International Journal of Engineering Inventions
e-ISSN: 2278-7461, p-ISSN: 2319-6491
Volume 11, Issue 10 [October. 2022] PP: 162-167

Study the effect of convex solar air heater with rectangular baffles on thermal performance

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Abstract

Sustainable solar energy may be converted into usable energy with the help of solar heater heating systems. Different designs for solar heaters have been developed to improve heat transmission when used to warm air or water. The primary goal of this effort is to improve the efficiency of a solar air heater that uses natural convection. Through computational fluid dynamics (CFD), the magnitude of a Nusselt number with varying heat fluxes was determined for a solar air heater with a convex form. Optimizing the pitch between two fins in a solar heater with a convex form to maximize heat transmission from the duct is also covered.

Date of Submission: 14-10-2022 Date of Acceptance: 30-10-2022

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1. Introduction

The sun receives an enormous amount of solar radiation, which may be used not only for thermal but also for electrical purposes. In order to kick off the transformation process, a solar collector is essential. Depending on the final energy or thermal use, a solar collector might be of the flat as well as concentrated form. For this reason, a solar collector is an appliance that uses the heat transfer liquid to transform the thermal energy of sunlight (water or air). Solar collectors could gather enough heat to meet energy needs immediately, or that heat can be stored for later use. Increasing the efficiency of solar collectors may help spread their usage in low-temperature heating applications, which would save significant amounts of energy. An energy balance on the solar collector's parts yields the instantaneous usable energy discovered by the collection. The physical qualities of the materials used in a solar collector must be taken into account in order to arrive at an accurate assessment of the energy generated. The energy receiver is exposed to sunlight, mostly in the form of short-wavelength light, through a transparent cover. In terms of transparency, low-iron glass excels. As a result, it is often employed since a glazing cover, as it significantly reduces heat losses. Natural convection solar air heaters rely heavily on the heat flux available on the absorber plate, from which the air draws energy and, thanks to the bouncing action, begins rising. As the name implies, natural convection solar air heaters rely mostly on convection to transfer heat, as opposed to sunlight. Natural convection, or the "chimney effect," is employed to boost the efficiency of solar air heaters. Here, ribs are employed internally in a solar air heater of convex shape to further boost its effectiveness. This study examines the impact of varying pitch ratios on solar air heater performance and uses the Nusselt number and heat transfer enhancement factor to determine optimal operating parameters. There was also an examination of how varying rib profiles can affect a solar air heater's efficiency. The impact of changing heat flow under various geometric constraints was also examined.

2. convex solar air heater

CFD simulation of flat plate slope solar air heater is validated, and then parametric simulation of curved form solar air heater is carried out. The 50-degree curvature radius of the convex form profile was addressed by Singh et al. while developing the 3D model of the convex solar heater. The impact of a solar air heater's convex and concave shapes at varying radii was studied by Singh et al., who concluded that a convex profile with a curvature of 50 degrees results in the highest heat transfer enhancement ratio. Because of this area, a heater with a convex profile of fifty degrees is used. Here, the Nusselt number is computed for a variety of heat fluxes and compared to the Nusselt numbers obtained by Singh et al. for the same heat flow in order to verify the convex shape profile solar heater study. The accompanying figure depicts a physical model of either a solar heater with only a convex profile.Nusselt number for a heat flow of 500 W/m2 on an inclined flat-plate collector. Below is a diagram depicting the pressure gradients and average velocity.Using contours, we can determine that the speed within the solar heater channel varies in a uniform and linear fashion, as seen in the preceding figure. Because of convective heat transfer, air velocity rises as it moves away out from base plate. The chimney is where the air, heated by the solar heater's absorber plate, exits. The pressure gradient within the solar air heater.According to the data shown in the preceding figure, the Nusselt number determined by computational fluid dynamics modeling for one convex solar air heater is quite similar to that determined by Singh et al. Because the % error is within the allowable range, we may conclude that the CFD study of the convex solar air heater is accurate. Therefore, the influence of changing pitch ratio and diverse form of ribs was investigated, and the heat transfer enchantment factor was determined for each instance of study, after the mathematical model for sloped and convex curved solar air heater had validated.

