SAND2017-11455C

Deflagration-to-Detonation Transition in Pre-mixed Nitrous Oxide Oxygen and Nitrogen Tetroxide - Fuel Mixtures for Pulsed/Detonative Propulsion Systems

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Introduction

Nitrous oxide (N_2O) has gained popularity as a unique oxidizer for propulsion applications due to its ability to exothermically decompose, producing nitrogen and oxygen. In the current work, the flame acceleration, deflagration-to-detonation transition (DDT), and detonation properties of bi-propellant mixtures with N_2O as an oxidizer are studied for potential applications in pulsed blow-down and detonation driven thrusters.

Discussion

A key requirement is that the performance of mixtures with N_2O should be compared to base line mixtures, e.g. mixtures with oxygen (O_2) or nitrogen tetroxide (NTO). The performance of N_2O versus O_2/NTO for such applications is investigated using theoretical Chapman-Jouguet detonation calculations of bi-propellant system with ethylene (C_2H_4) and acetylene (C_2H_2) fuels. These theoretical values are calculated using the Shock and Detonation Toolbox [1] in Cantera [2]. For example, the calculations predict that a 15% higher detonation pressure would be achieved using N_2O vs. O_2 at stoichiometric mixture ratio [3] thereby increasing the propulsive efficiency. An essential requirement for the application of bi-propellant mixtures to pulsed propulsion systems is rapid flame acceleration to achieve significant chamber pressure rise in a short distance with the potential to a prompt transition to detonation. Therefore, in the experimental portion of this work the DDT behavior of mixtures using C_2H_4 and C_2H_2 with N_2O and O_2 is investigated. While C_2H_2 is an exceptional theoretical energetic fuel, it presents serious practical storage concerns when considered for propulsion applications. C_2H_4 is a potential alternative, which is relatively easy to manage.

Conclusion

A series of experiments are conducted to measure the detonation pressures and DDT run-up distances for increasing initial pressures at stoichiometric mixture ratios. Detonation pressures are measured using high-frequency pressure transducers and run-up distances are measured using an axially mounted photo multiplier tube (PMT) module. Based on the experimental data detonation velocities are also estimated and compared to theoretical calculations. These detonations are studied in a closed combustion tube of L/d = 68 which is significantly long to observe propagation of a stable detonation post-DDT. Details of the combustion tube and the experimental setup are discussed in a previous paper [3]. The pre-compression of the bi-propellant mixtures during flame acceleration is also estimated and compared.

Bibliography

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This work is supported by the Department of Energy Geothermal Technologies Program. Sandia National Laboratories is a multi-mission laboratory managed and operated by National Technology and Engineering Solutions of Sandia, LLC., a wholly owned subsidiary of Honeywell International, Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525. The support and expertise of the Maurice Zucrow Laboratory staff and students has been invaluable in the progress of this work.