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DESIGN AND DEVELOPMENT OF A HYBRID PROPULSION SYSTEM FOR TÜRKİYE'S LUNAR
EXPLORATION PROGRAM

Abstract

In recent years, interest in lunar exploration has significantly increased, not only among governmental space agencies but also within the commercial space sector. In this context, the first Turkish lunar mission (AYAP-1) is planned to be launched in 2027, with an expected operational lifetime of approximately two years. During the mission, the spacecraft will perform multiple Earth-orbit maneuvers, lunar transfer operations, lunar orbit maneuvers, and a final descent firing prior to lunar impact. To support these mission requirements, a novel 750 N-class hybrid rocket propulsion system has been developed. The propulsion system utilizes a thermoplastic solid fuel grain in combination with nitrous oxide as the oxidizer, forming a non-toxic and green propellant combination. The hybrid rocket engine architecture offers a cost-effective and inherently safe propulsion solution suitable for orbital maneuvering and deep-space missions. The selected oxidizer provides long-term storability and self-pressurization capability, eliminating the need for an additional pressurization subsystem and thereby simplifying the overall system architecture while improving reliability. To enable the multiple restart capability required for lunar transfer operations, the propulsion system incorporates pyrotechnically ignited compact hybrid igniters with thermoset solid fuel grains. This approach enables up to three reliable ignition events with a cumulative firing duration of approximately 300 seconds. The propellant feed system includes a solenoid isolation valve, a main control valve, and three dedicated igniter valves to ensure operational redundancy and controlled ignition sequencing. Thermal durability for long-duration firings is achieved through the use of high-temperature-resistant composite nozzle materials, including three-dimensional woven carbon-carbon silicon carbide structures. The propulsion module structure is designed to withstand launch loads while meeting strict mass and volume constraints of the transfer vehicle. A lightweight yet high-stiffness architecture is achieved using carbon-wound composite struts as the primary load-bearing frame combined with aluminum honeycomb upper and lower panels. The welded aluminum oxidizer tank and the composite-cased hybrid motor jointly contribute to the structural load-carrying capability under both pressure and mechanical loads. As a result, vibration testing demonstrates a first structural mode above 80 Hz, meeting launch vehicle interface requirements. The developed propulsion system is expected to be the first hybrid rocket engine to operate in deep space as part of a lunar mission, representing a significant milestone for hybrid propulsion technology. The presented work covers system design, material selection, ignition architecture, structural development, and qualification testing of the propulsion module for lunar mission applications.