OPTIMIZATION OF FLAT-AND-EDGE RADIATOR SYSTEM OF COOL THERMOBATTERY COOL SHUTS

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The calculating methods of optimization of flat-and-edge radiator system of thermobattery cool shuts on maximal heat efficiency at minimal fanning intensity.

Introduction

The optimization of flat-and-edge radiator systems is used for the heat rejection in different thermoelectric transformers, in particular in heat chambers for the obtaining of the temperatures, below 300°K. It is led to the definition of optimal dimensions of edges, the distances between edges (edge numbers) on the radiator system foundation.

The multi-stage thermoelectric systems are used for the formation of heat chambers, by the volume in the limits ~10dm^3 (from -50 till +80°C). However, the boiler diagram, basing on the use of "hybrid" catenation of base high-temperature cascade on the base of compressive aggregate and outgoing low-temperature one-cascade thermoelectric battery (TB) is optimal one. The treatment of thermo-refrigerators with (~1-10) dm^3 sizes for the temperatures -50°C only on the base of many-stage thermo-batteries is the hard-hitting task. So in the ref. [1] the behavior of thermoelectric coolers (TC) with indirect number of cascades at the cinematic excitation has been investigated by the method of electro-hydrodynamic analogy and Lagrange equations of second order. The calculating schemes of the construction analysis of many-stage (TC) at the investigation by both methods have been proposed. It is shown, that the one-and four-cascade TC demand the vibroprotection at cinematic excitation. The exploitation of such production demands the supplying of their reliability in the conditions of external vibration influences. That's why the formation of the engineering technique, allowing to evaluate the construction ways of devices for the obtaining of lowered temperatures on the base of the many-stage systems on the stage of projection and product treatment is the actual task. The compressor aggregates and one-cascade TC can be such systems. They are extensively free from the vibration overworks. In total, the reliability of many-stage devices depends on their design philosophies [2]. The cascade choice at the construction is the definition one at the formation of many-stage systems [3-4]. For this purpose firstly let's consider TB calculation of radiator system with the help of heat exchangers.

The aim of this paper was the task solution of optimization of flat-and-edge heat exchanger in the form of the collection of its optimal outgoing characteristics.

Besides, the optimization of flat-and-edge heat exchanger, contacting with TB cool shuts and using for the heat rejection from the cubic capacity and decrease of its temperature, allows, firstly, to lead the T'_0-T_0 drop to minimum possible values and, secondly, to decrease the circulation intensity and power of fan heat generations till the values, defined by maximum assumed temperature gradient in the cubic capacity, correspondingly.

The solution of this task requires the consideration as fan aerodynamic characteristics, so the big collection of thermalphysic factors, connected between each other in a complicated manner, such as air flow regime, its corresponding heat - transfer factor, total hydraulic resistance of heat exchanger and the differential pressure of air flow on it, correspondingly.

Statement of problem

The heat exchanger (fig.1), containing the flat-and-edge system with the basis of sizes d x Z , N edges of the width δ and length l has been established on the one of the planes of which along direction, parallel to Z, fanned by fan with parameters in nominal conditions (heat exchanger efficiency, power, differential pressure of air flow, volume air speed): η_H, W_H, ΔP_H, ω_H.

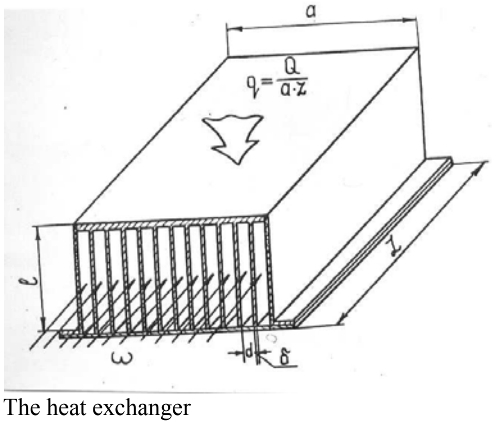

Fig.1. The heat exchanger

The heat power q is totally taken off from the radiator system foundation; initial flow temperature is equal to T_C.

