

Multi-objective Optimization of the Cavitation Generation Unit Structure of an Advanced Rotational Hydrodynamic Cavitation Reactor

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Table S1 CCD results for the four design variables.

No.	Point	Design variable				Objective	
		D (mm)	s (mm)	h (mm)	θ ($^\circ$)	V_{vapor} ($\times 10^{-8} \text{ m}^3$)	\overline{M}_z (N·m)
1	cube	9	1.5	1.5	6.25	3.802	1.149
2	cube	11	1.5	1.5	6.25	10.709	2.039
3	cube	9	2.5	1.5	6.25	0.702	0.968
4	cube	11	2.5	1.5	6.25	7.077	1.822
5	cube	9	1.5	2.5	6.25	3.046	0.848
6	cube	11	1.5	2.5	6.25	8.507	1.522
7	cube	9	2.5	2.5	6.25	0.601	0.644
8	cube	11	2.5	2.5	6.25	2.865	1.352
9	cube	9	1.5	1.5	18.75	6.344	1.336
10	cube	11	1.5	1.5	18.75	19.882	2.031
11	cube	9	2.5	1.5	18.75	2.263	1.188
12	cube	11	2.5	1.5	18.75	8.482	2.310
13	cube	9	1.5	2.5	18.75	4.586	0.852
14	cube	11	1.5	2.5	18.75	15.079	1.304
15	cube	9	2.5	2.5	18.75	1.859	0.777
16	cube	11	2.5	2.5	18.75	3.897	1.759
17	star	8	2	2	12.5	1.302	0.640
18	star	12	2	2	12.5	18.213	2.064
19	star	10	1	2	12.5	15.004	0.774
20	star	10	3	2	12.5	2.307	1.149
21	star	10	2	1	12.5	8.404	1.876
22	star	10	2	3	12.5	1.252	0.840
23	star	10	2	2	0	2.722	1.250
24	star	10	2	2	25	8.103	1.644
25	center	10	2	2	12.5	4.396	1.371

Table S2 ANOVA for the response surface regression of the total vapor volume (DF: degree of freedom, Adj SS: adjusted sums of squares, Adj MS: Adjusted means squares).

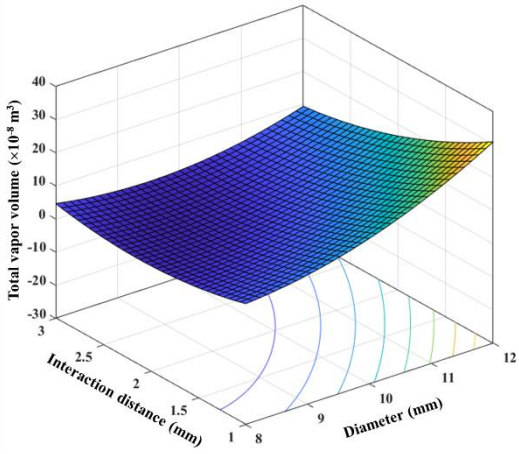
Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	14	733.636	52.403	36.59	0.000
Linear	4	617.365	154.341	107.78	0.000
x_1	1	316.224	316.224	220.83	0.000
x_2	1	201.875	201.875	140.98	0.000
x_3	1	45.729	45.729	31.93	0.000
x_4	1	53.537	53.537	37.39	0.000
Square	4	59.915	14.979	10.46	0.000
$x_1 * x_1$	1	40.161	40.161	28.05	0.000
$x_2 * x_2$	1	23.659	23.659	16.52	0.001
$x_3 * x_3$	1	0.064	0.064	0.04	0.835
$x_4 * x_4$	1	0.280	0.280	0.20	0.664
2-Way Interaction	6	56.356	9.393	6.56	0.001
$x_1 * x_2$	1	23.772	23.772	16.60	0.001
$x_1 * x_3$	1	10.215	10.215	7.13	0.017
$x_1 * x_4$	1	7.952	7.952	5.55	0.032
$x_2 * x_3$	1	0.003	0.003	0.00	0.964
$x_2 * x_4$	1	13.269	13.269	9.27	0.008
$x_3 * x_4$	1	1.145	1.145	0.80	0.384
Error	16	22.912	1.432		
Lack-of-Fit	10	22.912	2.291	*	*
Pure Error	6	0.000	0.000		
Total	30	756.548			

$S = 1.19665$, $R^2 = 96.97\%$, Adjusted $R^2 = 94.32\%$, Predicted $R^2 = 82.56\%$.

