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Preliminary Analysis of a Fully Solid State Magnetocaloric Refrigeration

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Outline

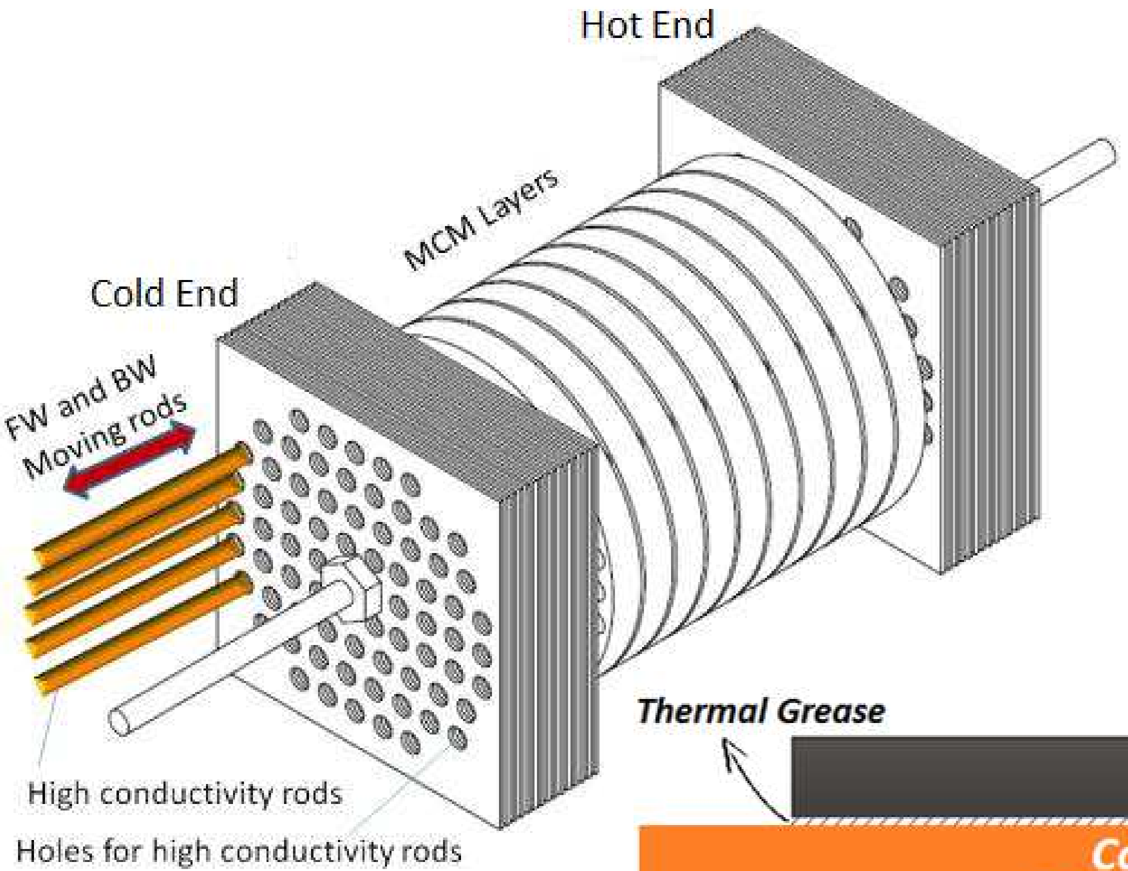
- Motivations
- Fully Solid State AMR
- Mathematic Model for the Solid State AMR
- Results and Discussions
- Conclusions

