

Supplementary Materials

Algorithm S1 Harris Hawks Optimization (HHO) Algorithm

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1: Initialize the population  $X_i$ ,  $i = 1, 2, \dots, N$ 
2: Evaluate the fitness of each hawk
3: Initialize the best solution found so far as the rabbit's location  $R$ 
4: for  $t = 1$  to  $T$  do                                 $\triangleright T$  is the maximum number of iterations
5:   for each hawk  $i$  do
6:     Update energy  $E$  of the rabbit from Eq.(1)
7:     if Rabbit's energy is high then            $\triangleright$  Exploration phase
8:       Update hawk's position based on Eq.(2).
9:     else                                      $\triangleright$  Exploitation phase
10:    Update hawk's position based on Eq.(3)
11:   end if
12:   Evaluate fitness of hawk  $i$ 
13:   if Fitness of hawk  $i$  is better than  $R$  then
14:     Update  $R$  with hawk  $i$ 's position
15:   end if
16: end for
17: Record the best solution found so far
18: end for
19: return Best solution found  $R$ 

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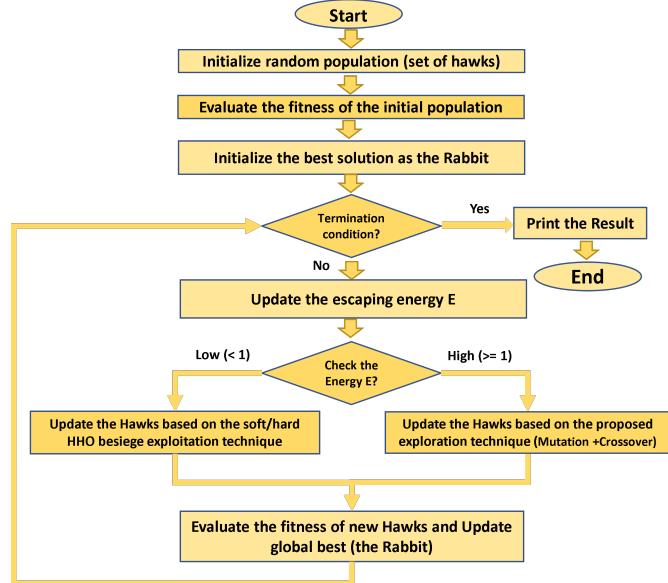


Figure S1: The flowchart of the proposed DHHO algorithm.

