Thermal Efficiency of Unglazed Solar Collector-Polymer Type

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Abstract: - In this paper, the thermal efficiency of the solar collector polymer have been studied. Base on the available technical paper, the thermal modeling of the polymer has been use for heat energy balance analysis. The variations of the overall heat losses coefficient have been analyzed in term of the performances. It showed the thermal performance of the polymer collector can achieved 0.76 during the zero reduce temperature conditions. The overall heat losses coefficients need to be reduced to obtain the higher thermal efficiency. Most of the factors depend on the design and environment conditions which refer to the top and bottom losses.

Key-Words: - Heat energy balance, polymer, collector, thermal efficiency, hot water.

1 Introduction

The solar thermal is a device to produce useful heat via working fluid such as air or water. It can be used as a water heating or space heating base on the type of working fluids. For the residential, the solar thermal produce hot water as a primary or pre heating system.

The performances of the conventional water heating collector base on various factor such as operating conditions, environment, material selection and designs of the collector.

Recently, the application of the polymer collector has been study by the researcher as a solar collector. The features such as low resistance, no corrosion, flexible, easy to manufacture, low cost and ease of handling made the device more practical and very potential [1], [2], [3].

In this study the thermal efficiency of the unglazed polymer collector has been study theoretically. The thermal modeling and some parameters obtain from the available technical papers.

2 Methodology

Fig.1, and 2, shows the cross section and side view of a polymer collector. The collector is unglazed and without insulation. The polymer made from polyolefins with black color.

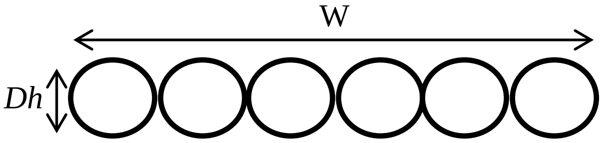

Fig.1 Frontal cross section of collector.

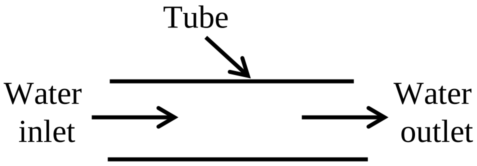

Fig. 2. Side view of collector.

3 Theoretical Analysis

Fig.3, show the heat transfer coefficient on polymer collector. To simplify the analysis, the following assumption has been made [4], [5].

a. Steady state analysis
b. All convection of heat transfer coefficient are equal and constant.
c. Thermo physical of polymer and working fluid are constants.
d. Useful heat transfer is uniform.
e. Some of the thermo physical of water such as density and specific heat are constant.

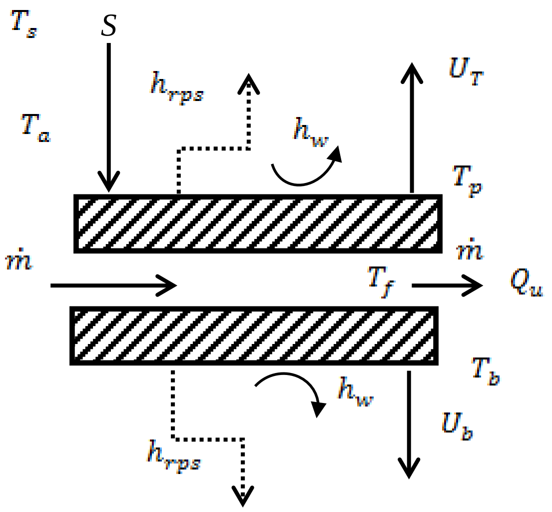

Fig.3, Heat transfer coefficient on collector.

The heat energy balance from Fig.3, can be written as follow [6].

At the top surface of polymer absorber

$$S - U_t(T_p - T_a) - \frac{k_p}{b}(T_p - T_f) = 0 \qquad (1)$$

For water flow channel

$$\frac{k_p}{b}(T_f - T_p) - q_u - \frac{k_p}{b}(T_f - T_b) = 0 \qquad (2)$$

For bottom surface of polymer absorber

$$\frac{k_p}{b}(T_f - T_p) - U_b(T_b - T_a) = 0 \qquad (3)$$

Eliminating Tb in Eqs (2) and (3), it derives as,

$$T_p = 2T_f - \frac{k_p/bU_b}{1 + k_p/bU_b} \times T_f - \frac{1}{1 + k_p/bU_b} \times T_a \qquad (4)$$