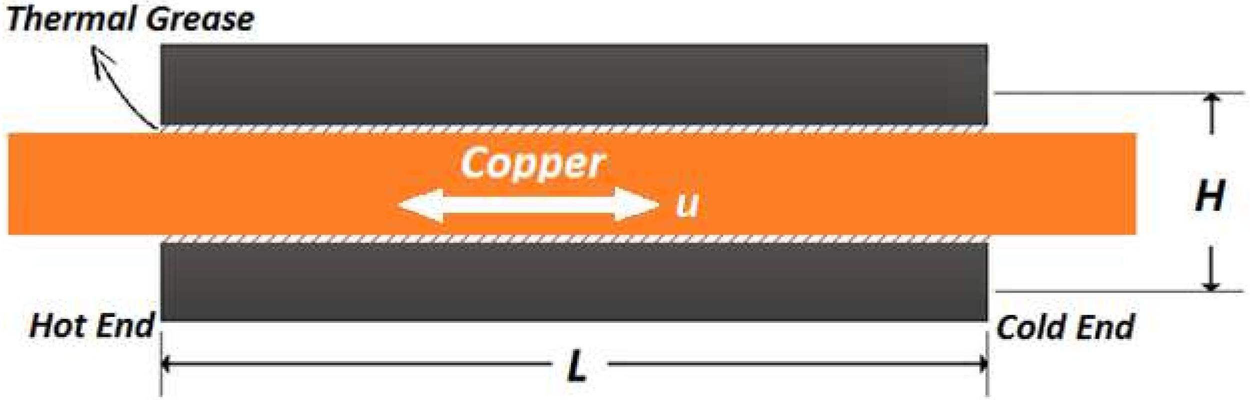
Motivations

- Magnetocaloric refrigeration is an alternative refrigeration technology with significant potential energy savings compared to conventional vapor compression refrigeration technology.

- Traditional AMR systems using heat transfer fluid contain complicated mechanical subsystems and components.

Fully Solid State AMR





Mathematic Model

$$(h_c+h_g)a_c(T_s-T_r)+(1-\varepsilon)k_r\frac{\partial^2 T_r}{\partial x^2}=(1-\varepsilon)\rho_r T_r(\frac{\partial s}{\partial B})_T\frac{\partial B}{\partial t}+(1-\varepsilon)\rho_r c_B\frac{\partial T_r}{\partial t}$$

$$-(h_c+h_g)a_c(T_s-T_r)+\varepsilon k_s\frac{\partial^2 T_s}{\partial x^2}=\varepsilon\rho_s c_s\frac{\partial T_s}{\partial t}+\varepsilon\rho_s c_s u\frac{\partial T_s}{\partial x}$$

h_c is the contact conductance between refrigerant and solid state sheet

$$h_c=\frac{1.25\theta k_m}{\sigma}(\frac{P}{H_0})^{0.95}$$

$$k_m=2k_r k_s/(k_r+k_s)$$

$$\sigma=\sqrt{\sigma_r^2+\sigma_b^2}$$

$$\theta=\sqrt{\theta_r^2+\theta_b^2}$$

Mathematic Model

The gap conductance is

$$h_g = k_g/Y$$

The effective gap thickness *Y* can be calculated by means of the simple power-law correlation equation