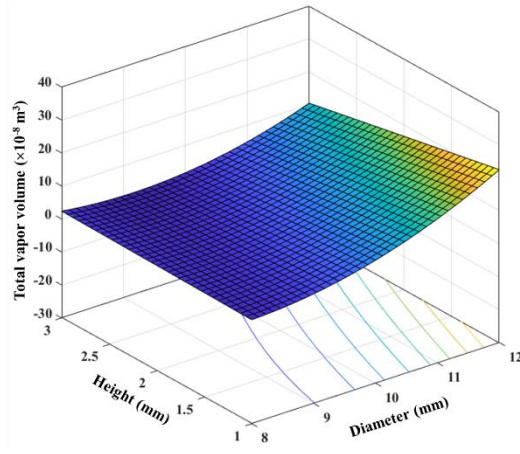
Table S3 ANOVA for the response surface regression of the total torque, corresponding to Table S2.

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	14	5.6559	0.40399	34.95	0.000
Linear	4	5.14939	1.28735	111.37	0.000
x_1	1	3.54437	3.54437	306.62	0.000
x_2	1	0.00998	0.00998	0.86	0.367
x_3	1	1.42812	1.42812	123.55	0.000
x_4	1	0.16693	0.16693	14.44	0.002
Square	4	0.28667	0.07167	6.20	0.003
$x_1 * x_1$	1	0.00287	0.00287	0.25	0.625
$x_2 * x_2$	1	0.21918	0.21918	18.96	0.000
$x_3 * x_3$	1	0.00381	0.00381	0.33	0.574
$x_4 * x_4$	1	0.0327	0.0327	2.83	0.112
2-Way Interaction	6	0.21984	0.03664	3.17	0.030
$x_1 * x_2$	1	0.05711	0.05711	4.94	0.041
$x_1 * x_3$	1	0.03477	0.03477	3.01	0.102
$x_1 * x_4$	1	0.00098	0.00098	0.09	0.774
$x_2 * x_3$	1	0.00464	0.00464	0.40	0.535
$x_2 * x_4$	1	0.10264	0.10264	8.88	0.009
$x_3 * x_4$	1	0.01969	0.01969	1.70	0.210
Error	16	0.18495	0.01156		
Lack-of-Fit	10	0.18495	0.01849	*	*
Pure Error	6	0	0		
Total	30	5.84085			

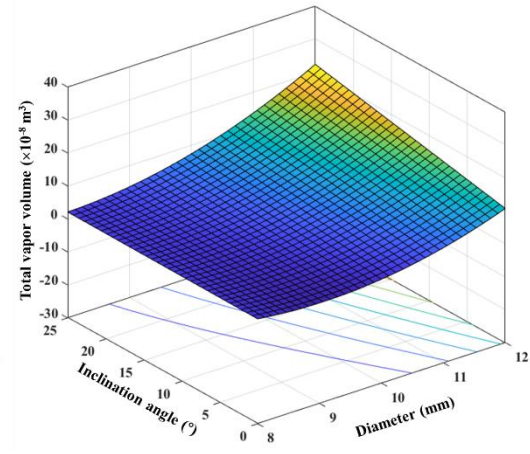
$S = 0.107515$, $R^2 = 96.83\%$, Adjusted $R^2 = 94.06\%$, Predicted $R^2 = 81.76\%$.



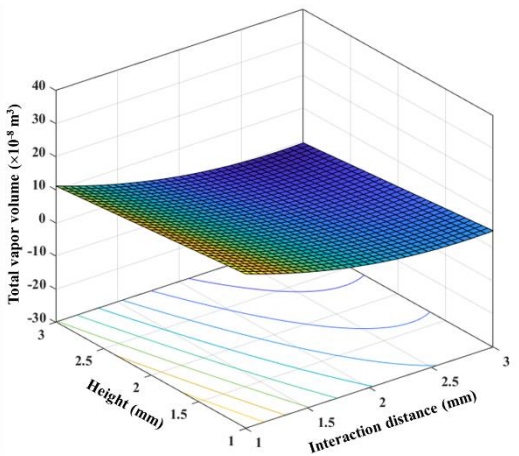
(a) D vs. s ($h = 2$ mm, $\theta = 12.5^\circ$)