3. Repercussions of Varying Pitch Ratios

Here, ribs are employed within the solar duct to increase the heat transmission rate from the convex-shaped solar air heater. Ribs with dimensions of 0.03 m in width and 0.02 m in height are used for this purpose, with each pitch ratio being separately evaluated. Taking into account pitch ratios of 0.1, 0.075, 0.05, and 0.025 m, this study determines the Nusselt number for each ratio geometry for each heat flux.

Throughout this situation, the pitched proportion of 0.075 m (where pitch ratio = ribs' intermediate distance) was taken into account. As can be seen in the diagram under, a solar air heating model with a spacing of 0.075 m can be seen graphically. Both Nusselt number as well as the turbulence-causing airflow vector around the ribs are both calculated.

The 0.075 m pitch ratio ribs of the absorber plate were subjected to a heat flow of 500 W/m2. Nusselt number values for solar air heaters with flat inclined and convex shapes are found to be much lower than those with rectangular ribs with a pitch ratio of 0.075 m. Nusselt number for 0.075:1 pitch ratio is greater than that for 0.1:1 pitch ratio. The following diagram also displays the speed and pressure changes.

4. Analysis of pitch ranges

The impact of pitch ratio on heat transmission was measured and compared over a range of flux. See the table that follows for a discussion of both the Nusselt number values for various pitch ratios.

The employment of ribs inside the solar air heater, as shown in the diagram above, improves the efficiency of the device at transferring heat. There is an increase in the Nusselt number for the solar air heater as compared to a standard convex solar collector because of the ribs. Heat transmission from a solar heater is maximized at a pitch ratio of 0.05 m, as shown in the above graph. The difference between a pitch ratio of 0.075 and 0.025 is hardly imperceptible. The graph demonstrates that the most heat is transferred from a convex solar air heater with rectangular ribs spaced at a pitch ratio of 0.05 m. Heat transfer enhancement factor (HTEF) was used to determine how much more efficiently heat could be transferred from the solar air heater's convex to its flat surface by utilizing ribs within the heater's convex form.

For calculating the HTEF following calculation was done.

$$H \qquad = \frac{N_{p \quad hr}}{N_{si \quad c}}$$

Based on the data shown above, it seems that a pitch ratio of 0.05 m results in the greatest improvement in heat transmission. It has been determined via study that a solar air heater with a 0.05 pitch ratio is more effective than one with a different pitch ratio. We can also observe from the figure above that the HTEF values for 0.075 and 0.025 m pitch are extremely similar to one another, but the values for 0.1 and 0.05 m pitch are considerably different from one another.

5. Conclusions

CFD testing shows that the value of the Nusselt number for a solar air heater with a pitch ratio of 0.05 m is much higher than for any other pitch ratio of ribs, indicating a greater heat transfer rate. The heat transmission capacity of a convex sun heater with ribs is much greater than that of a standard convex shape profile solar heater. Adding ribs to a solar air heater improves heat transmission by a factor of four to five compared to a conventional convex design. With a pitch ratio of 0.05 m, the turbulence between the ribs is much more than it is with other ratios, leading to a greater increase in heat transmission. The CFD research shows that the best shape for maximal heat transmission from the duct in a solar air heater is a pitch ratio of 0.05 m.

