VM cryocooler is one kind of Stirling type cryocooler working at low frequency. At present, we have obtained the liquid helium temperature by using a two-stage VM/pulse tube hybrid cryocooler. As a new kind of 4K cryocooler, there are many aspects need to be studied and optimized in detail. In order to reducing the vibration and improve the stability of this cryocooler, a pulse tube cryocooler was designed to get rid of the displacer in the first stage. This paper presents a detail numerical investigation on this pulse tube cryocooler by using the SAGE software. The low temperature phase shifters were adopted in this cryocooler, which were low temperature gas reservoir, low temperature double-inlet and multi-bypass. After optimizing, the structure parameters and the best diameters of orifice, multi-bypass and double-inlet were obtained. With the pressure ratio of about 1.6 and operating frequency 2Hz, this cryocooler could supply above 40mW cooling power at 4.2K, and the total input power needs no more than 60W at 77K. Based on the highest efficiency of 77K high capacity cryocooler, the overall efficiency of this VM type pulse tube cryocooler is above 0.5% relative Carnot efficient.

**Abstract**

**BACKGROUND**

- Single stage VM cryocooler: 7.35K
- VM/PT hybrid cryocooler: 2.6K
- VM multi-bypass PTC

**Structural parameters**

- Cryogen free
- Reliable
- High efficiency

**Thermal compressor**

<table>
<thead>
<tr>
<th>Diameter</th>
<th>95mm</th>
<th>Pulse tube I</th>
<th>D=12.5mm, L=100mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>20mm</td>
<td>Pulse tube II</td>
<td>D=8.9mm, L=80mm</td>
</tr>
<tr>
<td>300K heat exchanger</td>
<td>D=5mm, L=200mm</td>
<td>Regenerator I</td>
<td>D&lt;sub&gt;in&lt;/sub&gt;=12.5mm, D&lt;sub&gt;out&lt;/sub&gt;=20mm</td>
</tr>
<tr>
<td>77K heat exchanger</td>
<td>D=3mm, L=200mm</td>
<td>40mm 200# SS screen</td>
<td></td>
</tr>
<tr>
<td>Regenerator</td>
<td>D&lt;sub&gt;in&lt;/sub&gt;=26mm, D&lt;sub&gt;out&lt;/sub&gt;=44mm</td>
<td>50mm 0.4~0.45mm lead sphere</td>
<td></td>
</tr>
<tr>
<td>Regenerator</td>
<td>80# SS screen, L=120mm</td>
<td>Regenerator II</td>
<td>D&lt;sub&gt;in&lt;/sub&gt;=8.9mm, D&lt;sub&gt;out&lt;/sub&gt;=18mm</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>40mm 0.2~0.25mm Er,Ni</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>35mm 0.2~0.25HoCu&lt;sub&gt;2&lt;/sub&gt;</td>
</tr>
</tbody>
</table>

**SAGE SIMULATION**

- The lowest temperature of cold end was about 6.1K
- The temperature of multi-bypass was 48.9K
- The pressure ratio was about 1.6

**Pressure ratio & Acoustic power**

- The pressure ratio of cold end increased with the opening of double-inlet
- The input acoustic power decreased with the opening of double-inlet

**Cooling power & Multi-bypass**

- The optimal multi-bypass is about 0.4mm
- The cooling power is about 42mW at 4.2K
- Overall efficiency above 0.5% relative Carnot efficient

**Middle temperature & DC flow**

- DC mass flow rate increased with the opening of double-inlet
- DC mass flow rate would influence the temperature of multi-bypass

**Acoustic power distribution**

- Acoustic power was consumed about 7W in the regenerator I
- Acoustic power was consumed about 4W in the regenerator II
- 1W acoustic power flow through the double-inlet

**Regenerator detail**

- Pulse tube I
- Pulse tube II
- Multi-bypass
- Cold end
- Gas reservoir
- Regenerator I
- Regenerator II

**Preliminary Experimental result**

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