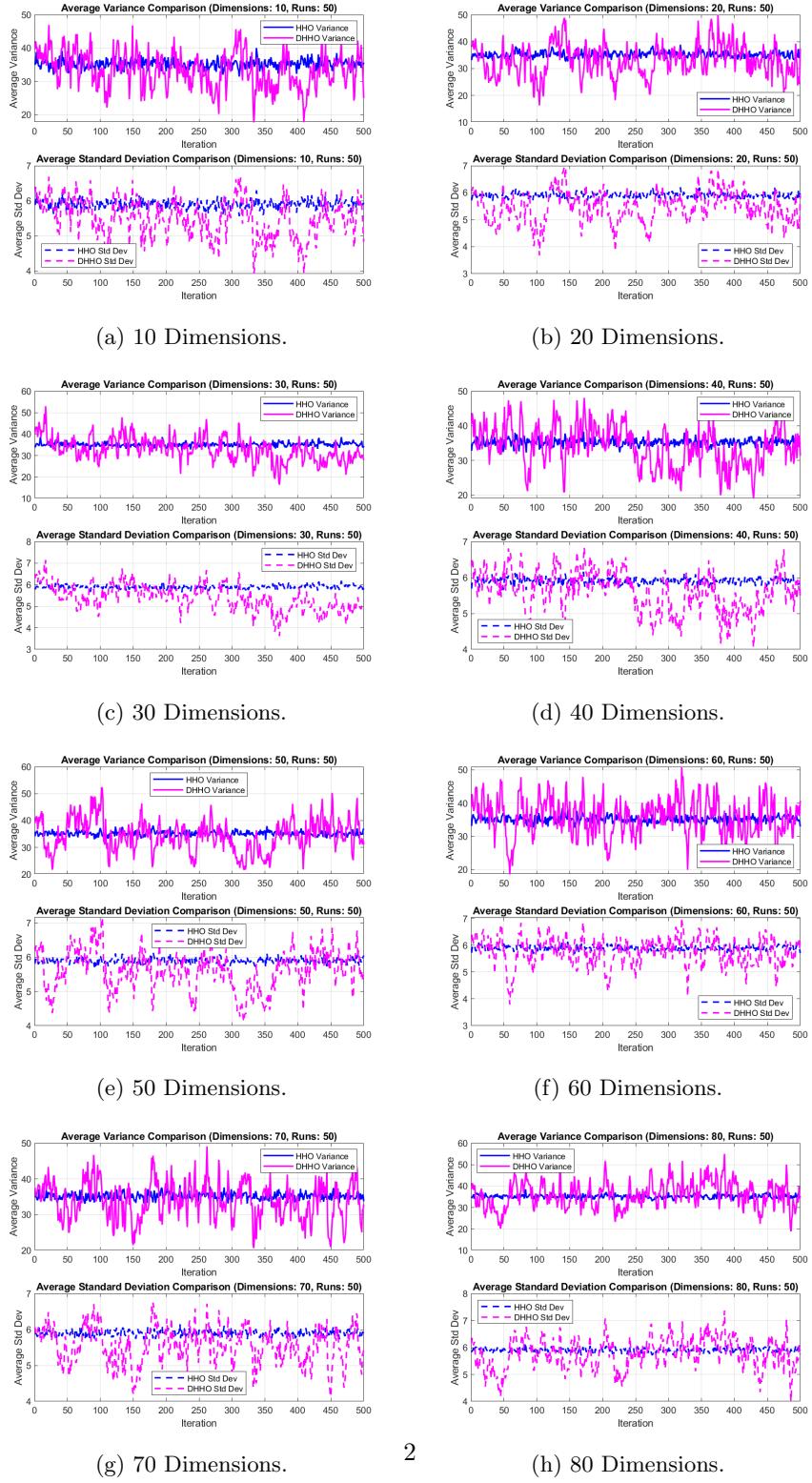


Figure S2: Population diversity plots (variance and SD) between HHO and DHHO exploration methods.

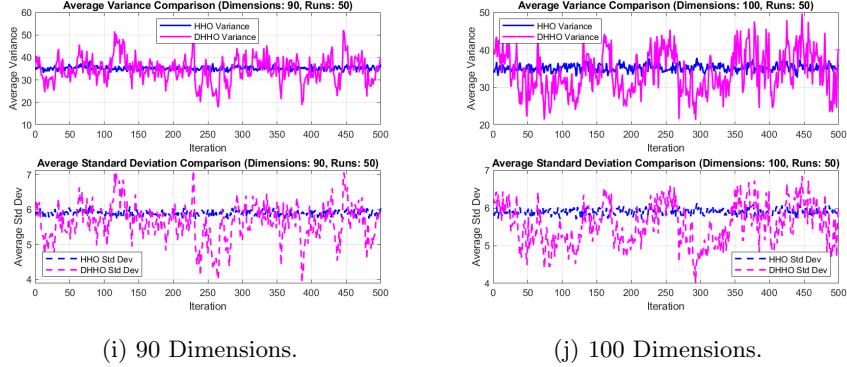


Fig. S2(Cont.) Population diversity plots (variance and SD) between HHO and DHHO exploration methods.

