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Solar Air Collector with Metal Wire Absorber

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Abstract: The heat transfer process in a solar air-heating collector with an absorber from a metal wire rope is considered. The criterion equation for determining the heat transfer coefficient is obtained.

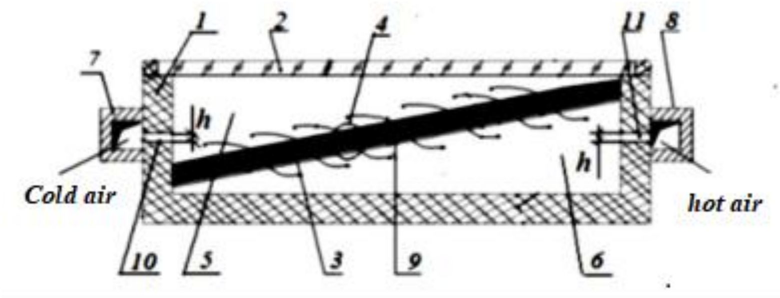
Keywords: absorber, solar air heating collector, metal wire entanglement, heat transfer coefficient, thermal efficiency, criterion equation.

Introduction.

In work [1], the prospects for using solar air-heating collectors (SHC) in the conditions of Uzbekistan are considered. Among various UHS designs, matrix air heaters are distinguished by their increased thermal engineering (HT) efficiency and simplicity [2].

We have developed a design and manufactured a matrix SVC (picture) with an absorber made of metal wire entanglement (MW).

The SVK contains a thermally insulated body 1 with a transparent coating 2 and a flat absorber 3, made in the form of an air-permeable structure 4, dividing the body 1 into upper supply and lower outlet air channels 5 and 6, connected to branch pipes 7 and 8 for supplying cold air and extracting hot air. The air-permeable structure 4 is made of MPP 9, and the absorber 3 is located obliquely to the bottom of the housing 1, ensuring a narrowing of the upper supply and expansion of the lower outlet air 38 channels 5 and 6 in the direction of air movement, and the channels are connected to the nozzles 7 and 8 by a longitudinal slot 10 and 11 .



Picture. Solar air heating collector with absorber made of metal wire mesh.

Determining the TT characteristics of an SVK with its known geometric dimensions is a difficult task. The mechanism of heat transfer in an MPP absorber is so complex that until now it has not been possible to find an accurate method for calculating the heat transfer coefficient. The only possible way to find the heat transfer coefficient for a UVC with an MPP absorber in such a case is to experimentally determine the necessary data and then generalize the results in criterion form.

Let us derive a criterion equation for determining the heat transfer coefficient of a UVC with an absorber made of MPP using the method of dimensional analysis. Heat transfer in a UVC with an MPP absorber can be represented as a power function of the following independent variables:

$$\bar{a} = f(D_{ekv}^{a}, W^{b}, \lambda^{c}, C_{p}^{d}, \rho^{e}, \nu^{f}, \delta^{k}, d^{1}) \qquad (1)$$

Let us express the dimensions of the variables of dependence (1) in the system of four quantities MLTΘ [3]: M-mass, L-length, T-time, Θ – thermodynamic temperature (table).

Let us substitute in dependence (1) instead of the symbols of the variables their dimensions:

$$MT^{-3}\Theta^{-1} = f\begin{bmatrix} L^{a}, (LT^{-1})^{b}, (LMT^{-3}\Theta^{-1})^{c}, (ML^{-1}T^{-1})^{c}, (L^{2}T^{-2}\Theta^{-1})^{d}, \\ (ML^{-3})^{e}, (L^{2}T^{-1})^{f}, L^{k}, L^{1} \end{bmatrix} \qquad (2)$$

In order for this equation to be homogeneous with respect to dimensions, the following relationships between exponents must be satisfied:

$$for \quad \left.\begin{aligned} M&: 1 = c + e \\ L&: 1 = a + b + c + 2d - 3e + 2f + k + 1 \\ T&: -3 = -b - 3c - 2d - f \\ \Theta&: -1 = -c - s \end{aligned}\right\} \qquad (3)$$

***Table* 1. Name and dimensions of dependency variables.**

Variable name	Designation	Dimension formula
Heat transfer coefficient	α	$MT^{-3}\Theta^{-1}$
Flow rate	W	LT^{-1}
Coefficient of thermal conductivity	λ	$LMT^{-3}\Theta^{-1}$
Density	ρ	ML^{-3}
Heat capacity	c_p	$L^{2}T^{-2}\Theta^{-1}$
Kinematic viscosity coefficient	ν	$L^{2}T^{-1}$
Equivalent diameter of metal wire mesh absorber	D_{ekv}	L
Thickness of metal wire mesh absorber	δ	L
Diameter of metal wire in putankas	d	L

Let us simplify relations (3) and express them in terms of a, b, d, c:

$$\left.\begin{aligned} a &= -1 + e - f - k - 1 \\ b &= e - f \\ d &= e \\ c &= 1 - e \end{aligned}\right\} \qquad (4)$$

Taking into account relations (4), dependence will take the form:

$$\bar{a} = f(D_{ekv}^{-1+e-f-k-1}, W^{e-f}, \lambda^{1-e}, C_p^{e}, \rho^{e}, \nu^{f}, \delta^{k}, d^{1}) \qquad (5)$$

Combining terms with the same exponents, we obtain a dependence of five dimensionless complexes:

$$\frac{\bar{a}\, D_{ekv}}{\lambda} = f\left[\left(\frac{D_{ekv}W}{\nu}\right)^{-f}; \left(\frac{D_{ekv}Wc_p\rho}{\lambda}\right)^{b}; \left(\frac{\delta}{D_{ekv}}\right)^{k}; \left(\frac{d}{D_{ekv}}\right)^{1}\right] \qquad (6)$$

Dimensionless complexes of dependence (6) are the well-known Nusselt (Nu), Reynolds (Re) and Peclet (Pt) criteria. Taking this into account, dependence (6) can be represented as a criterion equation:

$$\overline{Nu} = f\left[Re^{-f}, Pe^{e}, \left(\frac{\delta}{D_{ekv}}\right)^{k}, \left(\frac{d}{D_{ekv}}\right)^{1}\right] \qquad (7)$$

The resulting equation corresponds to the "π-theorem", since the number of dimensionless complexes is equal to the number of variables essential for the process, minus the primary quantities, i.e. 5 = 9 - 4.

The number Pe, obtained by reducing the original equation to a dimensionless form, can be represented as the product of two dimensionless Reynolds and Prandtl variables (Pr):

$$Pe = \frac{D_{ekv} W c_p \rho}{\lambda} = \frac{D_{ekv} W}{\nu} * \frac{\nu c_p \rho}{\lambda} = Re * P_r \qquad (8)$$

Here $P_r = \frac{\nu c_p \rho}{\lambda} = \frac{\nu}{a}$ Prandtl criterion, where $a = \frac{\lambda}{c_p \rho}$ thermal diffusivity coefficient, m^2/s.

Criterion equation (7) can serve as a basis for obtaining empirical dependencies for calculating $\overline{Nu}$ UVC with an absorber made of MPP

For experimental studies of SVC with an absorber made of MPP, based on the obtained criterion equation (7), an experimental methodology and a stand for its implementation have been developed.

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