IAF SPACE PROPULSION SYMPOSIUM (C4)
Solid and Hybrid Propulsion (2) (4)

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MICROWAVE DISCHARGE IGNITION OF METALIZED FUEL FOR HYBRID ROCKETS

Abstract

Hybrid rockets offer a safe propulsion system with throttling and start-stop capability. Therefore, several studies have considered installing hybrid rockets on small spacecraft. A reliable ignition system capable of re-ignition is crucial for expanding the use of hybrid rockets in space. Torch or pyrotechnic ignition systems are common but are not suitable for repetitive ignition. Other electrically powered methods, such as arc discharge and laser ignition, have been considered; however, concerns remain regarding electrode degradation and window contamination.

To address these challenges, we propose an ignition method for hybrid rocket fuel using microwave discharge. When microwaves are irradiated onto a metallic structure, the electric field (E-field) concentration effect can induce dielectric breakdown of the surrounding gas. Our approach aims to ignite the motor through the dielectric breakdown of oxidizer gas near the fuel, which is blended with metal. We selected magnesium as the metallic additive since it can also serve as a fuel component. Additionally, this ignition device functions as an energy conversion system, transforming electrical energy into thermal energy via plasma. Even after the solid fuel is depleted, the remaining propellant gas can be utilized as electric propulsion using the same combustion chamber, contributing to orbit maintenance.

We have experimentally demonstrated that magnesium powder can be ignited by microwave irradiation in air using a microwave oven. In this study, we simulated the electric field distribution for this experimental setup and obtained an E-field strength of approximately 1×10^4 V/m around the magnesium powder. The breakdown E-field strength of air at atmospheric pressure is reported to be 3×10^6 V/m. This confirms that a significant E-field concentration occurs around the magnesium powder, as we expected. Based on these findings, we then designed a combustion chamber and a microwave resonator to achieve microwave ignition of hybrid rocket fuel. The designed E-field strength is approximately 1×10^5 V/m, which is sufficient to initiate microwave discharge according to our prior experiments. Furthermore, we confirmed that the microwave absorption efficiency exceeded 95% in our experimental setup. Additionally, microwave discharge was successfully sustained under a vacuum condition of approximately 1 kPa.

By the time of the conference, we plan to demonstrate microwave ignition using the designed combustion chamber and fuel. These results highlight the potential of microwave-assisted ignition for hybrid rockets and its implications for future hybrid propulsion systems.