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

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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

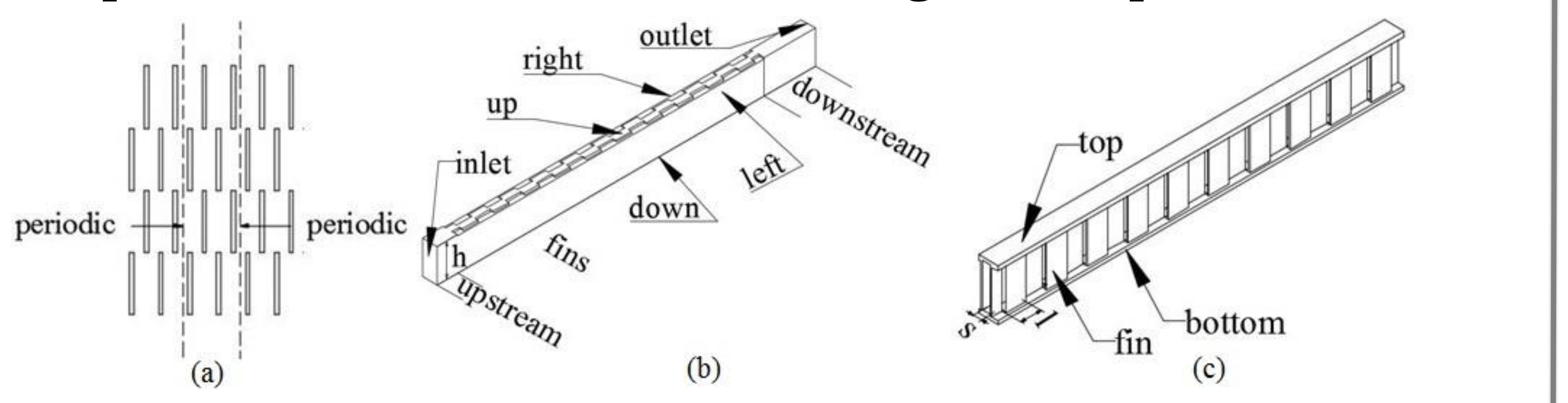
- To obtain the suitable correlations of j and f factors used in helium offset strip – fin heat exchangers in low temperature.
- To study the inner flow pattern of the offset strip – fin heat exchangers

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 94.5% of the f data and 92.7% of the j data for laminar region, and 95.4% of the f data and 90.9% of the j data for the turbulent regime within ±20% derivation. .
- The simulation results denoted that extraction section was applicable in solving the heat transfer and fluid flow problems to ignore the entrance effect.
- The simulation results will provide a selection in the design and dynamic simulation of the offset strip fin heat exchangers in helium systems.

Methods

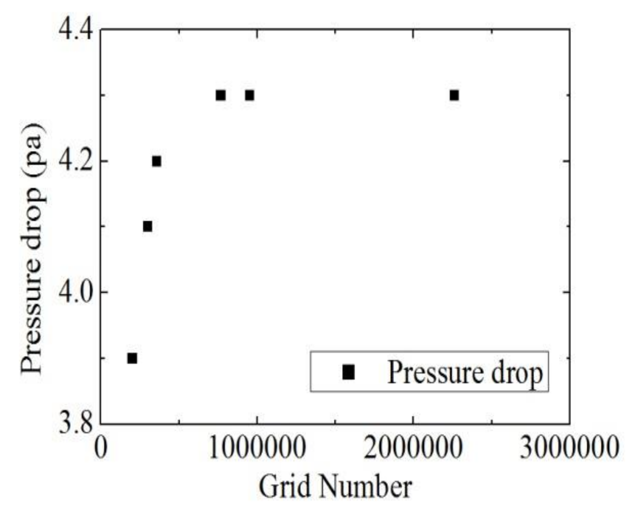
The top view and axonometric drawing of computation domain

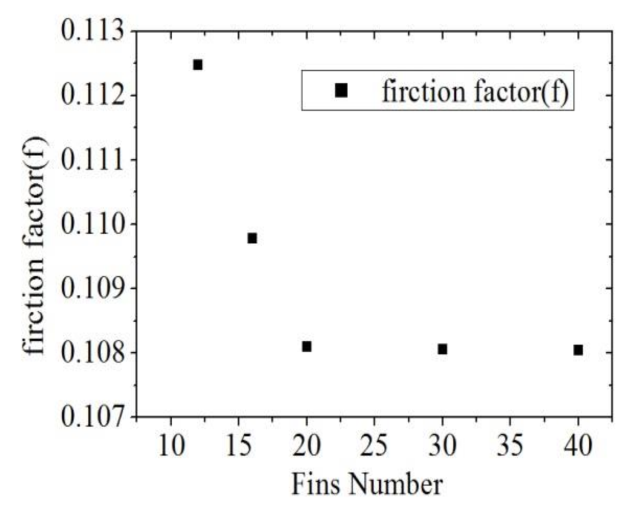


Usually, the fin-channel is assumed to be rectangular, and the fin offset is uniform and equal to half-fin spacing.

