CFD study on heat transfer and pressure drop characteristics of an offset strip-fin heat exchanger in helium systems

Cui Lv [1,3], Jihao Wu[1,2], Qing Li [1,2], Xiujuan Xie [1,2] Lai Feng Li [1,2] and Huiming Liu [1]

[1]Key Laboratory of Cryogenics, Technical Institute of Physics and Chemistry Chinese Academy of Sciences, Beijing 100190,China
[2]State Key Laboratory of Technologies in Space Cryogenic Propellants ,Technical Institute of Physics and Chemistry Chinese Academy of Sciences, Beijing 100190,China
[3]University of Chinese Academy of Sciences, Beijing 100049,China

Background

Plate-fin heat exchanger is a kind of the compact heat exchangers, which has high coefficient of heat transfer and large specific surface. The offset strip fins are widely used in the large scale cryogenic helium plants to meet the demands for saving energy and sources. In dynamic simulation of the large scale helium cryogenic systems, the j and f factors are needed parameters. However, the current available correlations were obtained on the occasion that air was taken as heat transfer medium. Moreover, the correlations in the open literatures are quite different even with same Re and geometries of fins. Therefore, it's necessary to derive the suitable correlations in helium systems.
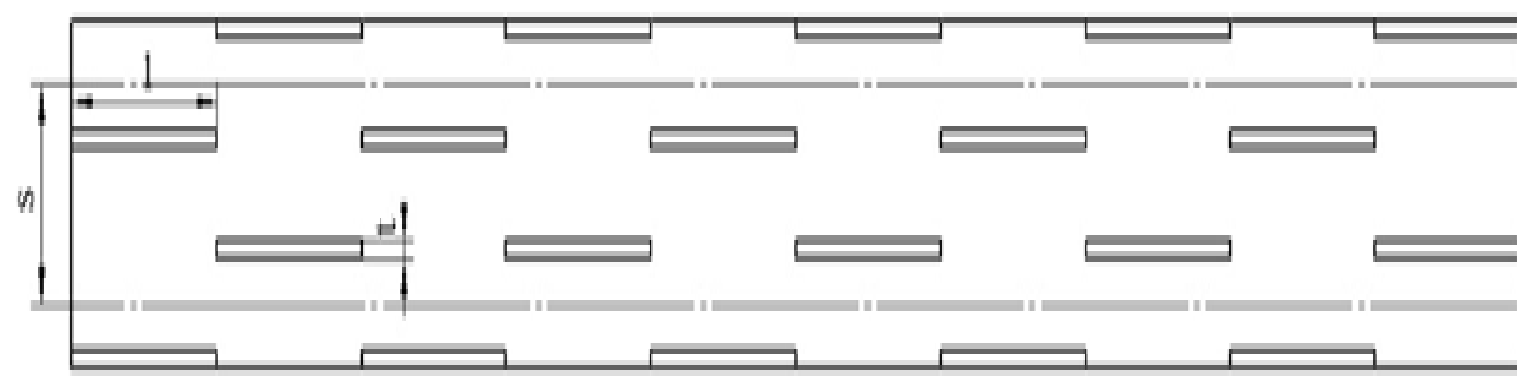
Objectives

