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小型超音速飛行実験機ＬＯＸタンク向け推薬捕捉機構の開発

Study on Examination of Propellant Supply System for LOX Tanks in Small-scale Supersonic Flight Experiment

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1. Introduction

The Aerospace Plane Research Center in Muroran Institute of Technology is development the small-scale supersonic flight experiment aircraft as a flying test bed for a technical demonstration in high-speed flight environment. In the small-scale supersonic flight experiment aircraft, the liquid supplying system for bioethanol (BE) and liquid oxygen (LOX) by nitrogen pressurant has been considered. However, it is feared that the risk of adverse effects on the attitude control of the aircraft and the propulsion system by the inclusion of pressurized gas in the supplied LOX increase due to sloshing by the acceleration during flight.

The purpose of this study is to research and develop the propellant management device (PMD) that can suppress the entrainment of pressurized gas in the LOX tank. In this study, measurements of bubble point pressure were taken to determine the specifications of PMD.

2. Theory and Methodology

PMD in this research uses a metal mesh to take advantage of the surface tension of the liquid. When the mesh gets wet, the surface tension of the liquid forms a liquid film on the mesh surface, and this film separates the gas and liquid, thereby suppressing gas entrainment. The pressure when gas entrainment occurs is the bubble point pressure, which is given by the following equation (1). [1)]

$$P_{BP} = \frac{4\gamma}{D} n_{sat} \times (1 - n_{Hot}(T_{Gas} - T)) \quad (1)$$

Where P_{BP} is bubble point pressure, γ is the surface tension of the liquid, D is the mesh diameter, n_{sat},n_{Hot} are coefficients, T_{Gas} is the temperature of the pressurized gas and T is the temperature of the liquid. Theoretically, gas entrainment can be prevented if the gas pressure does not exceed the bubble point pressure.

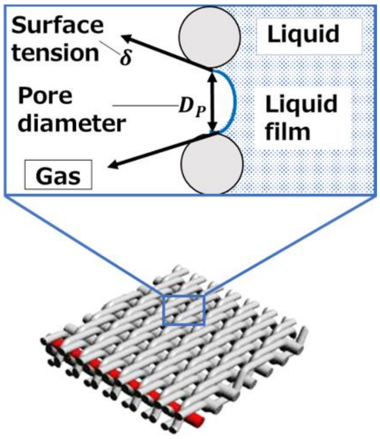

Figure 1. Liquid film on metal mesh.

3. Measurement of bubble point pressure

In this experiment, the bubble point pressure is measured with the stainless steel (SS) 325 × 2300 Dutch Twill screen. **Figure. 2** shows the piping system of the experimental apparatus, **Figure. 3** shows the experimental apparatus, **Figure. 4** shows the test section, and **Figure.5** shows metal mesh. As shown in **Figures. 4** and **5**, the metal mesh was inserted between a metal plate with holes and a polycarbonate cylindrical block to visualize the generation of bubbles from the gas supply area and the mesh surface. liquid nitrogen (LN_2) was used as the simulated liquid and helium gas (GHe) as the pressurized gas. After the metal mesh was immersed in LN_2 in a cylinder upward to form a liquid film, GHe was supplied, and when bubbles were generated from the metal mesh, the GHe supply was stopped and the maximum pressure value thereafter was recognized as the bubble point pressure. To reduce the temperature difference between LN_2 and GHe at the metal mesh, GHe is passed through a helical coil tube immersed in LN_2 before being fed into the metal mesh.

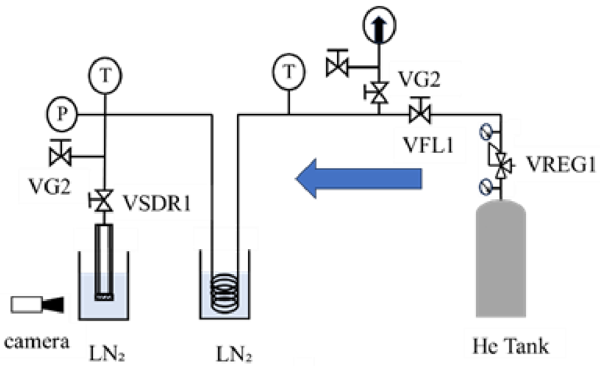

Figure 2. Piping system of the experimental apparatus.

