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RESEARCH OF THE HYDRAULIC RESISTANCE COEFFICIENT OF SUNNY AIR HEATERS WITH BENT PIPES DURING TURBULENT AIR FLOW.

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Abstract: This article examines the issues of hydraulic resistance of solar air heaters with concave tubes and reduction of pressure losses, as well as the determination of the air flow in concave tubes installed in the working chamber of the solar air heater and discusses the reduction of the number of common tubes to reduce pressure losses in the solar air heater and the installation of concave pipes to give air a swirling motion to eliminate a sharp decrease in the heat transfer process .

Key words: solar air heater, pressure, hydraulic resistance, immersion tube, absorber, air, laminar, turbulent, height, dynamic viscosity.

I.INTRODUCTION

Today, at this stage of the development of world civilization, the urgent task is the widespread introduction and use of renewable energy sources [1], associated with an excessive increase in energy demand [2], continuous growth of valuable energy [3], as well as a reduction in fuel and energy resources [4] and deterioration environmental conditions around the world [5.6.7] In this regard, close attention is paid to the development of new generations of solar energy installations with increased efficiency [8.7.] and minimal economic costs [9]. 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.

Scientific research is being conducted in the world aimed at creating energy systems using solar low-potential installations in heat supply systems [10.11], taking into account the optimization of heat and mass transfer processes [12.13.14], necessary for the development of operating [15], technological and design parameters [10], control and management schemes [16.], which provide continuity of hydrodynamic and thermal processes [17.18.19]. Improving the efficiency and development of new modern designs of solar installations [20], as well as improving the methodology of their thermal calculations are one of the most important research tasks in this field [21.22]. At the same time, increasing the efficiency of solar air-heating collectors, based on an improved design of absorbers and intensification of heat transfer processes [23.24.25.26], due to turbulization of the heat carrier flow [27], is relevant for heat supply systems [28].

Among renewable energy sources, solar energy in terms of resources [29], ecological purity [30.31] and ubiquitous prevalence is the most promising energy resource [32]. Among installations operating on renewable energy sources, solar air heating collectors stand out for their simplicity of design [33] and relatively high efficiency [34].The general direction of work on the creation of air solar collectors is to find ways to reduce heat loss to the environment [35], intensify heat transfer on the absorber [36] and reduce the cost of pumping air through the collector [37.38] by reducing the hydraulic resistance of the collector.

From the results of a study of the literature, it can be noted that the convective heat transfer rate can be increased by increasing the heat transfer surface, which is 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. (Fig. 1) This task is carried out using an artificial canopy, profiles the surface of the sunlight receiver, recesses or gaps are placed on the surface of the light receiver.[39]

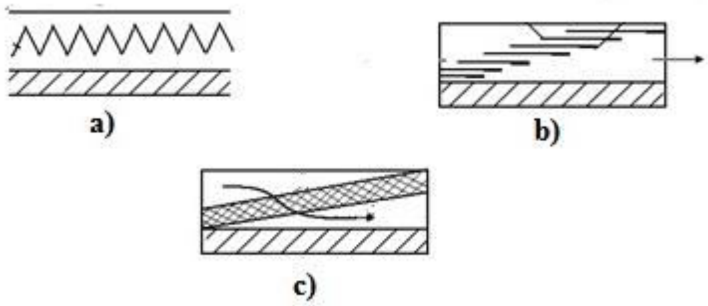

Fig 1. Types of solar air collector with high efficiency.
a – surface with a triangular channel; b – surface with a hole; c – net

II.DEVICE CHARACTERISTIC

A model of a solar water heater with a concave tube with low hydraulic resistance (Fig. 1) was developed; the device has a length l = 1200 mm, width = 400 mm, height h = 62 mm. This solar air heater has metal tubes in the working chamber with a small heat capacity and concave shape and is built in a checkerboard pattern. The length of each pipe is l = 150 mm. The average duct distance is l = 60 mm. At the base of the duct, a concave shape is given in two rows, this geometric figure has a depth h = 2 mm and a width = 15 mm. The geometric shape attached to the manifold ducts is internally concave along the outer surface of the channel and vice versa. When using a solar air heater, the inlet and outlet pipes are located at d = 15 mm when using a spray gun.