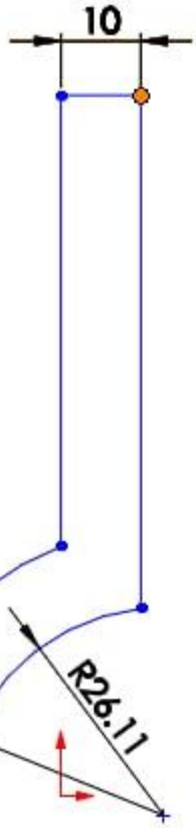

Fig.1 solid model of solar heater with convex profile

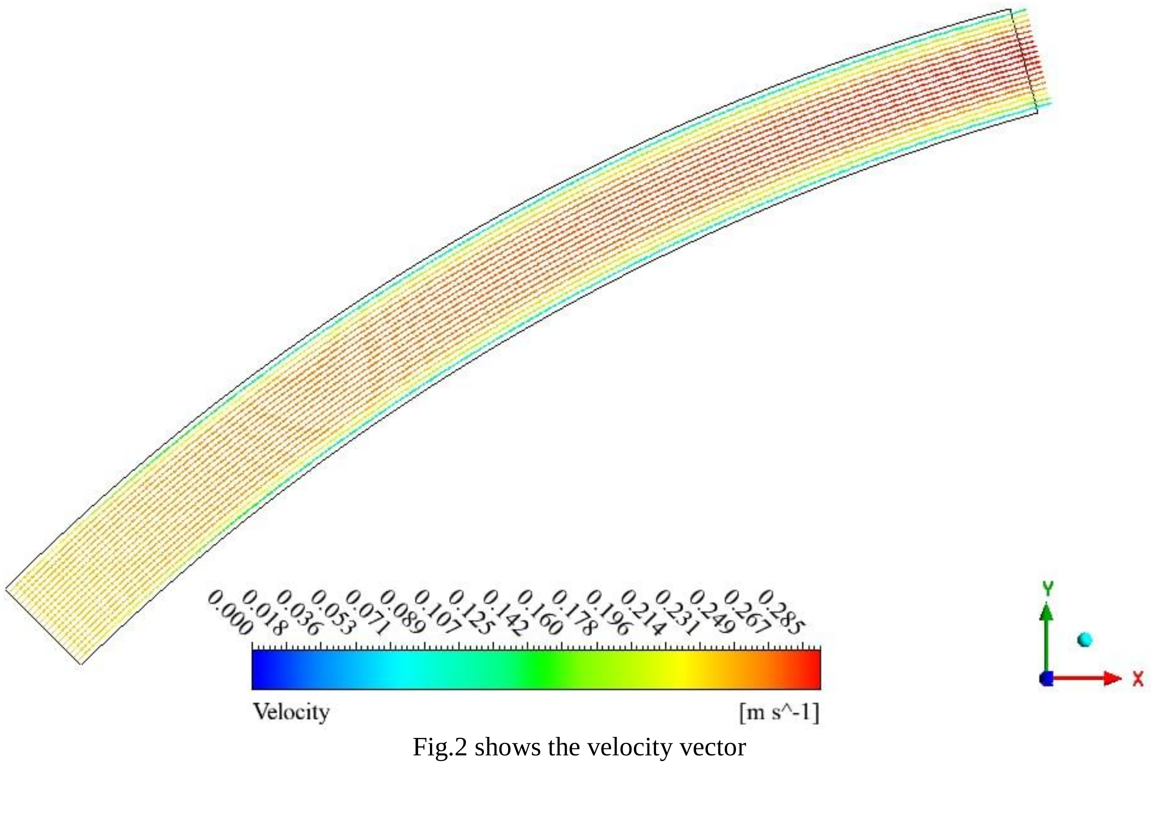

Fig.2 shows the velocity vector

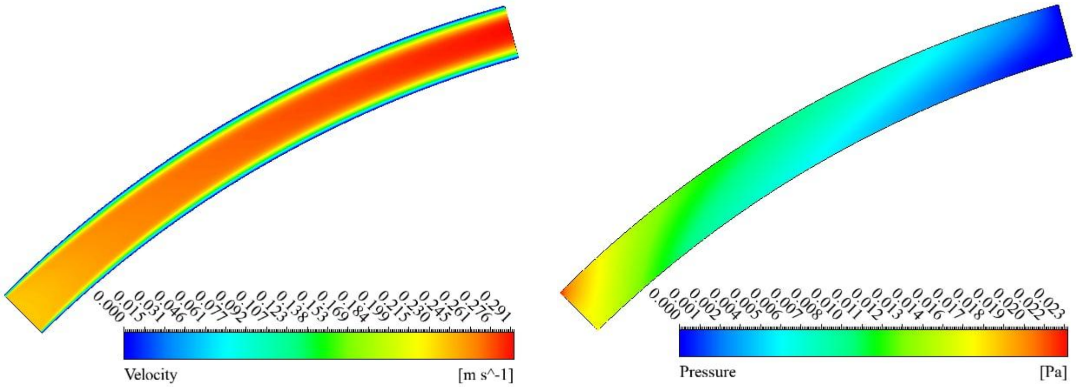

Fig.3 shows the pressure and velocity variation inside the solar air heater

