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C3Or2A-04: Numerical Investigation of Alternative Regenerators in Regenerative Cryocoolers Operating Below 20K

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In regenerative cryocoolers, the regenerator plays a pivotal role, and often represents the largest source of losses among all components. Traditional materials, such as stainless-steel mesh, exhibit insufficient heat capacity below 20K, which leads to a decrease in system efficiency. While materials like HoCu2 and Er3Ni offer higher volumetric heat capacity, they are typically fabricated into spherical forms, resulting in high flow resistance. In light of these limitations, this study investigated and compared three present alternative configurations through a numerical model of a Stirling cryocooler. The first approach involves coating stainless steel mesh with high heat capacity materials. Specifically, stainless steel mesh coated with HoCu2 and Er3Ni was examined. The results indicate that, around 20K, this configuration offers improved performance compared to HoCu2 spheres by reduced flow resistance. However, the limited volume fraction of the coating material still limits the heat capacity. The second approach explores open-cavity structures, which can be filled with helium under oscillating flow. Simulations of stainless-steel capillaries reveal that the excessively large hydraulic diameters, due to manufacturing limitations, result in insufficient heat exchange area, which leads to poor performance. The third approach investigates the use of highly adsorptive materials, such as carbon nanotubes, to retain helium through physical adsorption. Compared to HoCu2 spheres, carbon nanotubes demonstrate comparable performance around 10K and exhibit further improvement as the temperature decreases, if not considering the thermal effect caused by adsorption and desorption. These numerical investigations effectively guide the search for better regenerator configurations for temperature below 20 K.

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