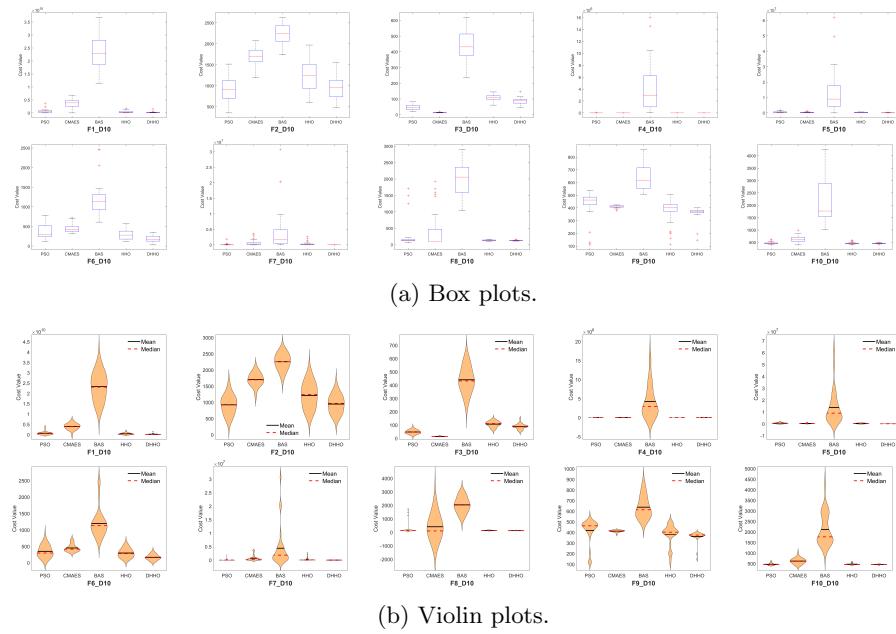
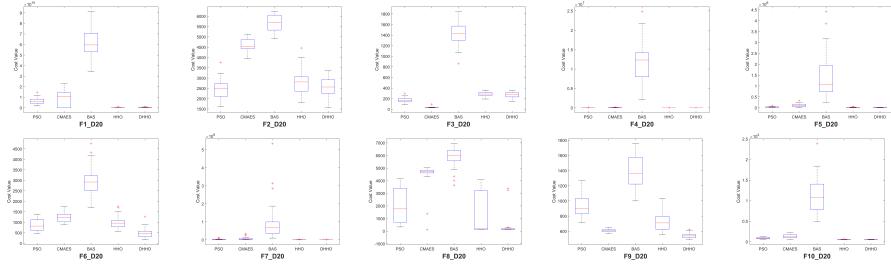
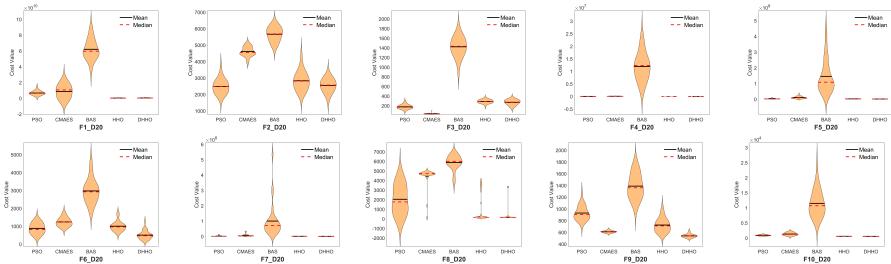


Figure S3: Box and violin plots for all the 10-Dim CEC2020/2021 functions for all the algorithms in 30 runs.



(a) Box plots.



(b) Violin plots.

Figure S4: Box and violin plots for all the 20-Dim CEC2020/2021 functions for all the algorithms in 30 runs.

