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COMPARATIVE ANALYSIS OF AIRFRAME CONFIGURATIONS FOR SCRAMJET-POWERED HYPERSONIC VEHICLE

Abstract

Reusable launch system (RLS) is a class of space transportation systems that offer advantages in various aspects including cost and operation frequency. Among various RLS configurations, rocket-scramjet-rocket three-stage-to-orbit is proposed. The first-stage rocket accelerates to hypersonic speed, where scramjet is operable; the second-stage scramjet booster further accelerates through an atmospheric flight; and the third stage is a rocket-powered orbiter that inserts payload into a target orbit. Using scramjet engines for the second stage is expected to allow for lower launch costs and trajectory flexibility.

Aerodynamic design of scramjet-powered vehicles plays an important role in determining transportation capability because of its substantial influence on the scramjet performance. Several configurations such as waverider, lifting-body, and winged-body vehicles are proposed with their own pros and cons. Waverider is characterized by the high lift-to-drag ratio and ideal pre-compression surface for scramjet engines, but the payload capacity is inferior to the others, and the third-stage orbiter is usually placed outside of it. Lifting-body vehicles have a high lift-to-drag ratio and a greater payload capacity than waveriders. Winged-body vehicles often have enough payload capacity to place an orbiter inside, but drag increases due to its wings. In addition, for designing a feasible airframe, it is indispensable to determine the size, weight, and allocation of internal components that establish the vehicle system. Some components such as tanks are directly related to vehicle size, while others such as valves and avionics are less affected by vehicle size. In particular, it requires careful attention to design a hydrogen-fueled vehicle because it needs greater capacity than a hydrocarbon-fueled one. Furthermore, it remains unclear which configuration is suitable for powered access-to-space vehicles equipped with hydrogen-scramjet engines.

The present study thus discusses the suitable airframe configuration for a scramjet-powered second-stage booster of the three-stage RLS for a small-satellite (¡ 150 kg) LEO launch mission. Each of three configurations (waverider, lifting-body, and winged-body vehicles) is considered separately and the vehicle system is developed through the following procedure for each configuration; (1) estimating the size and weight of components based on the scramjet propulsion system employed, (2) determining the vehicle airframe in an iterative process between (1) and (2), (3) evaluation of the vehicle aerodynamic characteristics using computational fluid dynamics (CFD) simulation, and (4) assessment of the feasibility and validity of vehicle design via trajectory calculation. The present study provides the insights and methodology to design feasible scramjet-powered hypersonic vehicles for future space transportation.