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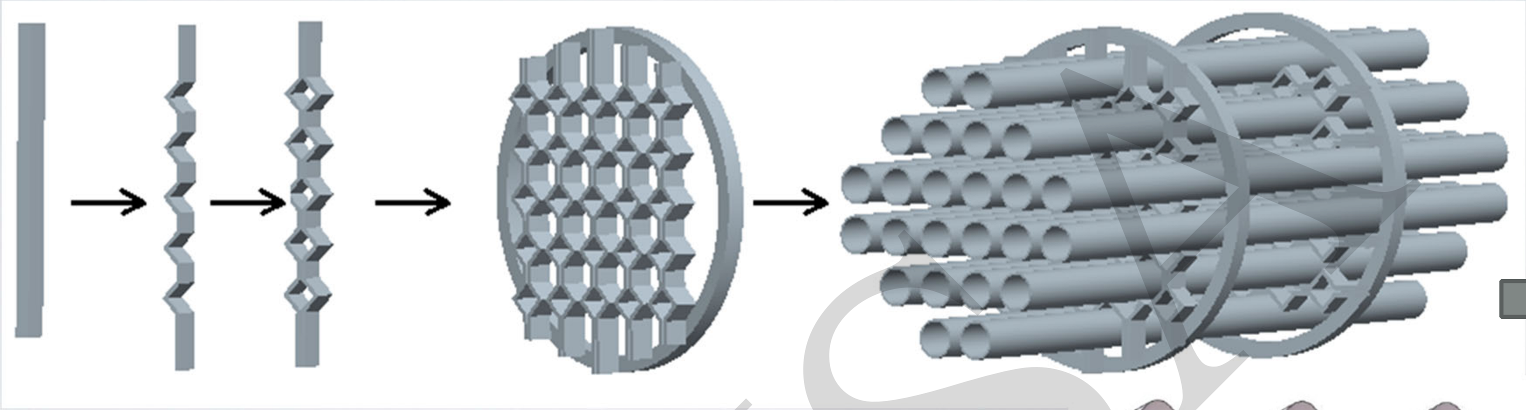
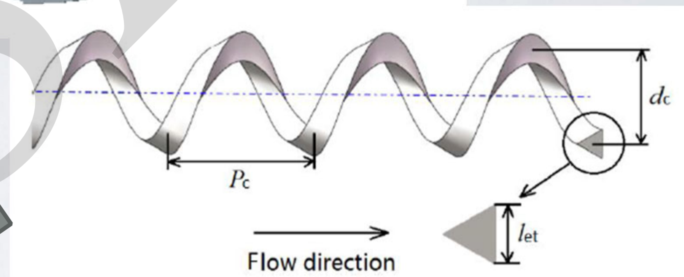
Parameters optimization of a parallel-flow heat exchanger with a new type of anti-vibration baffle and coiled wire using Taguchi method

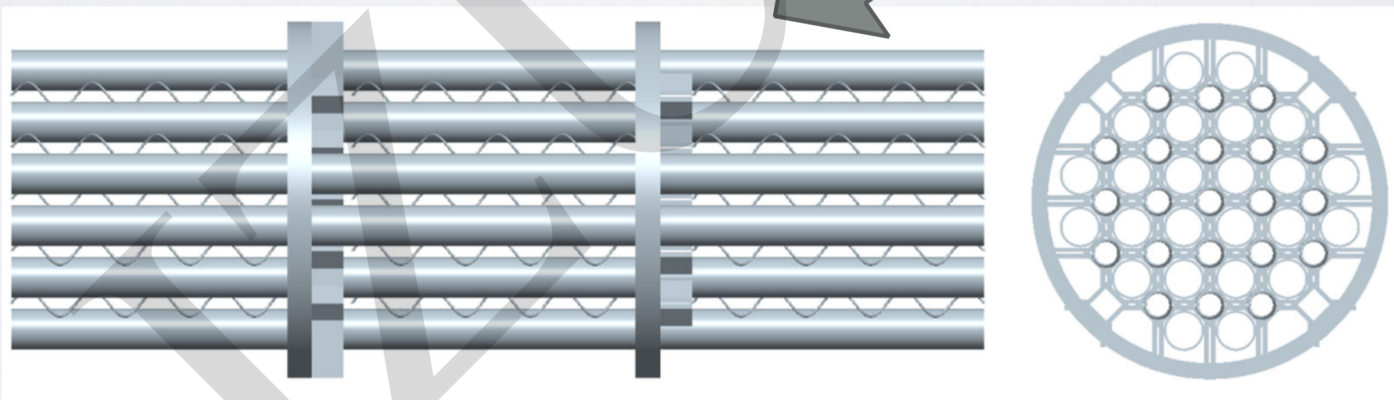
Key words:

