Abstract

The optimization of the parameters of high-temperature thermionic ventiles were carried out. The experimental and calculative results of the optimizing values of the vapour pressure, electrode temperatures of the ventile and its specific electrical power limit were obtained.

The operation of the high-temperature radiation-resistant current conversion plasma systems (HTP-systems) being the thermophysics design in the structure of the space nuclear power supply with TEC depends on the many factors: the operating ventiles temperature, the value of the electrical conversion power, the control current method, the efficiency of current control, the values of the operating current and voltage of EPT etc. It influences on the characteristics of the HTP-system in essential order:
- mass-dimention;
- electric;
- exploited;
- economic;
- ecologic.

The state parameters optimization of HTP-systems permits to increase its electrical power and specific mass power, current and voltage conversion efficiency largely. The optimization of the whole HTP-system divides on two parts:
- optimization of the parameters of the controlable thermionic ventile (grid switching ventile - GSV) - the entrance stage of current converter;
- optimization of the parameters of the high-voltage thermionic diode (HVTD) - the exit stage of the current converter.

The parameters optimization of GSV and HVTD is founded on the purpose function - its maximum power efficiency with taken into consideration the following factors: the operating temperature $T_v$, the losses of the electrical power in ventile $P_L$, the expenditures of the current control electrical power $P_c$, specific mass electrical power $P_y$.

For number of the optimizing parameters of thermophysics state of the ventile are following: the operating vapour pressure $p_v$, the electrode temperature $T_a$, $T_k$. Yet a certain optimizing parameter is the geometrical - the value of the interelectrod gap (IEG) length - $\Delta_{IEG}$. The optimization of the first three permits to increase the electrical characteristics of GSV or HVTD, namely - the operating voltage $U_v$ operating...
current $I_v$, operating power $P_v$, passing to EPT. The optimization of the geometrical factor permits to arrive the maximum electric efficiency at the expense of the decrease of the power losses in ventile.

The problem of the ventile optimization is multiparametrical because on its solution will influence the purpose function, external and internal factors. In this paper the authors shows one of the version of the approach for that. As the entrance parameters of optimization are using the operating parameters: operating current and voltage, temperature, the parameters of the current control circue, the value of power loss as the purpose function is the specific mass electrical power of the ventile.

Using the experimental data of mass electrical power of the semiconductive current converters may assume that the HTP-systems are profitable at the value of the specific mass electrical power $P_v > 1000 \text{ W/kg}$ (it surpasses this parameter of the semiconductive converter in two - three times). Therefore the problem of the parameters HTP-system optimization is reduced to the definition of the range of the operating parameters $- p_{co}, T_a, T_k$, where the value of $P_v$ is realized at the observance of the operating voltage value (this is voltage of TEC supply and operating EPT voltage).

On the foundation of this approach the analytic dependence between the ventile electrical characteristics and its thermophysics parameters were obtained:

$$P_{co}^{opt} = A k T_{co} \left[ \frac{1 + \gamma_i}{j_c U_b F(\kappa_d^2)} \right]$$

where $A$ - constant, $k$ - Bolzman constant, $T_{co}$ - vapour temperature in IEG, $\gamma_i$ - the secondary emission coefficient, $j_c$ - the breakdown current density, $U_b$ - the breakdown voltage, $F(\kappa_d^2)$ - the function depending on vapour heat conductivity. $\alpha, \beta, \varphi, \lambda$ - coefficients.

Calculations executing on this formula are showed the range of the possible cesium vapour pressure and its boundary, fig. 1. Results of the experimental investigations is correlated with the calculations.

On the foundation of this co-ordination of the electric strength characteristics of the ventile with its parameters of the disclose state of IEG (where the current density of the non-self-maintaining arc discharge is the function of the cathode temperature and vapour pressure) may carry out the optimization of the $p_{co}$ and $T_k$ in order to achievement the maximum of the arc discharge current density $j_{d}^{max}$. As result may get the value of the maximum specific electrical power of the ventile:

$$P_{v}^{max} = j_{d}^{max} \left( P_{co}^{opt}(U_b, T_{co}), T_{k}^{opt} \right) \cdot U_v,$$

where $T_{k}^{opt}$ - optimizing cathode temperature.

The calculative results and our experimental data are showed on fig. 2.
The investigations showed that the using of cesium filling ventiles are most efficiently at the its operating temperature not more 700 - 730 K, because the increase of this parameter lead to reduction of the operating voltage and gets worse the electric strength of IEG.

On the foundation of our experimental and calculative investigation results and data of the parameters of other types of the ventiles the comparative analysis were carried out:

<table>
<thead>
<tr>
<th>Type of ventile</th>
<th>Voltage of arc breakdown $U_b$, V</th>
<th>Ignition voltage $U_i$, V</th>
<th>Voltage drop in disclose state $\delta U_d$, V</th>
<th>Operat. temperature $T_o$, K</th>
<th>Specific mass power $P_y$, kW/kg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hg vapour 1000 - 10000</td>
<td>&lt; 40</td>
<td>20 - 50</td>
<td>320</td>
<td></td>
<td>0.01 - 0.5</td>
</tr>
<tr>
<td>gas fill. 1000 - with cold 10000</td>
<td>&lt; 100</td>
<td>100 - 200</td>
<td>320</td>
<td></td>
<td>0.1</td>
</tr>
<tr>
<td>gas fill. 1000 - with hot 10000</td>
<td>10 - 40</td>
<td>10 - 20</td>
<td>600</td>
<td></td>
<td>0.1 - 0.4</td>
</tr>
<tr>
<td>semiconductor 1000 - 2000</td>
<td>1.5 - 2</td>
<td>1.5 - 3</td>
<td>580 - 600</td>
<td>2 - 20</td>
<td>0.1 - 0.5</td>
</tr>
</tbody>
</table>

Conclusions

Our research works showed that the cesium filling ventiles with thermionic non-self-maintaining arc discharge are most perspective elements of the current conversion system for the space power propulsion plants because it surpass the all well-known types on the level of the operating temperature and specific mass electrical power.

![Graph 1](image1.png)

![Graph 2](image2.png)