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EXPERIMENTAL STUDY OF HEAT TRANSFER FOR VERTICAL SURFACES WITH DISCRETE FINS

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Abstract. *The results of an experimental study of the heat transfer of a vertical flat surface with discrete fins located in a staggered order are given. Parameters such as Nusselt number, total heat flux and temperature characteristics of the investigated surface are determined. A comparison was made between the obtained experimental data and the results in other papers for vertical surfaces with continuous flat-parallel fins. It is shown that for natural convection conditions, discrete finning in 1,3-1,7 times is more effective than flat continuous fins.*

Key words: ***vertical finned surface, natural convection, discrete fins, flat fins, Nusselt number, temperature***

Topicality. Fins as a way to increase the thermal efficiency of heat transfer surfaces has been widely used in various heat exchangers. Finned surfaces are used in heat exchangers for various purposes, devices for cooling electronic equipment, computer technology, heating and cooling devices for household appliances and a number of other devices [1,2]. In particular, in the devices under consideration, vertical surfaces are used with a plane-parallel fins under conditions of natural convection. Extensive experimental and theoretical studies of heat transfer for such surfaces have been carried out, where their high thermal efficiency is shown at small vertical dimensions of heat transfer surface [3-6]. As these sizes increase, the heat dissipation capacity of such surfaces decreases, which is due to the heating (cooling) of the external heat carrier and the drop in the temperature difference between the surface of finned wall and heat carrier. In order to increase the heat efficiency of the heat transfer surface, a surface with fins of small length located in a staggered manner was proposed. As the numerical simulation of surfaces with discrete fins has shown, the total heat flux that can be drawn from the surface can increase by 1.5-2.0 times [7]. This is due to a decrease in the length of the formation of boundary layer (BL) and its breakdown from the edge of the discrete fins, which leads to an increase of heat transfer coefficient on a discretely finned surface. At the same time, experimental studies devoted to studying of heat transfer for such surfaces were not carried out.

Purposes of research. Experimental study of heat transfer processes for vertical surfaces with discrete fins finishes under free convection conditions was conducted, where was determined of heat efficiency, local and integral characteristics of discrete fins.

Materials and methods of research. In the present study, the influence of geometric and thermophysical factors on the heat transfer conditions of vertical surface with discrete fins having a chess structure of the arrangement is experimentally studied. The research was carried out on an installation, the scheme of which is presented in Fig.1. In the course of experimental measurements, the fin temperature was measured, which was changed by changing the power of the electric heater, located at the base of fins on the bearing vertical surface. In Fig. 2a shows the chess arrangement of discrete fins. The scheme of distribution of thermocouples on fins for heat transfer surface with a discrete chess grinding is shown in Fig. 2b. A set of 12 thermocouples on plates with dimensions of 50×11 mm, located in the lower middle and upper part of the investigated surface gives an opportunity to have a fairly complete picture of the process of heat distribution in the fins. Thus, the system of 36 sensors allowed to establish the laws of heat transfer for such a configuration of finned surface with the number of fins in one row equal $M = 25$.

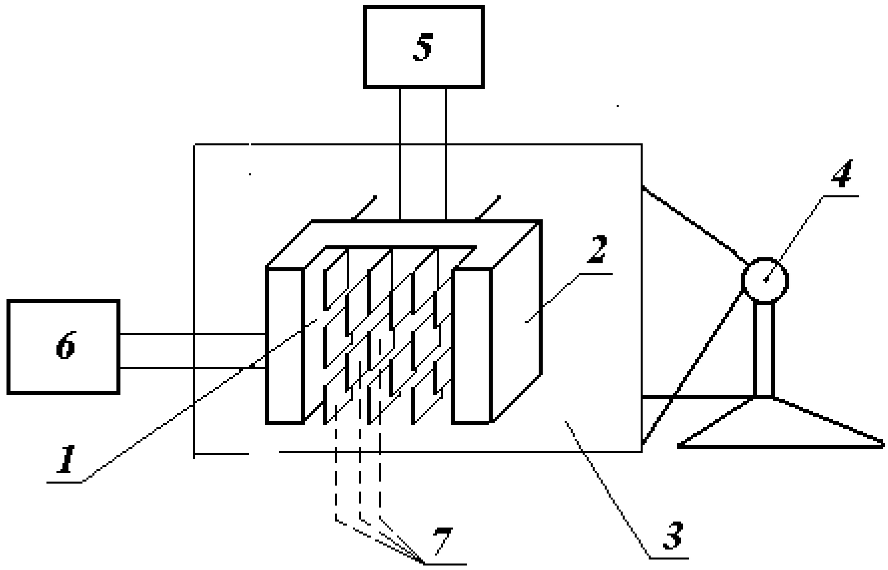
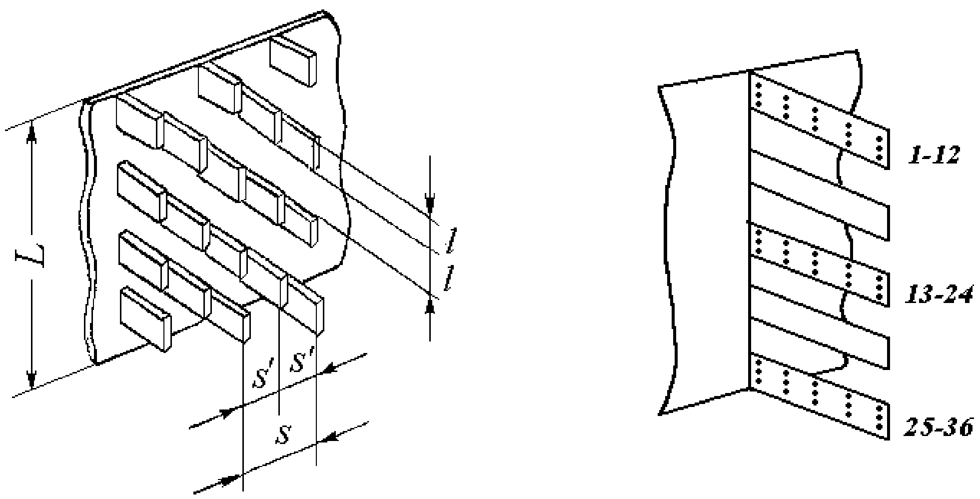


