Conceptual Study of a Rocket Dual Combustion Ramjet Combined-Cycle Engine for a Near Space Plane

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Near space is the region of Earth's atmosphere that lies between 20km and 100km above sea level. The area is of interest for military surveillance purposes and commercial interests for communications. Hypersonic vehicle is very suitable for flying in near space, and attracts great attention in recent years.

In hypersonic flight condition, scramjet shows good performance and is prosperously investigated all around the world. However, scramjet cannot be self-started. Therefore, the combined-cycle engine has been studied. Several kinds of combined-cycle engines have been proposed and studied for a long time, one of which is a well-known rocket based combined-cycle engine (RBCC). The RBCC is composed of an ejector-jet mode, a ramjet mode, a scramjet mode, and a rocket mode. In the scramjet mode, it's difficult for ignition and combustion stabilization, because it is difficult for liquid kerosene to combust in supersonic flow, or is less efficient when remaining the rocket being as a torch.

Dual Combustion Ramjet (DCR) was firstly proposed by Billig et al. of John Hopkins University (JHU) in 1980s. DCR combines the best features of a ramjet and scramjet, and has several merits such as wider range of operating Mach number (3.5~6.5), easier ignition and more stable combustion, higher performance at low Mach number, and more convenient cooling of the wall. One disadvantage is that it becomes deficient when the flight Mach number exceeds 6.5 or 7.

It's very attractive to combine rocket with DCR for a near space plane flying at the Mach number no more than 6.5. In the present study, a Near Space Plane (Fig.1) is presented, which is powered by Multi-Module Rocket Dual Combustion Ramjet (RDCR) Combined-Cycle Engine. The Multi-Module RDCR Combined-Cycle Engine is mounted under the venter of the near space plane airframe. The forebody of the Near Space Plane acts as a precompressor of the intakes, and the aftbody serves as part of the nozzle.

The RDCR Combined-Cycle Engine module consists of the intakes, rockets, preburners, a combustor and a nozzle(Fig.2).The intakes include a supersonic intake and a subsonic intake. There are two rockets, four preburners and one combustor in the RDCR Combined-Cycle Engine module.

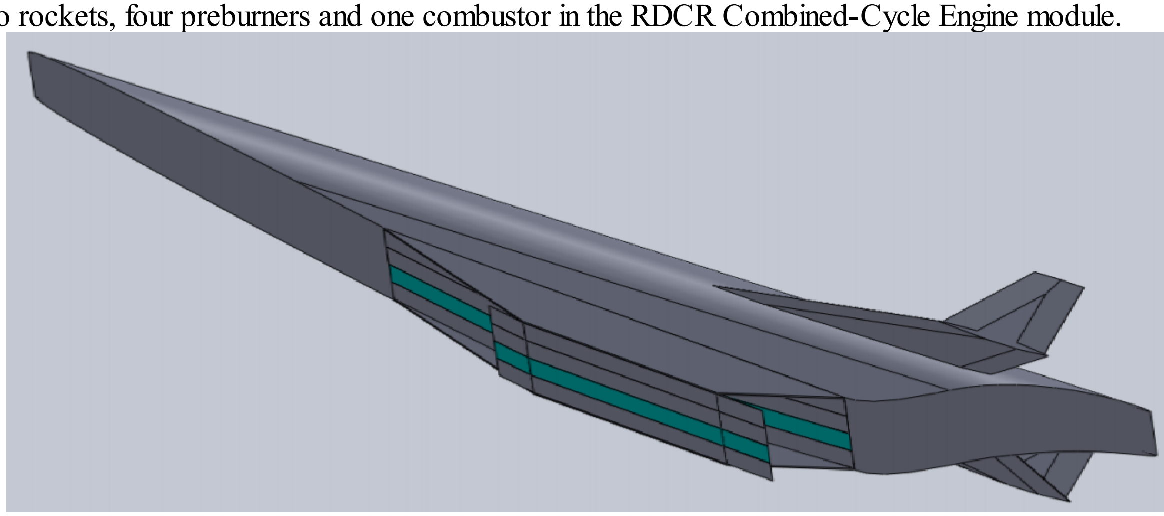

Fig.1Schematic of a Near Space Plane with Multi-Module RDCR Combined-Cycle Engine

