LASER IGNITION OF LIQUID OXYGEN / ETHANOL PROPELLANTS UNDER SIMULATED SPACE CONDITIONS

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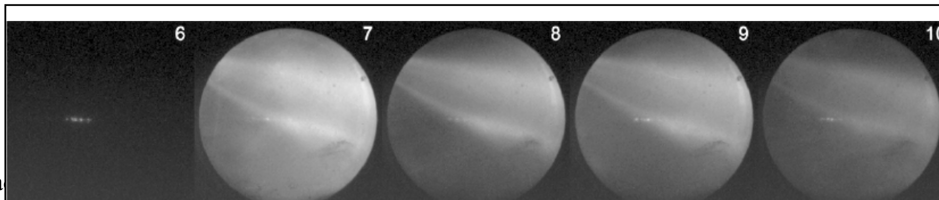
One of the promising propellant combinations considered for auxiliary space propulsion is liquid oxygen and liquid ethanol. Unlike the propellants presently used in the Orbital Maneuvering System (OMS), oxygen/ethanol propellants are not hypergolic. A convectional approach to provide ignition is the use of a high voltage electric spark ignition system installed in an ignition pre-chamber. The ignition electrodes are typically operated continuously, resulting in a high rate of electrode erosion and eventual variability in ignition characteristics. Alternatively, optical ignition systems with optical energy delivered through optical fibers have potential to eliminate some of these difficulties, as well as to significantly improve ignition of OMS and non-toxic Reaction Control System (RCS) thrusters. This work represents the first investigation of laser ignition characteristics in a two-phase, heterogeneous environment.

A prototype laser igniter for a small rocket thruster with a combustion chamber volume of approximately 41 ml (2.75 in^3) was demonstrated. Two operational modes of the igniter were tested. In the first mode, ignitable mixture was generated by a jet of gaseous oxygen impinging on a liquid spray of ethanol, resulting in secondary atomization of ethanol droplets. In the second mode, the ignitable mixture was obtained through injection of liquid oxygen and ethanol. The ignition energy was delivered with a focused beam of a pulsed Q-switched Nd:YAG laser through a small quartz widow in the igniter. Experiments demonstrated that LIP could be effectively used as a reliable ignition source with gaseous and liquid oxygen and ethanol sprays with the overall equivalence ratio of approximately unity. In a series of experiments, where the temperature of the manifold was maintained at –223 K, it was shown that lowering the temperature of sprays results in higher energy demand to obtain ignition. With the current design of the igniter, the laser pulse energy needed for reliable ignition of liquid oxygen and ethanol mixtures was measured at ~80 mJpp for a 1064 nm Q-switched Nd:YAG laser beam focused with a 100 mm focal length lens. It was observed that under the condition described in the text, the presence of laser-induced plasma did not guarantee successful ignition. Over the course of all of the experimental studies the igniter prototype withstood several hundred firing cycles without obvious signs of mechanical or thermal damage or wear. The combustion in the ignition chamber was very stable and sustainable. If it were not for the limited volume and possible overheating of the test facility vacuum reservoir, continuous oxygen/ethanol events could have been sustained after ignition. A high-resolution digital CCD camera (Nikon DCS 460) with a Micro Nikkor 2.8/105 lens was used to acquire images of the ignition event for each experiment, showing the combustion luminosity in the cases of successful ignition, as well as the presence and location(s) of the ignition plasma. A Digital/Analog converter was used to interface pressure transducers and thermocouples. Transient ignition chamber pressure was obtained using a Kistler 7061B pressure sensor and a charge amplifier yielding frequency response up to 150 kHz at -3dB. Because of inherent signal drift of this type of transducer, a vacuum gauge was used to determine the chamber pressure prior to the ignition sequence. Representative photographic results for the highest value of the laser pulse energy are shown below.



Upon a ... potentially used for space applications as a viable substitute for electric spark igniters.

Images of the ignition or failure events for the initial pressure 37.9 KPa and laser pulse energy 78 mJpp. Ignition of liquids oxygen and ethanol.