Submitted T_p in Eq (4) into Eq (1), it derives as,

$$q_u = F'[S - U_L(T_f - T_a)] \qquad (5)$$

where,

$$F' = \frac{H/U_b}{H/U_b + U_t/U_b} = 1/(1 + U_t/H) \qquad (6)$$

$$U_L = U_t\left(1 + \frac{1}{1 + (H/U_b)}\right) + U_b\left(1 - \frac{1}{1 + H/U_b}\right) \qquad (7)$$

for

$$H = \frac{k_p}{b} \qquad (8)$$

$$q_u = F_R[S - U_L(T_{f,i} - T_a)] \qquad (9)$$

$$F_R = \frac{\dot{m}C_p}{A_c U_L} \times [1 - e^{-A_c F' U_L/\dot{m}C_p}] \qquad (10)$$

$$\eta_{th} = F_R\left[\tau\alpha - U_L\left(\frac{T_{f,i} - T_a}{G}\right)\right] \qquad (11)$$

Table 1, Parameter for analysis [6]

Perimeter	Value	Unit
$\tau\alpha$	0.8	-
F'	0.94	-
F_R	0.95	-
b	2	*mm*
$\dot{m}$	0.015	*kg*
k	0.2	*W/m.°C*

4 Results

From the Eq (11), the thermal efficiency of the collector can be denoted as follows,

Y = 0.76 – 6.65X (12)

Y = 0.76 – 13.3X (13)

Y = 0.76 – 19.05X (14)

Y = 0.76 – 26.6X (15)

Which Y is the thermal efficiency of collector. It can be describe in Table 2 and Fig.4.

Table 2, Value of the $F_R U_L$ and τα

U_L (W/m^2. °C)	$F_R U_L$	τα
7	6.65	0.76
14	13.30	
21	19.05	
28	26.60	

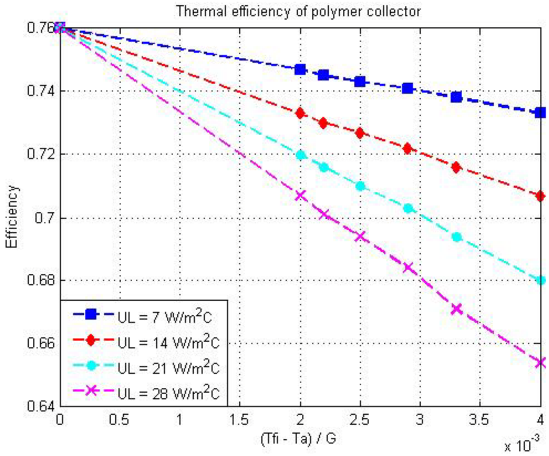

Fig.4, Thermal efficiency for polymer collector (U_L = 7, 14, 21 and 28 $W/m^2.°C$)

The highest efficiency is 0.76 during zero reduced temperature condition. The zero reduce temperature is the situation the value of x is zero which temperature fluid inlet equal to temperature ambient. The slope represented the losses of the collector to the surrounding. The highest losses will results the bigger negative slope for the collector.

5 Conclusion

Polymer collector can produce high thermal efficiency. Achieving 0.76 efficiency during zero reduce temperature is almost as good as conventional solar thermal collector. The overall heat losses need to be minimized to ensure the collector produce high efficiency. Therefore, it was a promising device due to the advantages such as cheaper, wear resistance and ease of manufacturability.

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Nomenclature

A_c	collector area (m^2)
b	plate thickness (m)
C_p	specific heat (J/kg.°C)
F	collector efficiency factor
F_R	heat removal efficiency factor
H	defines as k_p/b (W/m^2.°C)
k	thermal conductivity (J/m.°C)
L	Length (m)
$\dot{m}$	mass flow rate (kg/s)
q	heat rate (W/m^2)
S	energy absorb (W/m^2)
T	temperature (°C)
U	heat loss coefficient (W/m^2.°C)

Subscripts

a	ambient
b	base
f	fluid
i	inlet
L	overall loss
p	plate
r	radiation
s	sky
u	useful
w	wind

Greek letter

α	absorptivity
ε	emissivity
μ	dynamic viscosity
$\tau\alpha$	transmittance-absorbtance product
η	efficiency
σ	stefan-Boltzmann constant