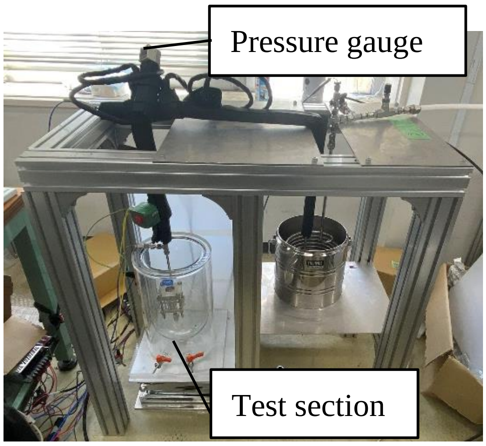

Figure 3. Appearance of the experimental apparatus.

Figure 4. Test section.

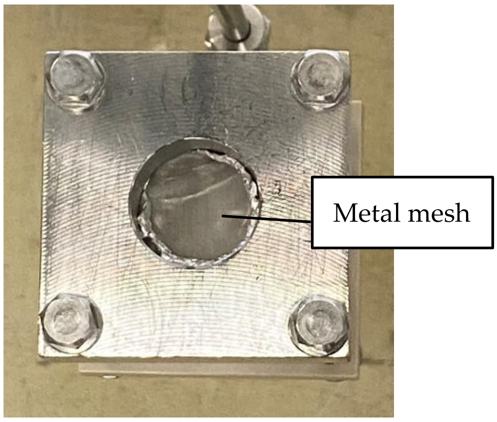

Figure 5. Metal mesh.

4. Experimental results

Figure.6 shows the pressure change during No.1 bubble point pressure experiment. The GHe supply was stopped when bubbles were generated from the metal mesh. The maximum pressure after that was 176 seconds after the start of the experiment and was 3.207kPa. A total of four similar experiments were conducted, and **Table 1** shows the bubble point pressure test results and their average values. As a result, the bubble point pressure was 3.201 kPa when the 325 × 2300 Dutch Twill screen was immersed in LN_2. Entering the value for the present experimental conditions into equation (1) yields 2.677 kPa, which is smaller than the value obtained in the present experiment. A possible reason for these discrepancy could be the difference between the mesh diameter used in the experiments and the mesh diameter used in the calculations.

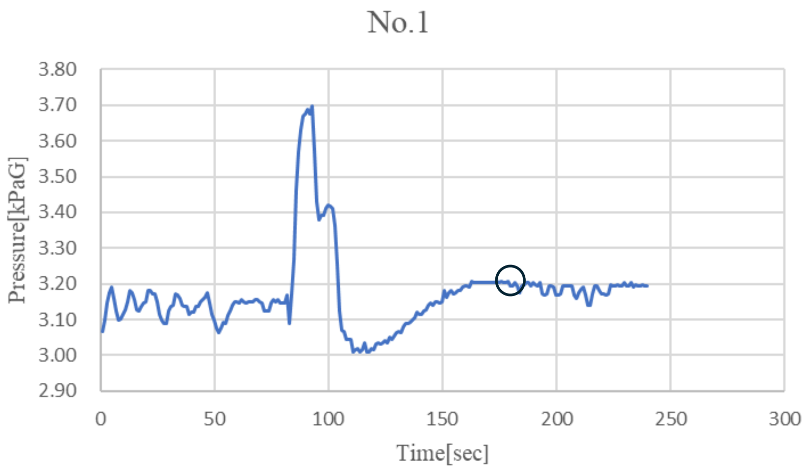

Figure 6. Pressure changes during No.1 bubble point pressure experiment

Table 1. Bubble point pressure test results and their average values

	bubble point pressure[kPaG]
No.1	3.207
No.2	3.207
No.3	3.207
No.4	3.185
average	3.201

5. Conclusion

To determine the specifications of PMD, bubble point pressure experiments were conducted with the flat metal mesh. Therefore, bubble point pressure was successfully measured in cryogenic liquids.

In the future, we plan to conduct bubble point pressure experiments with the cylindrical metal mesh, which is being considered for use as an internal device in small-scale supersonic flight experiment.

References

1) Jason W. Hartwig, Yasuhiro Kamotani：The static bubble point pressure model for cryogenic screen channel liquid acquisition devices，International Journal of Heat and Mass Transfer 101 (2016), 502–516