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Electrical and Thermal performance of solar photovoltaic thermal Energy Collection System With Rib Rouhgness

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Abstract— In this work, a parametric study of the enhancement achieved in electrical (cell) efficiency and thermal efficiency of providing roughness on the underside of the absorber plate. The performance parameters (enhancement of electrical efficiency and thermal efficiency). they have been evaluated based on mathematical simulation of PV/T system as function of relevant geometrical parameters, namely relative roughness pitch ,relative roughness height and angle of attack and design parameters, namely temperature rise and insolation. Results reveal that there is substantial enhancement in the performance parameters brought about the roughness as compared to those obtained with smooth absorber plate.

Index Terms— Relative roughness height, Angle of attack,Temperature Rise parameter, Solar Radiation Intensity,Relative Roughness Width

1 INTRODUCTION

Solar energy has the greatest potential of all the sources of renewable energy and if only a small amount of this form of energy could be used,it will be one of the most important supplies of energy specially when other source in the country have depleted.energy comes to the earth from the sun.this energy keeps the temperature of the earth above that in colder space ,causes current in the atmosphere and in ocean ,causes the water cycle and generates photosynthesis in plants.

Solar Collectors is a device for collecting solar radiation and transfer the energy to fluid passing in contact with it.and its associated absorber ,is the essential component of any system for the conversion of solar radiation energy into more usable form (eg heat or electricity).

1 Flat-Plate Collectors (FPC)
2.Compound Parabolic Collectors (CPC)
3. Evacuated-Tube Collectors
4 Parabolic Trough
5. Parabolic Dish

1.1 Solar Air Heater

A conventional solar air heater generally consists of an absorber plate with a parallel plate below forming a passage of high aspect ratio through which the air to be heated flows. As in the case of the liquid flat plate collector, a transparent cover system is provided above the absorber plate, while a sheet metal container filled with insulation is provided on the bottom and sides. The air to be heated flows between the cover and the absorber plate itself instead of through a separate passage, while in some arrangements the air flows between the cover and the absorber plate, as well as through the passage below the absorber plate

1.2 Photovoltaic (PV) Cell

The photovoltaic effect is the creation of voltage or electric current in a material upon exposure to light and is a physical and chemical phenomenon.the standard and obvious photovoltaic effect is directly related to the photoelectric effect, though they are different processes.The photovoltaic effect can be observed in nature in a variety of materials ,but the materials that have shown the best performance in sunlight.this effect can be described easily for p-n junction in a semi-conductor.in an intrinsic semiconductor such as silicon, each one of the four valence electron of the material atom is tied in a chemical bond ,and there are no free electron at absolute zero.

1.3 Photovoltaic Material

Research and development of photovoltaic solar cells is playing an ever larger practical role in energy supply and ecological conservation all over the world. Many materials science problems are encountered in understanding existing solar cells and the development of more efficient, less costly, and more stable cells.

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2 Procedure for Paper Submission

2.1 Review Stage

2.1 Introduction

There are two fundamental systems for enhancing the heat transfer coefficient between the absorber plate and air.

1.Increasing the area of heat transfer by using corrugated surfaces or extended surfaces called fins without affecting the convective heat transfer coefficient.

2.Increasing the convective heat transfer by creating turbulence at the heat-transferring surface. This can be achieved by providing artificial roughness on the underside of absorber plate.

2.2 Concept of Artificial Roughness

The thermal efficiency of solar air heaters is found to be low due to low Thermal performance of solar air heater can be increased by using artificial roughness on the absorber plate to make it rough to increase the heat transfer rate and friction factor characteristics. Due to this roughness, turbulent boundary layer with small laminar sub-layer is formed on the absorber plate. This laminar sub-layer offer very high resistance to the heat flow. So by breaking this layer to create turbulence the heat transfer rate and friction factor characteristics can be increased which further increases the thermal efficiency and thermo hydraulic performance of a solar air heater. Hence, it is necessary that the turbulence must be created in the vicinity of heat transfer surface i.e. laminar sub layer only where the heat exchange takes place and the flow should not be unduly disturbed so as to avoid excessive friction losses. This can be done by keeping the height of the roughness element to be small in comparison with the duct dimensions. Although there are several parameters that characterize the arrangement and shape of the roughness, the roughness element height (e) and pitch (p) are the most important. These parameters are usually specified in terms of dimensionless parameters, namely, relative roughness height (e/Dh) and the relative roughness pitch (p/e). The roughness elements can be two dimensional ribs or three dimensional discrete elements, transverse or angled ribs or V-shaped continuous or broken ribs.