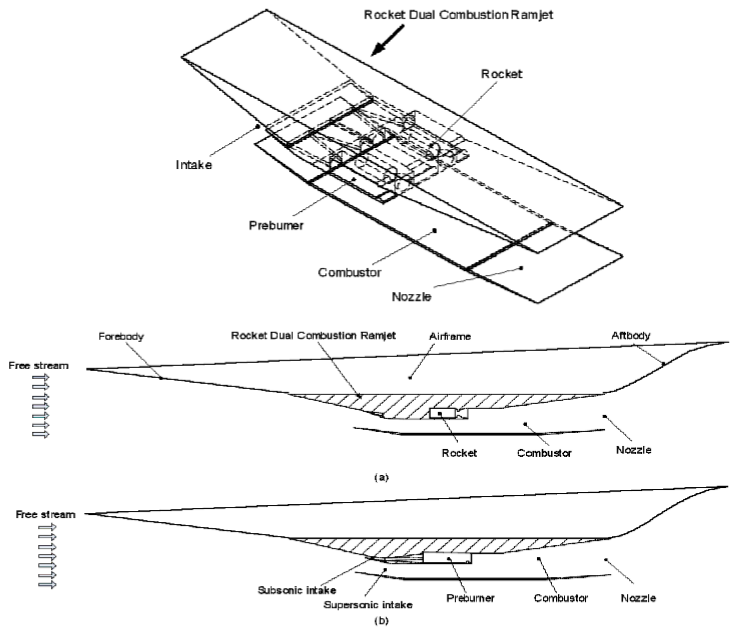

Fig.2 Schematics of RDCR Combined-Cycle Engine Module, (a) Section along the symmetry plane of the rocket, (b) Section along the symmetry plane of the preburner

The operating modes of RDCR Combined-Cycle Engine include an ejector-jet mode, an ejector-ramjet mode, a DCR ramjet mode and a DCR scramjet mode. The RDCR Combined-Cycle Engine operates in the ejector-jet mode under the situation that the Mach number is less than 3, in the ejector-ramjet mode or DCR ramjet mode from Mach 3 to Mach 6, and in the DCR scramjet mode from Mach 6 and upon. When the Mach number ranges from 3 to 6, the selection of the ejector-ramjet mode or the DCR ramjet mode depends on the multi-discipline optimization according to the tasks.

The trajectory of the Near Space Plane is sketched in Fig.3. The Near Space Plane with Multi-Module RDCR Combined-Cycle Engine will drop at 10km above sea level. Under the combination thrust of the gravity and the RDCR Combined-Cycle Engine, it accelerates to about Mach 2 at 5~8km above sea level, and then climbed to about 10~12km while the velocity being accelerated to about Mach 3. After that, Ejector-ramjet mode or DCR ramjet mode will be selected to accelerate the near space plane to about Mach 6. Ejector-ramjet mode provides more thrust with less efficiency, while DCR ramjet mode provides more efficiency and less thrust. A multi-discipline optimization should be carried out to decide which mode to choose. Then, the near space plane cruises under DCR scramjet mode which provides stable combustion and high efficiency. Finally, after reaching the target point, the near space plane will glide back and land horizontally with the aid of the ejector-jet mode.

