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Performance analysis and optimization of absorber plates of different geometry for a flat-plate solar collector: a comparative study

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Abstract

This paper presents a comparative study on the performance and optimization of several profile shapes namely, rectangular, trapezoidal and rectangular profile with a step change in local thickness (RPSLT). This analysis concentrates on the performance and optimization of RPSLT. A modification has been suggested for the analysis of RPSLT absorber plate that was observed by Hollands and Stedman [Solar Energy 49 (1992) 493]. The result indicates that there is optimum fin efficiency of trapezoidal profile for constant plate volume. The RPSLT profile of absorber plate is superior to other profiles because of higher performance and less difficulties in fabrication.

Keywords: Absorber plate; Flat-plate solar collector; Optimization; Plate efficiency; Plate profile

1. Introduction

A flat-plate solar collector is a special kind of heat exchanger that transforms solar radiant energy to internal energy of the transport medium in the tubes to be carried out as usable energy. It is widely used for supplying thermal energy at moderate temperatures. The common applications of the flat-plate collectors are mostly found in domestic hot water and space heating, industrial processes, vapor absorption refrigeration and air conditioning system. Therefore, due to their various applications, there is a continuing endeavor of a designer to determine thermal

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Nomenclature

Bi	Biot number based on the root thickness of the plate, $U_l t_b / k_p$
f	function defined in Eqs. (15) and (16)
g	used in Eq. (25)
g_1, g_2, g_3, g_4	defined in Eqs. (21)–(24) respectively
J	Jacobian determinant
k_p	thermal conductivity of the fin material (W/mK)
L	semi-pitch length of the absorber plat (m)
L_1	distance at which step change occurs (m) (see Fig. 2)
m	parameter, $[Z_0/(1-R)]\lfloor 1+\delta^2(1-R)^2/4\rfloor^{1/4}$
q	energy transfer rate (W)
Q	dimensionless energy transfer rate, $q/k_p(T_b - T_a - S/U_l)$
R	ratio of tip to base thickness, t_t/t_b
S	energy flux absorbed by the plate from Sun (W/m^2)
t_b	plate thickness at the root (m)
t_t	plate thickness at the tip (m)
T_1	local plate temperature for $0 \leqslant X \leqslant \alpha$ (K)
T_2	local plate temperature for $\alpha \leqslant X \leqslant 1$ (K)
T_a	ambient fluid temperature (K)
T_b	plate temperature at the root (K)
U	dimensionless plate volume, $U_l^2 V/k_p^2$
U_l	overall loss coefficient (W/m^{2}K)
V	plate volume (m^3)
x, y	coordinates (m)
X	dimensionless coordinate, x/L
Z_0	plate parameter, $\sqrt{Bi}/\delta$
Greek letters	
α	dimensionless step length, L_1/L
δ	aspect ratio, t_b/L
η	efficiency of the absorber plate
θ_1	dimensionless temperature, $(T_1 - T_a - S/U_l)/(T_b - T_a - S/U_l)$
θ_2	dimensionless temperature, $(T_2 - T_a - S/U_l)/(T_b - T_a - S/U_l)$
Subscripts	
opt	optimum
n	nth iteration

performance of flat-plate solar collectors. Many authors [1,2] have concentrated on the development of effective design methods for solar collectors. For their analysis, the cross-sectional area of the absorber plate has been taken constant. However, the collector receives energy from the sun