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Experimental investigation of Pressure-Volume-Temperature mass gauging method under micro-gravity condition by parabolic flight

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Gauging the volume or mass of liquid propellant of a rocket vehicle in space is an important issue for its economic feasibility and optimized design of loading mass. Various gauging methods have been being explored and investigated to overcome an uneven liquid interface problem under micro-gravity. Pressure-volume-temperature (PVT) gauging method is one of the most suitable measuring techniques in space due to its simplicity and reliability. This paper presents unique experimental results and analyses of PVT gauging method using liquid nitrogen under micro-gravity condition by parabolic flight. A vacuum-insulated and cylindrical-shaped liquid nitrogen storage tank with 9.2 L volume is manufactured by observing regulation of parabolic flight. PVT gauging experiments are conducted under low liquid–filled fraction condition from 26% to 32%. Pressure, temperature, and injected helium mass into the storage tank are measured to obtain ullage volume by gas state equation. Liquid volume is finally derived by considering the measured ullage volume and the known total tank volume. Two sets of parabolic flights are conducted and each set is composed of approximately 10 parabolic flights. In the 1st set of flights, the short initial waiting time (3 ~ 5 seconds) cannot achieve sufficient thermal equilibrium condition at the beginning. It causes inaccurate gauging results due to no information of initial helium partial pressure in the tank. The helium injection after 12 second waiting time at micro-gravity condition with high mass flow rate in the 2nd set of flights achieves successful initial thermal equilibrium states and accurate measurement results of initial helium partial pressure. Liquid volume measurement errors in the 2nd set are within 10% of the total tank volume.

Primary author: Mr SEO, Mansu (Cryogenic Engineering Laboratory, Mechanical engineering department, KAIST)

Co-authors: Mr YOO, DongGyu (Cryogenic Engineering Laboratory, Mechanical engineering department, KAIST); Ms PARK, Hana (Cryogenic Engineering Laboratory, Mechanical engineering department, KAIST); Prof. JEONG, Sangkwon (Cryogenic Engineering Laboratory, Mechanical engineering department, KAIST)

Presenters: Mr SEO, Mansu (Cryogenic Engineering Laboratory, Mechanical engineering department, KAIST); Prof. JEONG, Sangkwon (Cryogenic Engineering Laboratory, Mechanical engineering department, KAIST)

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