Development and Testing of a Green-Propellant Micro-Hybrid Thruster with Electrostatic Ignition

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Abstract of the Presentation.

As early as 1937 German scientists at Peenemunde experimented with highly unstable fuel blends of nitrous oxide (*N_2O)* and ethanol. These early tests mostly resulted in explosions and destroyed rocket engines.[i] More recently several companies have developed experimental nitrous oxide fuel blends (*NOFB*) with I_{sp} exceeding 300 sec. Although *NOFBx*[ii] has recently been cleared for tests on the International Space Station, this propellant remains highly experimental and has not been cleared for commercial transport by the US DOT. Recent work by Karabeyoglu et al. has raised concerns about the safety risks of mixing hydrocarbons with N_2O.[iii] Liquid oxidizer/fuel blends are highly explosive and require extreme care in transport and servicing. By adding small amounts of a liquid organic fuel such as alcohol or a hydrocarbon, the odds of an explosive decomposition event are significantly increased.[iv]

The proposed solution mitigates the explosion hazards of NOFB by separating the oxidizer from the hydrocarbon fuel formed as of a small cylindrical section of ABS thermoplastic. As N_2O vapor flows across the grain segment, current enters a 1000 VDC high-tension lead in the ABS fuel grain and produces an inductive spark that vaporizes a small amount of the material. The ablated fuel vapor plus residual energy from the spark "seed" a localized exothermic N_2O dissociation that produces sufficient heat to initiate combustion. The process is also effective when gaseous oxygen is used.

A low TRL (2-3) prototype demonstrating the feasibility of controlled hydrocarbon-seeding was recently tested at Utah State University.[v] The unit features a miniature 2.5 cm ABS fuel grain fabricated using a Stratasys Dimension® 3-D printer. The *9-N* thruster was pulse-fired up to 27 consecutive times on a single ABS grain segment. Ignition was achieved by as little as *12-15 Joules* energy input. This value is contrasted with the typical 30-minute pre-heat requirement for the ECAPS LMP-103S ADN-based monopropellant, requiring an energy input of *14,850 Joules* for catalytic dissociation.[vi]

The hydrocarbon-seeded micro-hybrid was also adapted as a non-pyrotechnic ignitor for a 900 N (200-lbf) thrust hybrid motor. The motor was successfully ignited 4 consecutive times with no hardware swaps or propellant additions. The amount of ABS seed material that can be fit into the injector cap is the only limit to the number of available repeat firings. This series of tests marks the first time a hybrid motor was ever ignited by other than a solid-propellant pyrotechnic charge or bi-propellant flame ignitor. Nitrous oxide hybrid motors are typically difficult to ignite and usually require multiple solid-propellant charges to initiate combustion, so this non-pyrotechnic ignition is a significant accomplishment.

The controlled hydrocarbon-seeding approach is fundamentally different from all other "green propellant" solutions offered by the aerospace industry. Although the proposed system is more correctly a "hybrid" technology; the system retains all the simple features of a monopropellant design. To date no optimization study has been performed to identify the best grain geometry for electrostatic ignition. Fortunately, because the grain segments are fabricated using rapid-prototyping technology, changing the grain geometry is as simple as modifying the 3-D printer CAD-file. Vacuum I_{sp} exceeding 270 seconds has been demonstrated (Ref v), a value significantly higher than those offered by competing "green" monopropellant options. The propellants of choice, *N_2O/GOX* and *ABS* are 100% non-toxic, non-explosive, and environmentally benign. Because the inert oxidizer and fuel components are mixed only within the combustion chamber, the system retains the inherent safety of a hybrid rocket and can be piggy-backed as a secondary payload with no overall mission risk increase to the primary payload, an excellent characteristic for secondary launch systems.

References

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