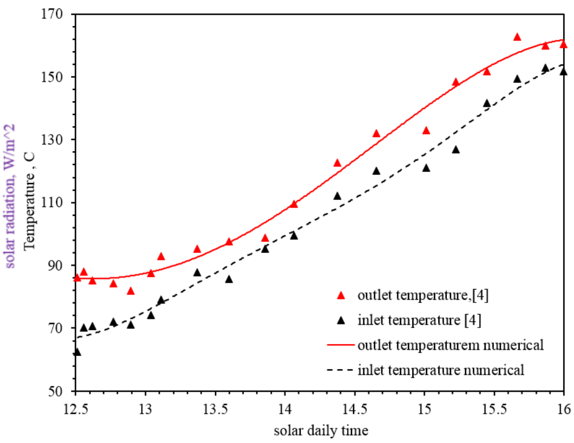
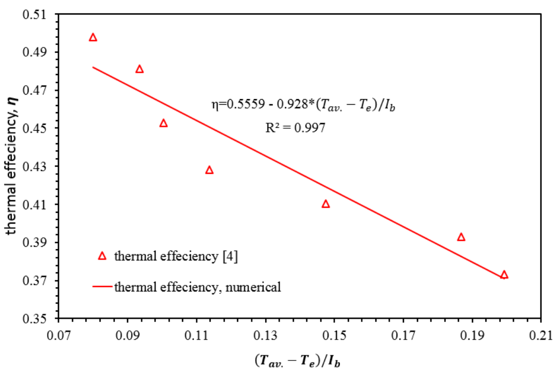


Fig. 4 test with transient

With the least square method, sT and ch are used to fit the efficiency curve in figure 4. A mild breeze blows and the temperature fluctuates between 16 and 18 C during the testing period. HTF has a mass flow rate of 168 grams per second.



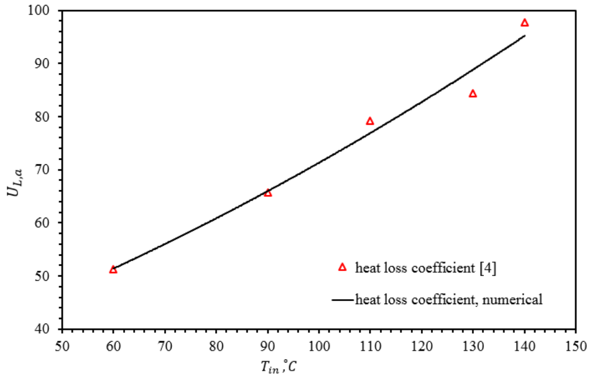


Fig. 5 thermal efficiency correlation

Fig. 6 coefficient for an absorber's heat loss

Figure 5 shows the optical efficiency of the system as the intercept of the efficiency curve. 55.7 percent on average, which is 11.4 percent below the ideal 67.1 percent optical efficiency. System efficiency is 45.2 percent at 90 C and 36.6 percent at 150 C when the direct radiation intensity is 675.9 W/m2. These are slightly lower results than expected. Heat loss coefficient $U_{L,a}$ for the triangular cavity absorber is shown in Figure 6. There are 110W/m at 150°C, which is more than the vacuum absorber.

Conclusions

A triangular cavity absorber is used in this linear Fresnel collector. On average, after 30 minutes of testing, the HTF reached 260.3°C and its no-load performance parameters were 0.364°C.m2 /W. There was a 55.7 percent average, which is 11.4 percent less than the ideal optical efficiency 67.1 percent. Under the experimental conditions, the system efficiency is 45.2% at 90 °C, and 36.6 % at 150 °C, with a heat loss coefficient of 110 w/m, according to the study.

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