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SIGNAL-TO-NOISE ANALYSIS OF THE ELEVATOR BOOSTING PERFORMANCE OF FLAT-TUBE-AND-FIN HEAT EXCHANGER

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In this work, after the elevators shaped by NACA 0012 were proposed for the Flat-tube-and-fin heat exchanger (FTFHE) with an experimental validation, a signal-to-noise (SNR) analysis was considered for the contribution rate (CR) of structural parameters. It is found that, for CR, chord length dominates with 43,44 % as the minimum 13,11 % escort orientation point. Besides those, the mounted angle of 0°, the chord length of 6,4 mm, the extruded length of 1 mm or Orientation point 6 might only benefit heat transfer, while 8°, 6 mm or 0,9 mm purely serves pressure loss disregarding orientation point.

Keywords: flat-tube-and-fin heat exchanger, NACA 0012, performance enhancement, elevator, SNR analysis

INTRODUCTION

Sharing the same design purpose with VGs, turning laminar flow into turbulent flow, guiding airflow with an elevator might be another innovation to improve the air-side comprehensive performance, and of course, that elevator should possess an ideal low-resistance geometrical configuration. From open elevator-related references, most qualified ones were discovered in aviation and marine fields. Since the first experimental data of airfoil was reported by Jacobs et al. [1], the wide application of airfoil enlightened related design and manufacture in many ways. Sun et al. [2] proposed a two-step approach for the solution to the adaptive leading edge based on NACA 0006, and compared it with Solid Isotropic Material with Penalization (SIMP) method in Altair OptiStruct. Then, the comparative outcome validated its effectiveness. In 2015, Garg et al. [3] optimized a NACA 0009 hydrofoil with 210 design variables and found that the optimized airfoil possessed a much lower negative suction peak and higher efficiency, the reference also compared the optimal results under single-point and multipoint configurations to assess lift coefficient.

As a supplement, this work tries to explain the signal-to-noise (SNR) and contribution rate (CR) of the proposed NACA 0012 elevator with an experimental validation on the applied numerical analysis. The objectives of this work are listed as follows: (a) A numerical analysis on the proposed elevator would be implemented. (b) An experiment would be performed to validate the correctness of the numerical analysis. (c) The SNR and CR of structural parameters would be examined as expected.

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PROPOSED MODEL OF ELEVATOR

According to structural parameters, a 3D elementary unit of the Flat-tube-and-fin heat exchanger (FTFHE) was completed and shown in Figure 1. Several main

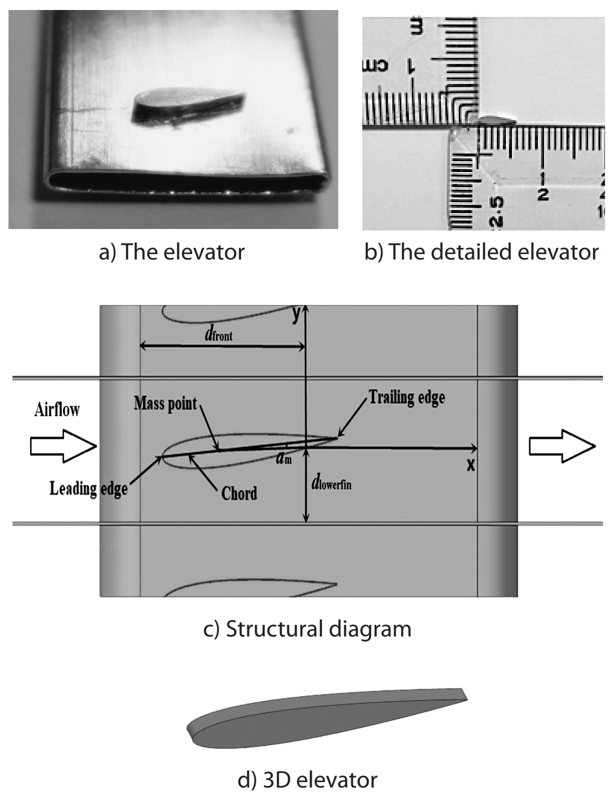


Figure 1 Effects of viscosity parameter, suction

Table 1 **Detailed boundary conditions**

Parameters	Value
Inlet velocity	6 m/s
Wall temperature	100°C
Operating temperature	45°C
Air temperature	45°C
Gauge pressure	0 Pa
Gravity	9,8 m·s^{-2}

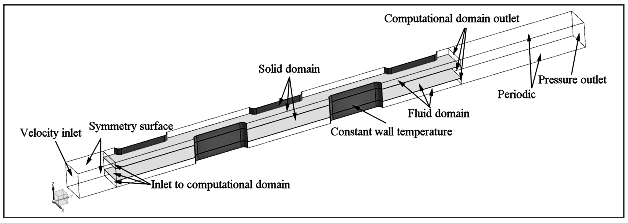


Figure 2 Effects of viscosity parameter, suction

structural parameters are listed as follows: Mounted angle is 4°, Geometrical profile is NACA 0012, Chord length is 6 mm, and Extruded length of elevator is 1mm.

