SPACE PROPULSION SYMPOSIUM (C4)
Propulsion Technology (3)

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MODELING AND EXPERIMENTAL VERIFICATION OF AUTO-IGNITION PROCESSES FOR A GREEN BI-PROPELLANT THRUSTER

Abstract

Currently used propellants for mono- and bipropellant systems such as hydrazine, NTO, MMH are highly toxic and therefore expensive to be implemented. So-called green propellants have drawn increasing interest in times with decreasing budgets for space missions and development tasks. They are promising a significant reduction of the overall development and operational costs at similar or better performance. AIT is developing a 1 N bipropellant thruster system operating exclusively with green propellants under contract of the European Space Agency. One of the main properties to be investigated is the ignition capability and ignition delay of such new propellants. For the investigated system hydrogen peroxide (87 wt%) is used as oxidizer. Kerosene and Ethanol are selected as fuel and their suitability is investigated for such a propulsion system. Their auto- ignition capability (quasi-hypergolicity) in the presence of decomposed hydrogen peroxide (i.e. steam and oxygen) shall be investigated experimentally. In contrast to pure hypergolic mixtures, the present auto-ignitable mixture of hydrocarbon/oxygen does not spontaneously ignite when they come into contact but necessitates well defined initial conditions with regard to pressure and temperature. Auto-ignition is dependent on various physicochemical parameters such as the type of reactants, reaction kinetics, initial pressure, initial temperature, and heat transfer process. Additionally for micro-propulsion systems the auto-ignition phenomenon is a strong function of the combustion chamber surface-to-volume ratio. An analytical non-adiabatic auto-ignition model of the ignition conditions for a choked and non-choked flow reactor has been developed assuming a one-step single forward chemical reaction based on the theory of residence time distributions and on Semenov's thermal ignition theory. Special focus is laid on the pressure temperature ignition behavior in correlation to the combustion chamber geometry. The analytical model shows well accordance to the pressure-temperature correlation function for a decomposed hydrogen peroxide/kerosene fuel mixture proposed by Walder in the early 1950s whereas the ignition delay is proportional to the characteristic chamber length, L*, of the engine. For the model validation, an experimental setup and a segmented combustion chamber was developed which allows to systematically investigate the auto-ignition conditions whereas the initial pressure, initial temperature and mass flow can be varied independently and with easy variation of the combustion chamber geometry.