❖ To obtain the suitable correlations of j and f factors used in helium offset strip – fin heat exchangers.
❖ To verify the applicability of orthogonal experimental method in solving the heat transfer and fluid flow problems.
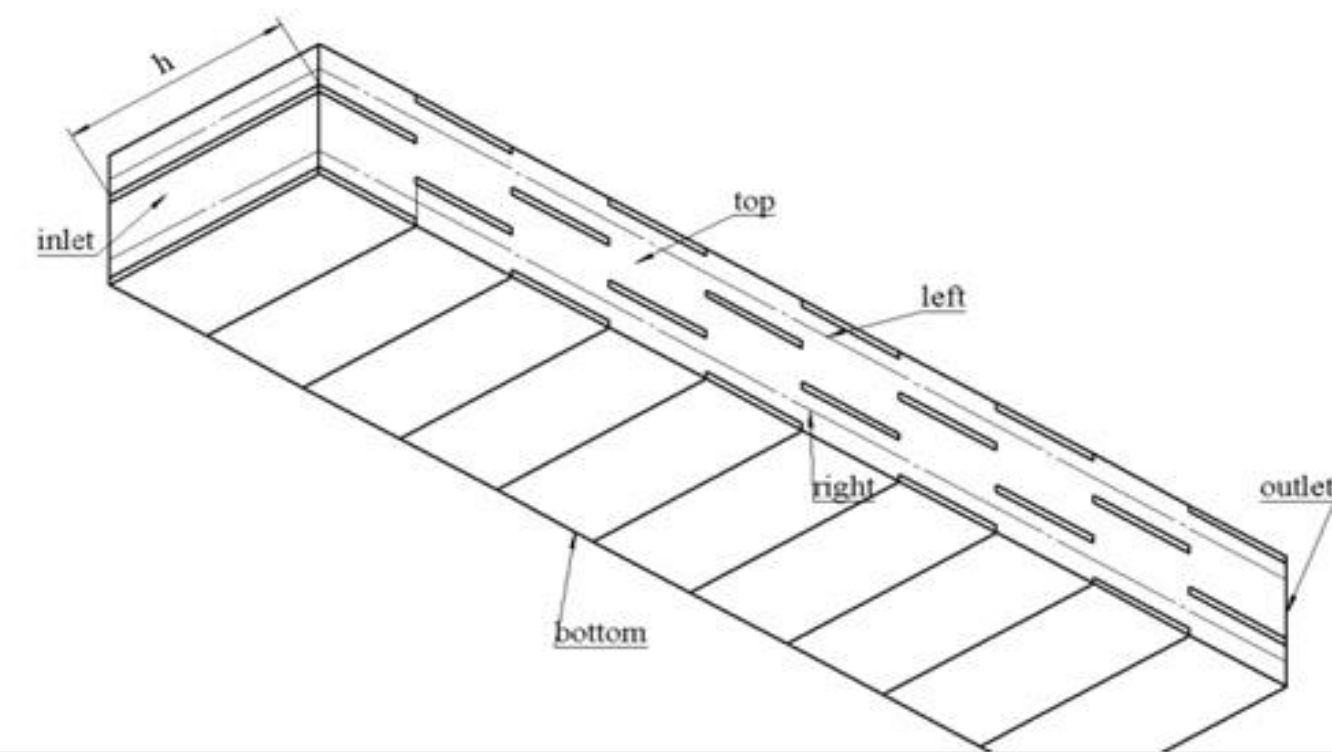
Conclusion

❖ The correlations for j and f factors of helium offset strip-fin heat exchanger had been developed by the multiple regression analysis, which can predict 90% simulation data within ±20% derivation.
❖ The simulation results denoted that orthogonal experimental method was applicable in solving the heat transfer and fluid flow problems.
❖ The comparison between the present and the open literatures' correlations revealed that the fluid medium will affect the j and f factors.
❖ The simulation results will provide a selection in the design and dynamic simulation of the offset strip fin heat exchangers in helium systems.

