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C3Or4B-03: A high effective meso-scale helical-tube-bundle recuperator spanning from 300 K to 30 K

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Recuperative heat exchangers play an important role and have a large influence on the overall efficiency in many cryogenic systems. The recuperators to achieve fast cooldown can be summarized as effective, compact, and low pressure-drop. Designing this type of heat exchanger has been a challenge, especially when the size and effectiveness objectives are becoming more and more strict with the development of the application scenarios. In this study, a meso-scale helical-tube-bundle heat exchanger is proposed, with the configuration as twisting several tubes into one bundle, then twisting several bundles into the whole geometry. All the tube paths are generated by 3D sinusoidal equations, leading to same developing length and average coil diameter, promoting uniform distribution and fluid mixing. The thermal and hydraulic performances of shell side flow and tube side flow are simulated respectively by Fluent. The Nu and friction factor correlations for both sides are developed and used in the whole heat exchanger model. A 1D finite difference model considering axial conduction, thermal properties variation and parasitic heat load is built to estimate the effectiveness and pressure drop of the whole heat exchanger. A geometry with 432 tubes in parallel is found to meet all design objectives: operation between 300 K and 30 K, mass flow up to 12 g/s, size 0.3 m×0.3 m×0.7 m, effectiveness > 0.99, pressure drop for both sides <1 bar.

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