Fig. 1. Scheme of the experimental installation:
1 - section under investigation; 2 - insulating casing; 3 - bed; 4 - turning mechanism; 5 - main heater; 6 - security heater; 7 - system of surface thermocouples



a) b)

Fig. 2 Surface with a discrete fins located in a staggered manner (a) and the arrangement of thermocouples (b)

As the determining dimension in calculating discrete fins, the value of the fin pitch $s = 2s'$ was used, where s' is the distance between adjacent rows (see Fig. 1). The size s' for intermittent fins takes the following values s' = 4, 9, 14 mm. For each of them a series of experiments was conducted in the range of temperature differences of 20-130°C.

An experimental study of heat transfer for vertical surfaces having intermittent fins with a chess structure of the finned location is carried out for the next range of changes in thermophysical and geometrical parameters $Ra_s s / L = 10 - 1{,}1 \times 10^4$; $s / h = 0{,}16 - 0{,}58$.

Results of research. The results of experimental data for surfaces with discrete fins are shown in Fig. 3 in the form $Nu_s = f(Ra_s s / L)$. The experimental data agree satisfactorily with the dependence for the mean number Nu_s

$$Nu_s = 0{,}314(Ra_s s / L)^{0{,}4} - 0{,}19. \quad (1)$$

The maximum error permitted by the dependence (1) in the parameter range

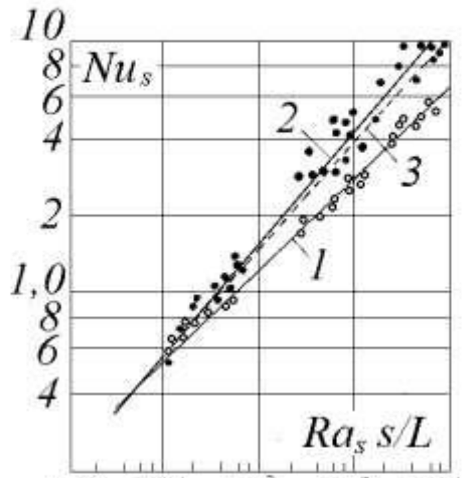


Fig. 3 Dependence of the Nusselt number Nu_s on the parameter $Ra_s s / L$:
1 - continuous fins [8]; 2 - discrete fins; 3 - calculation curve [9]

$10 \le Ra_s s / L \le 1{,}1 \times 10^4$ is 30%. It should be noted that for discrete fins, the distance s is double the distance between adjacent rows.

In Fig. 3 as a comparison, experimental data for vertical surfaces with continuous flat-parallel fins [8] and the calculated curve obtained in [9] are presented. The use of discrete fins leads to the intensification of heat transfer in a wide range of values $Ra_s s / L$. As follows from Fig. 3, the heat efficiency of discrete fins in comparison with the continuous fins increases with the increase of parameter $Ra_s s / L$ and the degree of intensification can reach 50-70%.

From (1) it follows that the degree of intensification increases with increasing value $Ra_s s / L$ and the distance between the plates *s*. Experimental data and analysis of temperature distributions on discrete fins show that the intensification of heat transfer is facilitated by an increase in the number of plates *M* in a row, a decrease in their length *l* and a decrease in the height *L* of the system. Thus, the intensification of heat transfer is all the more so as fins are the shorter, the larger their number and the wider cross-sectional step.