Methods

The top view and axonometric drawing of the offset strip fins
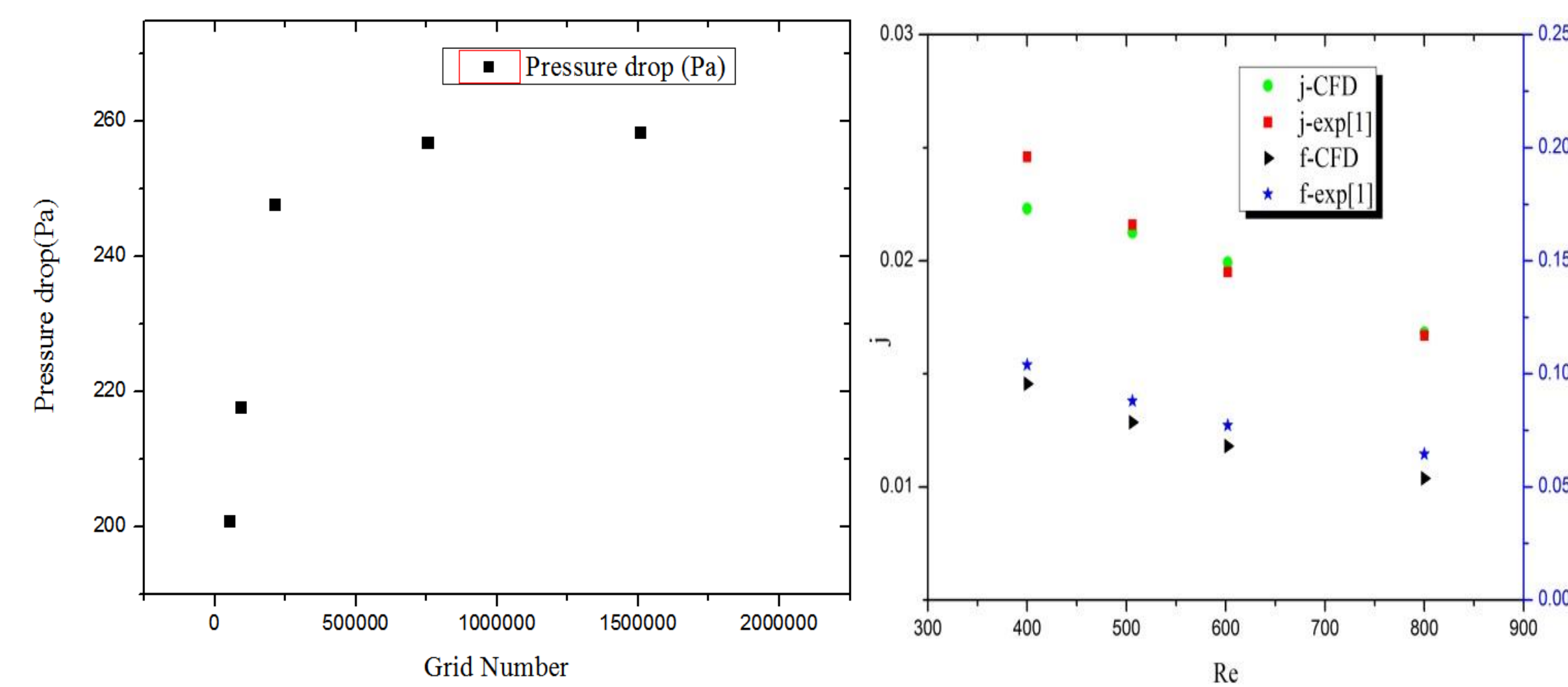

Usually, the fin-channel is assumed to be rectangular, and the fin offset is uniform and equal to half-fin spacing.

In order to neglect the entry effect, the model total length was chosen that the ratio of flow length to the hydraulic diameter was more than 60.

Mesh independence and the model verification

✓ The model verification used air as the heat transfer medium was carried out .

