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PERFORMANCE OF A SOLID PROPELLANT TRANS-MEDIA RAMJET: A THEORETICAL ANALYSIS

Abstract

With the development of air defense and antimissile technologies, higher requirements of penetration capability have to be met for anti-ship missiles. Trans-media missiles cruise at a supersonic speed (Ma 2 3.5) and a high altitude (<20km) in the air, and turn into a sea-skimming flight before diving into the water; assisted with drag-reducing supercavitation and water ramjet technologies, the missiles continue to navigate underwater at a high speed (>200kn) until hitting the target. With the high speeds and trans-media trajectories, penetration capability of the missiles can be greatly improved, owing to the enhancement in missile stealth, mobility and evasion. New concept trans-media ramjets utilize metal-rich (Mg or Al) solid propellants combusting with breathed-in air or seawater from the environment to generate thrust. The ramjets, which bring benefits of structure compactivity, simplicity, and reliability, could be ideal propulsion systems for trans-media missiles. This paper proposes a new scheme of trans-media ramjets. With one single aluminum-based solid propellant grain in the ramjet, trans-media operation can be accomplished. The ramjet works as a solid ducted rocket in the air, and then as a water ramjet underwater. Through thermodynamic calculation, theoretical performance of the trans-media ramjets under typical working conditions in the air and underwater was obtained, and influences of metal content, metal species, air/fuel and water/fuel mass ratios on the ramjet performance were also discussed. A formulation of aluminum-based solid propellants was put forward for further performance analysis of the ramjets. Based on this propellant formulation and a given trans-media trajectory, calculation of major operation and design parameters was performed. Due to the variation of inflow conditions along trans-media trajectories, working pressure of the ramjet combustion chamber changes at different trajectory stages. According to the requirements for thrust in the air and underwater, parameters such as mass flow rates of the gas, air/fuel and water/fuel mass ratios, and burning rate characteristics of the propellant were determined; nozzle throat diameters were also calculated under different working conditions, and adjustable nozzles are needed to adapt to the trajectory variation. The analysis results of the ramjet parameters demonstrated the feasibility of trans-media working, and ground test verification of the ramjet performance is in progress.