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Structural optimization of the rotary valve in a two-stage Gifford-McMahon-type pulse-tube cryocooler working at liquid helium temperatures

Qinyu ZHAO, Jun CHENG, Yanrui ZHANG, Haoren WANG, Bo WANG, Ruize LI, Hua ZHANG, Zhihua GAN

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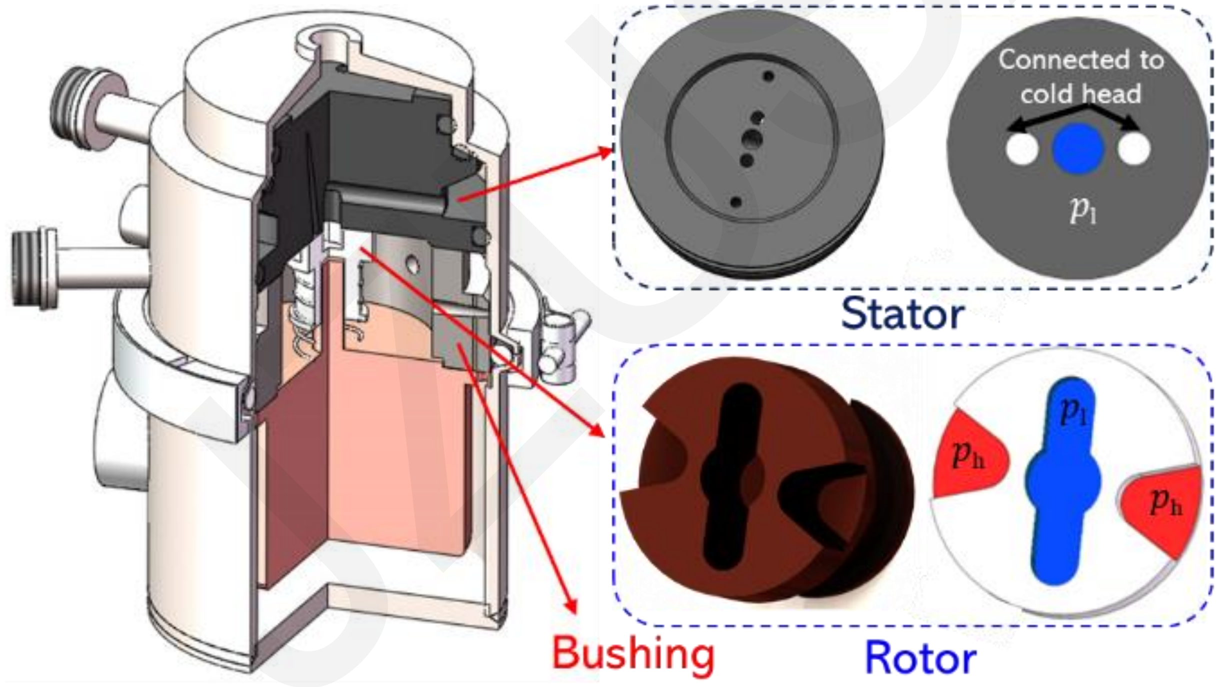
Structure of the rotary valve

■ The rotary valve, consisting of a suction valve and discharge valve, is a distribution valve that opens and closes periodically according to specific timing.



