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C2Or2C-03: Numerical Modeling and Improvement of Helium 3 Circulation Compressor of Closed Cycle Dilution Refrigerator for Space

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In recent years, demands for high sensitivity observation in astronomical missions are increasing. In astronomical observation, in order to achieve superior sensitivity and energy resolution, cooling down the detector for extremely low temperature (100mK or less) is necessary to reduce thermal fluctuation noise emitted from the detector itself. The purpose of this research is to improve the performance of a closed cycle dilution refrigerator for space, which is developed with the aim of cooling below 50mK. In order to achieve the cooling power of 1μW at 50mK, a low suction pressure (0.4 kPa or less) and enough helium 3 flow rate (50 μmol/s or more) are required for helium 3 circulation compressor. However, the compressor that enables low suction pressure with high flow rate has a high technical difficulty, and it is challenging to develop.
Previous studies suggest that the opening width of the suction and exhaust valves and piston stroke of the circulation compressor have a great influence on the flow rate performance.
In this study, numerical models of the piston dynamics, the valve dynamics and the flow around the valves were constructed, and the validity of each numerical model was evaluated by experiments. By coupling each model, the numerical model of the compressor system was constructed. Unknown parameters in this model were estimated by genetic algorithm.
Using this numerical model, the sensitivity analysis for the flow rate performance of the compressor was carried out on the piston drive frequency, phase, and the spring constant and mounting angle of the valves.
From the results of this analysis, it is suggested that the flow rate performance of the compressor increases greatly in the range of about 12 to 40 times from the current flow rate depending on the spring constant and mounting angle of the valves.

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