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Research paper

High-Performance Finned Tubes for Production Facility Heating Systems

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Abstract

The values of the optimal height of the ribs and their optimal placement step on the surface of the heating device are determined. It was possible to determine that the installation of rectangular rods with a step of 8.2 mm on the surface at an angle of 90 degrees to the horizon, leads to an increase in the local coefficient of convective heat transfer to 200% compared to the surface on which there are no rods. It was found that the simplex acts as a separate parameter that affects the local coefficient of convective heat transfer on a surface with rectangular bars.

Keywords *: experimental working area, free-convective flow, heat transfer coefficient, finned tube, coolant.*

1. Introduction

The values of the optimal height of the ribs and their optimum pitch of location on the surface of the heater were detected. The generalizing depends for calculation of heat transfer at the surface located at angle of 90 degrees to the horizon in the presence of rectangular rods under free convention were obtained. The growth of energy capacity, which is currently observed in all sectors of the economy, is increasingly raising the issue of energy saving. In this regard, many scientists have become increasingly focused on the study of convective heat transfer, involving the movement of macroscopic elements of the medium caused by the action of a non-uniform field of mass forces on the coolant particles.

The movement of the liquid and gaseous coolant in contact with the surface of the heat exchanger under free convection occurs, for example, when considering the operation of convectors and finned tubes. The heater convective type, in which the outer lateral area of the heat-transfer surface 9 times more heat receiving inner surface, is called the finned tube. Thus, finned tubes made of grey cast iron have a ribbed heating surface on the outside.

To increase the intensity of the heat exchange process between two heat carriers, separated from each other by a wall, the ribs supply the surface of the wall, the convective heat transfer from which will be less (Figure 1).

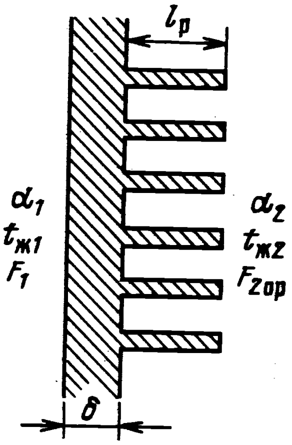

Figure 1:. Ribbed wall in section

Consider the heat exchange process between two heat carriers with temperatures $t_{ж_1}$ and $t_{ж_2}$, separated from each other by a ribbed wall thickness δ and having a coefficient of thermal conductivity λ. The temperature of the inner and outer surface of the ribbed wall are equal, respectively. The coefficient of convective heat transfer between the first coolant and the inner surface of the wall is equal to α_1, and the heat transfer coefficient between the ribbed surface of the wall and the second coolant is equal to α_2.

The temperature at the base of the edge is equal to the surface temperature between the edges t_{c_2}, and it will decrease by their end. Suppose that the temperature of the second coolant

$t_{ж_2} = \text{const}$. We define the total heat flow transmitted from the first coolant to the inner surface with an area F_1 through the ribbed wall and from the outer ribbed surface with an area $F_2 = F_р + F_м$ to the second coolant:

$$Q = \frac{1}{\left(\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{F_1}{\alpha_2(F_м + \eta_р F_р)}\right)}(t_{ж_1} - t_{ж_2})F_1 = k_р(t_{ж_1} - t_{ж_2})F_1$$

(1)

where $k_р = \frac{1}{\left(\frac{1}{\alpha_1} + \frac{\delta}{\lambda} + \frac{F_1}{\alpha_2(F_м + \eta_р F_р)}\right)}$ – the heat transfer coefficient of a ribbed wall;

$\frac{\delta}{\lambda}$ – internal thermal resistance of the ribbed wall;

$\eta_р = \frac{Q_р}{Q_р^/}$ – the efficiency coefficient of the ribs;

$F_м$ – area of intercostal areas;

$F_р$ – the area of the lateral surface of the edges.