In order to ignore the entrance effect, the extension section is established at the inlet and outlet of the fluid domain. Upstream section locates at 1.5 times hydraulic diameter from first fin in the flow direction while the downstream section sets as 5 times hydraulic diameter from the last fin.

Mesh independence and the model verification



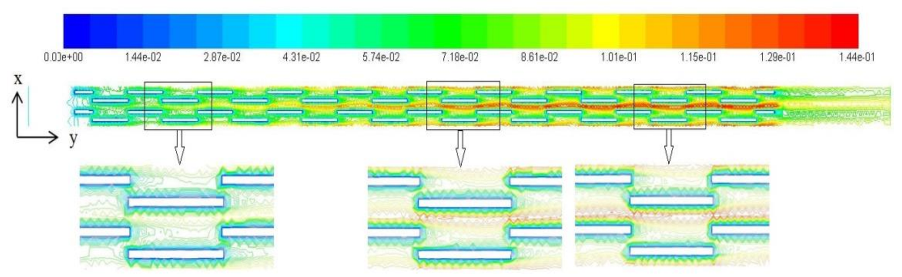


- ✓ The length of the model was confirmed by increasing the number of fins along the flow direction.
- ✓ The friction factor had no evident change until 20 fins, therefore 20 was chosen as the number of fins in simulation..

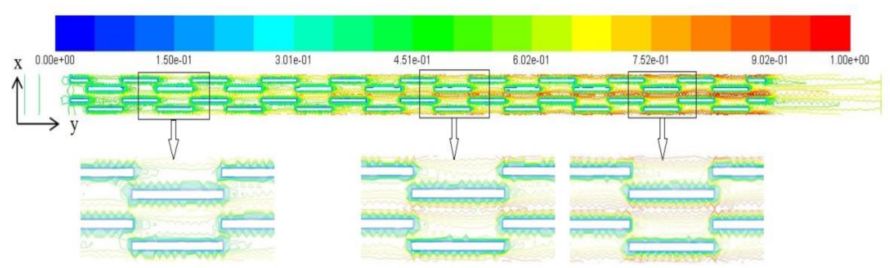
The pressure drop of model is tend to constant when the grid number is more than 800000. Hence, this grid number was chosen to calculate the j and f factors.

Results

The inner flow analysis of the model



Flow velocity contours when Re=462



Flow velocity contours when Re=4560

One of the advantages of the numerical method is that it can be used to observe the flow pattern in every part of the model

The contour of velocity didn't show the periodicity for the first eight fins because of the entrance effect. After the 8th fins, the flow field features get steady.