NUMERICAL PREPROCESSING

The boundary conditions applied to the numerical model are plotted in Figure 2. Others detailed boundary conditions are the same to Table 1.

The mixture of structural and unstructured grids were used for the grid configuration with a total grid amount around 7 million.

The pressure loss from post-processed experimental data was 0,25 Pa, while that from the numerical analysis was 0,26 Pa. For heat transfer coefficient, they were 29,8 W/(m^2·K) and 31,81 W/(m^2·K), respectively. The deviations on pressure loss and heat transfer coefficient were respectively 3,84 % and 6,31 %, which spared the accuracy of the implemented numerical analysis on the performance enhancement brought by the elevator.

SNR ANALYSIS ON STRUCTURAL PARAMETERS

SNR and CR from Reference [4] are written as

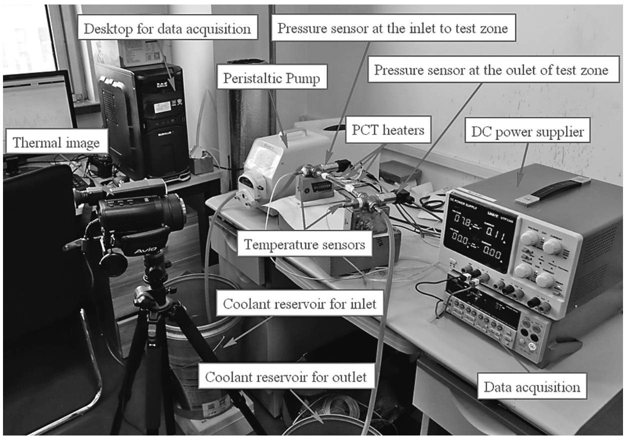
$$SN(\eta) = 10 \times \log\left(\frac{1}{s} \times \frac{S_m - V_e}{V_e}\right) \tag{1}$$

where V_i is the ith fluid inlet speed and JF_i is the ith fin thermal performance factor.

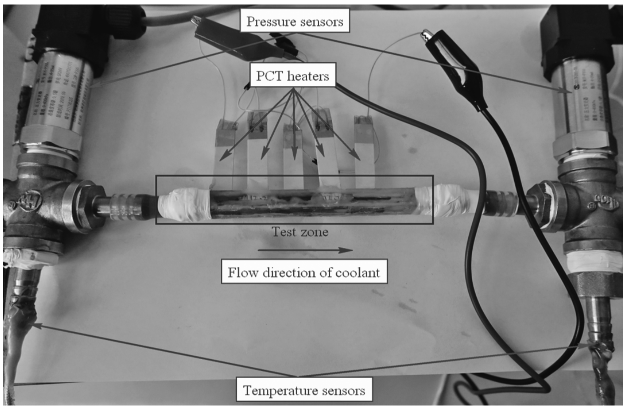
$$CR = \frac{SN_{\max} - SN_{\min}}{\sum_{i=1}^{n}\left(SN_{\max} - SN_{\min}\right)} \tag{2}$$

where n is the number of airflow and here n=6.

Pressure loss, heat transfer coefficient and JF factor of the combinations in Table 2 were examined under inlet velocities of 2, 4, 6, 8, 10, 12 m/s, and transformed through Equations (1) and (2) to obtain the SNRs in Table 2.



a Experimental rig



b Test zone

Figure 3 The introduction to the experimental rig

Predicted SNRs are exhibited in Figure 4. As mounted angle increased, its SNR presented a similar valley to that of extruded length while chord Length casted a peak. The SNR of orientation point fluctuated at first, then, shrunk from 15,382 to 15,350.

The SNR deviations and the CRs were calculated by Equations (1) and (2). The SNR deviations among levels under the same parameter were 0,04 for mounted angle, 0,106 for chord length, 0,066 for extruded length, and 0,032 for orientation point, respectively. The CRs among levels under the same parameter were 16,4 for mounted angle, 43,44 for chord length, 27,05 for extruded length, and 13,11 for orientation point, respectively.

The CR of each factor showed a clear difference in Figure 5. Chord length stood in front of others with 43,44 %. For a start, the increasing of chord length might enrich the contact area between heat exchanger and air, and narrow the air aisle for faster air velocity and more energy transportation. These changes improved the performance of heat exchanger with an acceptable cost. Secondly, extruded length affected heat exchange with a 27,05 % CR. It probably caused by the passage cross-section variation and the expansion of heat transfer surface. The following mounted angle contributed CR of 16,4 %. Its effects on the pressure loss and passage cross-section were unconsidered due to the