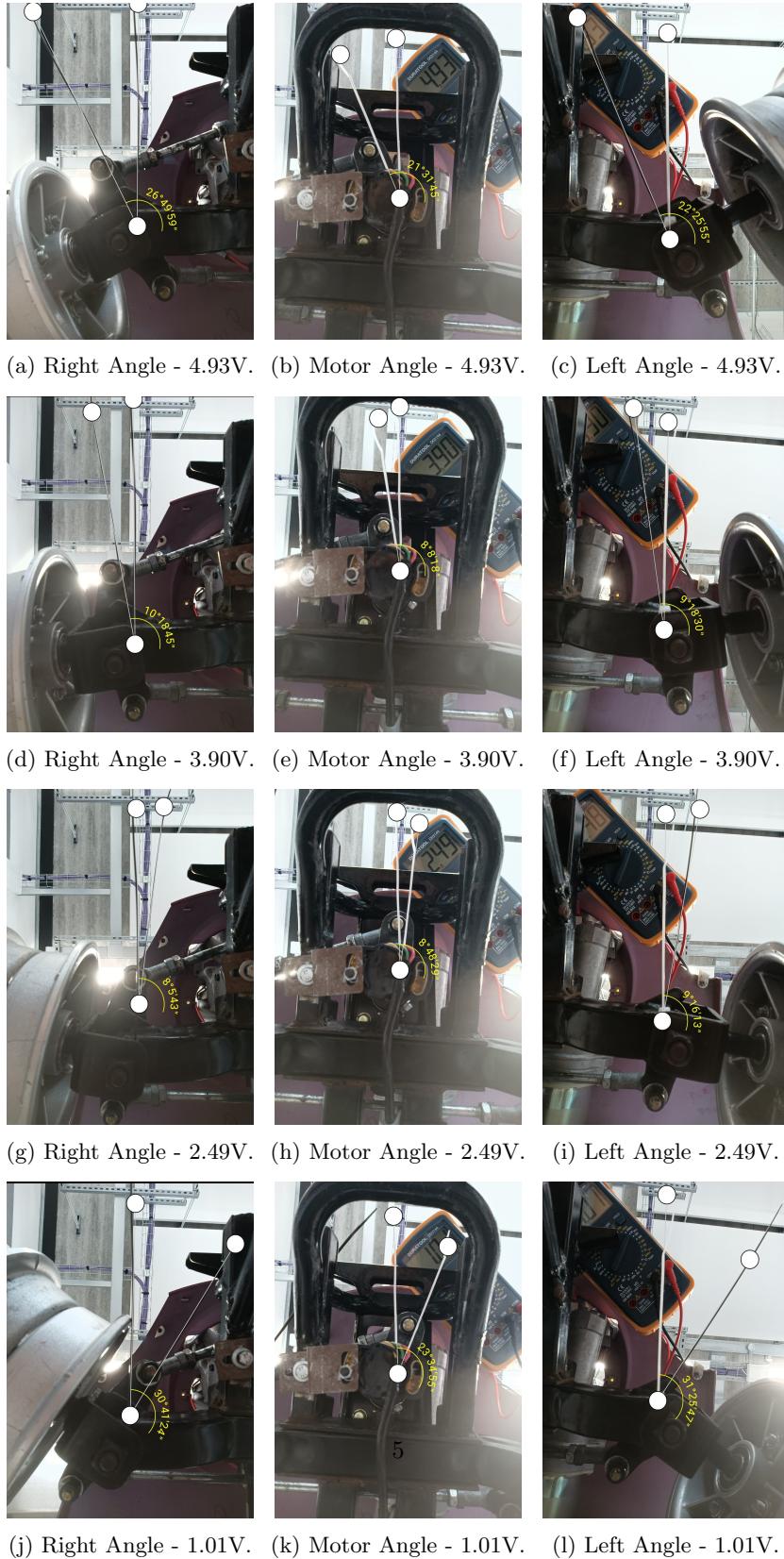
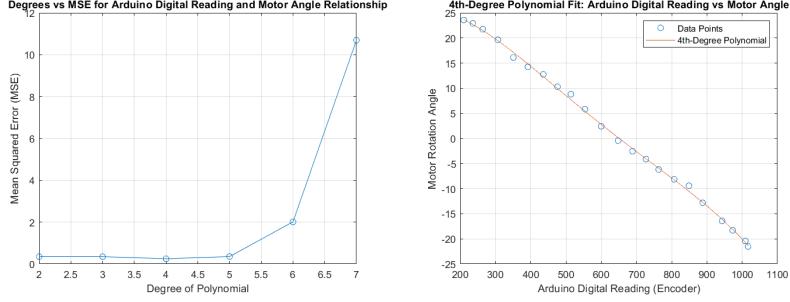
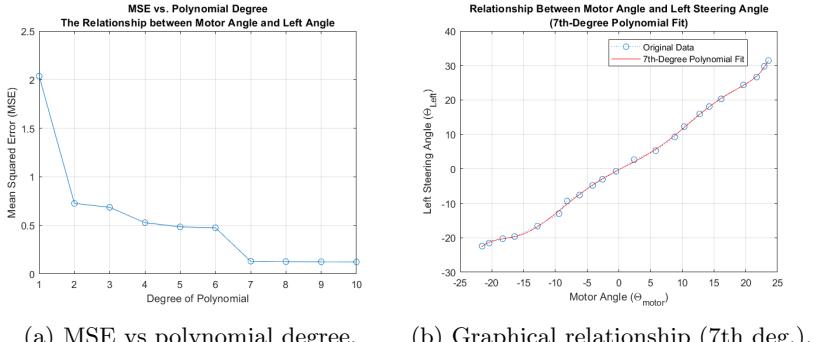