2.3Methods for providing roughness

The surface roughness is produced by several methods, such as sand blasting, machining, casting, forming, welding ribs and by fixing thin circular wires along the surface(metal rib grits). Different types of wire, rib or wire mesh with different shapes, orientations and configurations on the surface are used to create required roughness. The easiest method used for the enhancement of heat transfer is to provide artificial roughness on the underside of plate. Hence, the chief domain of concern for investigators is to find appropriate geometry of roughness element that would enhance the heat transfer between the absorber plate and flowing fluid with lowering the friction factor.

2.4 Multiple arc shaped elemen

Mr. Singh et al. [1] investigated effects of artificial roughness on heat transfer and friction characteristics having multiple arc shaped roughness element on the absorber plate as shown in Figure 3.1.

Mr. Alam et al. [4] investigated the effect of non-circulation perforation holes in terms of circularity of V-shaped blockages attached to one heated wall of rectangular duct. The V-shaped perforated blocks on absorber plate

Mr. Sethi et al. [12] carried out the fluid flow and heat transfer analysis for heat transfer enhancement in three-sided artificially roughened (Figure 3.3) solar air heater using small diameter wires

Mr. Prasad, **et al [9]** carried out the thermal performance of artificially roughened solar air heaters by using thin G.I. wires in twin flow air heaters, in comparison with single flow air heater

Mr. Sethi et al. [12] carried out an experimental investigation in order to analyses the effect of heat transfer and friction characteristics in solar air heater having dimple shaped elements arranged in angular fashion as depicted

Mr. Sainii and Mr. Verma et al [22] investigated the effect ofroughness geometry and operating parameters on heat transfer in a roughened duct provided with dimple shaperoughness geometry.

Mr. Karmare and Mr.Tikekar et al [16, 19] investigated lower side of absorber plate by roughening it with metal ribs ofcircular, square and triangular cross sections

Mr. Varun et al [18] carried out an experimental study onheat transfer and friction characteristics by using a combination of inclined and transverse ribs

Mr. Kumar and Mr. Saini et al [20] investigated the performance of a solar air heater duct provided with roughness geometry in form of thin circular wire in arc shaped geometery

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Mr.SainiiandMr.Sainiiet al [21] studied the effect of arc shaped ribs on the heat transfer coefficient and friction factor of rectangular solar air heater ducts

Mr. Aharwal et al [23] carried out an experimental investigation on heat transfer characteristics using artificial roughness in the form of repeated ribs of square section split rib with gap, inclined with respect to flow direction.

Mr. Lanjewaret al [13] carried out an experimental investigation of heat transfer and friction factor characteristics of rectangular duct roughened with W shaped ribs.

Mr. YadaviandiBhagoria et al [10] carried out flow analysis of artificially roughened solar air heater provided with circular transverse wire rib roughness on the absorber plate.

Mr. Kumar et al [11] carried out an experimental investigation of heat transfer and friction in the flow of air in rectangular ducts having multiple V- shaped rib.

Mr. YadaviandiBhagoria, et al. [8] carried out numerical investigation on the heat transfer and fluid flow characteristics of fully developed turbulent flow having repeated transverse square sectioned rib roughness on the absorber plate.