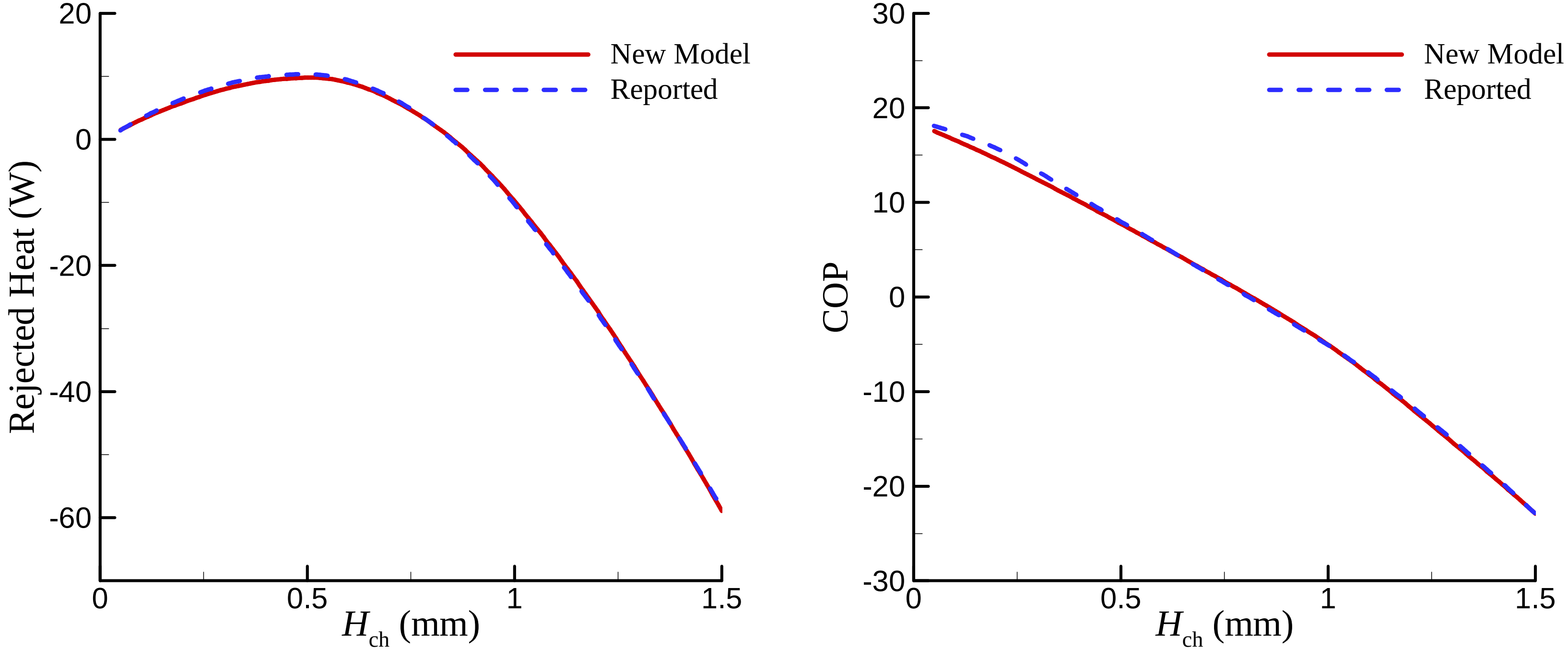
$$Y = 1.53\sigma(\frac{P}{H_0})^{-0.097}$$

Since the mean effective absolute surface slope and effective surface roughness are not independent, the correlation equation is

$$\theta = 0.125(\sigma * 10^6)^{0.402}$$

Code Validation