Leakage loss in the rotary valve

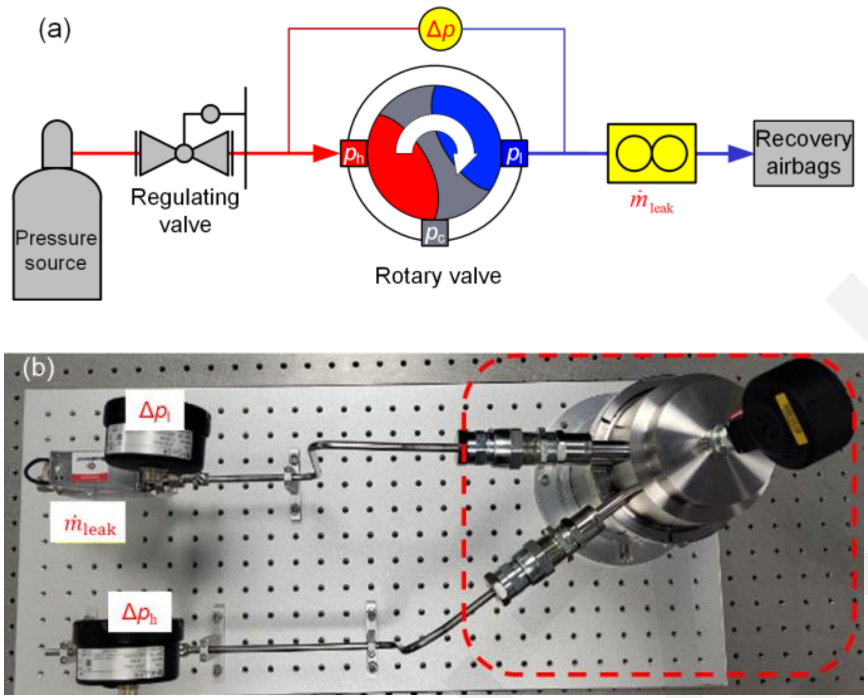


Fig. 3 Test platform for the leakage coefficient of rotary valve: (a) schematic diagram; (b) photograph

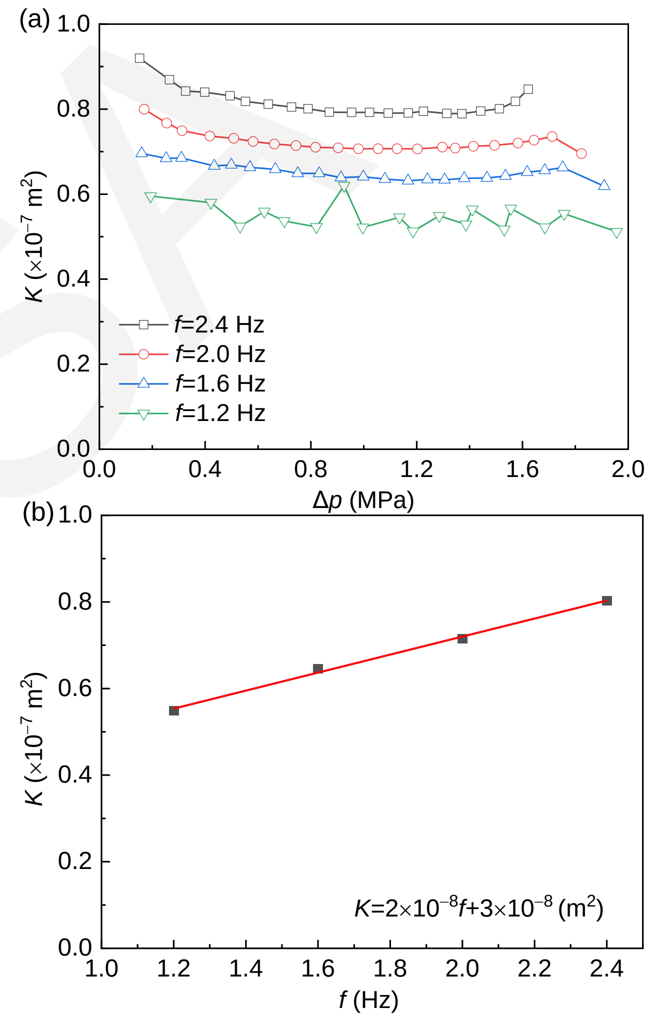


Fig. 4 (a) relationship between leakage coefficient and pressure difference with different operating frequencies; (b) linear fitting of leakage coefficient with operating frequency