The temperature of radiator system in arbitrary point is defined in stabilized mode from the equation

$$\frac{\partial^2 T(x,y)}{dx^2}+\frac{\partial^2 T(x.y)}{dy^2}+\frac{2\alpha}{\lambda_p\delta}\left[T(x,y)-T'_0(y)\right]=0 \qquad (1)$$

under boundary conditions

$$-\lambda_p\frac{\partial T(x,y)}{dx}\Big|_{x=0}^{1}=q_0^{(TB)} \qquad (2)$$

$$\frac{\partial T(x,y)}{dy}\Big|_{x=l}=0$$

At practically carrying out supposition about uniformity of air cooling, fanned through radiator system, i.e. at

$$T_B(y) = T'_{OH} - \frac{q_0^{(TB)} dy}{p\omega c} \tag{3}$$

leading down solutions of tasks (1), (2) to the equation with separating variables and further carrying out the averaging-out on total radiator system volume in the correspondence with the equation

$$\overline{T}_p = -\frac{1}{L}\int_0^L dy \int_0^L T((x,y)dy \quad , \tag{4}$$

it can be possible to obtain the following expression:

$$\overline{T}_p = T_C \pm \frac{1}{2} q \left[\frac{dL}{\rho\omega c} + \frac{1}{\alpha}\frac{d+\delta}{l} \right] . \tag{5}$$

As it was mentioned in the ref [4], the existence of optimal density of radiator edges dispersion, at which the minimal value of average temperature of thermal-dropping surface achieves at the given heat flux density defining by the minimum of average heat resistance of heat exchanger,

$$\overline{R}_T = \frac{2(T_p - T_c)}{q} = \frac{dL}{\rho\omega c} + \frac{d+\delta}{l} \tag{6}$$

is obtained from the following suppositions. The value of heat-exchange surface increases with increase of the density of edge situation. However, the last one is accompanied by the increase of aerodynamic resistance and at the defined dependence of fan efficiency on pressure leads to the decrease of air speed, created by it and heat-transfer coefficient, correspondingly.

Thus, the optimization of radiator system is defined by dependence of fanning speed, created by fan with known aerodynamic characteristics, on the distances between edges, realized finally in heat exchanger.

We use the perception of limit edge length, introduced in ref [4] at the finding of optimum of initial relation

$$l_{np} = \sqrt{\frac{\lambda_p \delta}{2\alpha} I_n \left[\sqrt{\frac{q_0}{\lambda_p t_g \beta}} + \sqrt{\frac{q_p}{\lambda_p t_g \beta} + 1} \right]} . \tag{7}$$

The physical meaning of introduced limit edge length consists in the fact, that it defines thermal effectiveness of the use of given space volume, secreted in device for heat-and-edge heat exchanger.

The non-dimensional form of initial relation

Introducing the non-dimensional variable x, defining dispersion density of edges on the foundation, we obtain:

$$x = \frac{D_{eq}}{\delta} \quad , \tag{8}$$

where

$$D_{eq} = \frac{4dl}{2(d+l)} = 2\frac{dl}{d+l} . \tag{9}$$

The relations [5-6] are known

$$\alpha = \frac{N_H \lambda_в}{D_{eq}} \tag{10}$$

(α are heat-transfer coefficients)
($\lambda_в$ is air thermal conductivity)

$$N_H = A_1 \operatorname{Re}^{\psi} \quad \text{(Nusselt's criterion),} \tag{11}$$

where parameter values A_1 and ψ are given in table 1.

Table 1.

Gas flow character in canals	A_1	ψ
Laminar	0.33	0.5
Vortical	0.018	0.8

$$R_e = \frac{\nu D_{eq}}{\gamma} \quad \text{(Reynold's criterion),} \tag{12}$$

(where ν is cinematic viscosity).