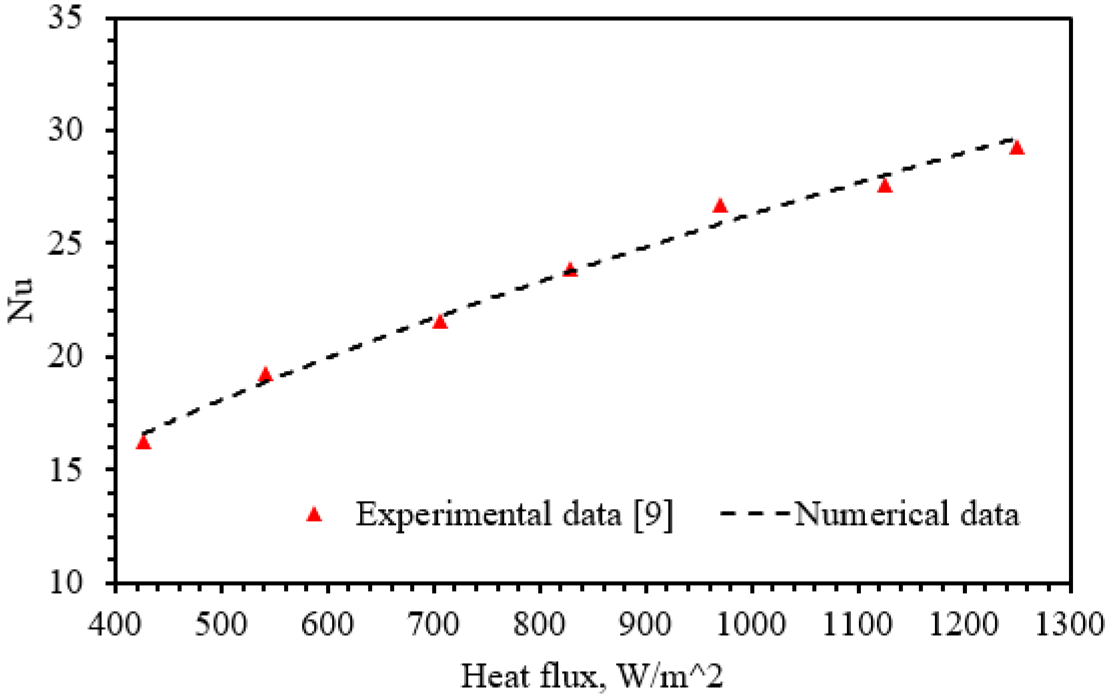

Fig.4 comparison of value of Nusselt number for convex shape solar air heater

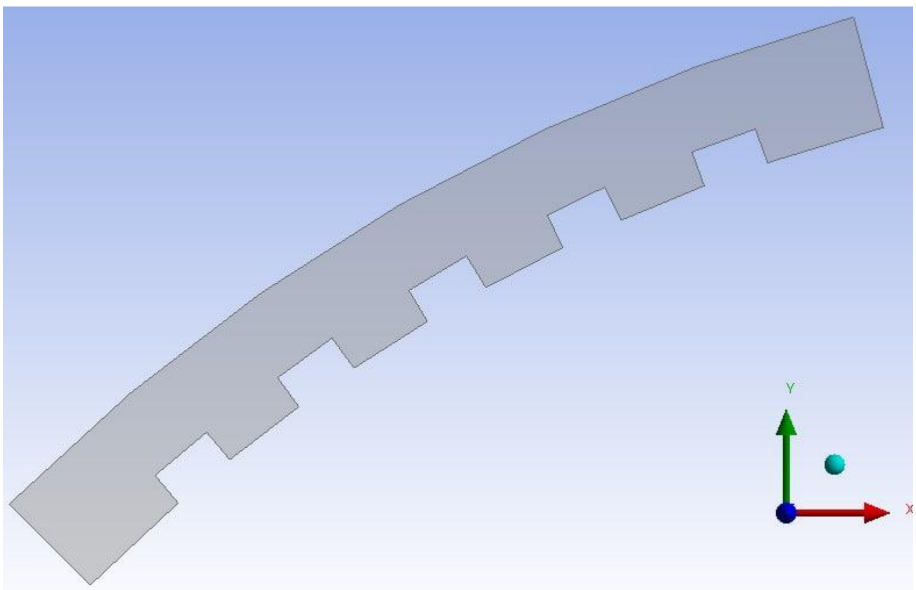

Fig.5 solid model of solar air heater having rectangular ribs with 0.075 m pitch ratio

