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INVESTIGATION OF AN AIR TURBOROCKET BASED PROPULSION SYSTEM

Abstract

It has been a long standing question that why rocket launch vehicles have to carry heavy oxidizer onboard during the atmospheric flight ascend while the ambient oxygen are readily available along the way. Air-breathing propulsion technologies have been highly developed since World War II for military and aviation applications. However, for wide range of flight speeds and altitudes of launch vehicles, more versatile design approaches need to be adopted to fulfill the propulsion system requirements. The concept of air turborocket has been proposed since the early 1930s by Robert Goddard but only saw few major applications in flight. Other concepts such as rocket-based and turbine-based combined cycles and the synergistic air-breathing rocket engines have been proposed since the early 1980s. These are also linked with the scramjet research works. Some of the proposed systems were so complex that had made the development works very challenging and costly. Among these concepts, air turborocket belongs to the turbine-based combined cycle family that enjoys system simplicity and has been theoretically demonstrated to deliver good thrust performance up to Mach 6 flight speed, which is suitable for the rocket ascend flight from 0 to 50 km altitude. In the present study, analysis of the air turborocket performance is conducted with reexamination of the derivations and assumptions made by Kerrebrock and Suzuki. It is found that some simplifing assumptions were employed in their works. With the assumptions removed, more realistic theoretical performance data of air turborocket are calculated in this study. When the theoretical concept is applied to practical designs, mixing efficiency and combustion efficiency of the propellant mixture become critical parameters that affect the overall performance of the air turborocket engine. To investigate the effects of these parameters and the internal flow designs for performance improvement, a multi-components, multiphysics computational fluid dynamics (CFD) method, is employed to provide detailed computational solutions of the flowfield from which design trends can be revealed numerically. The numerical method is Navier-Stokes flow solver with numerical algorithms suitable for flow conditions from low subsonic to hypersonic speeds. Design cases related to propellant/air mixing and mixture combustion in the afterburner section are modeled and analyzed in this study to assess the performance of the design and its variants. The performance trends revealed based on the computational results are important in guiding the design modification directions for the improvement of the overall thrust performance of the air turborocket.