The volume air speed ω is connected with linear velocity ν by relation:

$$\omega = S_{np} \cdot \nu \ . \tag{13}$$

For one's turn

$$S_{np} = (N+1)dl \tag{14}$$

$$N = \frac{d}{\delta + d} - 1 . \tag{15}$$

Making the transformations on the base of above mentioned relations, we obtain:

$$\operatorname{Re} = \frac{\omega\delta(x+2)}{dl\gamma} \tag{16}$$

$$\alpha = \frac{\lambda_в}{x\delta} A_1 \left(\frac{\omega\delta(x+2)}{dl\gamma} \right)^{\psi} . \tag{17}$$

We obtain the initial optimization equation in non-dimensional form, finally substituting formulas (7) and (17) in formula (6):

$$F(x) = \frac{dL}{\rho\omega c} + \frac{\delta}{2\lambda_B A_1} \left[\left[\frac{2\lambda_B A_1}{\lambda_p} \right]^{1-\psi} \cdot B_1^{2(\psi-1)}(x) \left[\frac{d\nu}{\omega} \right]^{\psi} x(x+2)^{2(1-\psi)} \right]^{\frac{1}{2-\psi}} . \tag{18}$$

The equation (18) shows, that the solution of given task is defined by the optimal step between edges of chosen width and supposes also known dependence of air speed ω on it, created by fan with defined aerodynamic characteristics.

The results on optimization of air heat exchangers for compression-thermo-electrical systems are obtained.

The value of volume air speed, realizing in heat exchanger, proves about the fact, that fan operating mode isn't nominal one in general. In general, the finding of task solution of optimization of heat exchanging node, necessarily proposing the change in defined limits of ω and ΔP parameters, is impossible without taking into the consideration of total fan characteristic, expressing the connection between ΔP, W and n with one hand and ω with other hand.

It is need to take into consideration the fact that fan dynamic characteristics are not always given in fan passports, especially in compact ones (for example, such characteristics are given in ref [7], that makes difficult the carrying out of optimization investigations of compact flat-and-edge heat exchangers). The relations [8], describing the fan work in stabilized mode, are known.

$$\overline{\eta}\,\overline{W} = \Delta\overline{P}\,\overline{\omega} \tag{19}$$

$$\Delta P = \rho\frac{v^2}{2}\left[\xi\frac{L}{D_{eq}} + \xi_0\right] \tag{20}$$

where (ξ for laminar flow, such motion character has the air, fanned through radiator system).

$$\xi = \frac{A_2}{\mathrm{Re}} \tag{21}$$

$$\xi = \xi_{in} + \xi_{out}\,. \tag{22}$$

Here, ξ_{in} and $\xi_{out.}$ are hydraulic resistances on the output and input in radiator system)[4].

The dependence A_2 in function on $\dfrac{D_{eq}}{e}$ relation, built on table data, given in [7], is presented on the fig.2.

The $\xi_{in}(D)$ and $\xi_{out.}(D)$ dependences for the smooth flat-and-edge radiator systems, not having breaks, are defined by following formulas [9]

$$\xi_{in} = 0{,}7\left[1-\frac{D}{D+2\delta}\right] - 0{,}2\left[1-\frac{D}{D+2\delta}\right]^2 \tag{23}$$

$$\xi_{out} = \left[1-\frac{D}{D-2\delta}\right]^2. \tag{24}$$

Using the expressions (8) and (9), it is possible to obtain

$$\xi_0 = \frac{1}{x+1} - \left[1{,}5 - 0{,}6\frac{x}{x+1} - 0{,}2\left[\frac{x}{x+1}\right]^2\right] \tag{25}$$