Viscosity loss in the rotary valve

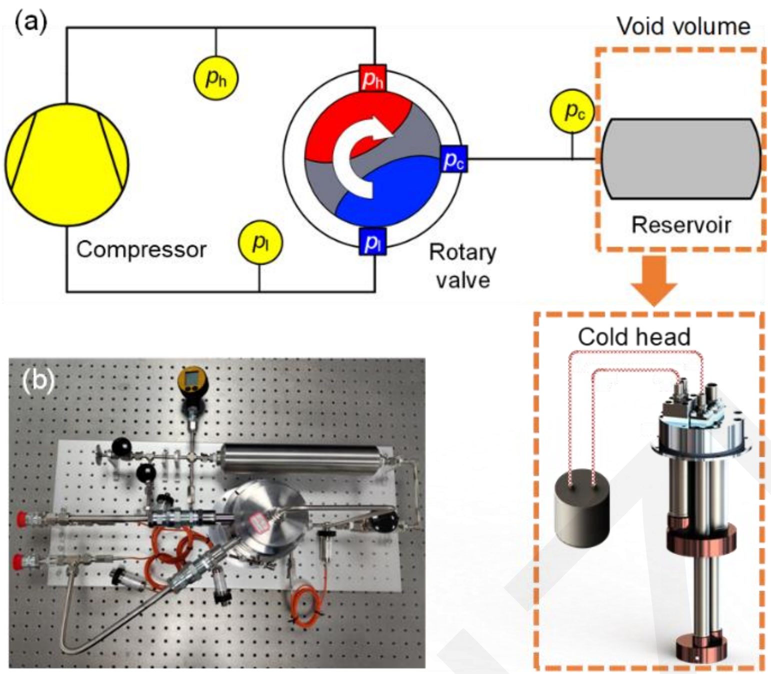


Fig. 5 Experimental platform used to assess viscosity loss in the rotary valve: (a) schematic diagram; (b) photograph.

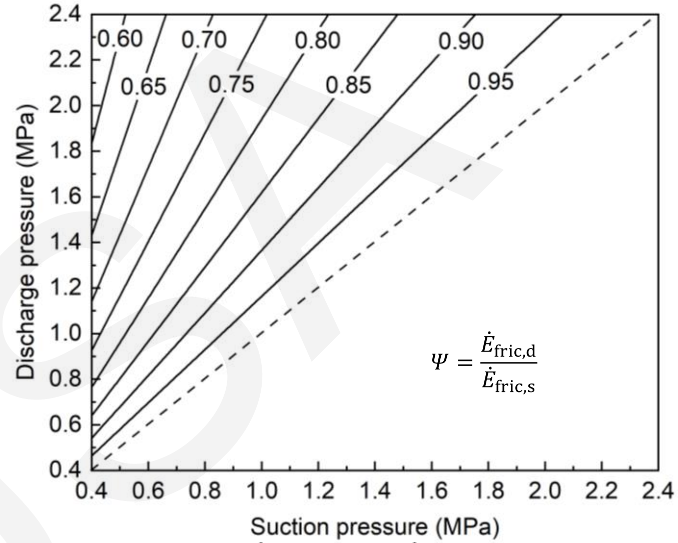


Fig. 7 Ratios of $\dot{E}_{fric,d}$ and $\dot{E}_{fric,s}$ with different suction and discharge pressures

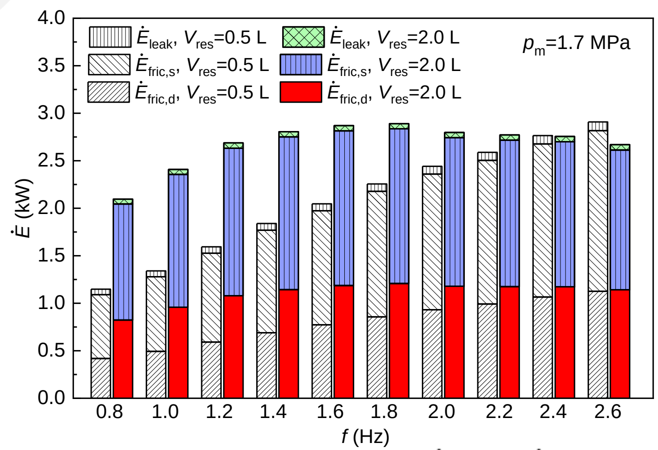


Fig. 8 Tested distribution of $\dot{E}_{fric,d}$, $\dot{E}_{fric,s}$, and $\dot{E}_{leak}$ in the rotary valve using two reservoirs with volumes of 0.5 L and 2.0 L

