IAF SPACE TRANSPORTATION SOLUTIONS AND INNOVATIONS SYMPOSIUM (D2)
Technologies for Future Space Transportation Systems (5)

Author: Dr. Yusuke Maru
Japan Aerospace Exploration Agency (JAXA), Japan, maru.yusuke@jaxa.jp

Dr. Hiroaki Kobayashi
Japanese Rocket Society, Japan, info@jrocket.org
Prof. Tetsuya Sato
Waseda University, Japan, sato.tetsuya@waseda.jp
Dr. Shinichiro Tokudome
Japan Aerospace Exploration Agency (JAXA), Japan, tome@isas.jaxa.jp
Prof. Shujiro Sawai
Japan Aerospace Exploration Agency (JAXA), Japan, sawai.shujiro@jaxa.jp
Dr. Satoshi Nonaka
Japan Aerospace Exploration Agency (JAXA), Japan, nonaka.satoshi@jaxa.jp
Dr. Yuki Sakamoto
Japan Aerospace Exploration Agency (JAXA), ISAS, Japan, sakamoto.yuuki@jaxa.jp

PERFORMANCE IMPROVEMENT OF VTOL REUSABLE SOUNDING ROCKET WITH AIR-BREATHING ENGINES TOWARDS REALIZING FUTURE SINGLE-STAGE-TO-ORBIT

Abstract

Since air-breathing engines can significantly improve specific impulse and launch capability, air-breathers have been expected as a future alternative to the established rocket vehicles. However, the weight of hypersonic engines increase due to the complicated cooling structure, heat exchanger, air intake, and variable nozzle structure. Because the heavy engine negates the effect of improving the specific impulse (Isp), the air-breather loses its feasibility as a space transportation system. In this study, we changed our conventional thinking and examined whether a new space transportation system could be realized by using a lightweight air-breather instead of the hypersonic air-breather. Conventional single-use rockets consume most of the propellant during atmospheric flight to accelerate a heavy vehicle after takeoff against gravity and aerodynamic drag force. For example, a reusable sounding rocket (payload 100 kg, altitude 100 km) proposed by ISAS/JAXA has a total take-off weight of less than 11 tons, of which propellants occupy 7 tons. The vehicle that is equipped with four reusable rocket engines with 4 tons of thrust consumes the half of the propellant to surpass transonic speed. If the air-breathing engine can generate thrust in the subsonic to transonic velocity range, it would greatly contribute to improving the launch capability. To generate large thrust comparable to the rocket engine in this region, air introduction by a turbomachinery (fan) is required with the engine thrust ratio of 13 or more to improve the launch capability of the rocket. Because the thrust ratio of low-bypass turbofans for fighter jets is about 10, reduction in engine weight is a major technical issue. In this study, in order to minimize the engine weight, we adopted an air turbo rocket (ATR) engine, which uses a gas generator for driving fan/turbine and is combined with the rocket engine. The ATR maintains good Isp performance up to about Mach 2, but drops its thrust sharply at Mach 2 and above. For this reason, the operation of the ATR is limited to the range of flight speed Mach 0-2 and altitude 0-13 km. Outside this range, the rocket engine is used. The flight analysis of the reusable sounding rocket showed that the ATR replacement increases the payload capability from 100 kg to 600 kg despite the weight penalty of the ATR. In addition to the

payload capability improvement, the risk of landing failure inherently possessed by vertical take-off and landing will be reduced.