Figure S5: Steering angle mapping readings.



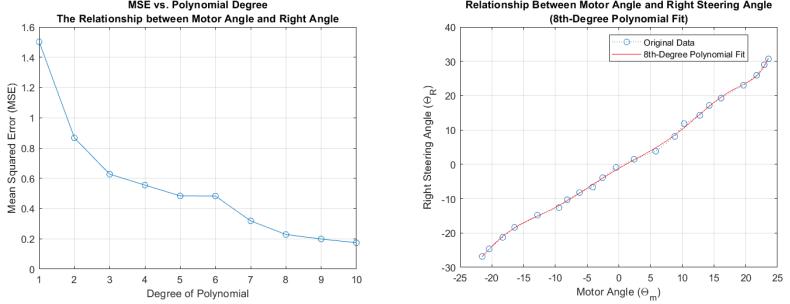
(a) MSE vs the polynomial degree. (b) Graphical relationship (4th deg.).

Figure S6: Regression results for the relationship between the motor rotation angle and the encoder digital reading.



(a) MSE vs polynomial degree. (b) Graphical relationship (7th deg.).

Figure S7: Regression results for the relationship between the motor rotation and left steering angles.



(a) MSE vs the polynomial degree. (b) Graphical relationship (8th deg.).

Figure S8: Regression results for the relationship between the motor rotation and right steering angles.

Table S1 shows each controller's steering angle response at 20 timestamps for different steering angles.

Table S1: Data collected during measuring the transient response for each controller (Manual, ZN, HHO, and the proposed DHHO) at different steering angles.

