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Theoretical Research of Efficiency of Air Solar Collector with Finned Absorber

Mincho S. Minchev[1*], Atanas I. Tashev[1], Dimitar G. Atanasov[1]

[1]*Department of Industrial Heat Engineering, Technical Faculty, University of Food Technologies, Plovdiv, Bulgaria*

***Corresponding author**: Prof. Mincho Stoianov Minchev, PhD; Department of Industrial Heat Engineering, Technical Faculty, University of Food Technologies, 26 Maritza Blvd. BG-4002 Plovdiv, Bulgaria, tel.: ++359 32 603* 680*; mobile:* ++359894337984*; E-mail:* minchev_m@abv.bg

Running title: **Efficiency of Air Solar Collector**

Abstract

The thermal efficiency of air solar collectors is an important indicator, which determines the effectiveness of the entire solar thermal system they are connected to. It depends mainly on the operating conditions (intensity of solar radiation, air temperature, air velocity in the collector, velocity of the wind), but also on the geometry of the air channel. In this study, the influence of the velocity of the heated air and the height of the fins on the efficiency of air solar collector with finned absorber has been evaluated by a mathematical model. From the results obtained, it can be seen that the increase in velocity value from 2 to 10m/s results in an increase of the optical efficiency of the air solar collector from 65% to 73%. The increase the height of the fins from 15 to 30mm leads to an increase in the efficiency from 65% to 69%, respectively. The resultant values of the efficiency are presented graphically as a function of the $\Delta T/G$ ratio over the entire range of the test. The results of the model study are validated by comparing with experimental data. The difference does not exceed 5%.

Practical applications

The results of this study can be used to optimize the operating conditions and the geometric dimensions of air solar collectors with finned absorber in order to achieve maximum efficiency.

Key words: air solar collector, efficiency, finned absorber, modeling

Introduction

Air solar collectors are used as a heat source for the air heating systems in buildings, for the drying of agricultural products and for the timber seasoning (Saxena et al., 2015). The search for ways to improve the thermal efficiency of air solar collectors is important for a more efficient utilization of the solar energy worldwide. Air solar collectors have the following major disadvantages: a low heat transfer coefficient from the absorber to the heated air, and a low thermal capacity of air. One way to improve the efficiency of air solar collectors is by increasing the heat exchange surface between the absorber and the heated air. Many researchers have published their results of theoretical and experimental studies on the effectiveness of air solar collectors (Tchinda 2009). Garg et al. (1991) have conducted an experimental analysis of four types of air solar collectors with fins between the absorber and the rear plate. The efficiency obtained of the test specimens is in the range 45-61%. It has been found that it grows by increasing the number of fins and decreasing the height of the air channel. Matrawy (1998) has developed a mathematical model of air solar collector with metal vanes attached between the absorber and the bottom plate. He also compared the effectiveness of a collector with a finned absorber and the effectiveness of one without fins (box frame absorber). A theoretical analysis and an experimental study of the effectiveness of air solar collector with finned absorber have been carried out by Chang et al. (2015). The influence of the air inlet mode, the setting angle and the medium flow on air solar collector performance has been analyzed. The difference between the calculation model and the experimental results does not exceed 9%. Pottlet et al.(1999) have conducted a theoretical study to optimize the geometry of three types of absorbers for air solar collectors: smooth absorber without fins, absorber with offset strip fins and one with continuous fins. The results indicate that the optimization of the geometry in the collector with continuous fins leads to an increase of efficiency by approximately 12% compared to a standard geometry. The purpose of this study is to evaluate the influence of the air flow velocity and the height of the fins on the efficiency of an air solar collector with finned absorber.

Materials and Methods

A scheme of the solar collector for heating the air, with a finned absorber, is presented in Figure 1. The inlet air flows into the space between the absorber and the bottom plate of the insulated collector. The heat flows included in the calculation algorithm are illustrated in the figure. The calculation of the efficiency of the collector is based on the following energy balances:

1. Energy balance of the air channel
2. Energy balance of the absorber
3. Energy balance of the glass cover

The incident solar radiation on the collector, the heat gains and all convective and radiative heat flows, indicated in Figure 1, are included in the equations of energy balances. The solution of the equations of the model and the computational algorithm are described in a previous article (Minchev et al.,2016). In the present model study, an evaluation of the influence of the air flow velocity and the height of the fins on the efficiency of the air solar collector has been made. The considered air solar collector has the following geometric dimensions: length of the absorber 1250mm, width of the absorber 400mm, thickness of the fin 0,4mm, distance between the fins 20mm, number of fins 19. The air flow velocity values that were set were 2,3,4,6,8 and 10m/s at the height of the fin (and the air channel) 20mm. The values of the height of the fin, for which the model study was conducted, were 15,20,25 and 30mm at a fixed air flow velocity of 3m/s. The efficiency of air solar collector is presented as a function of the Δt/G ratio, where $\Delta t = t_{in} - t_{out}$, K is the difference between the average air temperature in the collector and the outside temperature and G, W/m^2K is the global solar radiation falling on the plane of the collector.

Results

The results obtained are presented in Fig.2 and Fig.3. The values of efficiency that have been obtained can be described most accurately with a second order polynomial. It can be seen that the increase in velocity value from 2 to 10 m/s results in an increase of optical efficiency of the air solar collector from 65% to 73%. Increasing the height of the fins from 15 to 30mm leads to an increase in efficiency from 65% to 69%, respectively. The efficiency curves are parallel to each other, which means that the rise of efficiency will be the same for all the values of the Δt/G ratio in the studied range.

Discussion

The increase of the air flow velocity results in an increase of the heat transfer coefficient between the absorber and the heated air. The increase in the mass flow rate reduces the difference between the inlet and outlet air temperature. Both lead to an increase in the efficiency of the collector. On the other hand, the higher air velocity inevitably causes an increase in pressure drop and a higher consumption of electricity. From the presented results, it can be seen that the increase of the velocity from 2 to 3m/s, results in efficiency growth by 3% (from 65 to 68%). The increase of the velocity from 3 to 4m/s leads to an increase of efficiency by 2%, and from 4 to 5m/s - 1.5%, respectively. For velocity values greater than 5m/s, the growth of efficiency is less than 1%. Considering these results, we could recommend the use of velocities that are not higher than 4 m/s, due to high friction losses and low efficiency gains. The increase of the height of the fin from 15 to 20mm causes an increase in the efficiency of 2% and at 25 and 30 mm, the growth was by 1%. The height of the fin is related to the height of the air channel, and to the cross section of the collector, respectively. Therefore, when selecting the height of the fin, we must take into consideration the mass flow rate of the heated air. However, we recommend the height of the fin not to be less than 20mm. If the collector is used as a heat source to a dryer, it is necessary that the air be heated to a higher temperature. In this case, the high air velocity (the high mass flow rate value, respectively) is not appropriate, except when there is a recirculation of the drying air. If the collector is used for heating buildings, small temperature difference is acceptable, since it reduces the average air temperature in the collector and heat losses, respectively. In order to achieve the maximum efficiency of air solar collectors, it is necessary to optimize working conditions and geometric dimensions of the collector for each specific case.

Validation of the model

The simulation results for the efficiency of the air solar collector were verified by their comparison with experimental data, obtained under the same conditions. The experimentally tested air solar collector has the same geometric dimensions as described above. It is shown in figure 4. It was found that the model has the ability to predict the performance of the air collector accurately. The difference in the percentage between the results is less than 5%, which is within the acceptable limit. The comparison is presented in fig. 5.

Conclusions

In this paper, the influence of the air flow velocity and the height of the fins on the efficiency of an air solar collector with finned absorber has been evaluated. Considering the results, we can make the following conclusions and recommendations: The air flow velocity into the collector should not be higher than 4m/s, due to the high frictional losses and the low increase in thermal efficiency. When selecting the height of the fin, we must take into consideration the mass flow rate of the heated air, but it is better not to be less than 20mm.

