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SPACE PROPULSION SYMPOSIUM (C4)
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EVALUATION OF REQUIRED ENERGIES FOR DETONATION OF CHEMICAL ROCKET PROPELLANTS

Abstract

In order to handle increased demand of launch of ultra-small satellites in recent years, it is effective to simplify the handling of propulsion systems by eliminating hazardous nature of them. And a prime example of an essentially non-explosive propulsion system is a boundary layer combustion type, hybrid propulsion system which is safer due to the absence of a high energy substance for fuel or oxidizer. However, this safety aspect of hybrid is still not completely understood due to the challenges in explaining the experimental results within a theoretical framework. In this paper, our purpose is a comparison of deflagration-to-detonation transition (DDT) energy of propellants of each propulsion systems (solid, liquid and hybrid). At last, we aim to evaluate explosive properties of each propulsion type quantitatively. Our methodology is to first take a one-dimensional propellant surrounded by walls. We then select propellants for each propulsion type. Composite propellant for solid, combustible mixture gas of LOX/LH2 etc. for liquid, combustible mixture gas of LOX/solid hydrocarbon dust (plastic, etc.) for hybrid. When thermal or mechanical stimulus (energy) is given on the one end surface, we would like to know whether combustion is lead from deflagration to detonation. We use a simple chemical reaction model which is based on the Arrhenius equation and heat conduction. In a liquid and a hybrid, in addition to the thermal or mechanical energy, it is necessary to consider the energy required for oxidizer or fuel to evaporate. Furthermore, in a hybrid, we also have to consider about the energy required for fuel to become dust. This energy is estimated from dust size and the bond energy of molecular chain. The size of dust that would cause dust explosion might be of the order of hundreds of μm at the maximum. About the comparison result of required energy for DDT with the same propellant mass, we expect that this would be greatest for the hybrid because hydrocarbon fuel must break many bonds in order to be decomposed into dusts. In the future, based on this comparison of the propellant, we will obtain considerations about the required energies for detonation of the whole rocket engine with a certain specifications. A more realistic discussion of the safety assessment could be obtained by consideration of this factor.