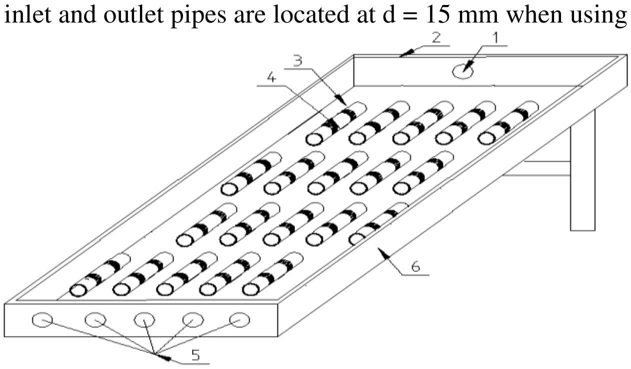

Fig.2 ***General schematic view of a solar air heater with concave tubes.***
Here *1-air outlet, 2-window, 3-black metal surface (absorber), 4-air duct, 5-channels for air inlet, 6-case*

III. METHOD OF THEORETICAL ANALYSIS

This solar air heater works in two ways:
- Blowing air into the inside of the collector;
- Air intake from the manifold.

During operation by the method of inflating air, diagonal inlet and outlet nozzles of the device are used.

In the case of air intake, each channel uses its own separate channels for air intake.

The channel diagram is a checkerboard shape that covers the entire airflow of the collector through the chamber.

The working chamber of the heater has a concave geometric shape in the air pipes (Fig. 2a). air striking these figures forms a vortex motion.

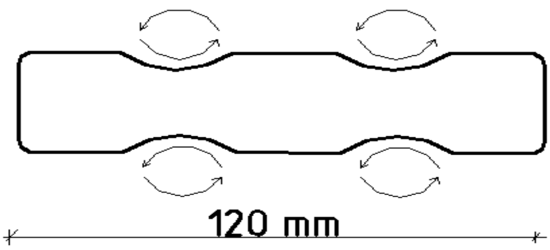

Fig.3a ***Circular motion on the concave parts of the air duct.***

The depth of the concave shape should not exceed h = 2 mm, the diameter of the tube (Fig.2b).

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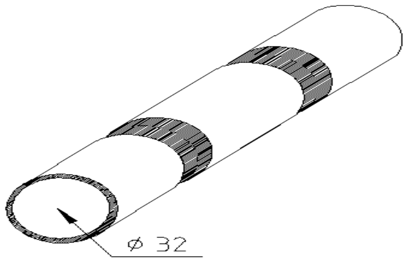

Fig.3b ***General view of the air duct***

The coefficient of hydraulic resistance in the air pipes of a solar air heater is determined as follows.

$$\xi_{co} = \xi_{fl} \cdot \left[1 + \frac{100(\lg Re-4.6)(1-\frac{d_{vn}}{D_{vn}})^{1.65}}{\exp(\frac{t}{D_{vn}})^{0.3}}\right] \exp\left[\frac{25(1-\frac{d_{vn}}{D_{vn}})^{1.32}}{(\frac{t}{D_{vn}})^{0.75}}\right] \quad (1)$$

Here $\xi_{fl}$is the hydraulic resistance coefficient of a smooth air pipe; Re is the value characterizing the air flow regime, d_{vn} is the diameter of the smaller part of the pipe, D_{vn} is the largest diameter of the pipeline, t is the number of steps in the pipe.

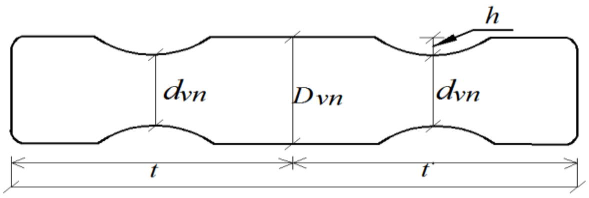

Fig.3d Schematic view of the steps of a concave air duct

The hydraulic resistance coefficient ξ_{fl} of a smooth air tube, as mentioned above, is determined as follows.

$$\xi_{fl}=\frac{0,316}{Re^{0.254}}\left(\frac{\mu}{\mu_{st}}\right)^{n} \quad (2)$$

Here, Re is the value characterizing the air flow regime, μ is the dynamic viscosity of air at certain temperatures, and μ st is the dynamic viscosity of heated surface air. n - the ratio of dynamic volatility to temperature differences is 1/3.

The Reynolds number is determined as follows.

$$Re = \frac{vd}{\nu} \quad (3)$$

Here is v-speed, d −diameter, ν -kinematic viscosity of air. The dynamic viscosity of air is determined by the following formula.

$$\mu = \mu_0 \frac{T_{0+C}}{T+C}\left(\frac{T}{T_0}\right) \quad (4)$$

Here μ is the dynamic viscosity in (Pa) at a given temperature T; μ_0-control viscosity in (Pa) at some control temperature T_0; T-set temperature in Kelvin; T_0 control temperature in Kelvin; Sutherland C-constant for the gas whose viscosity is to be determined.