✓ The comparison between simulation results and the experimental data revealed that the maximum relative error of j and f factors were 9.1% and 17% respectively.
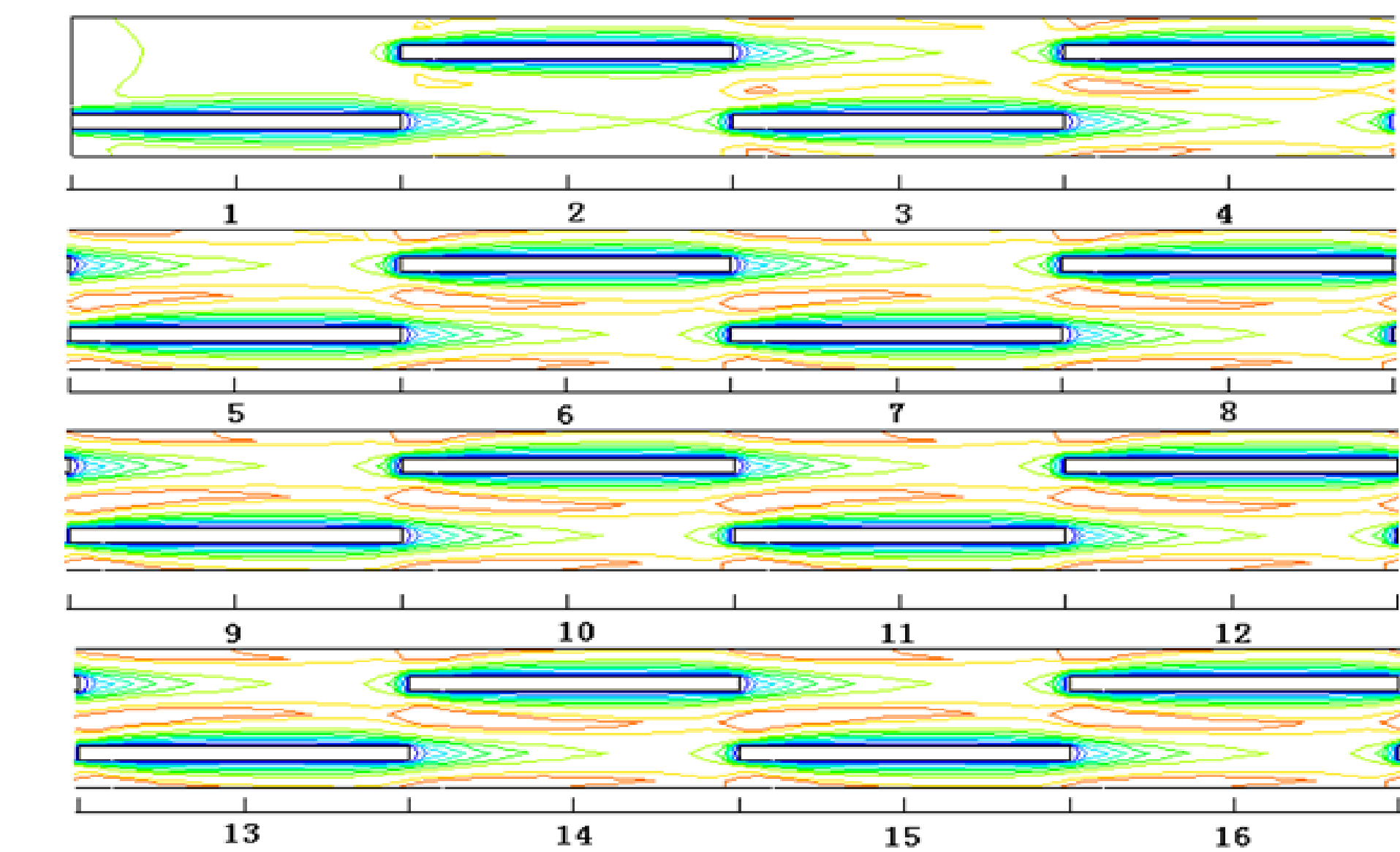