Structural optimization to reduce friction loss in rotary valves

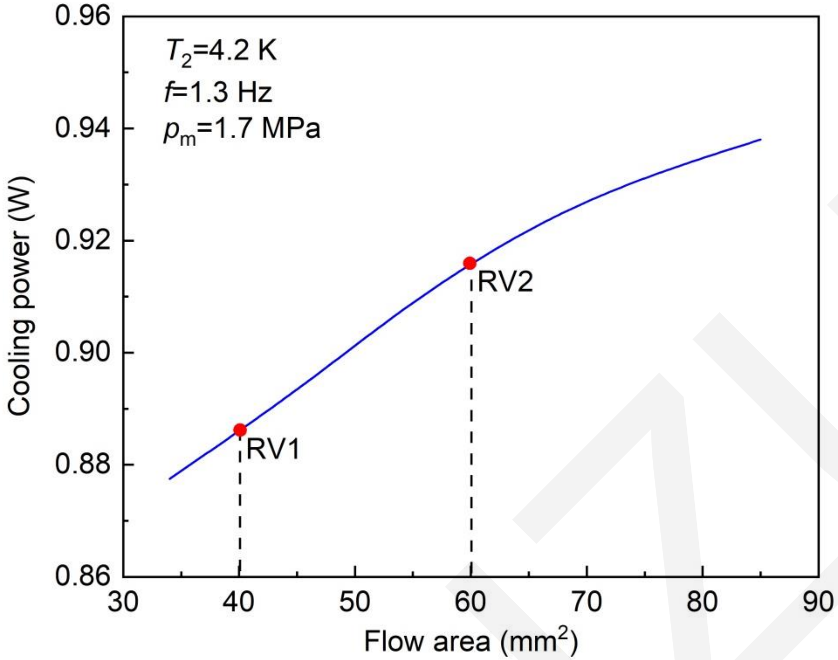


Fig. 9 Relationship between the flow area of the rotary valve and the cooling power of the GM-PTC at cooling temperature of T_2=4.2 K as plotted by Sage

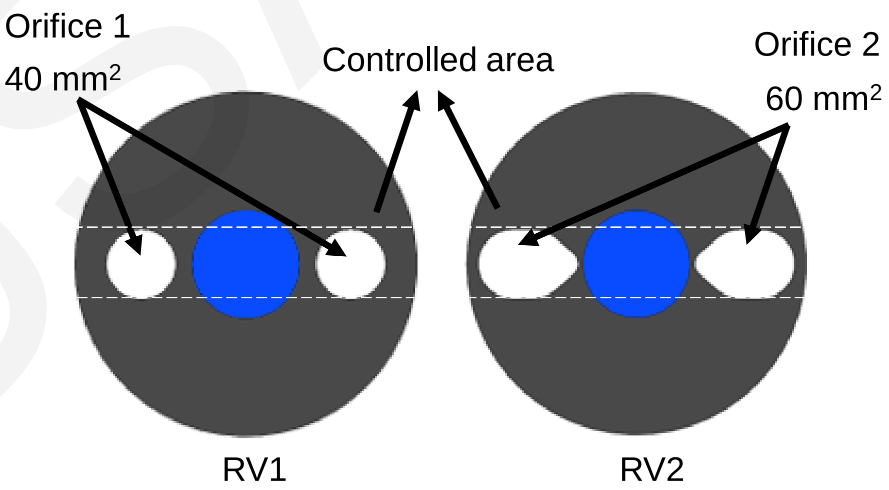


Fig. 10 Structure of the stators in both rotary valves (RV1 and RV2)

