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PERFORMANCE IMPROVEMENT OF REUSABLE SSTO WITH AIR-ADDITION SYSTEM

Abstract

Reusable single-stage-to-orbit (SSTO) vehicles designed with conventional technology tend to be large systems exceeding 1000 tons in mass, posing challenges for cost and operability improvements. This study investigates an innovative air-addition system for SSTO downsizing. The system, a type of liquid air cycle engine (LACE), is integrated with a rocket engine using liquid hydrogen and liquid oxygen as propellants. It liquefies atmospheric air during atmospheric flight using the cryogenic energy of liquid hydrogen and adds the generated liquid air to the liquid oxygen onboard for combustion in the rocket engine combustion chamber. Although the combustion temperature decreases due to the mixing of nitrogen from the air, resulting in reduced specific impulse, the amount of liquid oxygen, which constitutes the majority of the propellant mass, can be significantly reduced. However, the additional structural mass of the heat exchanger and intake must be considered to accurately evaluate the net effect.

This study is the continuation of previous study presented in the last IAC, and investigates the net performance improvement of the air-addition system for an SSTO under development by Innovative Space Carrier (ISC) towards 2040. The required heat exchanger size and intake shape are determined by considering the flight environment along the flight trajectory to LEO, and their masses are estimated. Air-addition becomes less effective at altitudes where the atmospheric density falls below a certain level necessary for air liquefaction. Additionally, air liquefaction becomes impossible at excessively high flight Mach numbers due to the increase in total temperature. Therefore, a different trajectory from the conventional optimal trajectory without air-addition can be flown to enhance the air-addition effect. This paper reports the results of flight analysis performed to optimize the trajectory considering these trade-offs.