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Hypersonic Air-breathing and Combined Cycle Propulsion, and Hypersonic Vehicle (7)

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PRELIMINARY DESIGN PROCEDURE OF GUN LAUNCHED SOLID FUEL RAMJET PROPULSION SYSTEM

Abstract

In this research, preliminary design procedure of gun launched solid fuel ramjet propulsion system was proposed. Recently, non-rocket space launch and flight have been investigated for cost reduction and sustainability. Around the same time, full-scale artillery shell utilizing solid fuel ramjet such as 155 mm HE-ExR of Nammo has been developed for range extension. Ramjet that operates efficiently at supersonic speed requires initial acceleration, and artillery is effective to provide it. Therefore, gun launched solid fuel ramjet propulsion system is promising candidate of non-rocket space launch and flight. Although numerous studies on each of components including inlet, combustion chamber, and nozzle have been conducted, study on integration of them is scarce. Hence, procedure about how to preliminarily design gun launched solid fuel ramjet propulsion system applicable to 155 mm series large caliber ammunition was suggested. Initial condition immediately after gun launch was set as design point, and all variables were feedback to each other. First, requirements such as range of 100 km or more, initial artillery shell mass of 50 kg or less, artillery shell diameter of 155 mm, artillery shell length of 1000 mm or less, and initial artillery shell velocity, also known as muzzle velocity, of 900 m/s were solicited in RFP (Request For Proposal). Second, external ballistics variables such as initial thrust of 3800 N and burning time of 15 s were established by using MATLAB. Third, propulsion system basic variables such as initial artillery shell Mach number of 2.65, oblique shock quantity of 1, initial combustion chamber pressure of 11.5 bar, initial specific impulse of 1000 s, and nose cone half angle of 30 deg were established by using NASA CEA (Chemical Equilibrium with Applications) and NASA Supersonic Cone Simulator. Fourth, inlet variables such as cowl lip arc diameter of 2 mm, cowl lip arc angle of 45 deg, cowl angle of 5 deg, diffuser throat width of 7 mm, subsonic diffuser width angle of 8 deg, and initial inlet total pressure recovery of 54.4946% were established by using Ansys Fluent. Fifth, combustion chamber and nozzle variables such as fuel regression rate of 1 mm/s and nozzle type of cone with convergence half angle of 45 deg and divergence half angle of 15 deg were established to satisfy artillery shell diameter and artillery shell length. Lastly, analyses on diffuser throat support, subsonic diffuser support, rotational speed, drag, and off-design point were performed by using Ansys Fluent.