SPACE PROPULSION SYMPOSIUM (C4)
Hypersonic and Combined Cycle Propulsion (5)

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DESIGN OF TSTO REUSABLE LAUNCH VEHICLE USING OXYGEN COLLECTION SYSTEM

Abstract

RLV(Reusable Launch Vehicle) is capable of launching a launch vehicle into space more than once. It contrasts with expendable launch systems, where each launch vehicle is launched once and then discarded. The objective of this paper is to represent the conceptual design of the RLV using air collection system. The air collection system collects air during flying in atmosphere and supply air to the rocket during flying in space. Thus the RLV using air collection system is very effective and economic launch vehicle. It is comprised of a carrier vehicle and an orbital vehicle. The carrier vehicle uses TBCC (Turbine Based Combined Cycle) engine and the orbital vehicle uses liquid rocket engine using collecting air as an oxidizer through air collection system. Fig 1 shows both the carrier and the orbital vehicle configuration for this study. A flexible and independent launch in various airports limits the maximum fuselage length of the airplane to 80 m. To reduce complexity as well as airframe and tank mass the cross-section of the body should be formed nearly cylindrically. However, sufficient volume should be provided for installation of the fuel tanks and the oxygen extraction system. To reduce the wave-drag a slender fuselage and a suitable area distribution is required. A high aerodynamic efficiency is advantageous for a cruise-mission. Therefore a proper embedding of the orbiter in the first stage is necessary. This may be achieved on the upper side, when using a high wing configuration. An orbital vehicle is double-delta plan form in a low-wing monoplane style like Space shuttle. To avoid thermal loads and local hot spots the transition between body and wing is smooth particularly in the front section. Fig 2 shows the conceptual design of the propulsion system which is referred to the reference. Configuration of the engine is duct and the ramjet engine parallels the turbojet engine. Flight of this vehicle is proposed for both subsonic and supersonic regime. The TBCC consists of turbo jet engines and ramjet engines, operating individually or simultaneously according to operation schedule. Operation schedule of engine depends on Mach number of the vehicle. Therefore flight envelop with certain Mach number of the vehicle is the most important factor to design a TBCC engine. Fig 3 shows 3-D flow analysis of orbital vehicle. Flight Mach number is 6.0 and angle of attack is 0 and 20. When angle of attack is 0, maximum velocity is shown at the tail and when angle of attack is 20, maximum velocity is shown at the upper side of the vehicle. Temperature of the vehicle head rises up to 2400K and the bottom surface rises up to 1500K at the angle of attack, 20deg.. Fig 4 shows the lift-drag ratio of the orbital vehicle at flight mach number 6.0. This result compared with space shuttle and the similarity is found. Fig 5 shows 3-D flow analysis of combined configuration of the RLV. Flight Mach number is 3.0 and angle of attack is 0 and 20 respectively. Velocity and temperature distribution is similar to the orbital vehicle, but the maximum temperature decreases to about 650 K due to Mach no. 3.0, and shock angle recedes from the body of the vehicle. Fig 6 shows the performance analysis, its validation, and numerical analysis of the TBCC engine. The numerical simulation shows the detail structures of internal and external flowfields and the interference between the exhaust gas and the vehicle body. Fig 7 shows the air collection scheme of turbojet engine. After air inflow, inhaled air is cooled in heat exchanger with hydrogen. The hydrogen obtained energy flows into the combustor. Air being cooled by hydrogen is compressed and cooled more in heat exchanger utilizing oxygen removed air.

The air is divided into the main flow and the sub flow. The main flow is cooled down to the dew point by hydrogen and flows into the distiller. The sub flow is compressed in compressor and is liquefied in heat exchanger. Liquefied air flows into distiller with the main flow. Since then in separator same process as general N2-O2 separation process is proceed. Table 1 shows that the vehicle with air collection system offers low weight and take-off thrust than that without collection system. Fig 8 shows specific impulse of established engine and TBCC engine with air collection system. The TBCC engine with air collection system has very high efficiency. Table 2 shows flight performance of an established launch vehicle and RLV with air collection system. Thrust per weight of a RLV is less than reference launch vehicles (Soyuz and Space Shuttle). Therefore fuel consumption of the RLV is less than the reference launch vehicles at take-off. And payload weight per total weight of a RLV is much greater than them. If vehicle's weight is same, RLV with air collection system can carry much more payload than the reference vehicles.