Let us to assume that the internal thermal resistance can be neglected , that is $\frac{\delta}{\lambda} = 0$, and the efficiency coefficient of the ribs $\eta_р$, equal to the ratio of heat transferred to the surface of the ribs in the environment, to the heat that this surface could transmit at a constant temperature of the wall equal to the temperature at the base of the ribs $Q_р^/$, we assume $\eta_р = 1$ Then the ratio (1) takes the final form:

$$Q = \frac{t_{ж_1} - t_{ж_2}}{\left(\frac{1}{\alpha_1 F_1} + \frac{1}{\alpha_2 F_2}\right)} \quad (2)$$

Thus, the presence of ribs on the external heat-generating surface of the finned tube increases the heat flow, and the temperature of the outer surface of the wall t_{c_2} will be approximately equal to the temperature of the second coolant $t_{ж_2}$. Structurally, the ribs are made as a whole with a wall.

The most common are cast iron flange finned tubes with a length of 0.75 to 2 meters with an internal diameter of 70 mm, the outer surface of which is provided with thin round ribs (Figure 2).

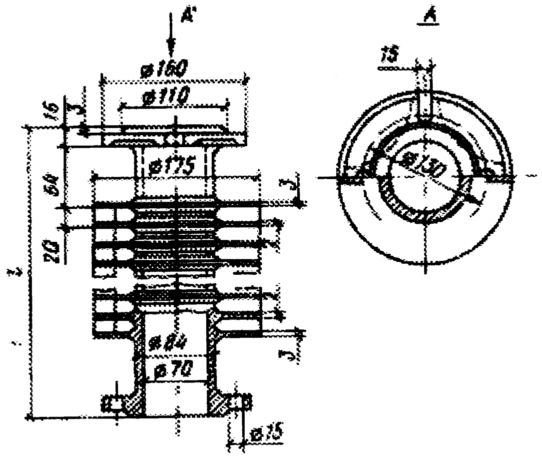

Figure 2:. Pipe heating cast iron ribbed TR-1 working at a pressure of up to 0.6 MPa (6 kgs/cm^2)

Finned tubes are used in rooms with temporary stay of people and in industrial premises in which there is no significant dust. To increase the local coefficient of convective heat transfer in heating pipes can be used on the outer surface of the ring with rectangular fins, which are installed at the same distance from each other. The presence of rings with rectangular fins increases the heat exchange surface and contributes to the increase in the rate of coolant, which in turn leads to an increase in the coefficient of convective heat transfer.

The author proposes the design of the heat exchanger, on the outer surface of which rectangular rods were installed at the same distance from each other.

2. Experimental part

The aim of the research was to determine the empirical relation in dimensionless form for the calculation of the local coefficient of convective heat transfer on the surface located in space at an angle of 90 degrees to the horizon, under free air convection. Also, the objectives of this study included the identification of the influence of the installation step on the surface of rectangular rods on the local coefficient of convective heat transfer.

For this purpose, two experimental work sites were created. The first heat transfer studies were carried out on a surface without rectangular rods, which was located in space at an angle of 90 degrees to the horizon and had a length L = 1.0 m and a width b = 0.36 m.

In the experiments, heating was realized at a constant heat flow from the wall ($q_w = \text{const}$).

The main parameters changed in the range: the product of the number Grashof on the Prandtl number $Gr_x\,Pr = \frac{gx^3\beta\mu c_p(t_{w_i} - t_0)}{\lambda\nu^2} =$ 7,5·10^4...4,6·10^9, the number of Grashof on the Prandtl number $Gr_x\,Pr = \frac{g\beta\mu c_p x^3 \Delta T}{\lambda\nu^2} = \frac{g\beta\mu c_p x^3 q_w x}{\lambda\left(\frac{\mu^2}{\rho^2}\right)\lambda} = \frac{g\beta q_w \rho^2 c_p x^4}{\mu\lambda^2} =$ 3·10^5 ...1,5·10^{12}; Prandtl number $Pr = 0{,}7$; heat flux density $q_w = 12...440$ W/m2; temperature difference: $\overline{t_w} - t_o =$ 7...49 °C.

