ТЕХНИЧЕСКИЕ НАУКИ

APPROXIMATE MODEL OF HEAT EXCHANGE AND SOLAR ENERGY EFFICIENCY IN A FLAT SOLAR AIR HEATER UNDER CONDITIONS OF NATURAL CONVECTION.


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ABSTRACT:
The article proposes a model of heat exchange between the absorber and the heating air layer in the flat structure of the solar air heater. The model used the calculated ratios for the boundary layer developing under conditions of free convection and the heat balance equations compiled for the air layer.

Key words: Solar heaters, air, collector, energy, heating, heat transfer, absorber, temperature, laminar.

Solar air heaters are devices that convert the energy of solar radiation into heat energy of heated air. Such devices are operated, as a rule, under conditions of natural convection and are used for heating private houses and are used in drying installations of farms. Given that these collectors are easy to manufacture, are not susceptible to corrosion, and also do not require the cost of pumping air, such devices have prospects for widespread use by the public. [1] Solar energy is one of the most useful renewable energy resources without any adverse effects on the environment. Solar energy is widely used for generating electricity, heating and various industrial applications. Solar air heaters are simple in design and generally used as solar thermal collectors. Solar air heaters are inexpensive and the most widely used collection devices because of their inherent simplicity. These air heaters absorb the irradiance and exchange it into thermal energy at the absorbing surface and then transfer this energy to a fluid flowing through the collector. An absorber plate is usually a thin metal sheet coated with an absorbing substance such as black or selective coating to absorb solar radiations. The glazing provides a rigid, protective structure for the entire collector assembly. Insulation beneath the absorber and fluid flow passages inhibits downward heat loss. Solar air heaters are found in several solar energy applications, especially for space heating, timber seasoning and agriculture drying.[2]

The air, which is stationary, in the form of a layer in the channel of the air manifold heats up over time, its temperature increases and gradually the air layer starts to move. As a result, a heated air flow is formed at the outlet of the collector, later used as a heat carrier.

One of the important tasks arising from the use of flat solar air heaters are the tasks of determining the air temperature at the exit of their collector and its efficiency.

The purpose of the article is to develop a model of heat exchange between the wall of the absorber and the air in the collector channel and to develop a formula for the efficiency of the solar heater.

The concept of efficiency, according to the authors, should be understood as its thermal efficiency, i.e. the degree of heating of the air leaving the heater. To solve this problem, a model of heat exchange between a flat wall and the absorption of solar energy and air was used.

When developing the model, the following assumptions are made:

- the developing boundary layer is the main thermal resistance between the absorber and the main air layer.
- the air in the channel consists of two layers; the first layer is formed under the action of lifting forces and is a free convective laminar boundary layer, the second layer is a fixed air layer, heated by heat transfer by thermal conductivity from the boundary layer.

Figure 1 shows the scheme of heat transfer in a flat solar air heater.

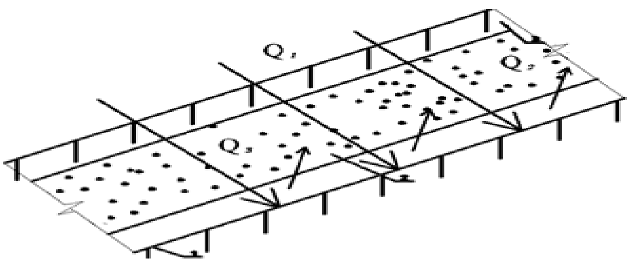

Fig.1 *Scheme of heat transfer in a flat solar air heater*

Q_1, Q_2, Q_3 -, respectively, the thermal energy of solar radiation incident on the surface of the heater Watt, thermal energy transferred to the boundary layer from the absorber wall Watt and thermal energy transmitted from the boundary layer to the fixed air layer Watt. 1 - absorber, 2 - air layer

The efficiency of the heater E is determined by the formula

$$E = \frac{\Sigma Q}{Q_1} \qquad (1)$$

$$\Sigma Q = Q_2 + Q_3 \qquad (2)$$

The heat flux absorbed by the boundary layer **Q_2** can be calculated using the formula recommended in [3].

$$Nu_x = 0.36(Gr_x \mathrm{Pr})^{1/4} \qquad (3)$$

$$\alpha_x = 0.36\left(\frac{\lambda}{d_э}\right)(Gr_x \mathrm{Pr})^{\frac{1}{4}} \qquad (4)$$

$$\overline{\alpha} = \left(\frac{4}{3}\right)\alpha_x \qquad (5)$$

$$Q_2 = \overline{\alpha} F \Delta t_1 \qquad (6)$$

where $\Delta t_1 = t_{ст} - t_0 F = aL$, here a and **L** are the width and length of the absorber m. $\overline{\alpha}$ is the average heat transfer coefficient from the wall of the absorber to the air boundary layer W/m^2 C^o.

$$Q_3 = (M_{сл}/\tau) C_p \Delta t_2 \qquad (7)$$

where $\Delta t_2 = t - t_0$ t is the temperature of the air layer, which increases with time τ.