Table 2 **SNR of the structure's combinations**

Combination	Mounted Angle	Chord Length	Extruded Length	Orientation Point	SNR
1	0	6	0,9	1	15,39
2	0	6,2	0,95	2	15,38
3	0	6,4	1	3	15,38
4	0	6,6	1,05	4	15,38
5	0	6,8	1,1	5	15,36
6	2	6	0,95	3	15,4
7	2	6,2	1	4	15,41
8	2	6,4	1,05	5	15,4
9	2	6.6	1,1	1	15,33
10	2	6.8	0,9	2	15,34
11	4	6	1	5	15,2
12	4	6,2	1,05	1	15,35
13	4	6,4	1,1	2	15,49
14	4	6,6	0,9	3	15,38
15	4	6,8	0,95	4	15,34
16	6	6	1,05	2	15,33
17	6	6,2	1,1	3	15,37
18	6	6,4	0,9	4	15,43
19	6	6,6	0,95	5	15,39
20	6	6,8	1	1	15,33
21	8	6	1,1	4	15,35
22	8	6,2	0,9	5	15,4
23	8	6,4	0,95	1	15,5
24	8	6,6	1	2	15,36
25	8	6,8	1,05	3	15,35

lower resistance of elevator. At last, orientation point held the minimum CR of 13,11 %, which meant that different orientation points improved little air velocity and heat transfer surface.

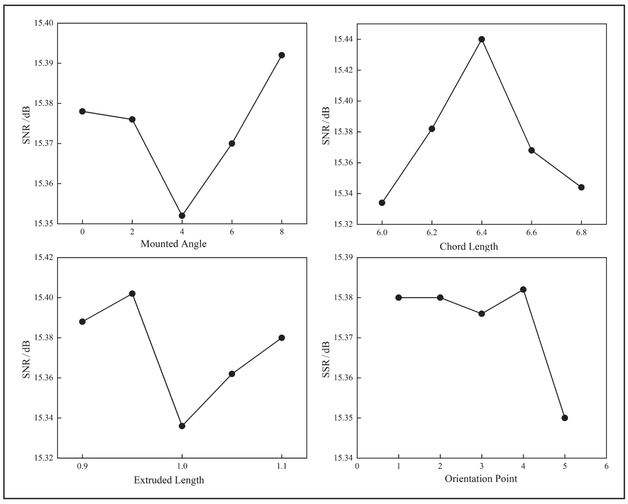


Figure 4 Temperature history comparison between experiment and simulation

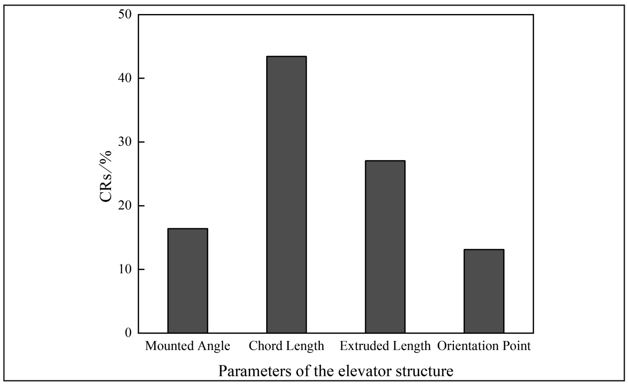


Figure 5 CR of structural parameters

CONCLUSION

In this work, a NACA 0012 elevator was proposed for FTFHE, and its numerical analysis was verified by an experiment. Then, the SNR and CR of the proposed NACA 0012 elevator were numerically examined. With those results, the following conclusions were made:

(a) The deviations on pressure loss and heat transfer coefficient are respectively 3,84 % and 6,31 %, which might support the correctness of the employed numerical analysis in this work.

(b) By SNR analysis, the biggest CR of 43,44 % belongs to chord length while the least CR of 13,11 % stays on orientation point, the rest of extruded length and mounted angle are 27,05 % and 16,4 %, respectively.

(c) Among popular implements, the air guiding by elevator maybe not the only way but a feasible one to strengthen comprehensive performance on a low cost, and hopefully explore a new view for similar research.

REFERENCES

[1] K. W., Eastman N. Jacobs, and R. M. Pinkerton, The Characteristics of 78 Related Airfoil Sections From Tests in the Variable-Density Wind Tunnel (NACA-TR-460). United States: National Advisory Committee for Aeronautics, 1933.

[2] R. J. Sun, G. P. Chen, C. Zhou, L. W. Zhou, and J. H. Jiang, "Multidisciplinary design optimization of adaptive wing leading edge," Science China-Technological Sciences, 56 (2013) 7, 1790-1797.

[3] N. Garg, G. K. W. Kenway, Z. J. Lyu, J. Martins, and Y. L. Young, "High-Fidelity Hydrodynamic Shape Optimization of a 3-D Hydrofoil," Journal of Ship Research, 59 (2015) 4, 209-226.

[4] J. M. Bi, J. X. Liu, P. Liu, and Y. K. Jiang, "Signal-to-noise research on comprehensive performance of plate heat exchanger for commercial electric vehicle," International Journal of Thermal Sciences, 165 (2021), NO.106967.

Note: The responsible translator for English language is B Z. Wang -NCST.