Flow visualization showed that along the entire length of the surface located in the space at an angle of 90 degrees to the horizon, there is a laminar flow regime of the coolant. In addition, studies were conducted on the surface length L = 1.0 m, width b = 0.36 m with rectangular rods of duralumin height H = 4.1 mm, which were installed along its entire length at first at a distance of 8.2 mm from each other, then at a distance of 12.3 mm, 20.5 mm, 41 mm, 82 mm, 164 mm and at the end at a distance of 328 mm.

In the experiments, heating was realized at a constant heat flow from the wall ($q_w = \mathrm{const}$).

The main parameters changed in the range: the product of the number Grashof for a Prandtl number

$$Gr_x\,Pr = \frac{g\beta\mu c_p x^3 \Delta T}{\lambda \nu^2} = \frac{g\beta\mu c_p x^3 q_w x}{\lambda\left(\frac{\mu^2}{\rho^2}\right)\lambda} = \frac{g\beta q_w \rho^2 c_p x^4}{\mu\lambda^2} =$$

$5{,}8\cdot10^5 ... 1{,}6\cdot10^{12}$; Prandtl number $Pr = 0{,}7$; heat flux density $q_w = 25...498$ W/m^2; simplex $\frac{T}{H} = 2...80$; temperature difference: $\overline{t_w} - t_o =$ 4...43 °C..

Flow visualization showed that laminar and transient modes of coolant motion are observed along the entire length of the surface located in the space at an angle of 90 degrees to the horizon with rectangular rods.

Since the rectangular rods were made of duralumin, the calculation of the convective heat transfer coefficients took into account the increase in the area of the heat transfer surface due to the surface area of the two side faces of each rectangular rod.

Empirical data processing is performed in the form of criterion dependence $Nu_x = c(Gr_x\,Pr)^k\left(\frac{T}{H}\right)^m$. In this relationship, the characteristic linear size used a coordinate along the length of the surface x, and the determining temperature was the temperature of the surrounding air t_o .

As a result, the criterion dependence was obtained, which is a power function and describes the results of the study of local heat transfer on the surface with rectangular rods in the investigated range under the conditions of free-convective flow of the coolant:

$$Nu_x = 0{,}82(Gr_x\,Pr)^{0{,}22} \qquad (3)$$

Where:

$$Gr_x\,Pr = \frac{g\beta q_w \rho^2 c_p x^4}{\mu\lambda^2} = 5{,}8\cdot10^5 ... 1{,}6\cdot10^{12} \;;$$

$$Pr = 0{,}7 \;;$$

$$\frac{T}{H} = 2...10 \;.$$

The criterion ratio (3) describes empirical data with a relative error of ± 20% with a confidence probability of 0.95. The determining temperature was the temperature of the surrounding air t_o :

$$Nu_x = 0{,}99(Gr_x\,Pr)^{0{,}22}\left(\frac{T}{H}\right)^{-0{,}07} \qquad (4)$$

where $Nu_x = \frac{\alpha x}{\lambda}$;

$$Gr_x\,Pr = \frac{g\beta q_w \rho^2 c_p x^4}{\mu\lambda^2} = 5{,}8\cdot10^5 ... 1{,}6\cdot10^{12} \;;$$

$$Pr = 0{,}7 \;;$$

$$\frac{T}{H} = 10...80 \,.$$

The criterion ratio (4) describes empirical data with a relative error of ± 20% with a confidence probability of 0.95. The determining temperature was the temperature of the surrounding air t_o .

3. Conclusion

Thus, it was possible to determine that the installation of rectangular rods with a step of 8.2 mm on the surface at an angle of 90 degrees to the horizon, leads to an increase in the local coefficient of convective heat transfer to 200% compared to the surface on which there are no rods. It is found that the simplex $\frac{T}{H}$ acts as a separate parameter that affects the local coefficient of convective heat transfer on a surface with rectangular bars.

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