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CONCEPT STUDY OF CHEMICAL MICROPROPULSION SYSTEM USING COMBUSTION OF MICRON-SIZED ALUMINUM PARTICLES AND WATER-VAPOR

Abstract

Cubesats, which appeared in the early 2000s, have shown their usefulness on low-earth orbit for education, technology demonstration, communication, and observation. Since CubeSat can be developed in a short period and at a low cost, its development cycle is quicker than that of large satellites, which will broadly accelerate space development. On the other hand, cubesats have had difficulty installing a propulsion system because of the severe limitation of mass, volume, and power. It is also necessary to ensure the high safety and handling ability without sacrificing performance not to compromise the advantage of a short period and low-cost development. For the above reasons, research on small propulsion for cubesats has been carried out, but most of them are cold gas thrusters or electric propulsions, and research on high thrust chemical propulsions, which involve dangers such as combustion, has been delayed. The chemical propulsion is indispensable for deep space exploration, such as planetary orbit insertion and asteroid sample return, because it can generate large velocity increments in a short time due to its high thrust. Therefore, the development of a small chemical propulsion system is urgently needed. This study proposed a chemical micro-propulsion system using the combustion of water vapor/powdered aluminum aiming to enhance the mission capability of cubesats. The objective of this study was estimated the potential propulsive capability and feasibility of the propulsion system. To estimate the propulsive capability, combustion efficiencies and specific impulse efficiencies were defined, and mixture ratio was chosen to maximize the products of the two efficiencies, energy efficiency. The combustion efficiency presented losses in the combustion chamber, and the specific impulse efficiency presented two-phase losses in the nozzle. Powder combustion should have unburned fuels and liquid-phase aluminum oxides. To estimate effects of these particles in the nozzle, two extreme situations were assumed: all particles stayed in the combustion chamber and all particles exhausted from the nozzle with same velocity and temperature as the combustion gas. In discussion chapter, one design example and the propulsive capability of it were shown. It achieved around 100 mN of thrust, 150-300 s of specific impulse and 170-330 m/s of velocity increments. Adding to that, the tank volumes were 0.9U for a water tank and 0.2U for a powdered aluminum tank. The volumes were feasible for cubesats. These performances can contribute to enhance mission capability of cubesats.