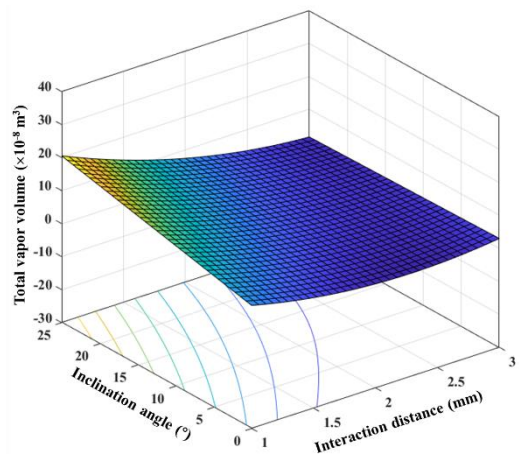
(b) D vs. h ($s = 2$ mm, $\theta = 12.5^\circ$)



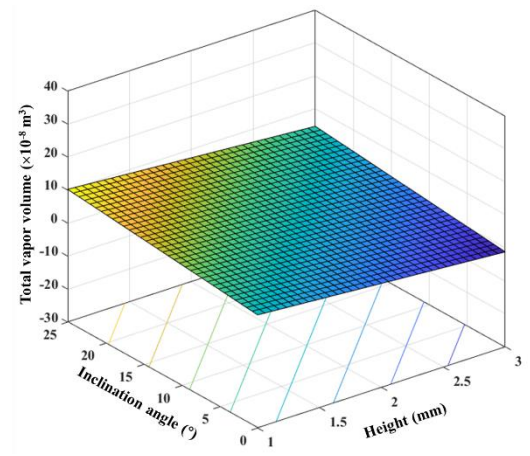
(c) D vs. θ ($s = 2$ mm, $h = 2$ mm)



(e) s vs. h ($D = 10$ mm, $\theta = 12.5^\circ$)

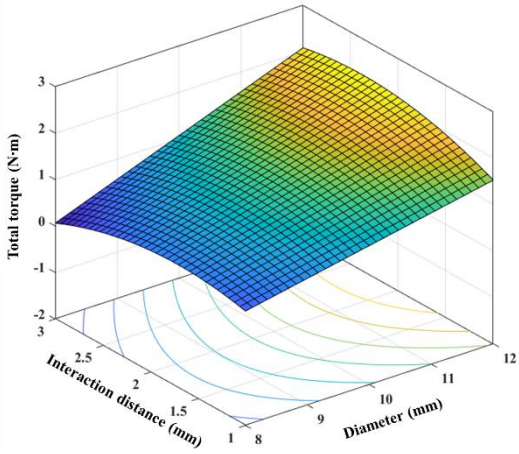


(f) s vs. θ ($D = 10$ mm, $h = 2$ mm)

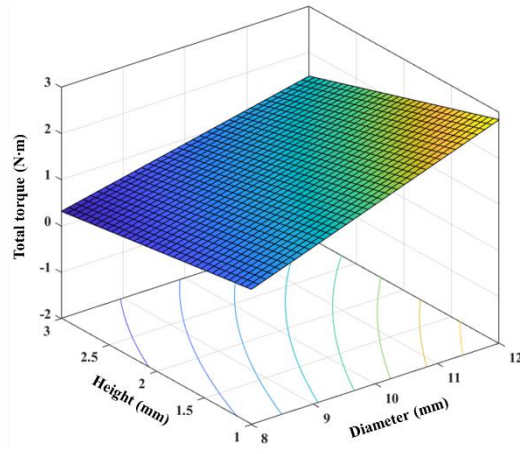


(g) h vs. θ ($D = 10$ mm, $s = 2$ mm)

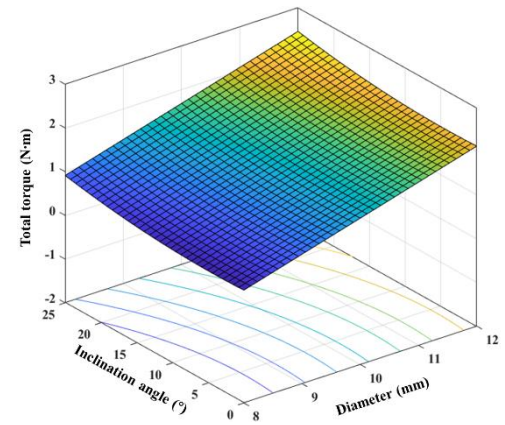
Fig. S1 2D contour and 3D response surface plots for the total vapor volume.



