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METHOD OF CALCULATION OF HEAT EXCHANGER BASED ON DIFFERENT SIZES SLIT CHANNEL

The main trend of development of computing devices and control systems is expanding their functionality and increase in the speed of action, that leading to increased power consumption, much of which is released in the electronic components in the form of heat and leads to an increase in temperature, which has a negative impact on the reliability of their operation. Since the creation of new and modernization of existing devices is usually under severe design constraints, the problem of heating thus becomes crucial, and its solution is complex scientific and engineering problems. Specifically to address this issue there was the method of calculation of one- and two-tier highly heat exchange device that base on slit channels with vertical slits of different sizes in height exchanger.

There was calculated power of microchannel copper (copper M2) and aluminum (aluminum A5) heat exchanger at a constant width of microchannels. The design of the heat exchanger is shown in Figure 1.

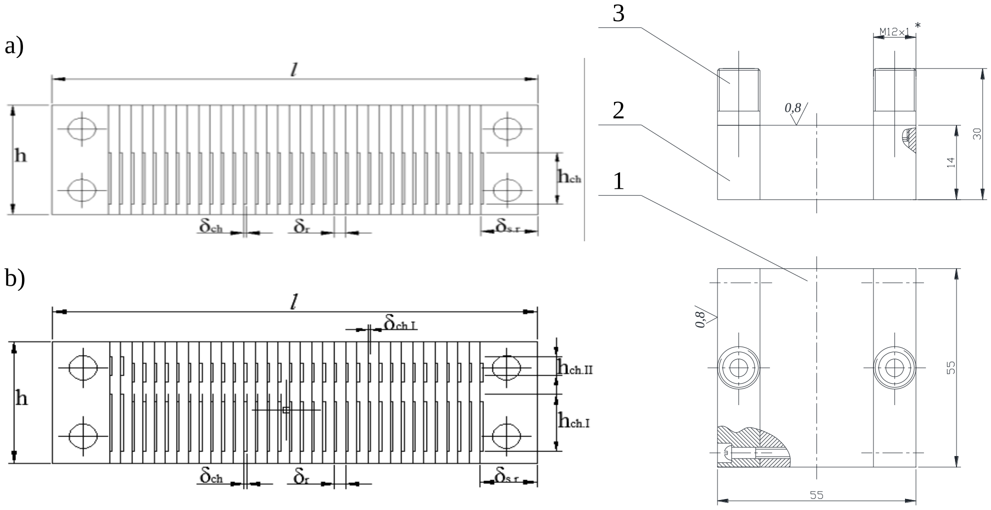

Fig. 1. a) Single-stage, b) Two-tier heat exchanger with constant bandwidth: 1 - building (heat sink), 2 - cell division coolant, 3 - coolant pipe input

TABLE 1

Initial data for the single-stage heat exchanger

Material	Copper (M2)	Aluminum (A5)
thickness of the ribs δ_r [m]	0.001	
rib height h_r [m]	0.0075	
channel width δ_{ch} [m]	0.0002	
thick horizontal fence $\delta_f{}^h$ [m]	0.005	
thick vertical barriers $\delta_f{}^v$ [m]	0.005	
coefficient of heat transfer from the walls to the coolant α [W/m^{2}K]	1200	
thermal conductivity of ribs λ_r [W/mK]	400	200

Method of single-stage heat exchanger:

1. We expect the performance of ribs:
   Pre-defined parameter ribs m_r:

$$m_r = \sqrt{\frac{2 \cdot \alpha_r}{\alpha_r \cdot \delta_r}} \tag{1}$$

The coefficient of efficiency ribs ε_r:

$$\varepsilon_r = \frac{th(m_r \cdot h_r)}{m_r \cdot h_r} \tag{2}$$

The effectiveness of lateral rib enclosure:
Parameter of vertical side fences m_f^v:

$$m_f^v = \sqrt{\frac{2 \cdot \alpha_f^v}{\lambda_f^v \cdot \delta_f^v}} \tag{3}$$

The effectiveness of the vertical fence ε_f^v:

$$\varepsilon_f^v = \frac{th(m_f^v \cdot h_f^v)}{m_f^v \cdot h_f^v} \tag{4}$$

Similarly, we find the efficiency of horizontal fencing.

