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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.

![Diagram of heat exchanger](image)

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

<table>
<thead>
<tr>
<th>Material</th>
<th>Copper (M2)</th>
<th>Aluminum (A5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>thickness of the ribs $\delta_r$ [m]</td>
<td>0.001</td>
<td></td>
</tr>
<tr>
<td>rib height $h_r$ [m]</td>
<td>0.0075</td>
<td></td>
</tr>
<tr>
<td>channel width $\delta_{ch}$ [m]</td>
<td>0.0002</td>
<td></td>
</tr>
<tr>
<td>thick horizontal fence $\delta_{fh}^h$ [m]</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>thick vertical barriers $\delta_{fv}^v$ [m]</td>
<td>0.005</td>
<td></td>
</tr>
<tr>
<td>coefficient of heat transfer from the walls to the coolant $\alpha$ [W/m$^2$K]</td>
<td>1200</td>
<td></td>
</tr>
<tr>
<td>thermal conductivity of ribs $\lambda_r$ [W/mK]</td>
<td>400</td>
<td>200</td>
</tr>
</tbody>
</table>

Method of single-stage heat exchanger:
1. We expect the performance of ribs:
   Pre-defined parameter ribs $m_r$:
   \[
   m_r = \sqrt{\frac{2 \cdot \alpha_r}{\alpha_r \cdot \delta_r}}
   \]  
   (1)
   The coefficient of efficiency ribs $\varepsilon_r$:
   \[
   \varepsilon_r = \frac{th(m_r \cdot h_r)}{m_r \cdot h_r}
   \]  
   (2)
   The effectiveness of lateral rib enclosure:
   Parameter of vertical side fences $m_{fv}^v$:
   \[
   m_{fv}^v = \sqrt{\frac{2 \cdot \alpha_{fv}^v}{\lambda_{fv}^v \cdot \delta_{fv}^v}}
   \]  
   (3)
   The effectiveness of the vertical fence $\varepsilon_{fv}^v$:
   \[
   \varepsilon_{fv}^v = \frac{th(m_{fv}^v \cdot h_{fv}^v)}{m_{fv}^v \cdot h_{fv}^v}
   \]  
   (4)
   Similarly, we find the efficiency of horizontal fencing.
2. The overall effectiveness of protections exchanger $\varepsilon_o$:
   \[
   \varepsilon_o = \varepsilon_f^v \cdot \varepsilon_f^h
   \]  
   (5)
3. Heat exchange in heat exchanger:
where: \( n \) - number of ribs, \( f_r = h_r \cdot l_r \) - the surface area of the ribs, \( l \) - length of edges.

Power exchanger:

\[
Q = \alpha \cdot F \cdot \varepsilon' \cdot \Delta t
\]

\[\text{(7)}\]

**TABLE 2**

<table>
<thead>
<tr>
<th>parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>base material thickness ( \delta_b ) [m]</td>
<td>0.003</td>
</tr>
<tr>
<td>thickness of the side wall ( \delta_w ) [m]</td>
<td>0.005</td>
</tr>
<tr>
<td>blocking wall thickness between the first and second tiers ( \delta_{b,w} ) [m]</td>
<td>0.005</td>
</tr>
<tr>
<td>thickness of the wall on the second tier ( \delta_w' ) [m]</td>
<td>0.003</td>
</tr>
<tr>
<td>height of the horizontal overlap ( h_{w,h} ) [m]</td>
<td>0.1375</td>
</tr>
<tr>
<td>vertical height of the fence ( h' ) [m]</td>
<td>0.1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tier</th>
<th>parameter</th>
<th>value</th>
</tr>
</thead>
<tbody>
<tr>
<td>first tier</td>
<td>thickness of the ribs ( \delta_r' ) [m]</td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td>rib height ( h_r' ) [m]</td>
<td>0.005</td>
</tr>
<tr>
<td></td>
<td>channel width ( \delta_{ch} ) [m]</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
<td>coefficient of heat transfer from the walls to the coolant ( \alpha_{r,t} ) [W/m²K]</td>
<td>1200</td>
</tr>
<tr>
<td>second tier</td>
<td>thickness of the ribs ( \delta_r'' ) [m]</td>
<td>0.0011</td>
</tr>
<tr>
<td></td>
<td>rib height ( h_r'' ) [m]</td>
<td>0.0025</td>
</tr>
<tr>
<td></td>
<td>channel width ( \delta_{ch}'' ) [m]</td>
<td>0.0002</td>
</tr>
<tr>
<td></td>
<td>coefficient of heat transfer from the walls to the coolant ( \alpha_{r,t}'' ) [W/m²K]</td>
<td>24000</td>
</tr>
</tbody>
</table>

**Method of Bunk exchanger:**

1. The effectiveness of edges of the first tier

The value of the parameter ribs \( m_{rif} \):

\[
m_{rif} = \sqrt{\frac{2 \cdot \alpha_r}{\lambda_r' \cdot \delta_r'}}
\]

\[\text{(8)}\]