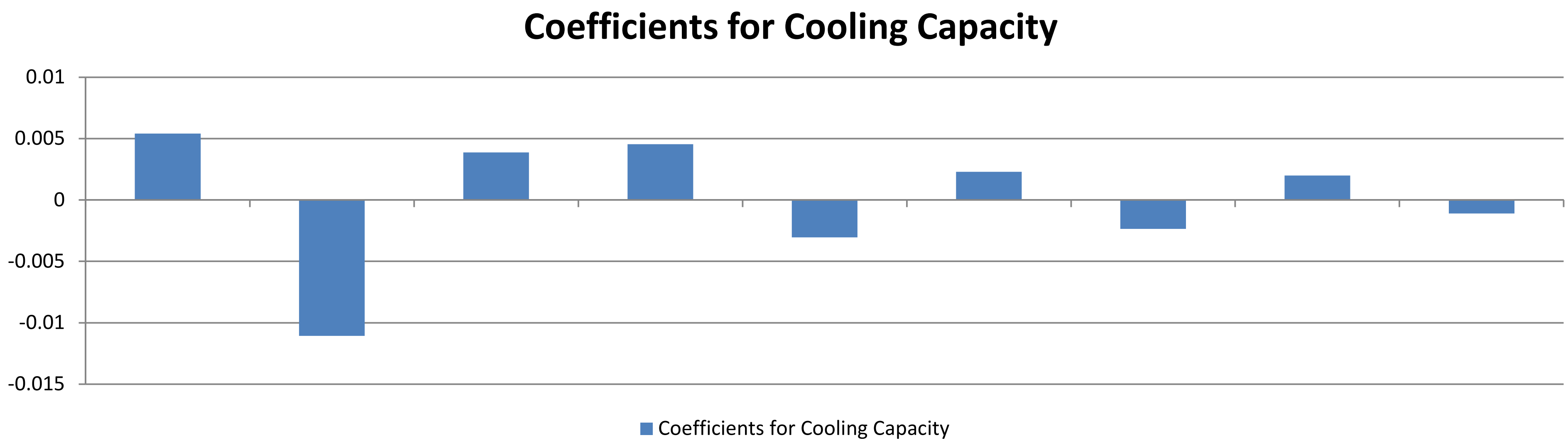
To verify our model, we compared the results of simulating an AMR made of Gd using water as the heat transfer fluid with published results from Petersen et al. (Petersen et al., 2008). The comparison in Figure 2 shows a good agreement.