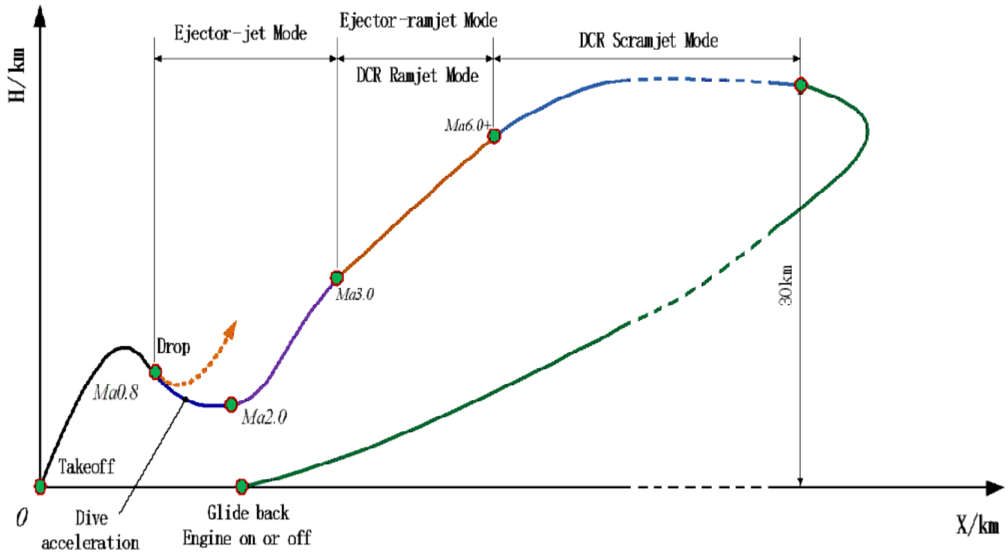

Fig.3The sketch of the trajectory of the Near Space Plane.

In the present study the trajectory of the near space plane is calculated, a feasible trajectory for the near space plane accelerating up to Mach 6 is acquired, and the flying height (Y), Mach number (Ma), dynamic pressure (q) and pitch angle (θ) change with time (t) are plotted in Fig.4.

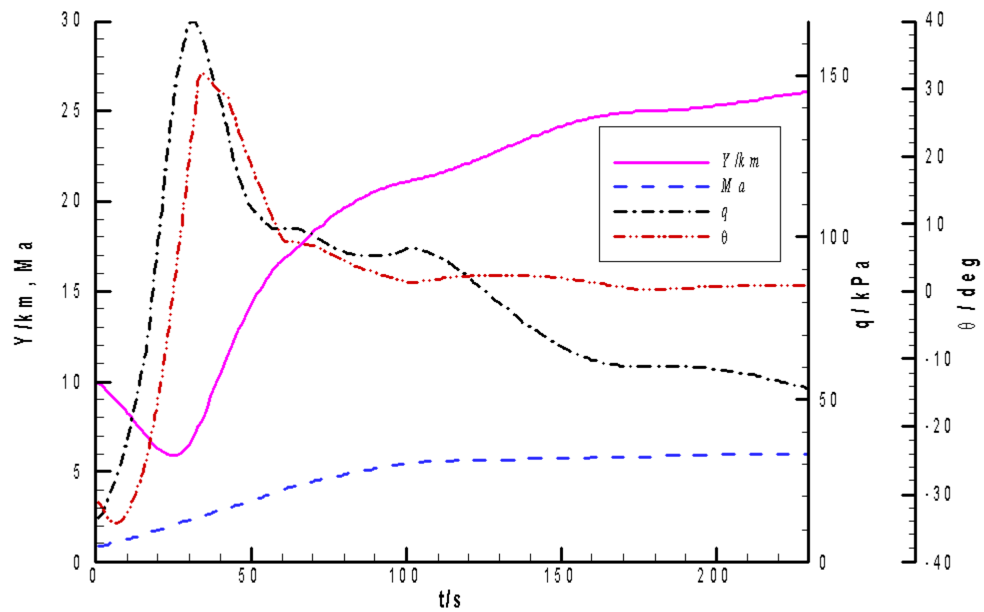

Fig.4The flying height, Mach number, dynamic pressure and pitch angle change with time.