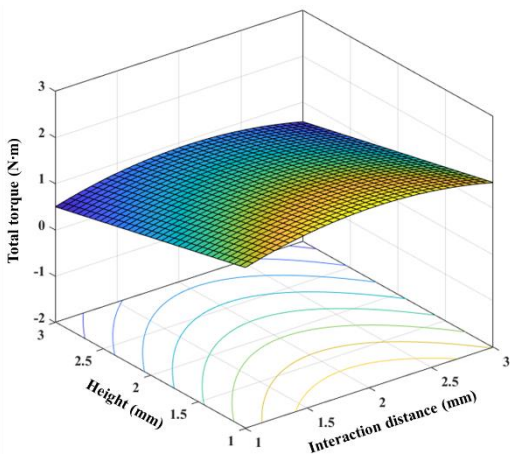
(a) D vs. s ($h = 2$ mm, $\theta = 12.5^\circ$)



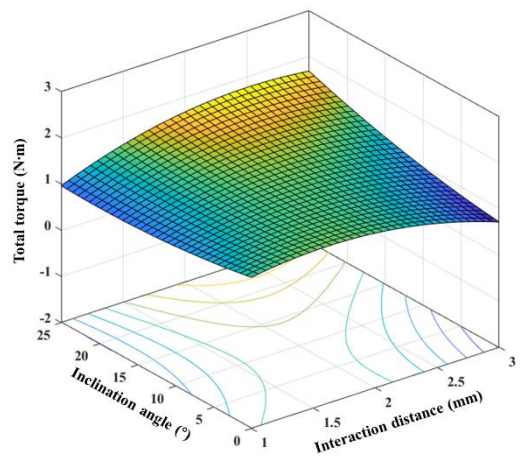
(b) D vs. h ($s = 2$ mm, $\theta = 12.5^\circ$)



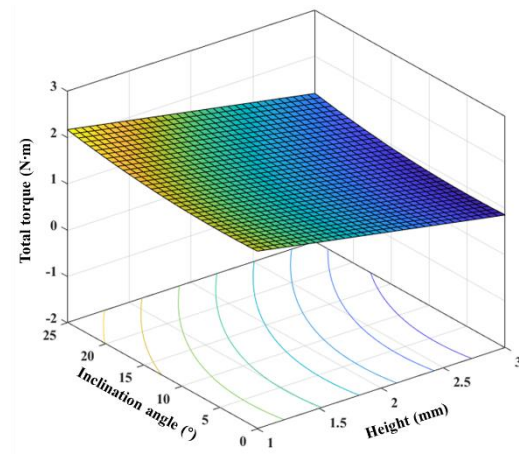
(c) D vs. θ ($s = 2$ mm, $h = 2$ mm)



(e) s vs. h ($D = 10$ mm, $\theta = 12.5^\circ$)

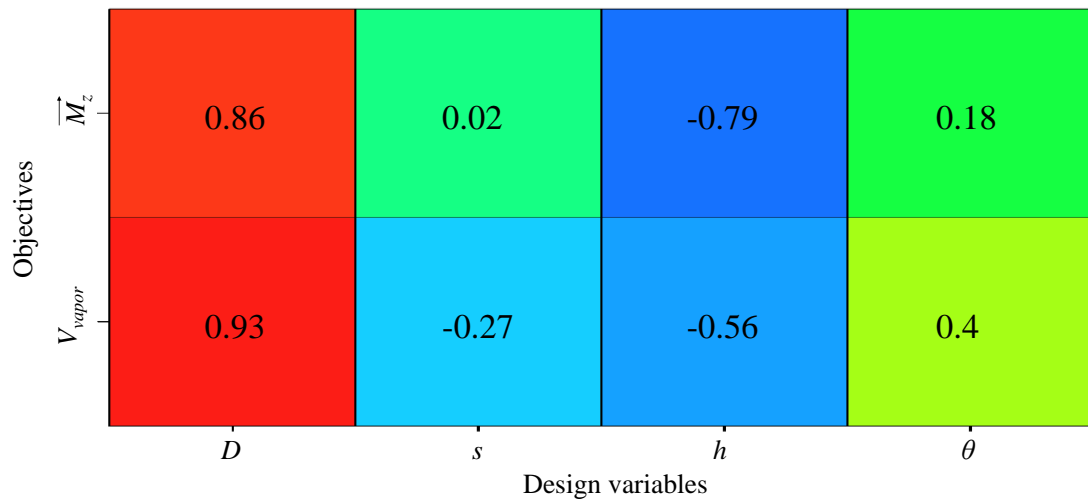


(f) s vs. θ ($D = 10$ mm, $h = 2$ mm)

