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Development of a Magnetic Exclusion-Based Bubble Removal Device

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Heat transport devices using temperature-sensitive magnetic fluids (TSMF-HTD) operate solely with a magnetic field and a heat source, initiating flow passively in response to temperature changes [1]. Owing to this simple and fully passive mechanism, they are promising for thermal management in space environments where reliability is paramount. However, in fluid loop systems, bubble entrainment reduces the driving pressure and can lead to fluid blockage and thermal spikes. Therefore, bubble removal is essential, yet phase separation based on gravity becomes ineffective under microgravity conditions.

In this study, a bubble removal device based on the magnetic ejection effect is proposed, utilizing magnetic buoyancy arising from the difference in magnetic susceptibility between gas and magnetic fluid [2]. Under a non-uniform magnetic field, the magnetic fluid is attracted toward high-field regions, while bubbles are expelled toward low-field regions, enabling passive gas–liquid separation. In this paper, a cylindrical bubble removal device that adopts a neodymium magnet sheet (see Fig. 1) is integrated into a TSMF-HTD loop system with an inner diameter of 2 mm and a total length of 1.2 m. Continuous bubble injection tests are conducted at gas volume fractions of 10% and 20%. In addition, the effects of gravity and long-duration operation are evaluated, and flow behavior is compared with and without a magnetic field.

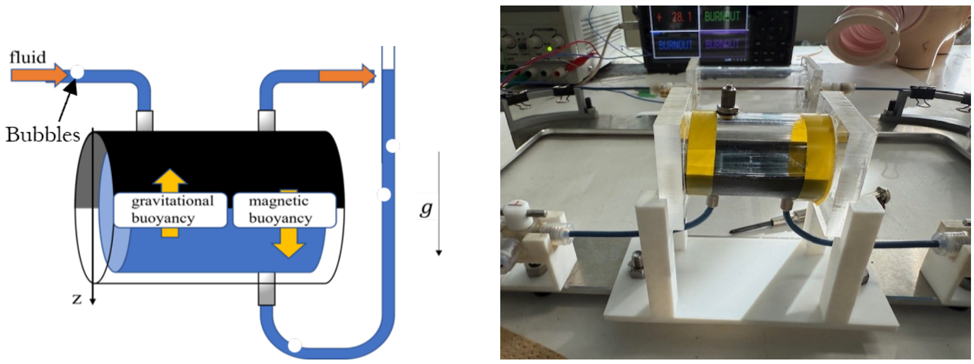

Figure 1:

The results show that stable flow is maintained even under continuous bubble injection, and bubble intrusion into the downstream region is effectively suppressed. Stable operation is also confirmed under conditions where gravity hinders bubble removal. Notably, continuous operation for over 90 minutes is achieved with a magnetic field, even though the total injected gas volume during this period is comparable to the entire volume of the flow channel. In contrast, the flow stops within approximately 24 minutes without a magnetic field. Furthermore, theoretical analysis shows that magnetic buoyancy acting on bubbles can reach 5.7 times that of gravitational buoyancy, supporting the proposed mechanism. These results demonstrate that the proposed method is an effective bubble-removal technique for TSMF-HTD systems, improving the reliability of future research for space applications.

Type:
Oral