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Author: Dr. Cheulwoong Kim
Korea Aerospace Research Institute (KARI), Korea, Republic of

Mr. Byoungjik Lim
Korea Aerospace Research Institute (KARI), Korea, Republic of
Ms. SeokHee Lim
Korea Aerospace Research Institute (KARI), Korea, Republic of
Mr. Moo Keun Yi
Korea, Republic of
Dr. Woongrae Roh
Korea Aerospace Research Institute (KARI), Korea, Republic of

INTEGRATED DEVELOPMENT OF AN EXPANDER CYCLE LIQUID ROCKET ENGINE AND UPPER STAGE PROPULSION SYSTEM

Abstract

The Small Launch Vehicle Research Division of the Korea Aerospace Research Institute (KARI) is developing an upper-stage propulsion system for small launch vehicles. From 2021 to 2023, research on the system development of small launch vehicles was conducted, and based on this, the upper-stage engine and propellant supply system are being developed. The upper-stage engine for the small launch vehicle is a 30 kN thrust expander cycle engine using liquid oxygen and methane as propellants. It has a specific impulse of over 362 seconds, a weight below 110 kg, and an operating time of over 560 seconds. The propellant mixture ratio is 3.4, and the combustion chamber pressure is 46 bar, and the entire thrust chamber was manufactured using 3D printer. The thrust chamber, made of Inconel 718, underwent a total of 22 combustion tests across two prototypes, accumulating 282 seconds of firing time. The main components of the turbopump were also additively manufactured and post-machined. The hydrodynamic performance tests and cavitation characteristic tests of the turbopump are scheduled to begin in mid-2025. The design and analysis of the upper-stage propulsion system, which will be equipped with a 3-ton-class expander cycle engine, have also progressed. The P&ID and operational sequence for the propellant supply system have been developed. Key features of the upper-stage propulsion system include the application of an autogenous pressurization system, adoption of a bleeding method for propellant line pre-cooling, and installation of all purge line solenoid valves (except for engine purge) in ground facilities. These measures have simplified the configuration of the upper-stage propulsion system. The upper stage propulsion system uses propellant tanks with a common bulkhead structure, manufactured using friction stir welding. These tanks are currently under testing, with plans to produce Qualification Model prototypes by the end of 2026. For tank pressurization, liquid oxygen is heated through a heat exchanger and injected into the oxidizer tank as gaseous oxygen, while the methane tank is pressurized using methane gas heated in the engine's regenerative cooling channels. The mass flow rate of pressurizing gas is controlled through three solenoid valves and orifice assembles. Research tests using real-propellants for autogenous pressurization were conducted from 2022 to 2023, and the design of the pressurization system is currently underway. The design of the 3-ton-class engine system, upper-stage propellant supply system, and pressurization system is being carried out by the same designer, who is striving to optimize the upper-stage propulsion system.