The pressure loss on the device is determined by the following formula.

$$\Delta h = \sum \xi * \frac{v^2}{2g} \quad (5)$$

Here $\sum \xi$ is the total hydraulic resistance coefficient, v is the average velocity, and g is the free fall velocity.

$$\sum \xi = \left(\xi_{fl} + \xi_{co}\right) \quad (6)$$

Theoretical analysis of experimental results

The concave tube solar heater was mainly tested at five different speeds, and at each speed experiment, the main parameters were obtained, including the air speed, the temperature of the heated air from the heater, and the temperature of the absorber and concave tubes.

Fig.4 ***The process of working a solar heater with concave tubes***

Table.1 The results were obtained at five different speeds from a concave-tube solar air heater.

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Inlet air speed m/s	Outlet air speed m/s	Time for experience	Outdoor temperature °C	Heated air temperature °C	Absorber surface temperature °C	Tube temperature °C
3.86	3.68	13^{30}-14^{00}	34	73	84	82
5.2	4.78			72	84	81
6.4	5.84			71	83	81
7.88	6.23			70	82	80
8.2	6.55			68	81	79

Table.2 The dependence of the Reynolds number on the coefficient of hydraulic resistance.

Re	5111	6766	8271	9559	9993
ξ_{fl}	0.036	0.033	0.031	0.03	0.0295
ξ_{co}	0.2	0.194	0.19	0.187	0.185
$\sum \xi$	0.236	0.227	0.221	0.217	0.214

Fig.4 ***Reynolds number versus hydraulic resistance coefficient***

ξ=f(Re)

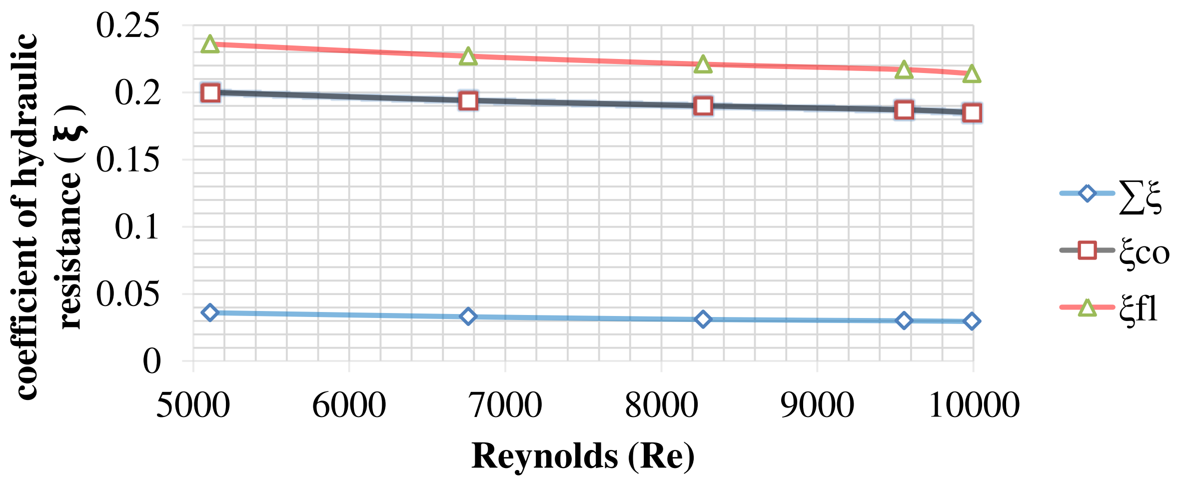

Table.3 Reynolds number versus speed

Re	5111	6766	8271	9559	9993
V m/s	3.77	4.99	6.1	7.05	7.37

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Fig.5 ***Reynolds number versus speed***
v=f(Re)

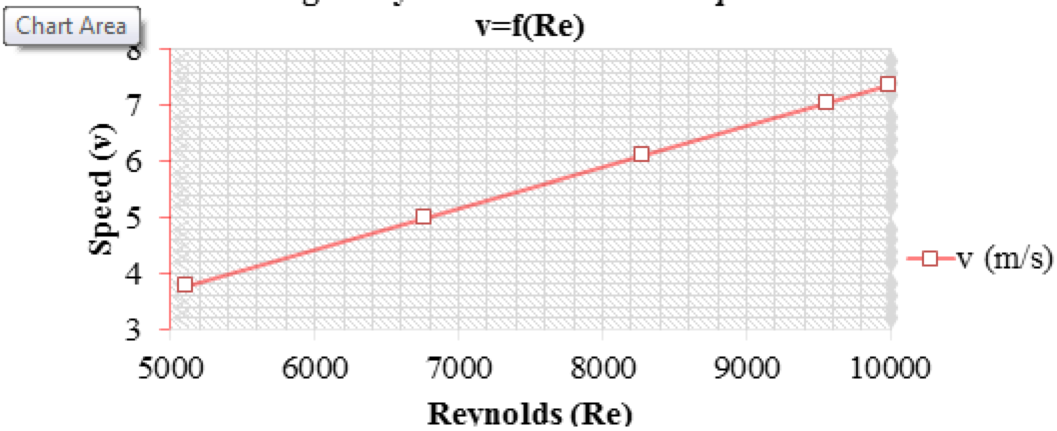

Fig.6 ***Reynolds number versus pressure loss***
Δh =f(Re)