Ref.	Alg.	0	0.0028	0.0063	0.0108	0.0165	0.0238	0.0331	0.0450	0.0601	0.0794	0.1039	0.1352	0.1750	0.2258	0.2905	0.3730	0.4781	0.6120	0.7826	1.0000
-21	Manual	0	-1.63	-3.71	-6.30	-9.23	-12.61	-16.19	-19.50	-22.03	-22.90	-20.21	-19.10	-19.49	-20.29	-20.57	-20.76	-20.90	-20.96	-20.99	
	ZN	0	-4.25	-9.67	-15.73	-18.40	-20.54	-21.47	-21.70	-21.62	-21.42	-21.19	-20.94	-20.71	-20.51	-20.36	-20.30	-20.32	-20.43	-20.58	-20.73
	HHO	0	-3.47	-8.48	-14.07	-17.04	-20.54	-21.47	-21.70	-21.62	-21.42	-21.19	-20.94	-20.71	-20.62	-20.63	-20.64	-20.71	-20.76	-20.80	-20.84
	DHHO	0	-3.70	-8.42	-15.75	-16.52	-18.87	-20.11	-20.80	-20.83	-20.84	-20.85	-20.86	-20.87	-20.88	-20.89	-20.90	-21.00	-21.00	-21.00	-21.00
-18	Manual	0	-1.40	-3.18	-5.40	-7.91	-10.83	-13.88	-16.71	-18.89	-19.63	-18.87	-17.53	-16.37	-16.70	-17.39	-17.63	-17.79	-17.91	-17.97	-17.99
	ZN	0	-3.65	-8.29	-13.48	-15.77	-17.60	-18.40	-18.60	-18.53	-18.36	-18.16	-17.95	-17.75	-17.58	-17.45	-17.40	-17.42	-17.53	-17.64	-17.77
	HHO	0	-3.24	-7.36	-12.11	-15.17	-17.80	-19.19	-19.39	-18.88	-18.21	-17.80	-17.68	-17.52	-17.79	-17.83	-17.87	-17.91	-17.94	-17.98	
	DHHO	0	-3.17	-7.21	-11.78	-14.16	-16.18	-17.27	-17.73	-17.88	-17.89	-17.88	-17.89	-17.91	-17.92	-17.97	-17.99	-18.00	-18.00	-18.00	
-15	Manual	0	-1.17	-2.65	-4.50	-6.59	-9.01	-11.56	-13.93	-15.75	-16.36	-15.73	-14.44	-13.64	-13.92	-14.49	-14.69	-14.83	-14.93	-14.97	-14.99
	ZN	0	-3.04	-6.91	-11.23	-13.14	-14.67	-15.34	-15.50	-15.44	-15.30	-15.13	-14.96	-14.79	-14.65	-14.54	-14.50	-14.59	-14.59	-14.70	-14.81
	HHO	0	-2.70	-6.13	-10.09	-12.64	-14.83	-15.99	-16.16	-16.18	-15.18	-14.89	-14.73	-14.74	-14.77	-14.80	-14.83	-14.86	-14.90	-14.93	-14.95
	DHHO	0	-2.64	-6.01	-9.82	-11.80	-13.48	-14.39	-14.77	-14.90	-14.91	-14.90	-14.90	-14.92	-14.95	-14.98	-14.99	-15.00	-15.00	-15.00	
-13	Manual	0	-1.01	-2.30	-3.90	-5.71	-7.81	-10.02	-12.07	-13.64	-14.17	-13.63	-12.51	-11.82	-12.06	-12.56	-12.73	-12.85	-12.94	-12.98	-12.99
	ZN	0	-2.63	-5.99	-9.73	-11.81	-12.71	-13.20	-13.43	-13.54	-13.26	-13.09	-12.96	-12.90	-12.86	-12.86	-12.87	-12.87	-12.87	-12.87	-12.84
	HHO	0	-2.24	-5.32	-8.74	-10.66	-12.56	-13.26	-13.46	-13.56	-13.26	-13.06	-12.96	-12.97	-12.97	-12.98	-12.98	-12.98	-12.98	-12.98	-12.96