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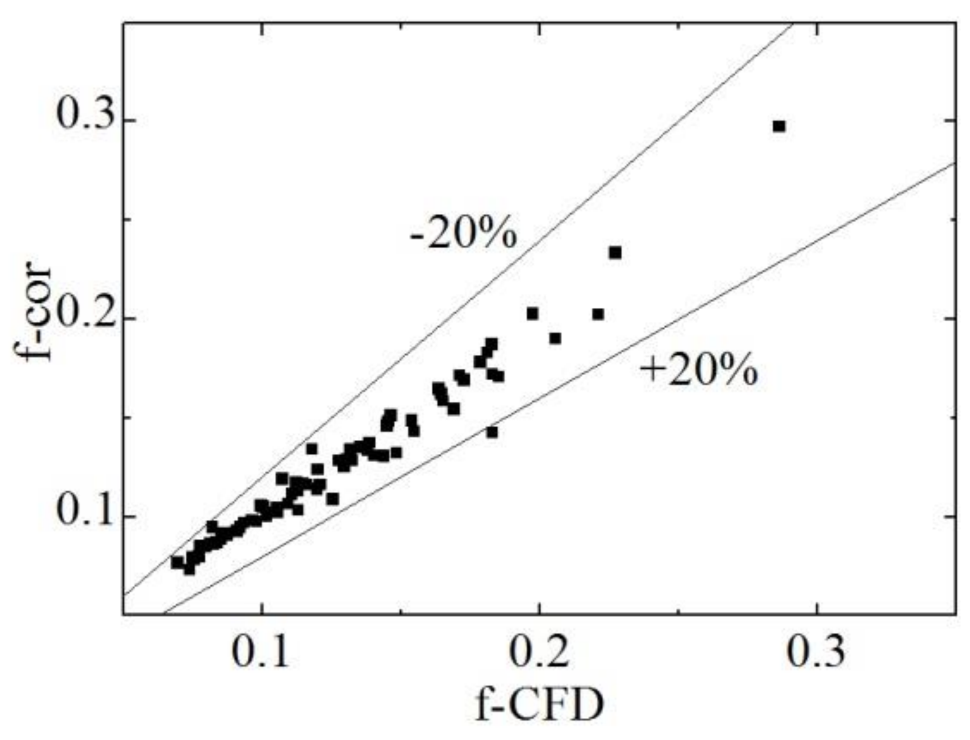
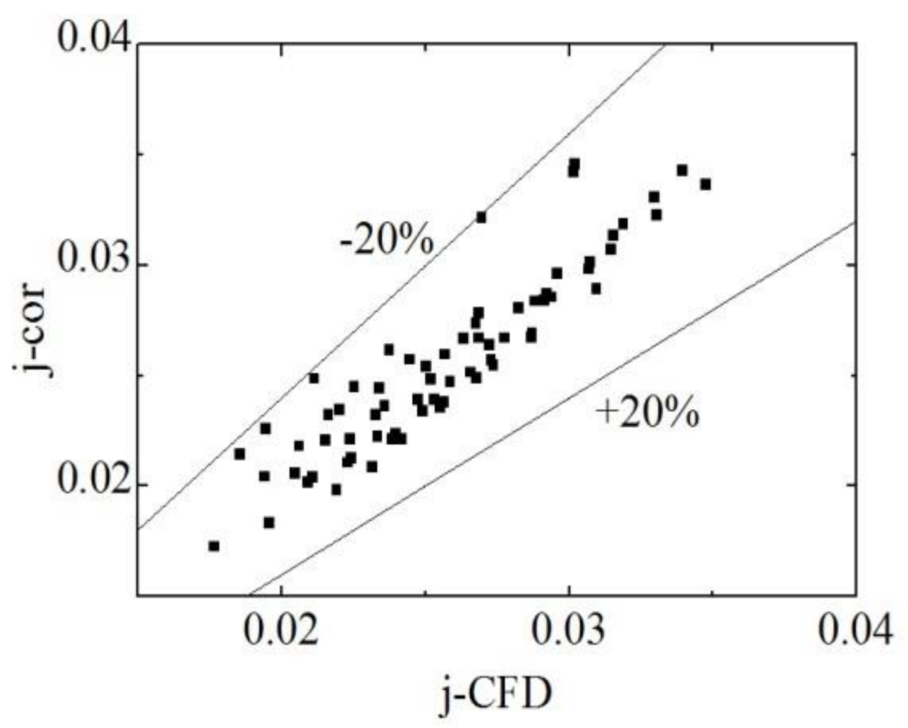
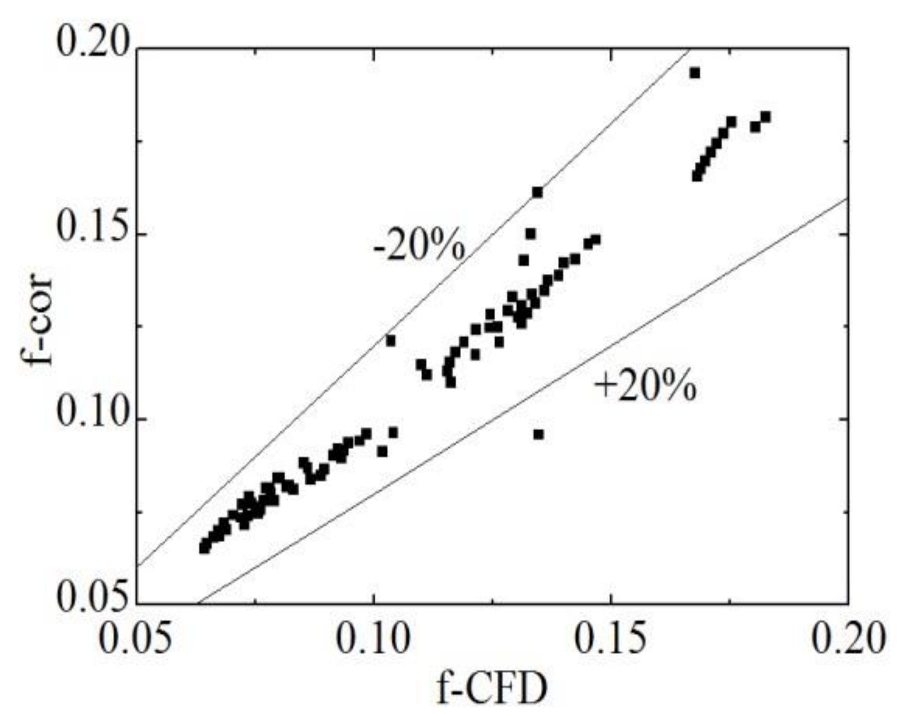
Results

