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Plate Temperature and Heat Transfer Characteristics of Artificially Roughened Solar Air Heater

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Abstract

Higher value of intensity of radiation on absorber plate of solar air heaters and effective heat removal from the plate by the carrier fluid, air, enhances thermal performance of solar air heaters. The paper deals with the experimental results of enhancing the intensity of radiation by means of booster mirrors and that of heat transfer by means of providing artificial roughness on the air flow side of the absorber plate. An enhancement in radiation of about 40% have been found over the normal incident radiation by means of booster mirrors leading to higher rate of heat collection. The thermal performance parameters F_R and F' have been found to increase in the range of 90% to 130% and 92% to 135% respectively in comparison to those of smooth solar air heaters without booster mirrors and in the range of 10% to 15% in comparison to roughened solar air heater without booster mirrors for the same pressure drop due to artificial roughness within the range of the parameters investigated.

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Keyword: Plate temperature; Booster mirror; Relative roughness pitch (p/ε); relative roughness height (ε/D); collector heat removal factor (F_R); plate efficiency factor (F').

Introduction

The present paper is with a view to introduce a more efficient solar air heater with respect to higher grade energy collection as well as higher rate energy collection. Literature is available in plenty aiming at to enhance the thermal performance of solar air heaters by providing artificial roughness of different geometry and orientation on the fluid flow side of the absorber plate [1-13]. Use of artificial roughness do increase the thermal performance but associated increased pressure drop increases the pumping power required. Proper selection of the height, pitch and shape of the roughness element make the system more efficient. The roughness height of the order of the viscous sub-layer thickness for fully developed turbulent flow breaks the viscous sub-layer which result in higher value of heat transfer from the plate and thermal performance of solar air heater increases [2]. However, pressure drop also increases. To elevate the plate temperature, booster mirrors of plane and curved types have been used[14-18]. Based on the work[2], selection of the set of values of roughness parameter p/ε, ε/D, and flow Reynolds number could be considered for the optimal thermo-hydraulic performance in roughened solar air

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heaters. Such solar air heaters combined with booster mirrors could yield even better results without adding more to pressure drop. As such, the present paper aims at to represent the results of investigation[19] in artificially roughened and boosted solar air heaters with respect to:

I. Plate and air temperature characteristics
II. Heat transfer characteristics
III. Thermal performance characteristics

Nomenclature

A_c	collector area, [m^2]
C_p	specific heat at constant pressure, [J/kgK]
D	hydraulic diameter of solar air heater duct, [m]
ε/D	relative roughness height
F'	collector efficiency factor
F_R	collector heat removal factor
F_o	collector heat removal factor referred to fluid outlet temperature
G	mass flow rate per unit collector area, [kg/sm^2]
h	heat transfer coefficient between the plate and air, [$W/m^2 K$]
I	intensity of solar radiation, [W/m^2]
$\dot{m}$	mass flow rate of air, [kg/s]
N_u	Nusselt number
p/ε	relative roughness pitch
T_a	ambient temperature, [K]
T_i	inlet air temperature, [K]
T_o	outlet air temperature, [K]
U_L	overall loss coefficient, [$W/m^2 K$]
τα	Transmittance-absorptance product
η	collector efficiency
η_i	collector efficiency referred to fluid inlet temperature
η_o	collector efficiency referred to fluid outlet temperature
ε	height of artificial roughness, [m]
Suffix	
S	smooth
SB	smooth with booster mirror