	DHHO	0	-2.29	-5.21	-8.51	-10.23	-11.68	-12.47	-12.89	-12.91	-12.92	-12.92	-12.93	-12.93	-12.93	-12.93	-12.93	-12.93	-12.93	-12.93	
-10	Manual	0	-0.78	-1.77	-3.00	-4.40	-6.01	-7.71	-9.28	-10.40	-10.90	-10.48	-9.63	-9.09	-9.28	-9.66	-9.80	-9.88	-9.95	-9.98	-10.00
	ZN	0	-2.03	-4.61	-7.49	-8.76	-9.78	-10.22	-10.33	-10.30	-10.20	-10.05	-9.97	-9.86	-9.77	-10.22	-10.37	-10.47	-10.67	-10.68	-10.73
	HHO	0	-1.80	-4.09	-6.73	-8.43	-9.89	-10.66	-10.77	-10.49	-10.12	-9.89	-9.82	-9.84	-9.86	-9.89	-9.91	-9.93	-9.95	-9.97	
	DHHO	0	-1.76	-4.01	-6.55	-7.87	-8.99	-9.59	-9.85	-9.93	-9.94	-9.94	-9.94	-9.95	-9.97	-9.98	-10.00	-10.00	-10.00	-10.00	
-7	Manual	0	-0.54	-1.24	-2.10	-3.08	-4.20	-5.40	-6.50	-7.34	-7.63	-7.34	-6.74	-6.37	-6.50	-6.76	-6.86	-6.92	-6.97	-6.99	-7.00
	ZN	0	-1.42	-3.22	-5.24	-6.13	-6.85	-7.16	-7.23	-7.21	-7.14	-7.06	-6.98	-6.90	-6.84	-6.79	-6.77	-6.77	-6.81	-6.86	-6.91
	HHO	0	-1.26	-2.86	-4.21	-5.90	-6.92	-7.46	-7.54	-7.34	-7.08	-6.92	-6.87	-6.88	-6.89	-6.90	-6.92	-6.94	-6.95	-6.97	-6.98
	DHHO	0	-1.23	-2.81	-4.18	-5.51	-6.29	-6.71	-6.89	-6.95	-6.96	-6.95	-6.95	-6.96	-6.96	-6.98	-6.99	-7.00	-7.00	-7.00	
-4	Manual	0	-0.84	-1.71	-3.07	-4.20	-5.38	-6.77	-7.34	-7.74	-8.08	-7.40	-6.36	-6.74	-7.02	-7.37	-7.92	-8.35	-8.98	-9.39	-4.00
	ZN	0	-1.72	-3.64	-5.30	-6.37	-7.96	-8.26	-8.41	-8.42	-8.48	-8.04	-7.99	-7.94	-7.94	-7.95	-7.95	-7.95	-7.95	-7.95	-7.95
	HHO	0	-1.64	-3.69	-5.37	-6.39	-7.96	-8.26	-8.41	-8.42	-8.48	-8.04	-7.99	-7.94	-7.94	-7.95	-7.95	-7.95	-7.95	-7.95	
	DHHO	0	-1.70	-3.60	-5.21	-6.35	-7.59	-8.34	-8.94	-9.07	-9.37	-8.97	-8.55	-8.96	-9.99	-1.00	-1.00	-1.00	-1.00	-1.00	
-1	Manual	0	-0.08	-0.18	-0.30	-0.44	-0.60	-0.74	-0.92	-1.05	-1.09	-1.05	-0.96	-1.01	-1.02	-1.02	-1.02	-1.02	-1.02	-1.02	-1.00
	ZN	0	-0.20	-0.46	-0.75	-0.88	-0.98	-1.02	-1.03	-1.03	-1.02	-1.01	-1.01	-1.00	-0.99	-0.98	-0.98	-0.99	-0.99	-0.99	-1.00
	HHO	0	-0.18	-0.41	-0.67	-0.84	-0.99	-1.07	-1.08	-1.05	-1.01	-0.99	-0.98	-0.98	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	
	DHHO	0	-0.10	-0.40	-0.65	-0.79	-0.90	-0.96	-0.98	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-0.99	-1.00	-1.00	-1.00	