Let's introduce the non-dimensional fan characteristics, which are more comfortable at the carrying out of mathematical operations:

$$\overline{\omega} = \frac{\omega}{\omega_H}$$

$$\Delta\overline{P} = \frac{\Delta P}{\Delta P_H} \tag{26}$$

$$\overline{W} = \frac{W}{W_H}$$

Taking into account the earlier mentioned relations, it is possible to obtain:

$$v = \frac{\overline{\omega}\cdot\omega_H}{d\cdot l}\cdot\frac{x+2}{x} \tag{27}$$

$$\Delta P = \frac{P}{2}\left[\frac{\omega_H\omega(x+2)}{dlx}\right]^2\left[\frac{A_2 vdL}{\delta^2\omega_H x(x+2)}\left[\frac{1}{\overline{\omega}}\right] + \varepsilon_0(x)\right] \tag{28}$$

Leading the expression (19) to the non-dimensional form

$$\overline{\eta}\,\overline{W} = \Delta\overline{P}\,\overline{\omega} \tag{29}$$

and transforming it, taking into account (27), we obtain

$$\eta_H\overline{W} = \eta\frac{p}{2}\frac{\omega_H^2}{d^2\Delta P_H}\left[\frac{x+2}{x}\right]^2\overline{\omega}\left[\frac{\overline{\omega}}{l}\right]^2\left[\frac{A_2 vdL}{\delta^2\omega_H x(x+2)}\left[\frac{1}{\overline{\omega}}\right] + \xi_0(x)\right]. \tag{30}$$

The solution of equation (30) is possible only by graphic-analytical method at the presence of $l(\omega, x)$ dependence of complex form. However, starting from the consideration of typical dynamic characteristics $\eta(\overline{\omega})$, given for example in ref. [10], at fan work on the one of curve $\eta(\omega)$ parts, it is possible to accept

$$\eta = b_1(\overline{\omega})\ , \tag{31}$$

where b_1 tangent inclination angle of curve part $\eta(\overline{\omega})$ in point, corresponding to stabilized mode in heat exchanger. In this case the equation leads to square equation respect of $(\overline{\omega}/l)$:

$$\left[\frac{\overline{\omega}}{I}\right]^2 + \frac{A_2 \nu L d}{\delta^2 \omega_H \varepsilon_0(x) x(x+2)} \frac{\overline{\omega}}{l} - 2\frac{b_1 W \overline{d}^2 \Delta P_H}{\eta_H \omega_H^2 \varepsilon_0(x)} \left[\frac{x}{x+2}\right]^2 = 0. \tag{32}$$

It is possible to obtain the dependence of $\overline{\omega}(x)$ air flow, created by fan in heat exchanger with the one from overall sizes $l_{зад.}$ solving (32) respect of $\frac{\overline{\omega}}{l}$, when $l_{пр} < l_{зад.}$restriction is imposed on $l_{пр}$ value:

$$\overline{\omega}(x) = l_{зад} \frac{A_2 \nu L d}{2\delta^2 \omega_H \xi_0(x) x(x+2)} \left[\sqrt{1 + A_5 \xi_0(x) x^4} - 1\right] \;, \tag{33}$$

where

$$A_5 = \theta \frac{b_1 \overline{W} P_H \delta^2}{\eta_H \rho A_2^2 \nu^2 L^2}. \tag{34}$$

The $\frac{D_{экв}}{l}$ relation, in one's turn defining A_2 dependence at $l = l_{зад.} = cons$, transforms in:

$$\frac{D_{экв}}{l_{зад}} = x \frac{\delta}{l_{зад}}. \tag{35}$$

The $A_2(x)$ dependences for different values of δ/l relation, and also $A_2(l)$ dependences at D_{eq} values, which are equal to 1mm, 2mm, 3mm, 4mm, are presented on the fig.2.

Thus, the dependence of volume air speed, created by fan in flat-and-edge heat exchanger is described by explicit equation (35) that takes into consideration whole collection of influencing factors for each chosen value δ and l.