2. The overall effectiveness of protections exchanger ε_o':

$$\varepsilon_o' = \varepsilon_f^v \cdot \varepsilon_f^h \tag{5}$$

3. Heat exchange in heat exchanger:

$$F = 2 \cdot n \cdot f_r \tag{6}$$

where: n - number of ribs, $f_r = h_r \cdot l_r$ - the surface area of the ribs, l - length of edges.

Power exchanger:

$$Q = \alpha \cdot F \cdot \varepsilon_r' \cdot \Delta\bar{t} \tag{7}$$

TABLE 2

Initial data for the two-tier copper and aluminum heat exchanger

base material thickness δ_b [m]	0.003
thickness of the side wall δ_w [m]	0.005
blocking wall thickness between the first and second tiers $\delta_{b.w}{}^h$ [m]	0.005
thickness of the floor on the second tier δ_{ov} [m]	0.003
height of the horizontal overlap $h_{ov}{}^h$ [m]	0.1375
vertical height of the fence $h_f{}^v$ [m]	0.1
first tier	
thickness of the ribs δ_{rI} [m]	0.001
rib height h_{rI} [m]	0.005
channel width $\delta_{ch.I}$ [m]	0.0002
coefficient of heat transfer from the walls to the coolant α_{rI} [W/m^{2}K]	1200
second tier	
thickness of the ribs δ_{rII} [m]	0.0011
rib height h_{rII} [m]	0.0025
channel width $\delta_{ch.II}$ [m]	0.0002
coefficient of heat transfer from the walls to the coolant $\alpha_{ch.II}$ [W/m^{2}K]	24 000

Method of Bunk exchanger:

1. The effectiveness of edges of the first tier
   The value of the parameter ribs m_{rI}:

$$m_{rI} = \sqrt{\frac{2 \cdot \alpha_{rI}}{\lambda_{rI} \cdot \delta_{rI}}} \tag{8}$$

Efficiency ratio ribs ε_{pI}:

$$\varepsilon_{pI} = \frac{th(m_{rI} \cdot h_{rI})}{m_{rI} \cdot h_{r\,I}} \tag{9}$$

2. The effectiveness of protections:
   The value of horizontal overlap m_{ovI}^{h}:

$$m_{ovI}^{h} = \sqrt{\frac{2 \cdot \alpha_{ovI}^{h}}{\lambda_{ovI}^{h} \cdot \delta_{ovI}^{h}}} \tag{10}$$

The effectiveness of horizontal overlap ε_{ovI}^{h}:

$$\varepsilon_{ovI}^{h} = \frac{th(m_{ovI}^{h} \cdot h_{ovI}^{h})}{m_{ovI}^{h} \cdot h_{ovI}^{h}} \tag{11}$$

The effectiveness of the vertical fence ε_{fI}^{v}.
The effectiveness of protections first stage heat exchanger ε'_{fI}:

$$\varepsilon'_{fI} = \varepsilon_{ovI}^{h} \cdot \varepsilon_{fI}^{v} \tag{12}$$

The effectiveness of the first stage heat exchanger ε'_{I}:

$$\varepsilon'_{I} = \varepsilon_{rI} \cdot \varepsilon'_{f1} \tag{13}$$

3. The effectiveness of the ribs of the second tier:
   The value of the parameter ribs m_{rII}:

$$m_{rII} = \sqrt{\frac{2 \cdot \alpha_{rII}}{\lambda_{rII} \cdot \delta_{rII}}} \tag{14}$$

Efficiency ratio ribs ε_{rII}:

$$\varepsilon_{rII} = \frac{th(m_{rII} \cdot h_{rII})}{m_{rII} \cdot h_{rII}} \tag{15}$$

