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Design of a moving magnet type free piston Stirling cryocooler for futuristic space application

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The usage of free-piston Stirling cryocoolers is increasingly prevalent in space technology, particularly to cool infrared sensors on satellites and space related devices. The distinctive characteristics of free-piston Stirling cryocoolers render them highly suitable for cooling these infrared sensors, primarily due to their effective and dependable cooling capabilities, which are crucial for ensuring optimal sensor performance. Free piston Stirling cryocoolers are capable of producing the cooling effect that ranges from milli watts to few watts according to the cooling process. The weight constraint of the cryocoolers is very important for space applications. Therefore, miniature type Stirling cryocoolers are suitable for space applications. In this study, an integral type free piston Stirling cryocooler was designed and optimized by using SAGE software. The design features an electromagnetically driven, resonating mechanism with a clearance seal setup to ensure optimal efficiency, COP, and minimal system vibration. The engineered integral type free piston Stirling cryocooler can achieve a no-load temperature of 50 K, with a corresponding refrigeration capacity of 1000 mW and upratable to 1500 mW at 80 K. Initially, a parametric evaluation of the cryocooler was carried out to assess the impact of various design features and operational parameters. The parametric analysis was done and focused primarily on factors such as regenerator wire mesh geometry, phase angle, and displacer clearance, with regard to their influence on the cooling performance of the cryocooler. For the compressor part of the integral type free piston cryocooler, the liner motor required was designed using Ansys Maxwell software. In this context, a linear motor of the moving magnet type was chosen. The moving magnet-type linear motor generates axial forces by means of Lorentz force, propelling the piston to compress the working fluid. An advantageous aspect of employing linear motors in cryocoolers is the pure rectilinear motion generated by them which further mitigates wear and tear, ultimately leading to an extended operational lifespan. The study was also conducted by replacing the single mesh regenerator with a multi-mesh regenerator. Parametric analysis of the modified integral type cryocooler with a multi-mesh regenerator was also conducted to find out the optimum combination of the multi-mesh regenerator to improve the performance of the system. From the analysis, it was evident that in an integral type cryocooler with a multi-mesh regenerator, the performance of the system increases when the coarser mesh is arranged at the hot side and the finer mesh is arranged at the cold side of the regenerator tube.

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