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Hydrodynamic Analysis of Air Solar Collectors

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ABSTRACT: This article describes the development of a new type of solar air collectors with concave triangular air channels. Also, analyzes of the calculation method of their main parameters are given: Factors that influence the heat transfer processes in the working chamber of the collector, including the order of air movement, air flow in the channels, the design of the heated surface, and the acceleration of the heat transfer process.

KEYWORDS: Sun rays, convective heat transfer, absorber, molasses, laminar and turbulent movements, pressure, boundary layer.

I.INTRODUCTION

The sun is the most powerful and optimal source of clean energy. World energy demand is constantly growing, which leads to an increase in the weight of the use of alternative energy sources. In this regard, the sun is one of the richest sources of energy and practically never runs out. Energy efficiency and solar energy technology are considered as an important element in providing buildings and industrial facilities with all kinds of energy. Solar energy, obtained in the form of radiation, can be converted into direct or indirect energy into other forms of energy, such as heat and electricity.

The use of solar air heaters is the easiest way to convert sunlight into heat energy. These types of heaters are cheaper than other types of heaters. Furthermore, these solar heaters are widely used because of their simplicity of the structure. Solar air heaters are mainly used for heating rooms with air and drying agricultural products. In a forced-air heating system, the solar collector collects direct and diffused solar rays in the form of heat when the solar rays arrive, and directs thermal energy to the desired place.[1]

From the results of a literature study, it can be noted that the convective heat transfer rate can be increased by increasing the heat transfer surface affected by the air flow, or by increasing the convective heat conductivity coefficient from the heated surface. It is necessary to establish the optimal turbulent flow regime to increase thermal conductivity and, accordingly, reduce the size of the solar radiation heater, its mass or increase its heat capacity in previous measurements and increase heat transfer through the air stream from the surface of the absorbing radiation. This task was performed using artificial turbulence that profiles the surface of the sunlight receiver, placing recesses or gaps on the surface of the light receiver.[2]

II. DEVICE CHARACTERISTICS.

Static condition of the newly developed triangular channel flat solar air heater:

A model of a triangular channel flat solar air heater has been developed. The length of the device is l = 800 mm, width a = 400 mm, height h = 62 mm (Fig. 1). The heated air outlet (1) of this solar air heater is installed in the center of the solar air heater in width and above the center in height, and the diameter of the heated air outlet pipe is d = 20 mm.

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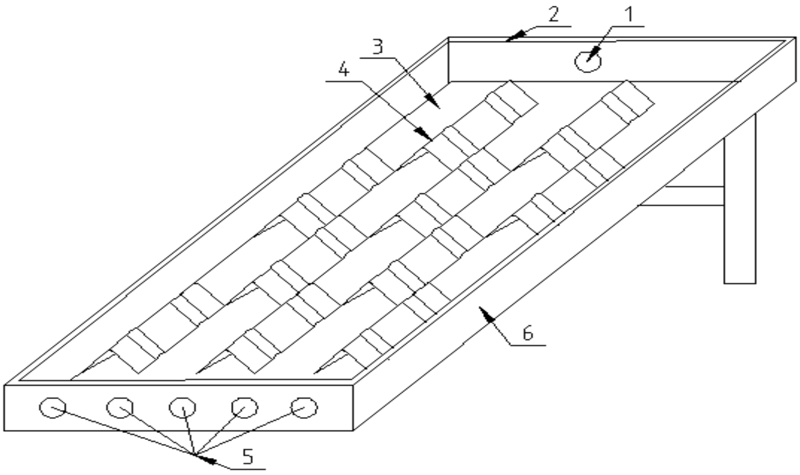

Figure 1.Scheme of triangular hollow channel solar air collector

1-air outlet, 2-windows, 3-darkened metal surface (absorber), 4-air channel, 5-air intake vents, 6-corpus

The dynamic condition of a triangular channel flat solar air heater:
The working principle of this solar air heater is as follows. As a result of sunlight on the working surface of the collector, the absorber (3) heats up and sucks air out of the heated (1) pipe of the collector with the help of an suction fan. The collector receives air flow from the outside environment along the working surface in an amount equal to the consumption of heated air through the air intake pipes (5). This air flow increases its temperature under the influence of convective heat exchange. Convective heat exchange takes place on the working surface of the absorber (3) and along the inner and outer surfaces of the triangular channels (4). The internal convex geometric shape (Fig. 2) given to the triangular-shaped air canals serves the function of forming a cyclone.