To calculate the heat transferred from the boundary layer to the air layer **Q_3**, it is necessary to calculate the temperature **t** characterizing the degree of heating of air in a flat channel. The specified temperature can be determined from the heat balance equation recorded between the amount of heat transferred from the boundary layer to the air layer. We assume that the laminar boundary layer is a narrow layer of the same thickness and there is an ideal contact between the air layer and the boundary layer. Then the heat balance equation at the boundary layer boundary - the main air layer has the form

$$qF = Q_3 \qquad (8)$$

Here **q** is the heat flux density from the boundary layer to the main air layer W/m^2 .

$$q = \frac{\lambda dt}{dx} = \lambda(t_{пс} - t_0)/(\frac{h}{2} - \delta) \qquad (9)$$

Here $t_{пс}$ is the average air temperature across the boundary layer.

h is the height of the channel heater m.[4]

From the balance equation (8) we obtain the expression for the temperature of the air layer

$$t = t_0 + \lambda(t_{пс} - t_0)\tau/(\frac{h}{2} - \delta)^2 \rho C_p \qquad (10)$$

The average air temperature across the boundary layer can be calculated according to as

$$t_{пс} = t_0 + (t_{ст} - t_0)/3 \qquad (11)$$

To calculate the efficiency of a flat solar air heater, we will take the following sequence of calculations:

- With the known power of the incident solar radiation **Q_1**, the temperature of the absorber $t_{ст}$, the initial temperature of the air t_0 the formula (10) is calculated over the cross-section of the air temperature in the boundary layer;

- Calculate the heat flux from the absorber wall to the boundary layer **Q_2** using the formula (6) For a given time of air heating, the heat flux transferred from the boundary layer to the fixed air layer **Q_3** is calculated using the formula (7); Calculate the total heat flux **ΣQ** by the formula (2); Based on the known power of solar radiation **Q_1**, the thermal efficiency **E** is calculated using formula (1).[5]

For the conditions of the city of Fergana (Republic of Uzbekistan) in August 2018, full-scale tests of a flat solar air heater having the following geometrical dimensions $a = 0{,}5$ м$L = 1m$ were carried out. The height of the solar collector channel was 0.05 m.

Experiments were conducted on August 27, 2018 from 9^{00} to 18^{00} hours. Were measured: the air temperature at the inlet to the collector $t_0 = 26$ C^0 and the air temperature at the exit of the collector $t' = 36$ C^0. The average power of solar radiation during the day **Q_1** was 410 W / m^2.

Figure 2 - 3 shows the results of calculating the average heat transfer coefficient from the absorber to the air boundary layer, the average cross-sectional temperature of the air in the boundary layer, the air layer temperature and the efficiency indicator of a flat stove operating in free convection.

Findings:

1. A model is proposed for heat exchange between the air layer and the absorber in a flat solar air heater operating in free convection;
2. The efficiency of a flat stove with free convection is calculated;
3. It was concluded that to increase the thermal efficiency of the heater, it is necessary to organize the intensification of the convective heat exchange process at low Reynolds numbers.

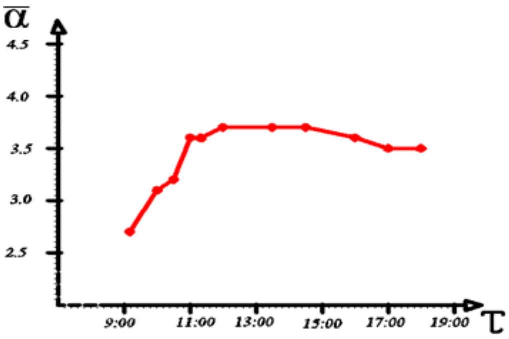

Fig.2 *Heat transfer coefficient from the absorber wall to the boundary layer*

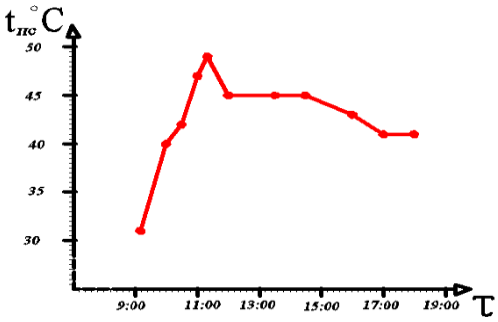

Fig.3 *Average cross-section of air temperature in the boundary layer formula (10)*

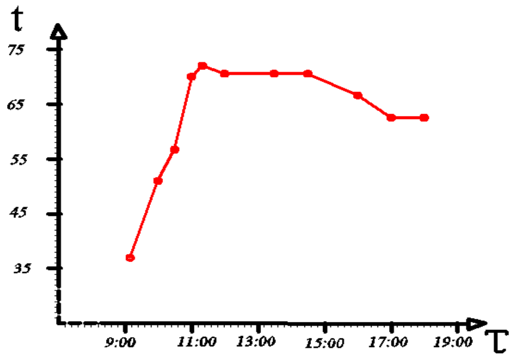

Fig.4 *Air layer temperature*

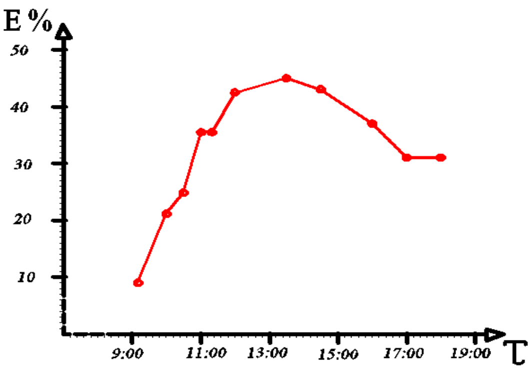

Fig.4 *Thermal efficiency of the air heater E, formula (1).*

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