In experimental studies, as noted above, temperature distributions were measured in separate intermittent fins located on different sections along the height of finned system. Measurements were made for the 1st, 13th and 25th fins, starting with the lower one. Some measurement results are shown in Fig. 4. In Fig. 4 also presents the results of numerical simulation of heat transfer for discrete fins with chess location which is obtained in [9]. The temperature distributions are given in the dimensionless form, where $\theta = \frac{\bar{T} - T_{g\infty}}{T_0 - T_{g\infty}}$, $X = \frac{x}{h}$ (*x* is the coordinate along the fin height, *h* is the fin height, $T_0, T_{g\infty}$ is a temperature at the base of fin and external heat carrier, respectively. As follows from the above distributions, for the fins located in the lower part of the finned system, the greatest drop in temperature along the fin height is observed. This is due to the maximum values of the temperature

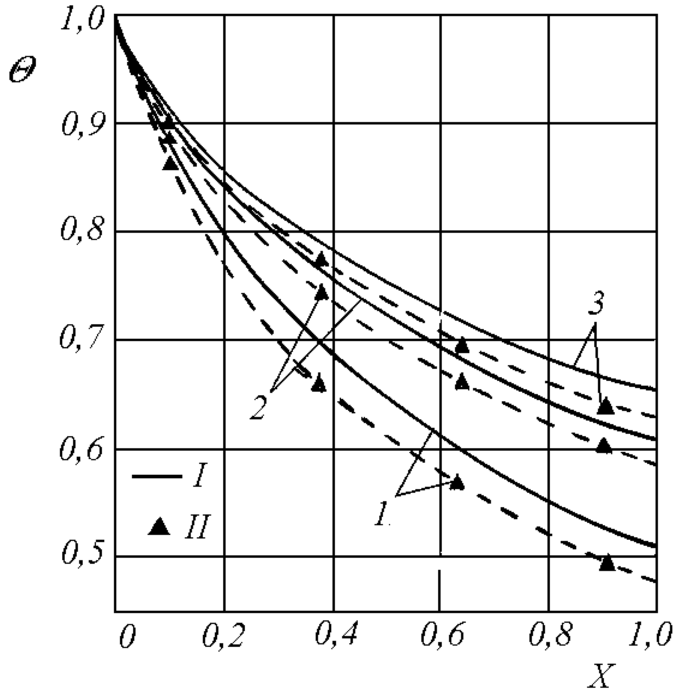


Fig. 4 Temperature distributions in the fins located on different parts of the base:

I – calculation [9]; *II* – experiment; *i*=1; 2 – 25; 3 – 49

difference between the fin surface and the external air in the lower part of the finned system, at which the values of heat transfer coefficients on the streamlined surface are maximum. The obtained distributions show that in the lower part of a system with discrete fins the intensity of heat transfer is substantially higher than in its upper part. Therefore, it is advisable to reduce the vertical dimensions of the finned surface.

Thus, as a result of experimental studies, it has been established that the discretization of fins leads to an intensification of heat transfer processes in comparison with continuous flat-parallel finning.

Conclusions

1. Experimental investigations of the processes of heat transfer for vertical surfaces with discrete fins, located in a staggered order for the conditions of natural

convection, have been carried out.

2. It is shown that the use of the system of short fins leads to intensification of heat transfer by 30-70% in comparison with the continuous flat-parallel finning.

3. As a result of the processing of the experimental data, a criterion dependence for the Nusselt number from the Rayleigh number was obtained, which allows conducting calculations of heat transfer surfaces with a discrete fins.

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ЕКСПЕРИМЕНТАЛЬНЕ ДОСЛІДЖЕННЯ ТЕПЛОПЕРЕНОСУ ВЕРТИКАЛЬНИХ ПОВЕРХОНЬ З ДИСКРЕТНИМ ОРЕБРЕННЯМ

В. Г. Горобець

Анотація. *Наведено результати експериментального дослідження теплообміну вертикальної плоскої поверхні з дискретним ребрами, розташованими в шаховому порядку. Визначено такі параметри як число*

Нуссельта, сумарний тепловий потік, що відводиться і температурні характеристики досліджуваної поверхні. Проведено порівняння отриманих експериментальних даних з результатами, отриманими в інших роботах для вертикальних поверхонь з безперервним плоскопаралельним оребренням. Показано, що для умов природної конвекції дискретне оребрення в 1,3-1,7 рази ефективніше від плоского оребрення.

Ключові слова: ***вертикальна оребрена поверхня, природна конвекція, дискретне оребрення, плоске оребрення, число Нуссельта, температура***

ЭКСПЕРИМЕНТАЛЬНОЕ ИССЛЕДОВАНИЕ ТЕПЛОПЕРЕНОСА ВЕРТИКАЛЬНЫХ ПОВЕРХНОСТЕЙ С ДИСКРЕТНЫМ ОРЕБРЕНИЕМ

В. Г. Горобец

Аннотация. *Приведены результаты экспериментального исследования теплообмена вертикальной плоской поверхности с дискретным оребрением, расположенным в шахматном порядке. Определены такие параметры как число Нуссельта, суммарный отводимый тепловой поток и температурные характеристики исследуемой поверхности. Проведено сравнение полученных экспериментальных данных с результатами, полученными в других работах для вертикальных поверхностей с непрерывным плоскопараллельным оребрением. Показано, что для условий естественной конвекции дискретное оребренние в 1,3-1,7 раза эффективнее плоского оребрения.*

Ключевые слова: ***вертикальная оребренная поверхность, естественная конвекция, дискретное оребрение, плоское оребрение, число Нуссельта, температура***