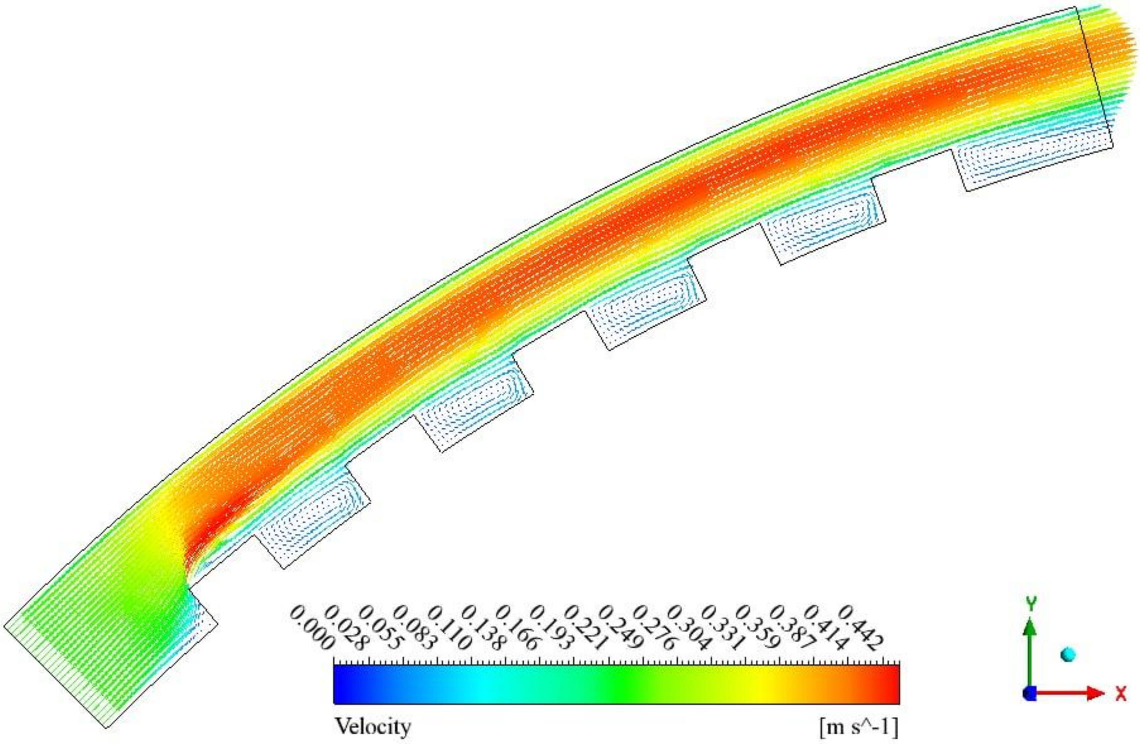

Fig.6 variation and flow behavior of velocity vectors

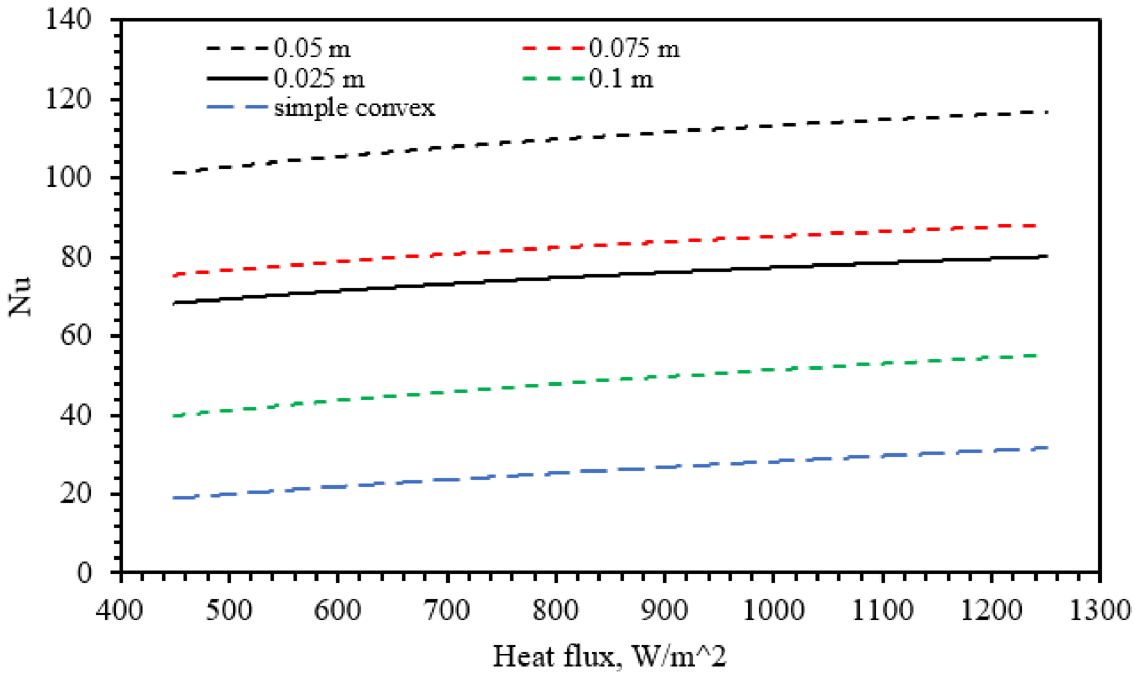

Fig.7 comparison of value of Nusselt number for different pitch ratio