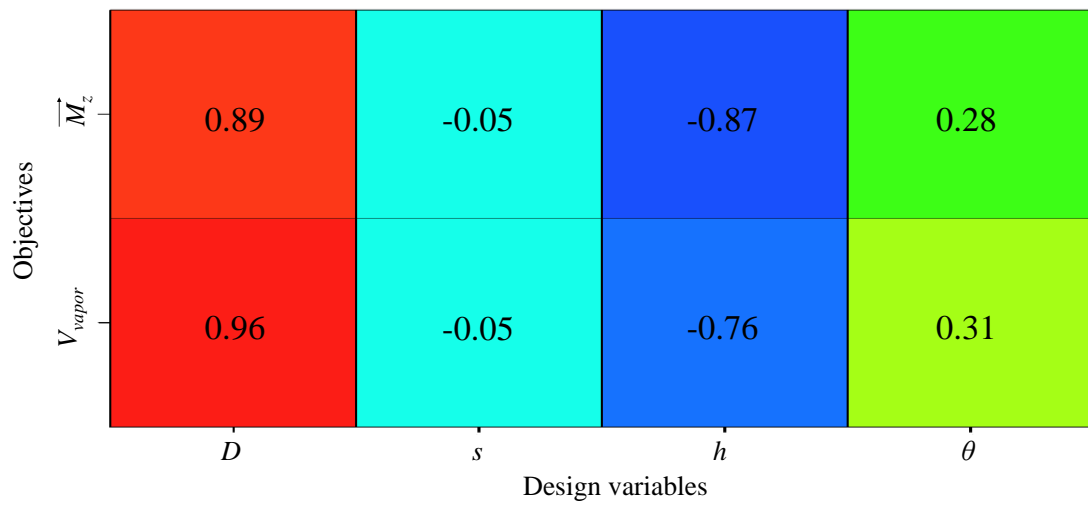


(g) h vs. θ ($D = 10$ mm, $s = 2$ mm)

Fig. S2 2D contour and 3D response surface plots for the total torque.



(a)



(b)

Fig. S3 Correlation table of the design variables and objectives for (a) all points and (b) Pareto Front.

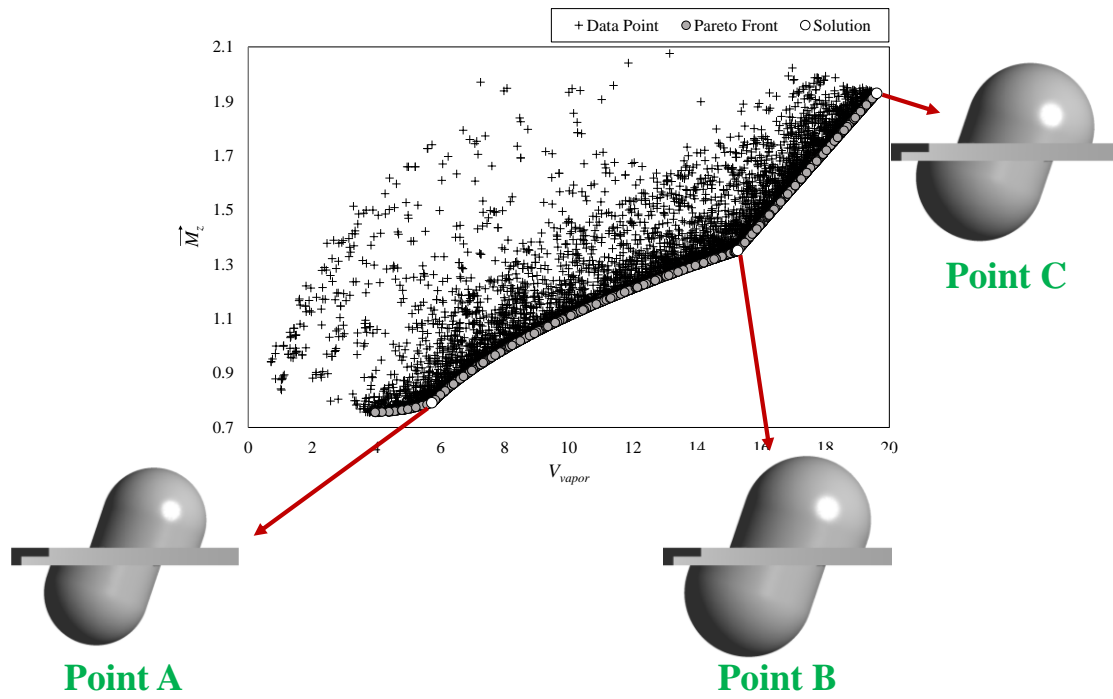


Fig. S4 selected optimized solution from the Pareto front.