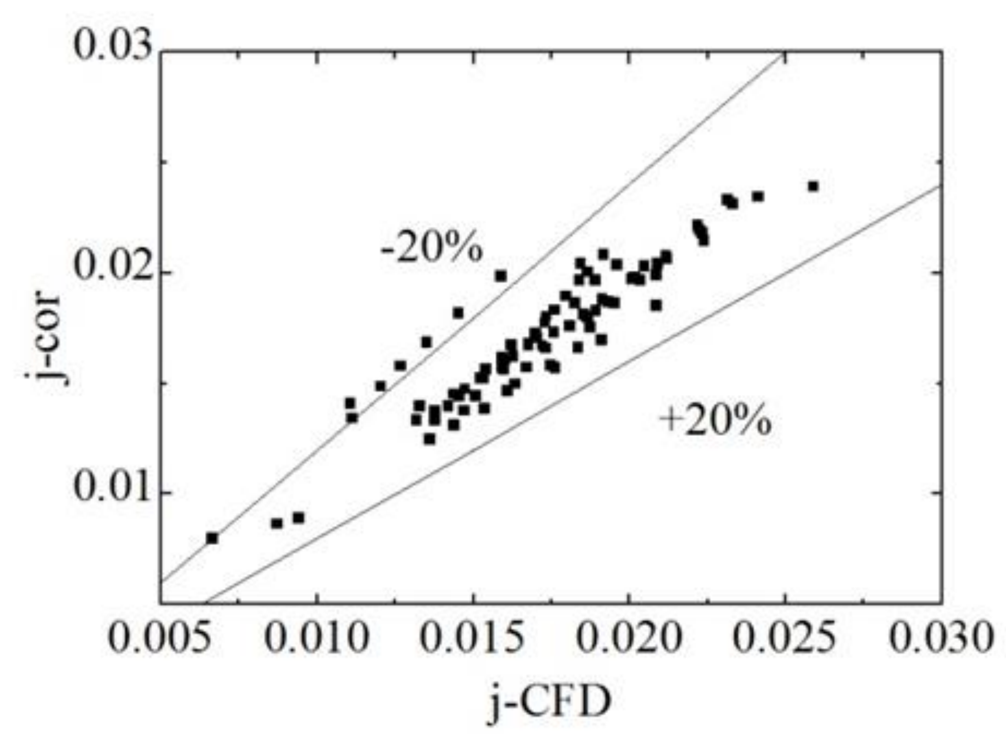
The comparison between the regression data and the CFD results in laminar and turbulent region





Comparison of correlation for f and j by correlations with CFD results in laminar region





Comparison of correlation for f and j by correlations with CFD results in turbulent region

Re<2000

$$f = 5.03481\alpha^{-0.10076}\beta^{1.31996}\gamma^{-0.81296}\delta^{-0.77202}\mathrm{Re}^{-0.34911}$$

$$j = 0.22941\alpha^{-0.24959}\beta^{1.01751}\gamma^{-0.19180}\delta^{-1.01836}\mathrm{Re}^{-0.26808}$$

Re>2000

$$f = 5.16371\alpha^{-0.11744}\beta^{1.42472}\gamma^{-0.86023}\delta^{-0.49087}\mathrm{Re}^{-0.23028}$$

$$j = 1.42661\alpha^{-0.24933}\beta^{0.56220}\gamma^{-0.21336}\delta^{-0.60461}\mathrm{Re}^{-0.54842}$$

- ✓ The above correlations predict 94.5% of the f data and 92.7% of the j data for laminar region, and 95.4% of the f data and 90.9% of the j data for the turbulent regime within ±20% derivation..

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