2.5 Solar Photovoltaic Thermal Energy Collection System

Depending on the advantages, such as highly electric energy quality and cleanness, solar photovoltaic power generation has been the development direction of China and even world green energy. Now, important factors to affect or restrict the development of solar photovoltaic industry are low efficiency and high cost of photovoltaic power generation. From a traditional view, we only pay attention to the improvement of silicon or amorphous materials to improve the efficiency of the solar photovoltaic power generation; while the power generation efficiency of silicon batteries seriously depends on the temperature actually. According to statistics, the output power increases by 0.2-0.5% per 1k temperature decrease of the solar cell module [1]. General commercial solar cell has Photovoltaic conversion efficiency at 6-15%. The majority of unemployed solar radiation energy is absorbed by the cell and converted into heat energy except that the minor part is reflected. If the energy can be discharged timely and effectively utilized, energy saving will be notable. This solar photovoltaic/thermal (PV/T) system (or solar electric and thermal combination system) has been a new concept of the solar power generation in recent years, which has been concerned by scholars at home and abroad. Research and development on solar photovoltaic/thermal system.

Hegazy [2000] performed a broad examination of the warm, electrical, hydraulic and general performance of four sorts of level plate PV/T collectors. As in Fig. 2.18, these included: channel above PV as Mode 1, channel-underneath PV as Mode 2, PV between single-pass channels as Mode 3, lastly the twofold pass configuration as Mode 4.

Sopian et al. [2000] added to a twofold pass PV/T air collector (Fig. 2.19) for sun powered drying application. Sun powered cells were put between the glass spread and safeguard plate. The air first enters the channel made by the glass spread and photovoltaic board and next it enters the channel made between the photovoltaic board and back plate

Garg et al. [1991] exhibited an investigation of a PV/T air cross breed framework, this framework included a plane promoter and a level plat collector mounted with photovoltaic cell.

Tonui and Tripanagnostopoulos [2007] reported a change of heat extraction accomplished by adjusting the channels of PV/T air framework.

Sopian et al. [1996] introduced an enduring state recreation of the single and twofold pass joined photovoltaic warm air collector. The reenactments showed that the twofold pass photovoltaic warm collector has prevalent performance amid the operation.

Garg and Adhikari [1997] added to a reproduction model to examine the performance of single glass and twofold glass mixture photovoltaic warm air heating collector

Joshi et al. [2009] did an assessment of a mixture sun based photovoltaic warm vitality accumulation framework. Two sorts of PV module (glass to tedlar and glass to glass) were used to research.

Tripanagnostopoulos et al. [2002] displayed a crossover PV/T test model to examine the temperature impact on PV electrical effectiveness.

Tripanagnostopoulos [2007] likewise demonstrated (Fig.2.21) that the electrical productivity of PV module increments by 2% with the utilization of diffuse reflector.

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Sarhaddi et al. [2007] researched the warm and electrical performance of a sun oriented photovoltaic warm (PV/T) air collector.

3 EQUATIONS

INTRODUCTION

As pointed out before hybrid Photovoltaic/thermal (PV/T) solar framework produces power and heat all the while and produce a higher vitality change rate of retained solar radiation than run of the mill PV modules. PV cooling adds to enhanced PV electrical productivity and surrounding air dissemination is used as a basic mode for heat extraction. A photovoltaic-thermal (PV/T) air heater is a collector that consolidates thermal and photovoltaic frameworks in one single hybrid producing unit.

3.1 System Model

A commonly used photovoltaic module Siemens SP75, monocrystalline silicon solar cell has been combined with solar air heater having roughened absorber plate for consideration of analysis .The photovoltaic module consists of 36 solar cells arranged in 9×4 matrix connected in series (Fig. 3.2). Each cell has an effective area of 0.0139 m^2. The module is operated at maximum power point. The absorber plate is artificially roughened on the underside with continuous W-down ribs. Artificial roughness in the form of W-ribs is characterized by the main geometrical parameter, namely, relative roughness height (e/D_h), relative roughness pitches (p/e), and flow angle of attack (α).