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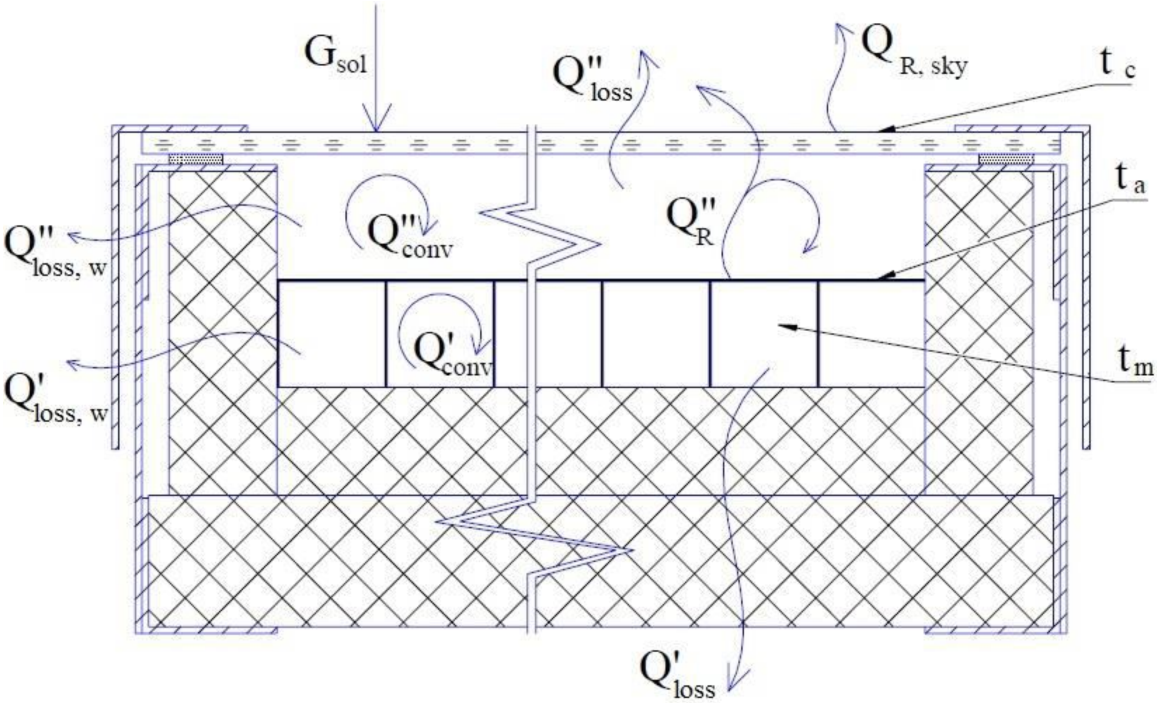

Figure.1. A scheme of an air solar collector with finned absorber and the heat flows, included in the calculation algorithm.

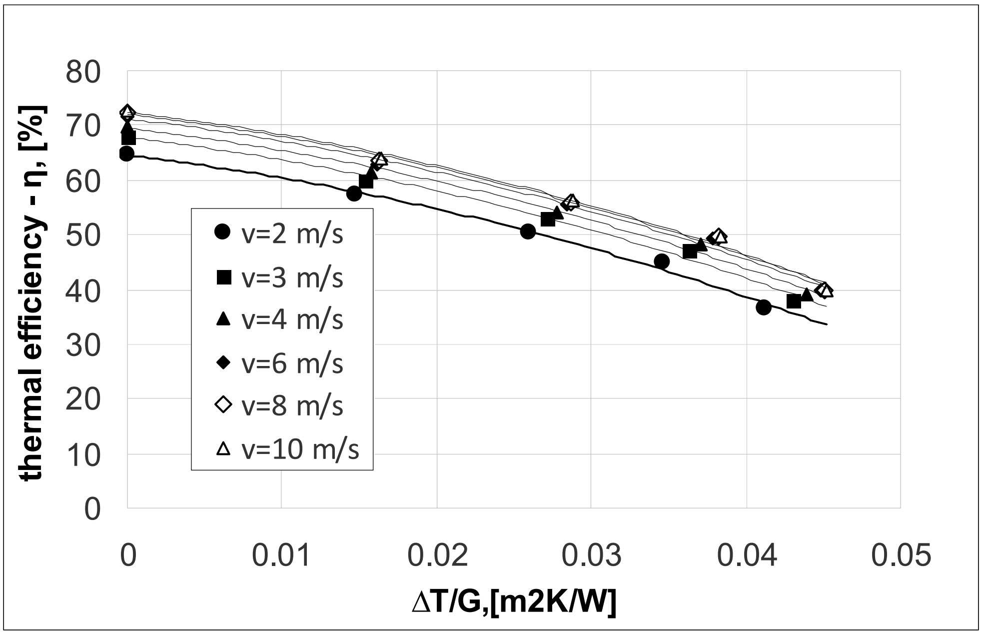

Figure 2. The influence of the air flow velocity on the efficiency of the air solar collector.