Optimization; Parallel-flow; Anti-vibration; Hexagon clamping baffle; Coiled wire; Taguchi method

1.Background







Shell and tube heat exchanger with a new anti-vibration baffle and wire coils is proposed.
Effect of geometric parameters on thermal performance?
Parameters optimization to obtain maximum PEC?

2.Design of experiments

Table 3 Levels of each factor

Code	Factors(unit)	Level 1	Level 2	Level 3
A	Baffle distance, L_b (mm)	300	350	400
B	Baffle width, b (mm)	10	20	30
C	Coil pitch, P_c (mm)	20	30	40
D	Coil diameter, d_c (mm)	13	14	15
E	Side length of equilateral triangle, l_{et} (mm)	2	3	4

$$\nabla(\rho V\phi) = \nabla(\Gamma_{\phi}\mathrm{grad}\phi) + S_{\phi}$$

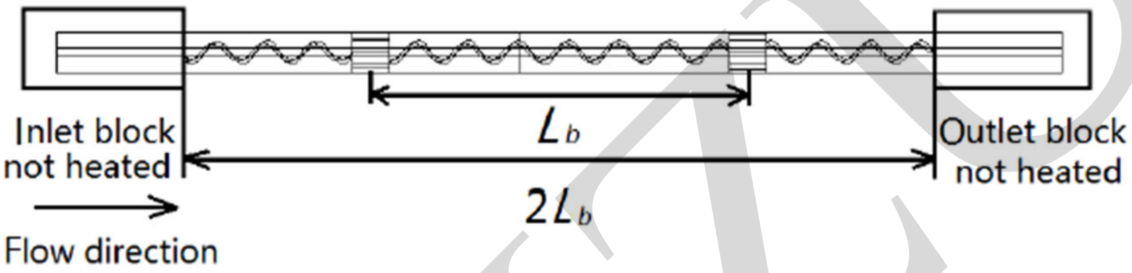


Fig.6. Schematic diagram of the computational domain of the HCBetsw-STHX

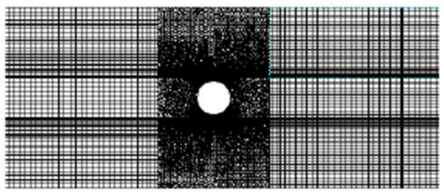


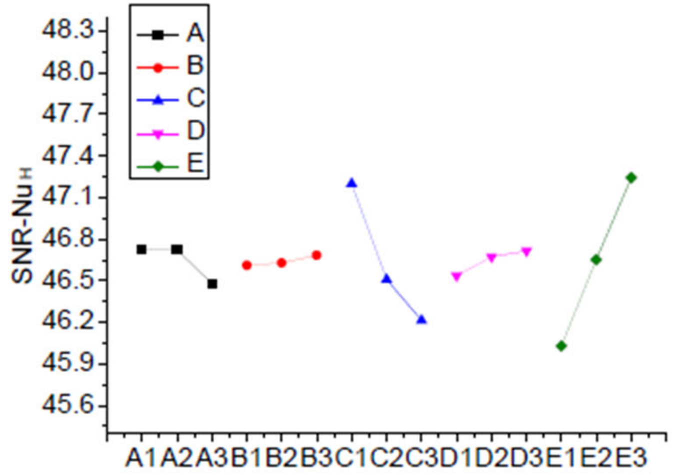
Table 4 The orthogonal array of L18 (3^5)