Substituting (7) instead of $l_{зад}$ in (33), we obtain more general dependence $\omega(x)$, basing on previously given limiting heat efficiency of edge of given width

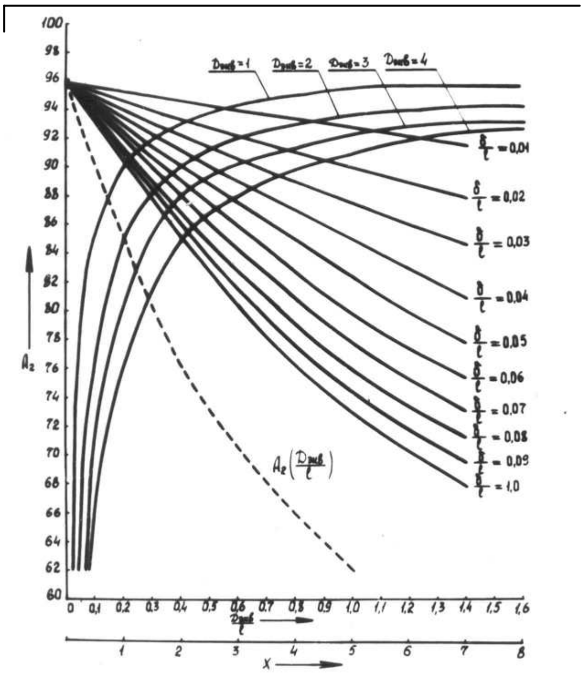

Fig.2. The A_2 dependences on x and $\frac{D_{eq}}{\partial}$.

$$\overline{\omega}(x) = \sqrt{A_3} \frac{d\nu}{\omega_H} \left[\frac{1}{2} A_2(x) \frac{L}{\delta}\right]^{\frac{2-\psi}{2}} \frac{B_1(x) x^{\frac{\psi-1}{2}}}{(x+2)\xi_0(x)_2} \left(\sqrt{1 + A_5 \xi_0(x) x^4} - 1\right)^{\frac{2-\psi}{2}} \;. \tag{36}$$

Substituting (36) in formula (7) we find $l_{np}(x)$ dependence which is taken into consideration at the projection of flat-and-edge with the given edge efficiency.

$$l_{np} = \delta \sqrt{A_3}\, x b_1(x) \left[\frac{2x\xi_0(x)}{A_2(x)\frac{L}{\delta}\left[\sqrt{1 + A_5 \xi_0(x) x^4} - 1\right]}\right]^{\frac{\psi}{2}}. \tag{37}$$

Substituting l_{np} form (36) into (35), we find

$$\frac{D_{экв}}{l} = \frac{1}{\sqrt{A_3} B_1(x)} \left[\frac{A_2(x)\frac{L}{\delta}\left[\sqrt{1 + A_0 \xi(x) x^4} - 1\right]}{2x\xi_0(x)}\right]^{\frac{\psi}{2}}. \tag{38}$$

The $\varpi(x)$ dependence for edges, the width of which changes from 0,2 mm till 1 mm, obtained by calculating way, is presented on the fig.3.

The ϖ, ν, $\Delta\overline{P}$, and $\overline{R}_T$ dependences on x are given on the fig.4. As it is seen from this figure, function minimum $R_T(x)$ is observed at some x values; this $x_{ОПТ}$ value and $l_{ПРЕД}$ value, corresponding to it, are defined at chosen edge width, given density of heat-flow rate and fan.

The unique solution of optimization task of flat-and-edge heat exchanger is collection of its optimal output characteristics.

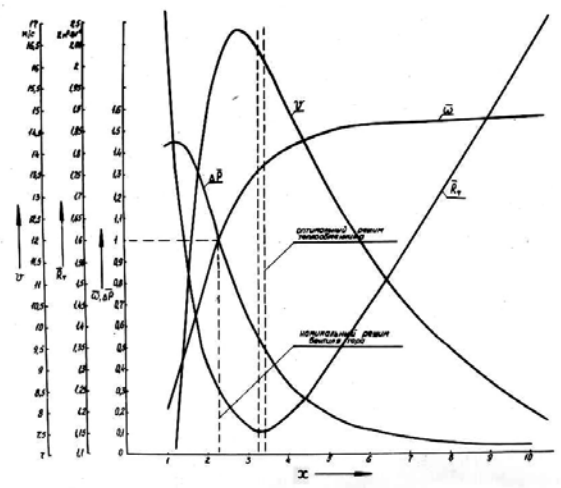

Fig.3. The dependence of non-dimensional expense ϖ on non-dimensional edge step *x*.