$Nu=.0613(Re)^{0.9.79}(e/D_{h)})^{0.4487}(\alpha/60)^{0.1331)}{}_{\{exp(-0.5307(LN(\alpha/60))^{2)}\}}$

3.2 Performance Parameters

Table 3.2: Range of variable parameters:

Parameters	Value/Range
Angle of attack (α), degree	30-75
Relative roughness height (e/D_h)	0.018 – 0.034
Solar radiation intensity (I), W/m^2	500– 1000
Temperature rise parameter (ΔT/I), K-m2	0.001-0.025

$$Q_u = [I(\tau\alpha) - U_l(T_{pm} - T_i)]A_p \text{........(1)}$$

$$\eta_{th} = \frac{Q_u}{A_p I} \text{................................(2)}$$

$$P_{new} = V_{new} I_{new} \text{..........................(3)}$$

$$Nu = 3.35 * 10^{-5} Re^{0.92} \left(\frac{e}{D}\right)^{0.77} \left(\frac{\propto}{90}\right)^{-0.49} * exp^{[-0.61(Ln(\propto/90))^2]} \left(\frac{P}{e}\right)^{8.54} exp^{[-2.0407(Ln(P/e))^2]} \text{................(4)}$$

$$\text{Photovoltaic cell efficiency ratio} = \frac{\eta_{pv}}{\eta_{pvs}} \text{.........(5)}$$

Photovoltaic cell efficiency (□pv) is then calculated as:

$$\eta_{pv} = \frac{P_{new}}{I \times A_p} \text{.........................(6)}$$

Enhancement parameter

$$E = \frac{\left(Q_u + \frac{P}{\eta c}\right)_r}{\left(Q_u + \frac{P}{\eta c}\right)_s} \text{..................(7)}$$

4. RESULT AND DISCUSSION

4.1 Electrical Efficiency

In Figs. 4.1 and 4.2 the variety of cell effectiveness with temperature rise parameter for distinctive estimations of relative roughness hright (e/Dh) is indicated. It is seen that the greatest effectiveness is accomplished for estimation of relative roughness of 0.034. It is because of the way that an increment in relative roughness quality, results in breakage of the sub layer because of ribs, builds the rate of heat transfer by making neighborhood divider turbulence. Roughness geometry

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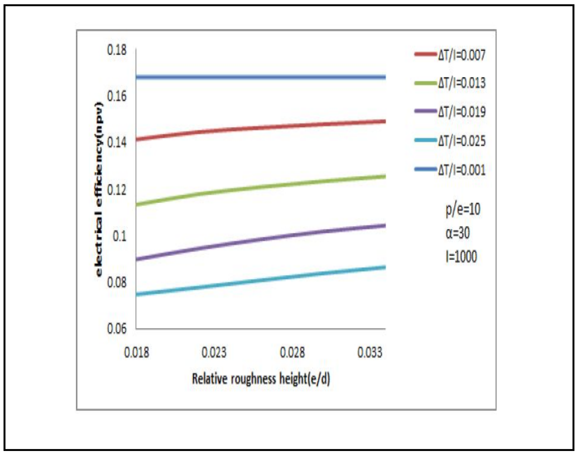
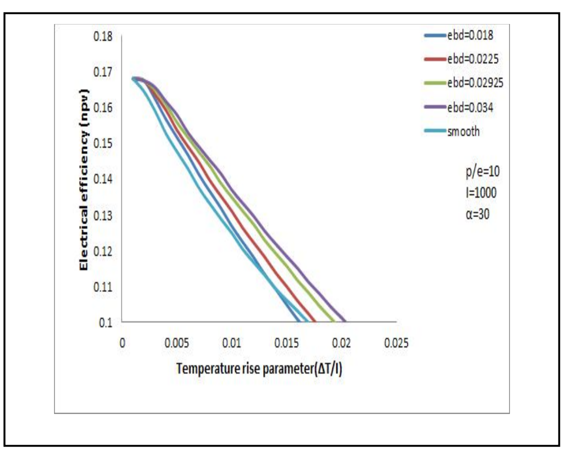
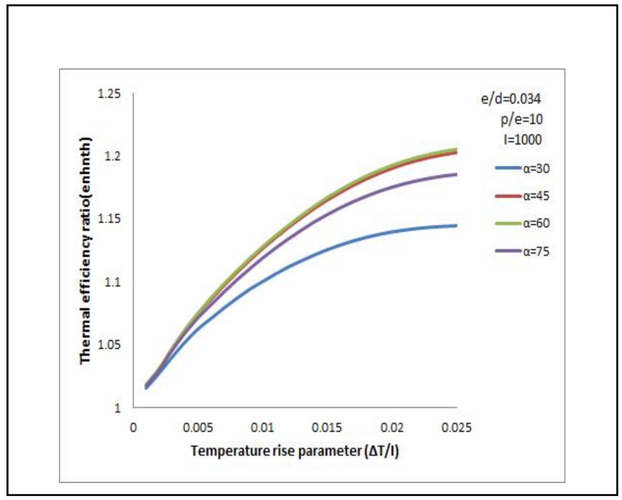
the thick sub-layer bringing on more turbulence, along these lines, bringing about expansion in electrical productivity.