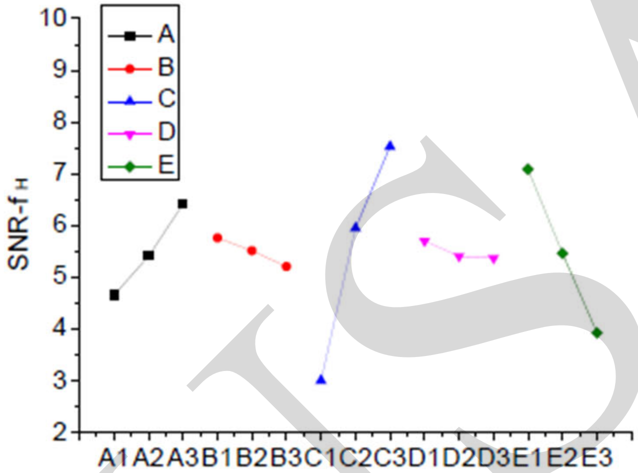
Case no.	Control factors				
	A	B	C	D	E
Case 1	1	1	1	1	1
Case 2	1	2	2	2	2
Case 3	1	3	3	3	3
Case 4	2	1	1	2	2
Case 5	2	2	2	3	3
Case 6	2	3	3	1	1
Case 7	3	1	2	1	3
Case 8	3	2	3	2	1
Case 9	3	3	1	3	2
Case 10	1	1	3	3	2
Case 11	1	2	1	1	3
Case 12	1	3	2	2	1
Case 13	2	1	2	3	1
Case 14	2	2	3	1	2
Case 15	2	3	1	2	3
Case 16	3	1	3	2	3
Case 17	3	2	1	3	1
Case 18	3	3	2	1	2

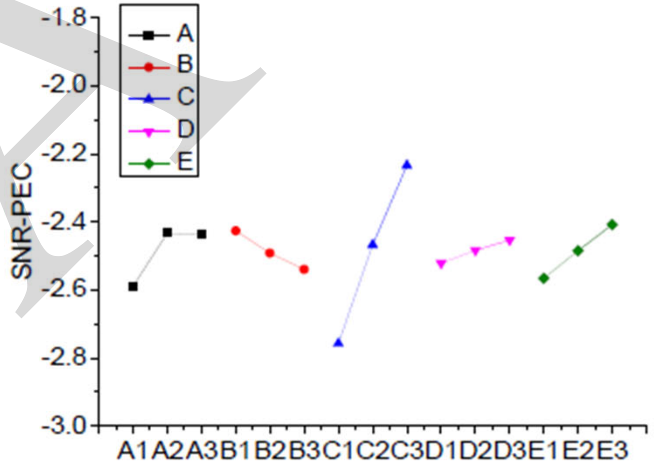
3.Result analysis

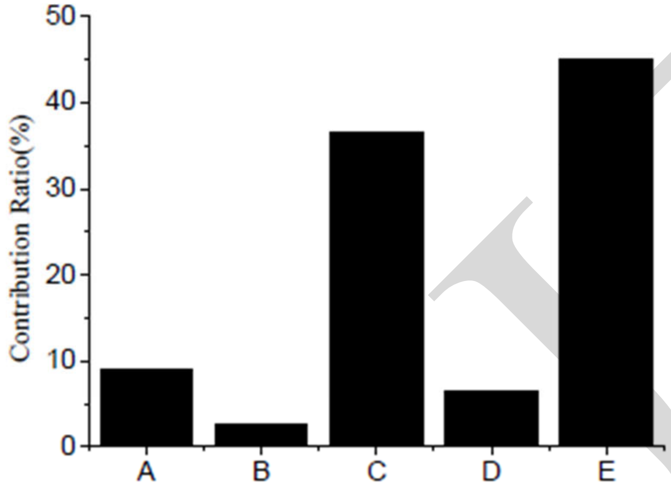
Table 5 Raw data and corresponding SNRs for each case

