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Title

Characteristics of a superheated wall cooling through pulsed injection of a liquid jet

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Abstract

Bipropellant thrusters are generally employed for attitude control of small-scale spacecraft and satellites. In addition, they are used in touchdown processes for planetary exploration of the spacecraft and are planned to be applied to the new lander vehicles for lunar or mars landing. For these processes, the thrusters are operated in the pulse-firing mode, in which the combustion and its termination are repeated. To achieve higher performance of them for the allowance of the more difficult missions, the operational range of the thrusters need to be expanded.

For the thermal management of the thrusters, the liquid film cooling technique is applied for protecting the chamber wall from high-temperature combustion gases. During the non-injection duration in the pulse-firing mode, the stored heat around the throat part is transferred to the injector faceplate side owing to the heat conduction inside the chamber wall; this phenomenon is called heat soak-back [1]. The operational range of the thrusters is restricted by the cooling requirement because the liquid film cooling does not fully perform in some cases because of heat soak-back.

In the present study, therefore, we conducted the pulsed cooling of the superheated wall, in which a liquid jet was intermittently injected to the surface above the Leidenfrost temperature of the liquid, for pursuing the well-controlled liquid film cooling enabling the expansion of the operational range of the thrusters. In the cooling tests, the pulse frequency and duty cycle were changed while keeping the injection flow rate of the liquid constant; that is, we controlled the injection and non-injection periods by adjusting the opening and closing of the solenoid valve at a constant injection flow rate. Additionally, two types of metal plates (aluminum alloy and copper) were used in the tests to investigate the thermal properties such as the thermal diffusivity which influences the temperature rise during the non-injection duration and may eventually affect the liquid film behavior. In the cooling tests, the liquid film behavior and wall temperature were simultaneously measured by using a high-speed camera and an infrared camera, respectively. For evaluation of the cooling performance, the temperature of the metal plate, the amount of the removed heat by the liquid film, and the wetting front position were compared.

References

[1] S. Takata, et al., “Design verification results of japanese 120N Bi-propellant thrusters (HBT-1) based on its first flight in HTV3,” 49th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, AIAA-2013-3754, 2013.