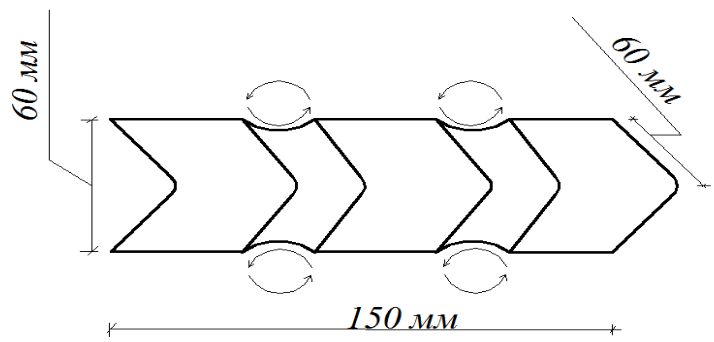

Figure 2. Scheme of a channel which gives circulation to air

The thermal insulation layer (7) between the absorber and the corpus of the solar air heater prevents heat loss from the heated absorber and promotes the transfer of existing heat to the air.

The thermal conductivity of the corpus of the solar air heater (6), consisting of low-porosity plastic, ensures that there is no heat loss in the working chamber of the collector.

III. METHOD OF THEORETICAL ANALYSIS

According to the analysis of the flow, it can be divided into a boundary layer on the channel surface and an external flow. The boundary layer plays a key role in dynamic and heat transfer processes with a washable flow body. The loss of energy is determined by the phenomena of interruption in motion and the failures arising from them.[3]

Based on the research work, the laminar boundary layer is represented as follows. [4]

$$\frac{\partial}{\partial x}(\rho V) + \frac{\partial}{\partial y}(\rho V) = 0 \qquad (1)$$

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$$\partial U\frac{\partial U}{\partial x}+\rho V\frac{\rho U}{\partial y}=-\frac{\partial P}{\partial x}+\mu\frac{\partial^2 U}{\partial x^2} \qquad (2)$$

$$\rho U s_\rho\frac{\partial T}{\partial x}+\rho V s_\rho\frac{\partial T}{\partial y}=\lambda\frac{\partial^2 T}{\partial y^2} \qquad (3)$$

$$\rho U_\omega=0,\ T=T_\omega(y=0) \qquad (4)$$

$$U=U_\infty,\ T=T_\infty(y=\infty) \qquad (5)$$

The following symbols are derived from these equations: ρ – the density of heat carrier (air); U, V – the longitudinal and transverse components of the velocity of the flow; U_ω, U_∞, - the flow temperature at the channel wall and at a certain distance from it; T – the flow temperature; T_ω, T_∞ - the flow temperature in and out of the channel wall; s_ρ– the specific heat capacity; λ– the heat capacity. We will re-express the equation of the law of mass compression for taking into account the effect of pressure and friction gradient on heat transfer.

$$\rho U_\infty, S=const \qquad (6)$$

$$\rho\frac{\partial U_\infty}{\partial x}+U\frac{\partial S}{\partial y}=0 \qquad (7)$$

$$\frac{\partial U_\infty}{U_\infty\partial x}+\frac{\partial S}{S\partial x} \qquad (8)$$

$$S=(a-\delta^*)b \qquad (9)$$

Of these formulas A and B are the height and width of the profiled channel. Given the similarity of the air channel to the diffuser-confuser, and by determining the angle of opening of the duct through U, we obtain. [5]

$$\frac{x\partial U_\infty}{U_\infty\partial x}=\frac{xdS}{SdS}=\frac{xd(a-b^*)b}{(a-b^*)bdx}=\frac{x}{(a-b^*)bdx}\left[\frac{da}{dx}-\frac{d\delta^*}{dx}\right] \qquad (10)$$