1	Manual	0	0.08	0.18	0.30	0.44	0.60	0.77	0.93	1.05	1.09	1.05	0.96	0.91	0.93	0.97	0.98	0.99	1.00	1.00	1.00
	ZN	0	0.20	0.46	0.75	0.88	0.98	1.02	1.03	1.03	1.02	1.01	1.01	0.99	0.98	0.97	0.97	0.97	0.98	0.99	
	HHO	0	0.18	0.41	0.67	0.84	0.99	1.07	1.08	1.05	1.01	0.99	0.98	0.98	0.99	0.99	0.99	0.99	1.00	1.00	
	DHHO	0	0.10	0.40	0.67	0.84	0.99	1.06	1.07	1.08	1.05	1.01	0.99	0.99	0.99	1.00	1.00	1.00	1.00	1.00	
4	Manual	0	0.31	0.71	1.20	1.76	2.29	3.08	3.71	4.20	4.36	4.19	3.85	3.64	3.71	3.86	3.92	3.95	3.98	3.99	4.00
	ZN	0	0.72	1.64	3.22	3.47	3.96	4.26	4.41	4.20	4.05	3.96	3.83	3.94	3.94	3.95	3.95	3.96	3.97	3.98	3.99
	HHO	0	0.72	1.64	3.22	3.47	3.96	4.26	4.41	4.20	4.05	3.96	3.83	3.94	3.94	3.95	3.95	3.96	3.97	3.98	3.99
	DHHO	0	0.70	1.60	2.62	3.15	3.59	3.84	3.94	3.97	3.98	3.97	3.97	3.98	3.99	3.99	3.99	4.00	4.00	4.00	
7	Manual	0	0.54	1.24	2.10	3.08	4.20	5.40	6.50	7.34	7.63	7.34	6.74	6.37	6.50	6.76	6.86	6.92	6.97	6.99	7.00
	ZN	0	1.42	3.22	5.24	6.13	6.85	7.23	7.21	7.14	7.06	6.98	6.90	6.84	6.79	6.77	6.77	6.81	6.86	6.91	
	HHO	0	1.26	2.86	4.21	5.90	6.92	7.46	7.54	7.34	7.08	6.92	6.87	6.88	6.89	6.90	6.92	6.94	6.95	6.97	
	DHHO	0	1.23	2.81	4.58	5.51	6.29	6.71	6.89	6.95	6.96	6.95	6.96	6.96	6.96	6.97	6.97	7.00	7.00		
10	Manual	0	0.78	1.77	3.00	4.40	6.01	7.71	9.28	10.49	10.90	10.48	9.63	9.09	9.28	9.66	9.80	9.88	9.95	9.98	10.00
	ZN	0	2.03	4.61	7.49	8.76	9.78	10.66	11.30	11.71	12.29	13.43	13.58	13.26	13.11	12.74	12.88	12.94	12.98	12.99	
	HHO	0	1.80	4.09	6.73	8.43	9.89	10.66	10.77	10.49	10.12	9.89	9.82	9.84	9.86	9.77	9.70	9.67	9.68	9.73	
	DHHO	0	1.76	4.01	6.55	7.87	8.99	9.95	9.93	9.94	9.94	9.94	9.95	9.97	9.97	9.98	10.00	10.00	10.00		
13	Manual	0	0.27	0.72	1.33	2.01	2.70	3.57	4.20	4.87	5.41	5.11	5.74	6.25	6.73	7.23	7.74	8.24	8.74	9.24	
	ZN	0	2.63	5.99	9.73	11.30	12.71	13.29	13.43	13.58	13.26	13.11	12.74	12.69	12.61	12.58	12.74	12.84	12.94		
	HHO	0	2.34	5.32	8.75	10.96	12.86	13.86	14.01	13.64	13.15	12.86	12.77	12.77	12.80	12.82	12.85	12.88	12.91	12.96	
	DHHO	0	2.29	5.21	8.51	10.23	11.68	12.47	12.80	12.91	12.92	12.91	12.92	12.92	12.92	12.92	12.93	13.00	13.00		
15	Manual	0	1.17	2.65	4.50	6.59	9.01	11.56	13.93	15.74	16.36	15.73	14.44	14.49	14.69	14.83	14.93	14.97	14.99		
	ZN	0																			