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Study and Development of Gas-Liquid Equilibrium Pressure Regulator System

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This study introduces a new pressure regulator system for thrusters aimed at small satellites, which is called the Gas-Liquid equilibrium pressure regulator system. The idea originates from the Gas-Liquid equilibrium thruster that is mounted on the solar sail demonstrator IKAROS of JAXA.
In conventional thruster systems, nitrogen or helium is normally utilized as pressurized gas that pushes out the fuel via a diaphragm attached inside the fuel tank. In order to keep the thrust power through the mission period, a high pressure gas tank and a pressure control valve are necessary, and they increase the total system weight. The system becomes simpler and lighter by excluding the pressure control valve, which is called the blow down system, but the thrust power drops down as the amount of fuel decreases and the gas volume increases.
In the Gas-Liquid equilibrium pressure regulator system, liquefied gas HFC-218 is adopted as pressurized gas instead of nitrogen or helium. HFC-218 is a kind of alternative freon, whose vapor pressure is from 0.5 MPa to 1 MPa under the room temperature. If enough amount of HFC-218 is filled in the fuel tank as liquid state, it basically keeps the liquid state and holds the saturated vapor pressure. The advantage of this system is that it maintains the pressure and keeps the thrust power without a high pressure gas tank or a pressure control valve. Furthermore, the pressure can be controlled by controlling the temperature of the liquefied gas. Since it is already proved by an experiment that HFC-218 does not penetrate the diaphragm or melt into hydrazine which is normally used as fuel, the compatibility of HFC-218 with thruster system is quite good.
In addition to this, the system where HFC-218 and nitrogen are both utilized as pressurized gas is also proposed. This system is called the hybrid Gas-Liquid equilibrium pressure regulator system. Adding nitrogen not only increases the total pressure, but also gives the index of remaining amount of fuel by showing the slight drop of the total pressure cooccurring with the fuel decrease.
Operated for attitude control of a satellite, the injection is basically pulselike and the interval is comparatively long. Therefore, it is obvious that the tank pressure is always held at the saturated vapor pressure. Operated for orbit control, however, the injection time is long and the gas volume changes fast. Under such a dynamic change, HFC-218 does not necessarily keeps gas-liquid equilibrium state because it takes a while for the liquid to evaporate, and the pressure drops a little.
This study also shows the specification of the system based on the results of injection experiments. It proves that the Gas-Liquid equilibrium pressure regulator system is useful and has advantages even when it is used for long term injection.