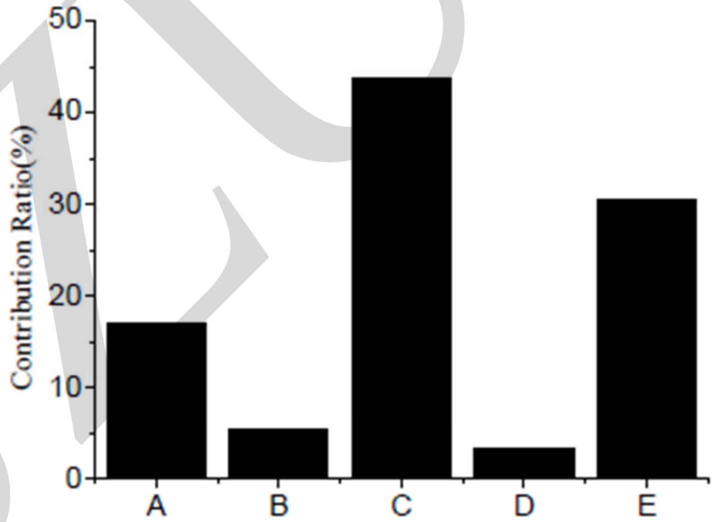
Case no.	Nu_H	SNR-Nu_H	f_H	SNR-f_H	Nu_H/Nu_R	f_H/f_R	PEC	SNR-PEC
Case 1	213.02	46.569	0.621	4.132	1.361	6.900	0.715	-2.916
Case 2	213.29	46.579	0.558	5.066	1.363	6.196	0.742	-2.593
Case 3	220.26	46.859	0.560	5.035	1.407	6.219	0.765	-2.324
Case 4	229.27	47.207	0.688	3.254	1.504	8.551	0.736	-2.668
Case 5	233.07	47.350	0.635	3.950	1.529	7.892	0.768	-2.293
Case 6	191.57	45.646	0.360	8.877	1.257	4.475	0.763	-2.354
Case 7	219.25	46.819	0.518	5.719	1.466	7.044	0.765	-2.330
Case 8	190.88	45.615	0.333	9.551	1.276	4.531	0.771	-2.257
Case 9	230.71	47.261	0.688	3.242	1.542	9.368	0.732	-2.714
Case 10	211.15	46.492	0.474	6.483	1.349	5.264	0.775	-2.209
Case 11	245.74	47.810	0.917	0.751	1.570	10.184	0.724	-2.802
Case 12	199.97	46.019	0.475	6.470	1.278	5.272	0.734	-2.686
Case 13	199.67	46.006	0.414	7.658	1.310	5.150	0.759	-2.400
Case 14	201.76	46.097	0.402	7.909	1.324	5.003	0.774	-2.226
Case 15	252.26	48.037	0.914	0.785	1.655	11.362	0.736	-2.661
Case 16	213.35	46.582	0.431	7.308	1.426	5.866	0.791	-2.038
Case 17	207.07	46.322	0.510	5.851	1.384	6.938	0.726	-2.783
Case 18	206.02	46.278	0.456	6.829	1.377	6.199	0.750	-2.501