$$a=a_0+xtg\gamma \qquad (11)$$

$$\frac{x\partial U_\infty}{U_\infty\partial x}=\frac{xdS}{SdS}=\frac{xd(a-b^*)b}{(a-b^*)bdx}=\frac{x}{(a-b^*)bdx}\left[\frac{da}{dx}-\frac{d\delta^*}{dx}\right] \qquad (12)$$

$$\frac{x\partial U_\infty}{U_\infty\partial x}=\frac{x}{\partial x(a-b^*)}=\frac{xtg\gamma}{a-\delta^*}) \qquad (13)$$

The extrusion thickness of the boundary layer is expressed by the modifiers η of the auto-model δ:

$$\delta^*=\eta\frac{x}{\sqrt{Re}} \qquad (14)$$

$$\eta\frac{x\sqrt{Re}}{x}\int_0^y(1-\frac{\rho U}{(\rho U)_\infty})dy \qquad (15)$$

$$d\delta^*=\eta\frac{1}{2}\frac{1}{\sqrt{Re}} \qquad (16)$$

$$\frac{dP}{dx}=-\left(\frac{xdU_\infty}{U_\infty dx}\right)=\frac{x\eta\frac{1}{2}\frac{1}{\sqrt{Re}}}{a-\eta\frac{x}{\sqrt{Re}}}=\frac{xtg\gamma}{(a-\eta)\frac{x}{\sqrt{Re}}}\frac{\frac{1}{2}\eta}{\frac{a\sqrt{Re}}{x}-\eta}\frac{tg\gamma}{\frac{a\sqrt{Re}}{x}-\eta} \qquad (17)$$

Heat transfer also occurs depending on the pressure in the diffuser-confuser channels to dissolve the friction mass in the channels. [6.7.8]

According to studies, there can be three types of coolant movement in the receiving devices: continuous, pre-intermittent and intermittent. The current can be laminar and turbulent. To solve the boundary layer problem, you can use the following method. We accept the following deviations; Structural methods for solving problems of the boundary layer in a free-form profile in which the flow is stable and cannot be compressed by air without two-dimensional heat transfer of the flow are based on solving the momentum equation.

$$\frac{d\delta^{**}}{\partial x}+\frac{dV_0}{\partial x}\frac{\delta^{**}}{V_0}(2+H)=\frac{\tau_\omega}{\rho_0 V_0^2} \qquad (18)$$

Here: δ^{**} - the thickness of impulse loss; δ^* - the thickness of extrusion; v_0, ρ_0 - the velocity and density at the outer boundary of the boundary layer; $N=\delta^*/\delta^{**}$; τ_ω–the tension of wall friction. The extrusion thickness of the boundary layer with the exact profile and velocity is determined by the following expressions.

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$$\delta^* \int_0^\delta (1 - \frac{\rho v}{(\rho_0 v_0)}) dy \qquad (19)$$

- the thickness of impulse loss

$$\delta^{**} \int_0^\delta \frac{\rho v}{(\rho_0 v_0)} (1 - \frac{v}{v_0}) dy \qquad (20)$$

Because the impulse equation has three indeterminate parameters — δ **, δ *, and τω — the problem is solved by a series of profiles and velocities related to one parameter to an equation with one unknown, according to the approximate solution method. Instead of such a parameter, the amount of φ, called the form parameter, has been proposed, which allows the development of structural methods of boundary layers on the theoretical basis of the existence of internal scales of turbulence. [9.10.11.12] The method of calculating the lost viscosity of the turbulent boundary layer is also of special importance. [13]

In this method, the dimensions in the viscosity condition decrease faster than dimensions in the entire boundary layer.

IV. CONCLUSION AND FUTURE WORK

Based on the results of experimental research conducted on a solar air collector with a botanical channel in the form of a triangle, developed in a new way, the development of a mathematical model of the air flow in the air channels of the collector is required.

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