Efficiency ratio ribs \( \varepsilon_{rif} \):

\[
\varepsilon_{rif} = \frac{\theta (m_{rif} \cdot h_r')}{{m_{rif} \cdot h_r'}}
\]

\[\text{(9)}\]
2. The effectiveness of protections:

The value of horizontal overlap $m_{ovl}^h$:

$$m_{ovl}^h = \sqrt{\frac{2 \cdot \alpha_{ovl}^h}{\lambda_{ovl} \cdot \delta_{ovl}^h}}$$  \hspace{1cm} (10)

The effectiveness of horizontal overlap $\varepsilon_{ovl}^h$:

$$\varepsilon_{ovl}^h = \frac{th(m_{ovl}^h \cdot h_{ovl}^h)}{m_{ovl}^h \cdot h_{ovl}^h}$$  \hspace{1cm} (11)

The effectiveness of the vertical fence $\varepsilon_{vf}^v$.

The effectiveness of protections first stage heat exchanger $\varepsilon_{fi}^f$:

$$\varepsilon_{fi}^f = \varepsilon_{ovl}^h \cdot \varepsilon_{vf}^v$$  \hspace{1cm} (12)

The effectiveness of the first stage heat exchanger $\varepsilon_i^f$:

$$\varepsilon_i^f = \varepsilon_{ci} \cdot \varepsilon_{fi}$$  \hspace{1cm} (13)

3. The effectiveness of the ribs of the second tier:

The value of the parameter ribs $m_{vll}$:

$$m_{vll} = \sqrt{\frac{2 \cdot \alpha_{vll}}{\lambda_{vll} \cdot \delta_{vll}}}$$  \hspace{1cm} (14)

Efficiency ratio ribs $\varepsilon_{vll}$:

$$\varepsilon_{vll} = \frac{th(m_{vll} \cdot h_{vll})}{m_{vll} \cdot h_{vll}}$$  \hspace{1cm} (15)

The effectiveness of protections:

The value of horizontal overlap $m_{ovl}^h$:

$$m_{ovl}^h = \sqrt{\frac{2 \cdot \alpha_{ovl}^h}{\lambda_{ovl} \cdot \delta_{ovl}^h}}$$  \hspace{1cm} (16)

The effectiveness of horizontal overlap $\varepsilon_{ovl}^h$:

$$\varepsilon_{ovl}^h = \frac{th(m_{ovl}^h \cdot h_{ovl}^h)}{m_{ovl}^h \cdot h_{ovl}^h}$$  \hspace{1cm} (17)
Similarly, we find the performance of vertical barriers $\epsilon_{II}^v$.

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

$$\epsilon'_{III} = \epsilon_{ov}^h \cdot \epsilon_{III}^v$$  \hspace{1cm} (18)

Find the overall performance of the second stage heat exchanger:

$$\epsilon'_{II} = \epsilon_{II} \cdot \epsilon_{III}^v$$  \hspace{1cm} (19)

Calculate the heat transfer surface first layer:

$$F = n \cdot f_{II} \cdot 2$$  \hspace{1cm} (20)

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

Heat output of the first stage heat exchanger:

$$Q_I = \alpha_I \cdot F \cdot \epsilon'_{II} \cdot \Delta t$$  \hspace{1cm} (21)

Heat exchange of the second tier:

$$F = n \cdot f_{II} \cdot 2$$  \hspace{1cm} (22)

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

Heat output of the second stage heat exchanger:

$$Q_{II} = \alpha_{II} \cdot F_{II} \cdot \epsilon'_{III} \cdot \Delta t$$  \hspace{1cm} (23)

To $\Delta t_1 = 10^\circ C$, $\Delta t_2 = 20^\circ C$, $\Delta t_3 = 30^\circ C$, 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:

$$Q_I = Q_{I1} + Q_{II1};$$
$$Q_2 = Q_{I2} + Q_{II2};$$
$$Q_3 = Q_{I3} + Q_{II3}.$$

The calculation results are summarized in Table 3.
TABLE 3

<table>
<thead>
<tr>
<th>Material</th>
<th>Copper</th>
<th>Aluminum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature pressure [°C]</td>
<td>Thermal power Q [W]</td>
<td></td>
</tr>
<tr>
<td>Single-stage heat exchanger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δt₁ = 10</td>
<td>1125</td>
<td>813</td>
</tr>
<tr>
<td>Δt₂ = 20</td>
<td>2250</td>
<td>1625</td>
</tr>
<tr>
<td>Δt₃ = 30</td>
<td>3375</td>
<td>2437</td>
</tr>
<tr>
<td>Bunk exchanger</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Δt₁ = 10</td>
<td>1420</td>
<td>1004</td>
</tr>
<tr>
<td>Δt₂ = 20</td>
<td>2839</td>
<td>2007</td>
</tr>
<tr>
<td>Δt₃ = 30</td>
<td>4269</td>
<td>3011</td>
</tr>
</tbody>
</table>

Conclusions

More efficient heat exchanger is made of copper, due to higher thermal conductivity of copper (400 W/m²K) compared with aluminum (200 W/m²K), 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


Abstract

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

Streszczenie