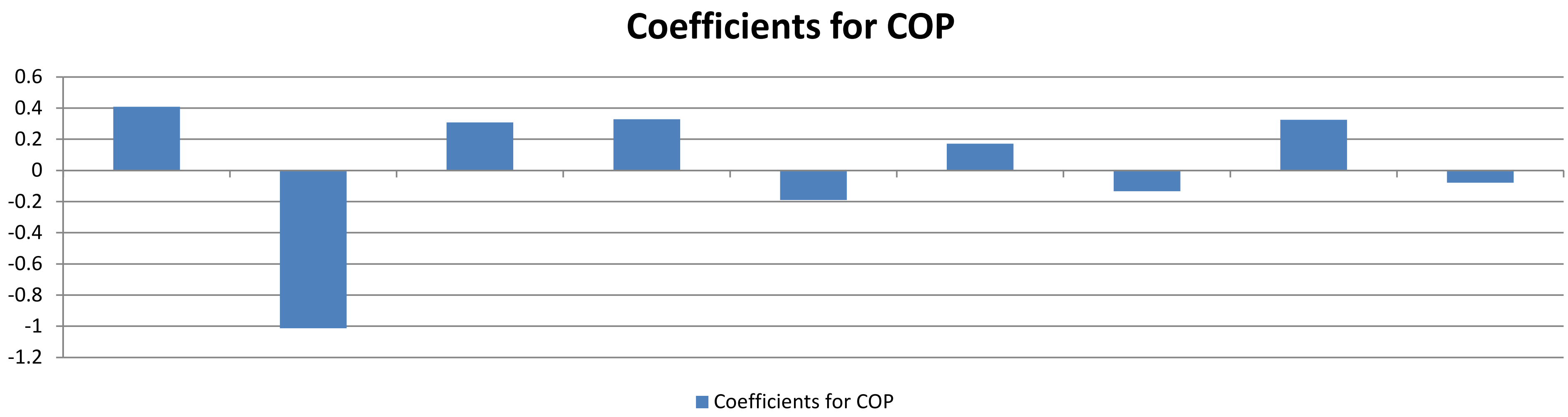


Experimental Design

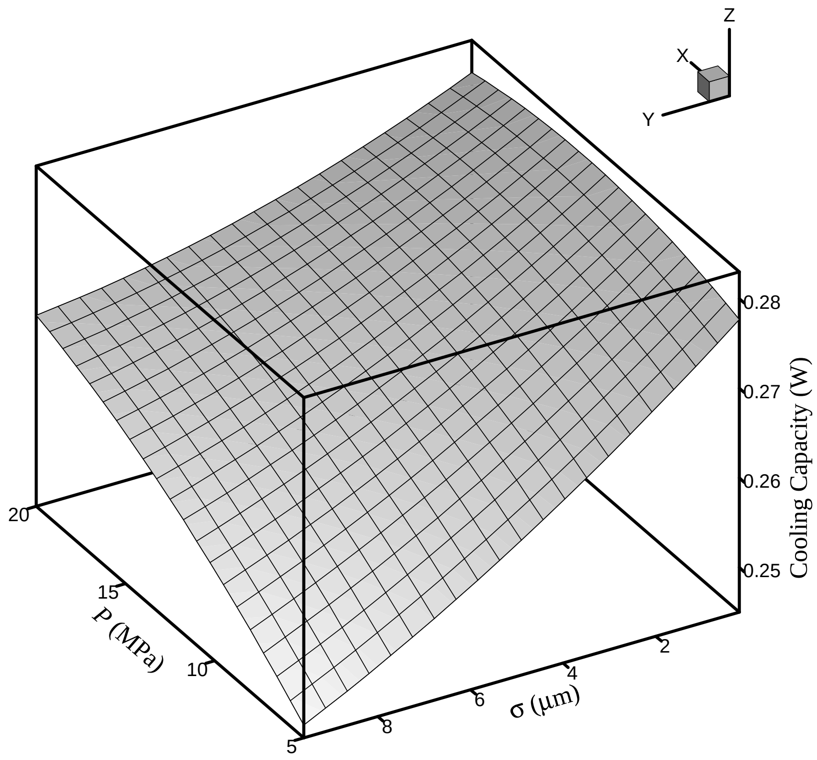
Run	Pressure (MPa)	Roughness (μm)	Conductivity (W/(m·K))	Coded Pressure	Coded Roughness	Coded Conductivity
1	5	0.2	0.45	-1	-1	0
2	20	0.2	0.45	1	-1	0
3	5	9.6	0.45	-1	1	0
4	20	9.6	0.45	1	1	0
5	5	4.9	0.2	-1	0	-1
6	20	4.9	0.2	1	0	-1
7	5	4.9	0.7	-1	0	1
8	20	4.9	0.7	1	0	1
9	12.5	0.2	0.2	0	-1	-1
10	12.5	9.6	0.2	0	1	-1
11	12.5	0.2	0.7	0	-1	1
12	12.5	9.6	0.7	0	1	1
13	12.5	4.9	0.45	0	0	0
14	12.5	4.9	0.45	0	0	0
15	12.5	4.9	0.45	0	0	0