The pressure drop of model is tend to constant when the grid number is more than 753664. Hence, this grid number was chosen to calculate the j and f factors.
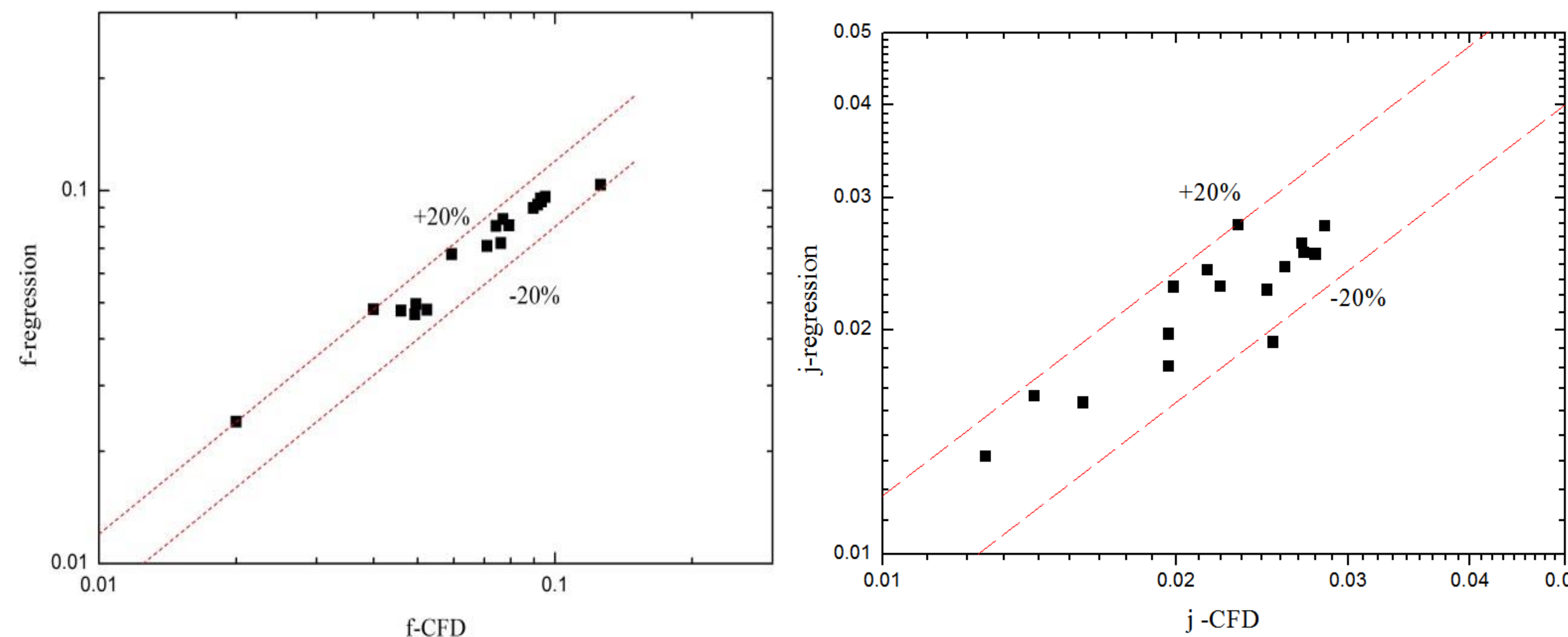
Results