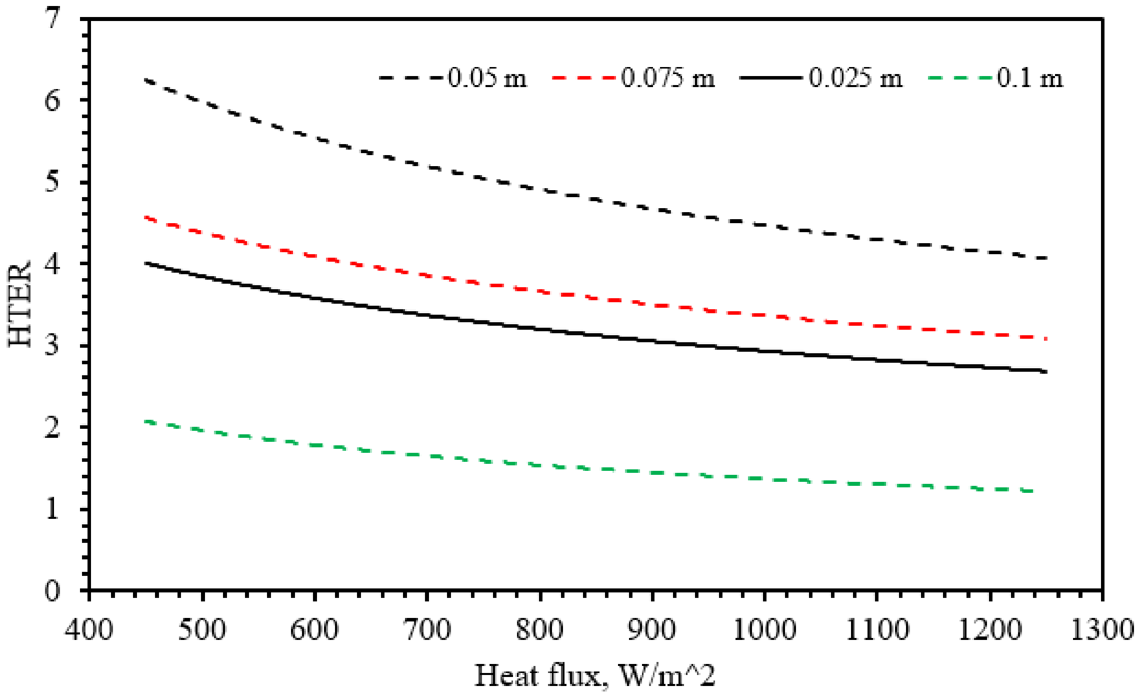

Fig.8 value of heat transfer enhancement factor for different pitch ratio

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