Computations Fluid Dynamics Based Evaluation of Cryogenic Heat Transfer in Helical Tube Heat Exchangers

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Dilution refrigerators are used in advanced physics systems such as quantum computing because they can cool materials to temperatures near absolute zero. A key component of these systems is the heat exchanger, which transfers heat between cryogenic fluids. Improving heat exchanger performance can increase cooling efficiency and reduce energy losses. This project investigated how increasing the number of helical coils inside a heat exchanger affects heat transfer performance and fluid flow resistance. Computational Fluid Dynamics simulations were performed using ANSYS Fluent to model cryogenic fluid flow through two heat exchanger configurations: a single-coil design and a four-coil design. The models were created in ANSYS and analyzed under specific operating conditions, including constant properties. The independent variable was the number of coils in the exchanger, pitch between coils, and manifold taper ratio. The dependent variables measured were heat transfer rate, heat exchanger effectiveness, and pressure drop. Additional simulations evaluated the effect of a tapered manifold on fluid distribution among the coils. Results showed that increasing the number of coils increased heat transfer surface area and improved thermal performance. The four-coil design demonstrated higher heat transfer rates and greater effectiveness compared to the single-coil configuration, although pressure drop also increased due to additional flow resistance. These results demonstrate how computational modeling can be used to optimize cryogenic heat exchanger designs used in ultra-low temperature physics applications.

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