SNR-Nu H
A
B
C
D
E
48.3
48.0
47.7
47.4
47.1
46.8
46.5
46.2
45.9
45.6
A1A2A3B1B2B3C1C2C3D1D2D3E1E2E3


SNR-f H
A
B
C
D
E
10
9
8
7
6
5
4
3
2
A1A2A3B1B2B3C1C2C3D1D2D3E1E2E3


SNR-PEC
A
B
C
D
E
-1.8
-2.0
-2.2
-2.4
-2.6
-2.8
-3.0
A1A2A3B1B2B3C1C2C3D1D2D3E1E2E3


Contribution Ratio(%)
50
40
30
20
10
0
A
B
C
D
E


Contribution Ratio(%)
50
40
30
20
10
0
A
B
C
D
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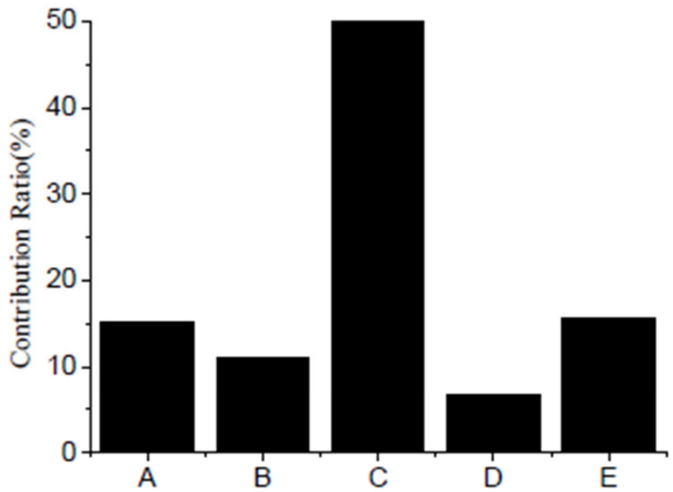
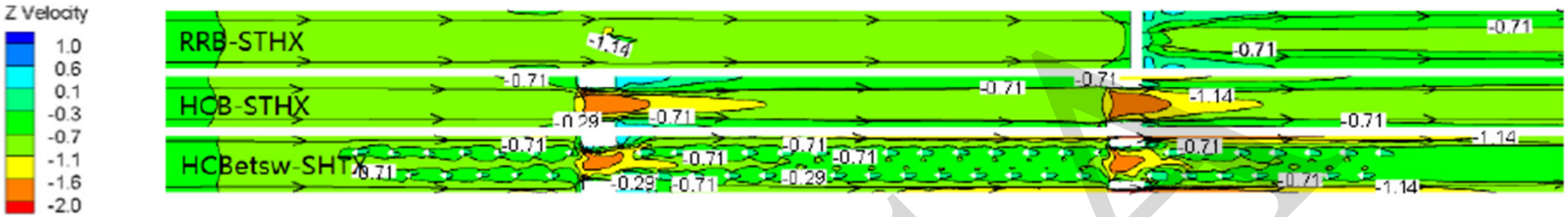
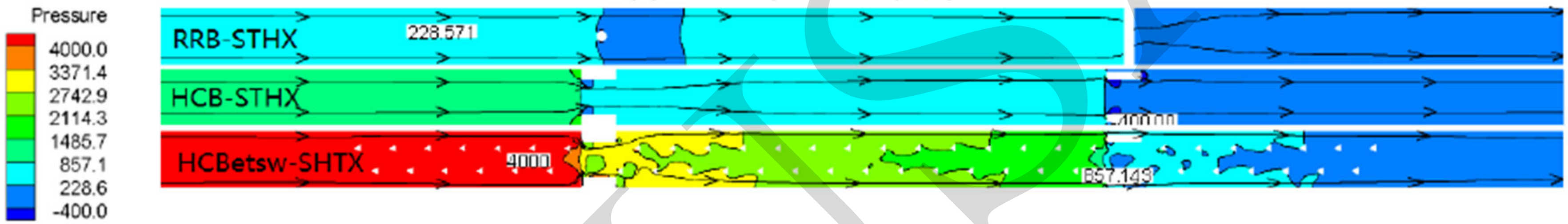
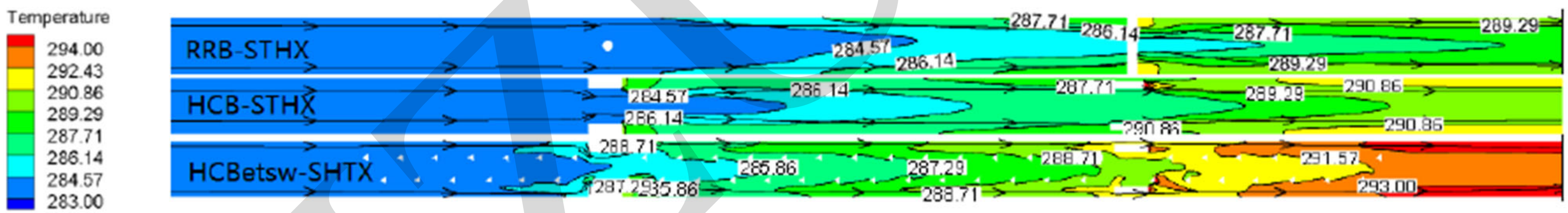