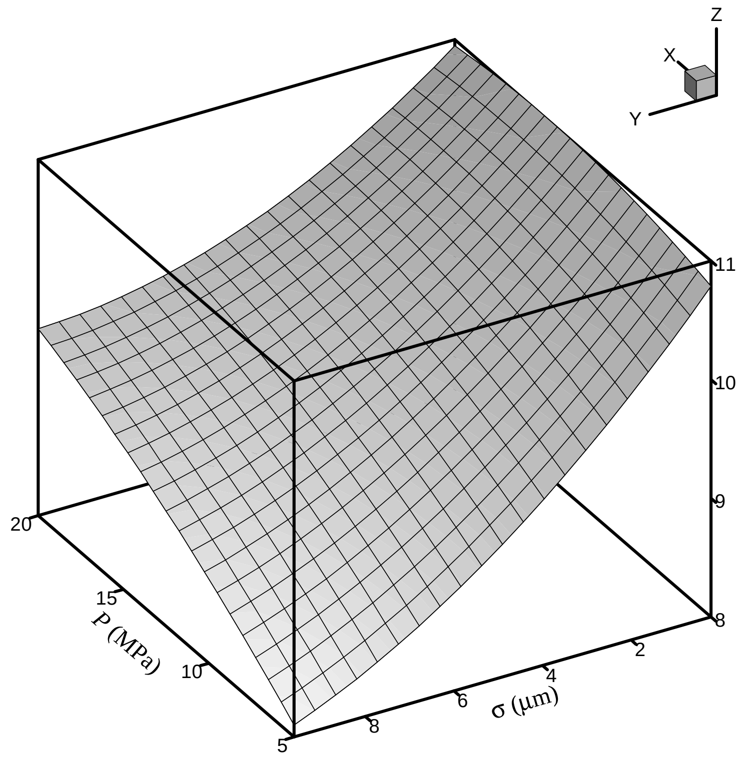
Experimental Design



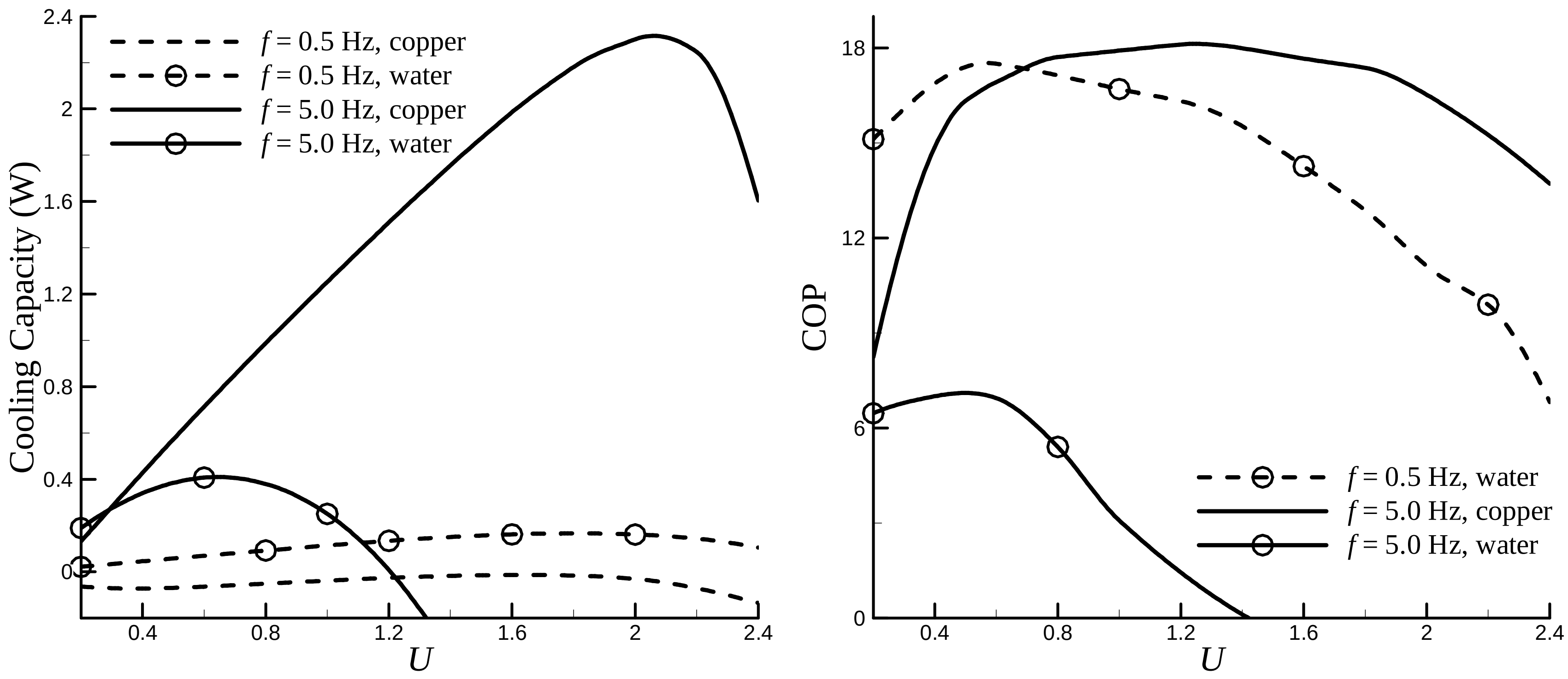


Experimental Design





Performance Comparison Between Solid State and Traditional AMR



Conclusions

- The sensitive analysis results reveal that the effective surface roughness σ is the most impactful on Cooling Capacity and COP.
- The solid state AMR has a high performance in high working frequency.
- The solid state AMR is able to offer a great Cooling Capacity and COP simultaneously, which the traditional AMR cannot meet.

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