The inner flow analysis of the model

The characteristics of the inner flow of the model:
➢ The inlet velocity increased when it passed the minimum cross-section.
➢ The contour of velocity showed the periodicity until the ninth fin because of the entrance effect.

The comparison between the regression data and the CFD results

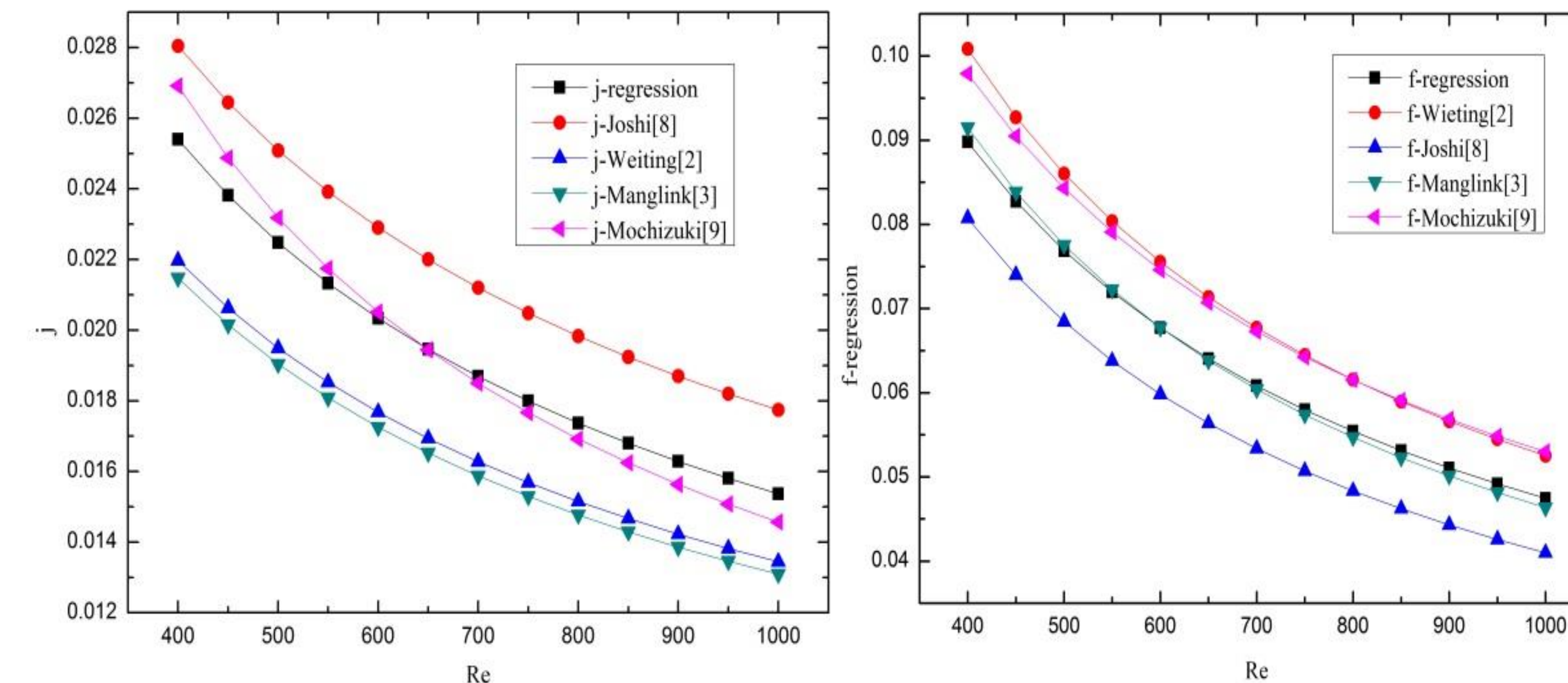➢ The orthogonal experimental design was used to reduce the number of the simulation.

➢ The data in the orthogonal table was fitted by multiple regression method to derive the correlations of j and f factors .

$$j = 0.377 R_e^{-0.5485} \left(\frac{s}{h}\right)^{-0.4544} \left(\frac{t}{l}\right)^{0.2074} \left(\frac{t}{s}\right)^{-0.3448}$$

$$f = 10.63 R_e^{-0.6959} \left(\frac{s}{h}\right)^{-0.3185} \left(\frac{t}{l}\right)^{0.3219} \left(\frac{t}{s}\right)^{-0.0295}$$

The correlations and CFD results were in good agreement, and the 90% of the simulation data were correlated within ±20% derivation.

The comparison between present results and the available empirical correlations

✓ The trends between different correlations are same, this results can be proved that the orthogonal experimental method is the effective way to solve the multifactor problems of the thermodynamic filed.

✓ There exists difference between different correlations because the fin geometries used in the experiment and fluid medium were not same.

Contact information: wujihao@mail.ipc.ac.cn