[C2PoB-03]

Development of 1 kW Striling cryocooler with using linear compressor

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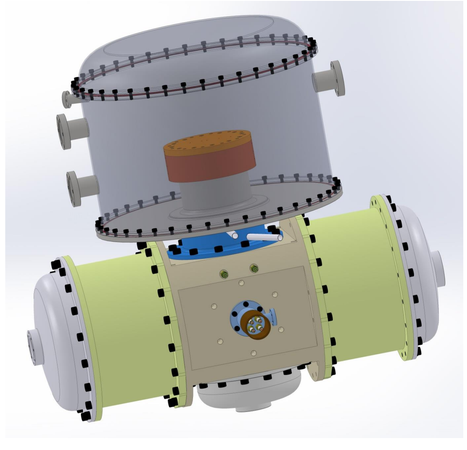
◆ Introduction



[Linear drive Stirling cryocooler (KIMM)]

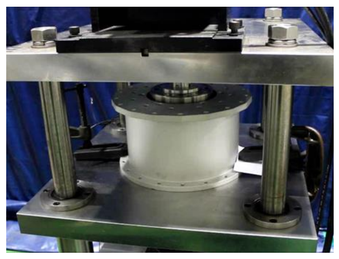
Background

- ✓ Large cooling capacity cryocooler is required for cryogenic cooling system of HTS applications.
- ✓ Crank-driven Stirling cryocooler is widely used at present.
- ✓ Issued problem of vibration absorption, oil removal and frequent maintenance in crank-driven Stirling cryocooler
- ✓ Double-acting linear compressor has characteristics of maintenance-free, inherently vibration-free, high efficiency.
- ✓ Gamma-type Stirling cryocooler with linear compressor is suggested.

Objectives

- ✓ Development of 1 kW (at 77 K) Stirling cryocooler driven by linear compressor

◆ Design and fabrication



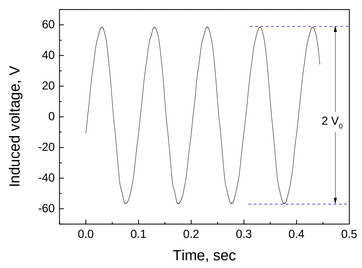
$$v(t) = K_E \frac{dx(t)}{dt} \Rightarrow K_E = \frac{V_0}{\omega X_0}$$

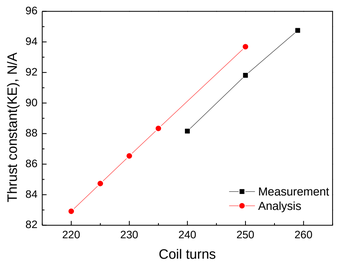
K_E : Thrust constant (N/A)

V_0 : Induced voltage amplitude (V)

X_0 : Displacement amplitude (m)

ω : Angular velocity (rad/s)

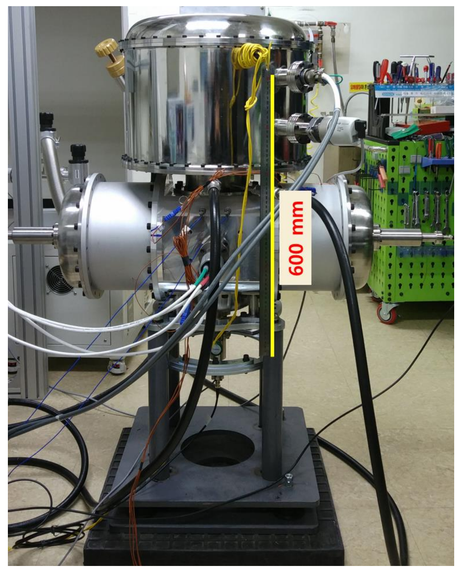




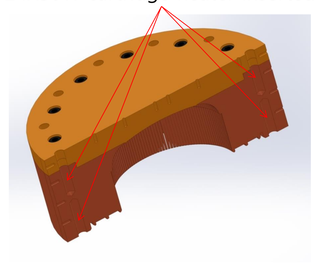
[Experimental measurement of thrust constant]
: excitation w/ fixed stroke & measuring induced voltage w/ oscilloscope

[Design and fabrication specifications]

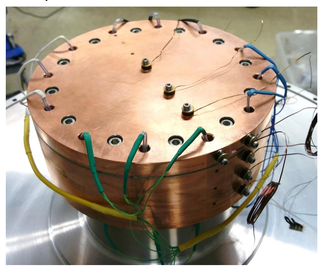
Linear compressor	
Type	Dual-opposed, moving magnet, flexure supported
Linear motor	Thrust const. (N/A) = 85.5 (designed), 94.8 (fabricated)
Rated electricity	380 V(1ϕ), 31.6 Arms, 12.0 kW (at 60 Hz)
Piston	100 mm (dia.), 30 mm (designed stroke) 4.5 kg (moving mass)
Cold part	
Displacer	γ-type driving 83 mm (dia.), 24 mm (designed stroke) 24 mm (connecting rod dia.)
Regenerator	Din = 86 mm, Dout = 130 mm, Length = 80 mm
Heat exchanger	Slit-type for cold/warm-end heat exchanger Water cooled heat rejection
Experimental condition	
Working fluid	Helium / 2,500 kPa charged at RT
Frequency	45 Hz Max. input current < rated current