Test of the cooling capacity

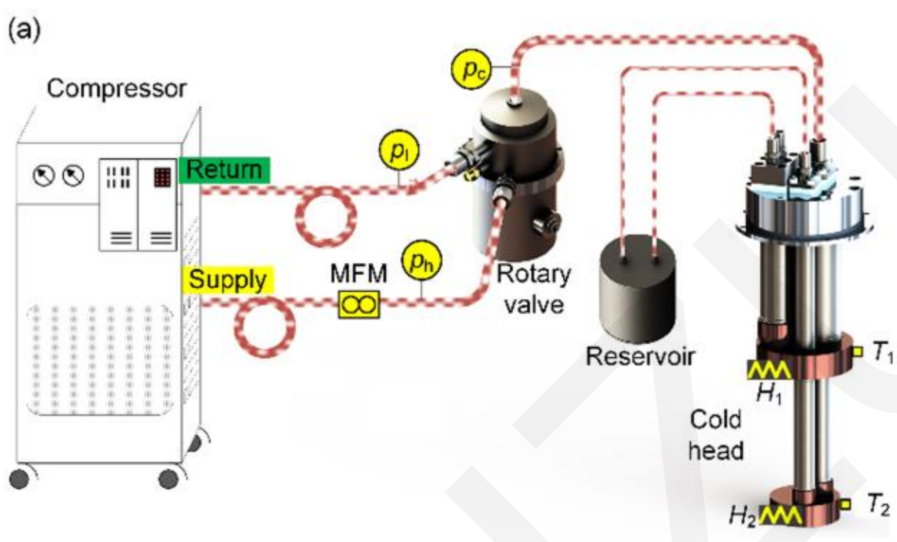


Fig. 14 Test platform of a two-stage GM-PTC

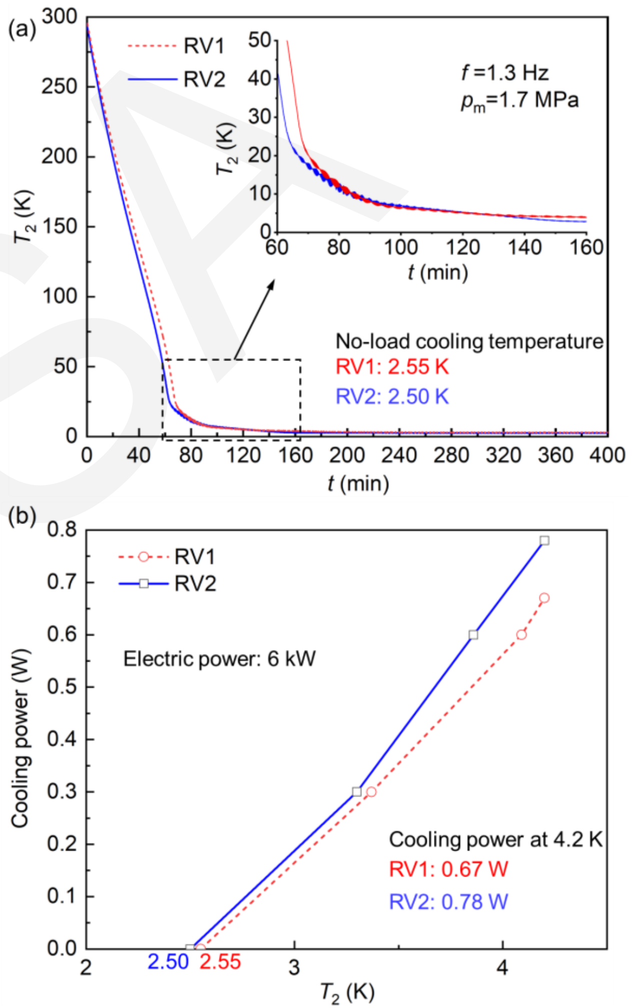


Fig. 15 Comparison of the cooling performance of a two-stage GM-PTC with an RV1 or RV2 rotary valve installed: (a) cool-down curve; (b) cooling power

Conclusions

- **The leakage loss is less than 2.5% of the total exergy loss and the viscosity loss accounts for more than 97.5% of the total exergy loss.**

- **When the input power of the compressor is 6 kW, the GM-PTC provides a cooling power of 0.78 W at 4.2 K when replacing RV1 with RV2, which leads to an improvement of 16.4% in the cooling efficiency of the GM-PTC.**