Contribution Ratio(%)
50
40
30
20
10
0
A
B
C
D
E



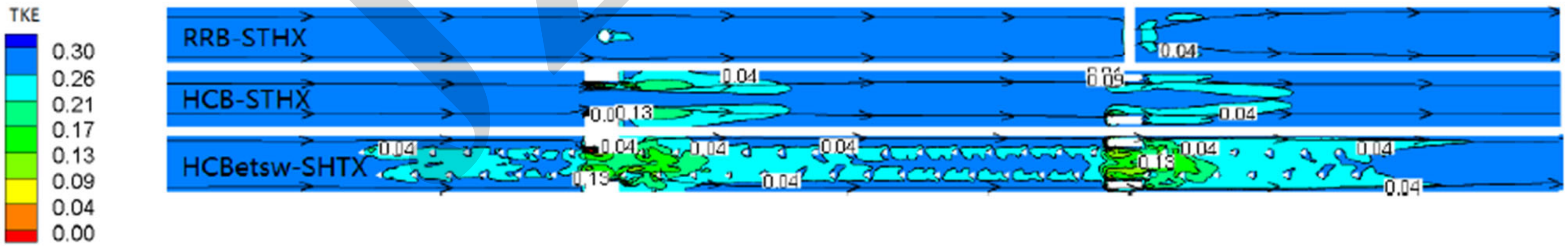
(a) Z velocity contour (m/s)



(b) pressure contour (Pa)



(c) temperature contour (K)



(d) TKE (m^2/s^{-2})

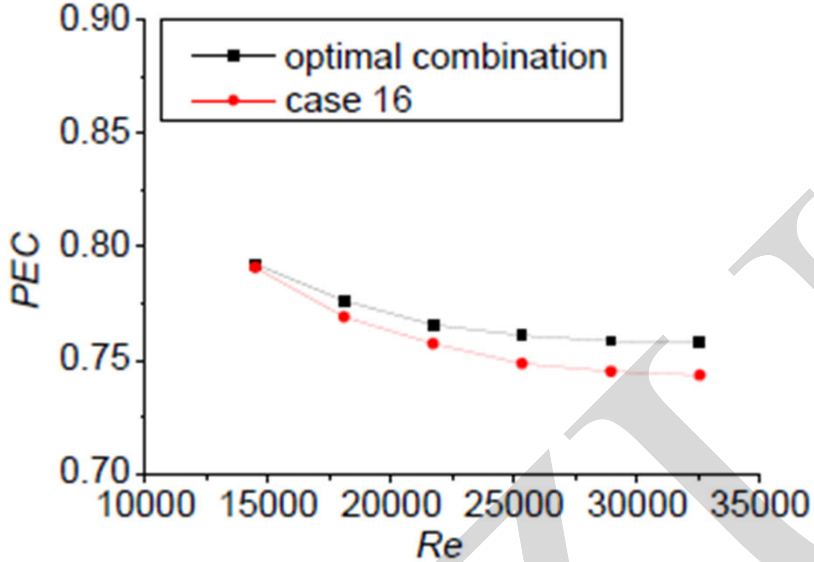


Fig.18. Variations of *PEC* with *Re* for HCBetsw-STHX with different factor combinations

Fig.18 indicates that the optimal combination has higher PEC than case 16 in a wide range of *Re*. The PEC of the optimal combination is improved by 0.19-1.92% with *Re* ranging from 14,465 to 32,547. The results further prove that optimization by the Taguchi method is a reasonable one.

4. Conclusions

1) Over the parameters investigated, the *Nu* of the HCBetsw-STHX is 1.278–1.655 times that of the RRB-STHX, while the *f* of the HCBetsw-STHX is 4.475–11.362 times that of the RRB-STHX. Although the PEC of the HCBetsw-STHX is smaller than that of the RRB-STHX, the HCBetsw-STHX can behave better than the RRB-STHX when the flow induced tube vibration is serious or the mass flow of the shell side is small. Furthermore, the HCB is quite suitable for a large and heavy tube bundle as its rigidity is much greater than that of the RRB.

2) The control geometric parameters of the HCBetsw-STHX include baffle distance (A), baffle width (B), coil pitch (C), coil diameter (D), and the side length of the equilateral triangle (E). The results show that the order of the factor effectiveness for *Nu* is E>C>A>D>B, for *f* is C>E>A>B>D, and for the PEC is C>E>A>B>D. The conclusion can be drawn that the coil pitch has a great influence while the baffle width and the coil diameter have little effect. In addition, through intuitive analysis and ANOVA, that conclusion can be further demonstrated.

3) For the PEC of the HCBetsw-STHX, the optimal geometric parameter combination is A2B1C3D3E3. The confirmation tests demonstrate that optimization using the Taguchi method is reasonable. Compared with the best case in the 18 cases, the optimal factor combination improves the PEC by 0.19%–1.92% for *Re* in the range from 14000 to 33000.