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THE WATER ELECTROLYSIS HALL EFFECT THRUSTER (WET-HET): UNLOCKING CHEMICAL-ELECTRICAL HYBRID PROPULSION WITH WATER

Abstract

Electrically-powered spacecraft propulsion, first demonstrated experimentally in the early 1960s, has revolutionized the spacecraft industry. The dominant electric thruster technologies today are Gridded Ion Engines (GIE) and Hall Effect Thrusters (HET). In almost all cases the propellant used for both technologies is xenon, with a very small fraction of thrusters using krypton. While krypton offers economic advantages over xenon (which currently costs in excess of £3000/kg), it can only be stored as a sparse gas and is therefore only suitable for very low delta-V missions. As an alternative to xenon, we propose that a HET could be modified to operate on hydrogen and oxygen produced in situ using water electrolysis. The propellant is stored as water, with hydrogen and oxygen being produced only as they are consumed, illuminating the need for any gas phase storage. The combination of chemical inertness, high storage density, low storage pressure and low cost of water makes it an extremely attractive propellant. Furthermore, ice and water are found on many near-earth objects, several planets and moons, suggesting future In-Situ Resource Utilization (ISRU) potential. Despite its potential advantages, water itself is incompatible with sensitive thermionic materials utilized by the neutralizing cathodes of HETs and GIEs. The novelty of our approach is to electrolyze the water and supply the neutralizing cathode with dry hydrogen while feeding the thruster with oxygen. Hydrogen has been shown to be highly compatible with conventional thermionic emitter materials, out-performing even xenon and krypton. Furthermore, hydrogen ions help to mitigate contamination of the cathode emitter from exposure to oxygen and water vapour contained within the thruster plume. The strongest argument for such a hydrogen/oxygen HET is that water electrolysis is already being utilised as a propellant in chemical spacecraft propulsion. An architecture can be envisioned for a single spacecraft to utilize both electric and chemical means of propulsion with water being the common propellant. By having the option to operate a single propulsion system in a high thrust chemical mode or a high impulse electric mode provides an unmatched flexibility to spacecraft operators. Such a chemical-electrical hybrid propulsion system would be the first of its kind. We have developed the Water ElecTrolysis Hall Effect Thruster (WET-HET) to demonstrate this concept experimentally. We present the mechanical, magnetic, and thermal designs of this unique thruster. Additionally, we present the first direct thrust measurements of the device performed within the Imperial Plasma Propulsion Laboratory.