The larger values of this ratio are seen to correspond to higher values of temperature rise parameters, the lower values of temperature rise represent very high flow rate where the effect of roughness almost vanishes because of relatively high heat transfer coefficient even with smooth absorber plate and under such condition, the heat transfer coefficient (as also the friction factor) become independent of surface condition





4.2 Enhancement in Thermal Efficiency

In fig show the enhancement in thermal efficiency (defined as the ratio of the thermal efficiency (η_{th}) of roughened solar air heater to thermal efficiency (η_{ths}) of the conventional smooth duct flat plate solar air heater) as function of temperature rise parameter ($\Delta T/I$) for fixed value of solar radiation intensity (I=1000 W/m^2).

As expected the maximum enhancement in thermal efficiency corresponds to value of relative roughness pitch (p/e) of 10 has been observed for the fixed values of relative roughness height, flow angle of attack and insolation. The value of enhancement increases with increase in temperature rise parameter and ranges from 1.025 to 1.34. It shows the variation of enhancement with relative roughness pitch for different values of temperature rise parameter.

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6.CONCLUSION

- 1.There is a significant improvement in enhancement of photovoltaic thermal collection system (PV/T) by providing different types of roughness elements on the absorber plate. Provision of roughness brings improvement in the cell efficiency depending upon the value of geometrical parameters of the roughness and design conditions.
- Thermal energy collection efficiency of the system has been found to increase the value that would have been obtained if no roughness was provided, the maximum enhancement corresponding to relative roughness pitch of 10, relative roughness height of 0.034 and angle of attack of 30^0.
- It has been found that enhancement of performance of both thermal energy collection and electrical power generation when artificial roughness is used, depends strongly upon the value of operating (design) parameters also. Maximum enhancements are obtained for highest temperature rise parameters (ΔT/I) and insolation values of 0.025 km^2/W and 1000 W/m^2 respectively in the range of parameters investigated.

TABLE 1

L	Length of the absorber plate
L_{pg}	Air gap between absorber plate and glass cover
$\dot{m}$	Mass flow rate
N	Number of glass cover
Nu	Nusselt number
β	Cell packing factor
p	Pitch of rib
P_m	Pumping power
P	Electrical power ouput
p/e	Relative roughness pitch
Pr	Prandtl number
q	Electron charge
Q_u	Useful heat gain
Re	Reynolds number
T	Temperature
T_a	Ambient temperature
Tcell	Cell temperature
t_e	Thickness of the collector edge
t_g	Thickness of glass cover
t_p	Thickness of absorber plate
T_{fm}	Mean bulk air Temperature
T_i	Inlet temperature of the air flow
T_o	Outlet temperature of the air flow
T_{pm}	Mean plate temperature
Δt	Cell temperature difference
ΔT	Temperature rise across the duct
ΔT/I	Temperature rise parameter
U_b	Bottom loss coefficient
U_s,U_e	Side/Edge loss coefficient
U_T	Top loss coefficient

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