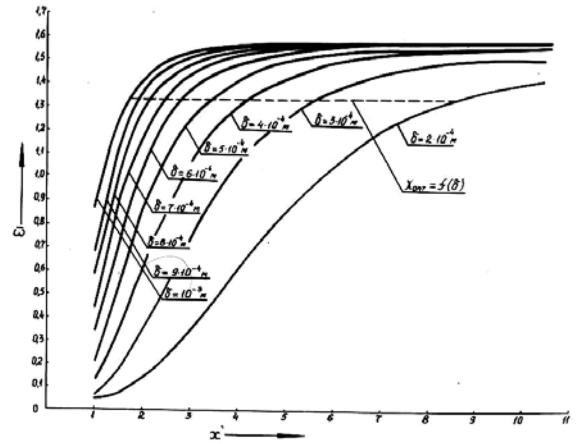

Fig.4. The dependences ϖ, ν, $\Delta\overline{P}$, and $\overline{R}_T$, realizing in air heat exchanger, on non-dimensional edge step *x*.

[1] *T.O. Carik, A.G. Shayko-Shaykovskiy, E.I. Timofeeva, A.V. Klepikovskiy*. J. Termoelektrichestvo №3, 2004, s.66-69. (in Russiam)

[2] *N.N. Proshkin.* J. Termoelektrichestvo, №2, 2000, s.57-65. (in Russiam)

[3] *T.A. Ismaylov, Sh.A. Yusufov*. Modelirovaniye i raschet termoelektricheskoqo okhladitelya vozdushnoqo potoka dlya sistem okhlajdeniya radioelektronnikh sistem, Termoelektriki i ikh primeneniya. Dokladı VIII mejqosudarstvennoqo seminara, 2002, s.390-395

[4] *A.I. Gryadunov, D. Mamatisakov.* Metodika optimizatsii radiatornikh sistem s ploskimi rebrami, J.Geliotekhnika, №1, 1976, s.76. (in Russiam)

[5] *M.A.Mikheyev, I.M. Mikheeva.* Osnovi teploperedachi, M-: Energiya 1973.

[6] *A.V. Likov.* Teplomassobmen: Spravochnik, M.: Enerqiya, 1972. (in Russiam)

[7] *A.D.Altshul, P.G. Kiselev.* Gidravlika i aerodinamika, M-: Stroyizdat, 1975. (in Russiam)

[8] *M.P. Kalinushkin.* Ventilyatronie ustanovki, M.: Visshaya shkola, 1962. (in Russiam)

[9] *Tadeush Khobler.* Teploperedacha i teploobmenniki, L.-Goskomizdat, 1961, s.820. (in Russiam)

[10] *V.F. Goshtenar*. J.Voprosi radioelektroniki, seriya TRTO. vip.1, 1975. (in Russiam)

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MÜSTƏVİTİLLİ RADİATOR SİSTEMİNİN SOYUQ TƏRƏFLİ TERMOBATAREYASININ OPTİMALLAŞDIRILMASI

İşdə müstəvitilli radiator sisteminin soyuq tərəfli termobatareyasının optimallaşdırılmasına baxılır.
Minimal intensivlik üfürmə şəraitində maksimal istilik effektliyinin optimallaşdırılması hesablama üsulları verilir.

Ф.К. Алескеров, А.Ш. Кахраманов

ОПТИМИЗАЦИЯ ПЛОСКОРЕБЕРНОЙ РАДИАТОРНОЙ СИСТЕМЫ ХОЛОДНЫХ СПАЕВ ТЕРМОБАТАРЕИ

В работе описаны расчетные методы оптимизации плоскореберной радиаторной системы холодных спаев термобатареи на максимальную тепловую эффективность при минимальной интенсивности обдува.

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