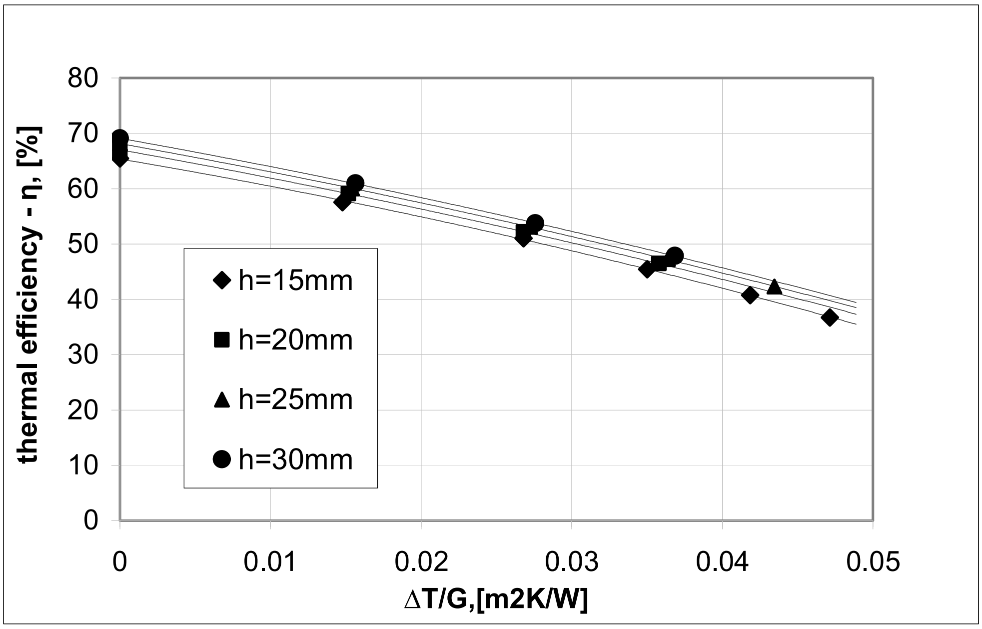

Figure 3. The influence of the height of the fins on the efficiency of the air solar collector.

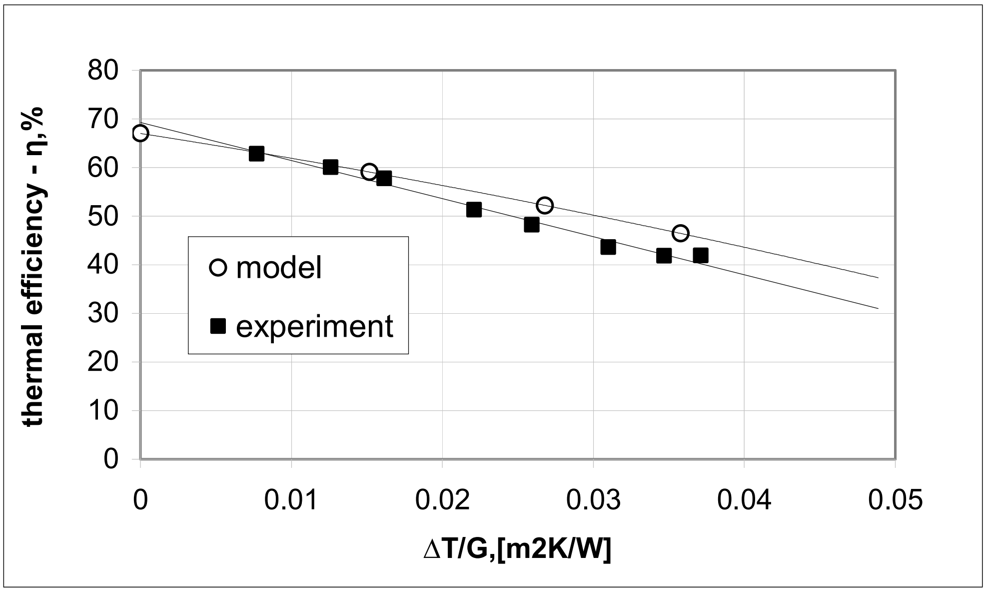

Figure 4. A comparison of the simulation results and the experimental data.

Figure 5. The experimentally tested air solar collector.