24X50W cartridge heater inserted

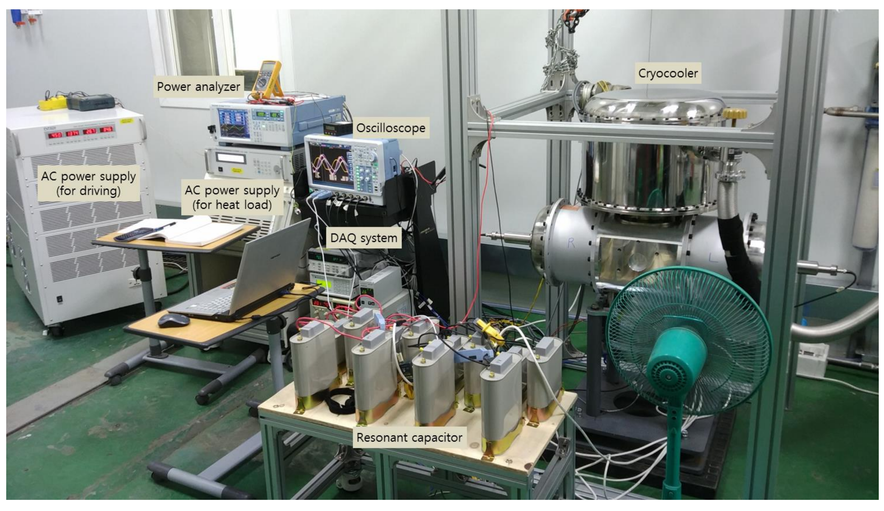


8 temperature sensors (DT-670-CU)

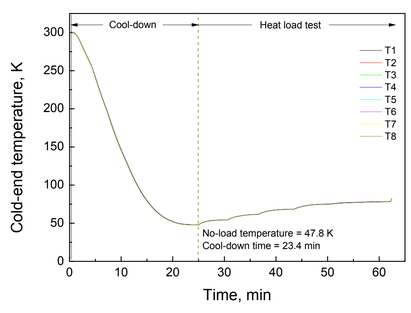


[Photo of 1st prototype]

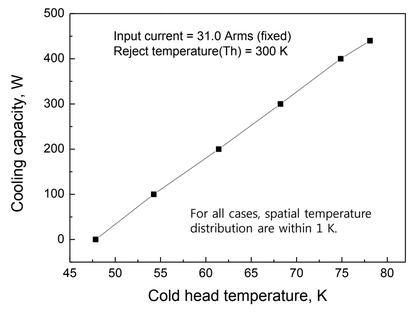
◆ Cooling performance test



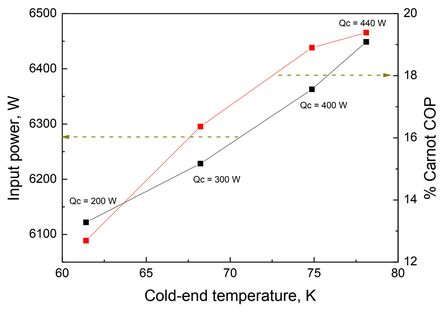
[Experimental setup for cooling performance test of Stirling cryocooler]



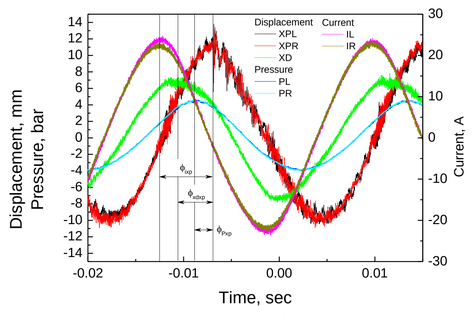
[Cool-down curve]



[Cooling capacity]



[Input power & efficiency]



[Measurement of waveform]

Qc	Tc	Xp0 (L/R)	Xd0	ϕ_{ixp} (L/R)	ϕ_{xdxp} (L/R)	P0 (L/R)	ϕ_{Pxp} (L/R)	Input power	PV power	η_{comp}
W	K	mm	mm	deg	deg	kPa	deg	W	W	-
0	47.8	9.69/9.89	6.21	105/105	60	366/370	36/36	6258	4668	0.746
100	54.3	9.73/9.95	6.41	102/103	61	376/379	35/35	6334	4730	0.747
200	61.4	9.64/9.85	6.51	100/101	62	379/382	34/34	6122	4624	0.755
300	68.2	9.66/9.89	6.68	98/99	62	386/390	33/33	6228	4626	0.743
400	74.9	9.82/10.04	6.92	97/97	62	397/401	33/32	6363	4713	0.741
440	78.1	9.85/10.14	7.03	95/95	62	407/410	32/32	6449	4783	0.742

[Fit data of waveform (input current level fixed with 31.0 Arms)]

◆ Summary

- ➢ A high cooling capacity γ-type Stirling cryocooler driven by linear compressor is developed and tested.
- ➢ From cooling performance test,
  - • No-load temperature = 47.8 K / Cool-down time = 23.4 min. / Cooling capacity = 440 W at 78.1 K with 6.45 kW input / 19.4 of % Carnot COP
- ➢ Displacement of piston and displacer, dynamic pressure of compression space, input voltage/current are measured in waveforms.
  - • Compressor works at its resonance and shows 75 % of efficiency.
  - • Phase difference among piston, displacer, pressure, current are closed to the designed value, but stroke of piston and displacer are small.
- ➢ It is guessed that small stroke of piston and displacer results from large piston diameter and excessive pressure loss in regenerator. We will improve cooling performance by modifying dimensions of regenerator and piston in next prototype.

에프에스 Finished solution　SUNAM　KITECH 한국생산기술연구원　KIMM 한국기계연구원 KOREA INSTITUTE OF MACHINERY & MATERIALS