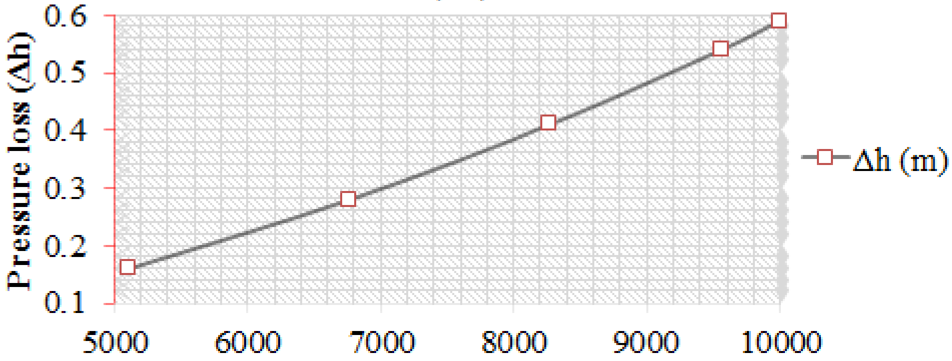

Table.4 Reynolds number versus pressure loss

Re	5111	6766	8271	9559	9993
Δ*h* m	0.16	0.28	0.41	0.54	0.59

Table 5. Reynolds number versus temperature of heated air

Re	5111	6766	8271	9559	9993
t °**C**	73	72	71	70	68

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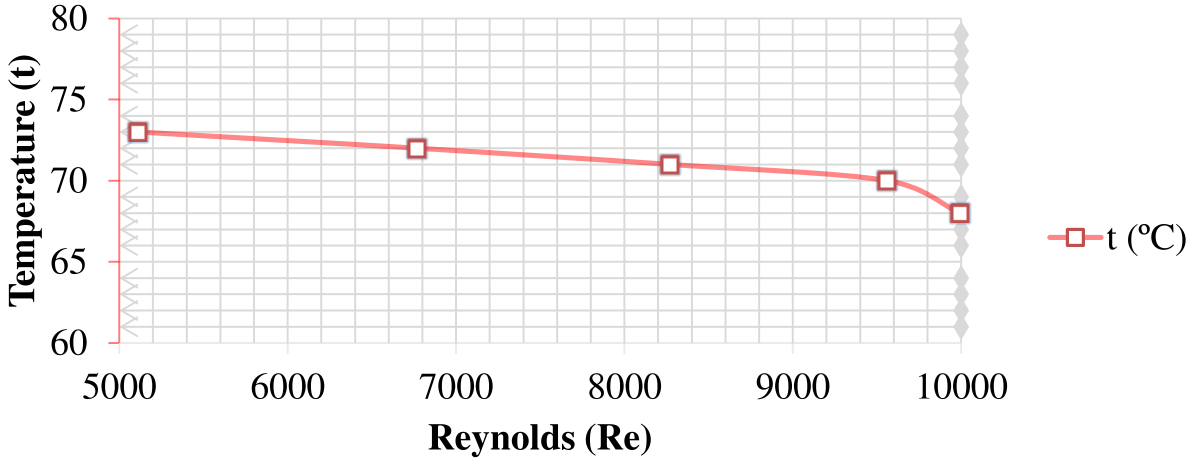
Fig.7 ***The dependence of the Reynolds number on the temperature of the heated air*** **t=f(Re)**



VI. EXPECTED EFFICIENCY

- Relative to a common full-channel solar air heater, the air duct consumption is halved.
- Through the geometric shape specified by the air channel, the rotational movement of air is transmitted and the possibility of maximum increase in air temperature is created.
- Relative to a common full-channel solar air heater, the local resistance coefficient of the device will be reduced.
- Due to the reduction of local resistance, the device works efficiently even at low speeds.[40]

VII. CONCLUSION

By replacing common pipes in the working chamber of a solar air heater with pipes with a concave geometric shape, a decrease in the hydraulic resistance coefficient and pressure loss without reducing the heat transfer coefficient of the device was achieved.

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