The effectiveness of protections:
The value of horizontal overlap m_{ovI}^{h}:

$$m_{ovI}^{h} = \sqrt{\frac{2 \cdot \alpha_{ovI}^{h}}{\lambda_{ovI}^{h} \cdot \delta_{ovI}^{h}}} \tag{16}$$

The effectiveness of horizontal overlap ε_{ovI}^{h}:

$$\varepsilon_{ovIv}^{h} = \frac{th(m_{ovI}^{h} \cdot h_{ovI}^{h})}{m_{ovI}^{h} \cdot h_{ovI}^{h}} \tag{17}$$

Similarly, we find the performance of vertical barriers ε_{fII}^{v}.

We find the overall efficiency of the heat exchanger of the second tier of protections:

$$\varepsilon'_{fII} = \varepsilon_{ovI}^{h} \cdot \varepsilon_{fII}^{v} \tag{18}$$

Find the overall performance of the second stage heat exchanger:

$$\varepsilon'_{II} = \varepsilon_{rII} \cdot \varepsilon'_{fII} \tag{19}$$

Calculate the heat transfer surface first layer:

$$F = n \cdot f_{rI} \cdot 2 \tag{20}$$

where: n - number of edges, $f_{rI} = h_{rI} \cdot l_{rI}$ - surface area of the fins, l_I - edge length.

Heat output of the first stage heat exchanger:

$$Q_I = \alpha_I \cdot F_I \cdot \varepsilon'_{rI} \cdot \Delta t \tag{21}$$

Heat exchange of the second tier:

$$F = n \cdot f_{rII} \cdot 2 \tag{22}$$

where: n - number of edges, $f_{rII} = h_{rII} \cdot l_{rII}$ - surface area of the fins, l_{II} - edge length.

Heat output of the second stage heat exchanger:

$$Q_{II} = \alpha_{II} \cdot F_{II} \cdot \varepsilon'_{rII} \cdot \Delta t \tag{23}$$

To $\Delta t_1 = 10$°C, $\Delta t_1 = 20$°C, $\Delta t_1 = 30$°C, find the heat output of the first (Q_{I1}, Q_{I2}, Q_{I3}) and second $(Q_{II1}, Q_{II2}, Q_{II3})$ layers, and the total thermal power:

$$Q_1 = Q_{I1} + Q_{II1}$$
$$Q_2 = Q_{I2} + Q_{II2}$$
$$Q_3 = Q_{I3} + Q_{II3}$$

The calculation results are summarized in Table 3.

TABLE 3

Results of calculation of heat exchangers

Material	Copper	Aluminum
Temperature pressure [°C]	Thermal power Q [W]	
Single-stage heat exchanger		
$\Delta t_1 = 10$	1125	813
$\Delta t_2 = 20$	2250	1625
$\Delta t_2 = 30$	3375	2437
Bunk exchanger		
$\Delta t_1 = 10$	1420	1004
$\Delta t_2 = 20$	2839	2007
$\Delta t_2 = 30$	4269	3011

Conclusions

More efficient heat exchanger is made of copper, due to higher thermal conductivity of copper (400 W/m^{2}K) compared with aluminum (200 W/m^{2}K), and this leads to an increase in the coefficient of efficiency ribbing. Power Bunk copper heat exchanger with reduced bandwidth in the second tier is 26% higher than with single-stage heat exchanger surface temperature is below 13°C. Aluminum power by 23.7% with the temperature of the surface, which reduces to 9°C.

References

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Abstract

This paper presents calculation of power of microchannel copper and aluminium heat exchanger at a constant width of microchannels.

Metodyka obliczeń wymienników ciepła oparta na podstawie różnych wymiarów szczeliny kanału

Streszczenie

W pracy przedstawiono obliczenia siły w mikrokanałach miedzianych i aluminiowych wymienników ciepła przy stałej szerokości mikrokanałów.