47th STUDENT CONFERENCE (E2)
Student Conference - Part 1 (1)

Author: Ms. Krishti Das
Delft University of Technology, The Netherlands, The Netherlands, das.krishti07@gmail.com

Ms. Fiona Leverone
Delft University of Technology (TU Delft), The Netherlands, The Netherlands, F.K.Leverone@tudelft.nl
Dr. Angelo Cervone
Delft University of Technology (TU Delft), The Netherlands, a.cervone@tudelft.nl

DESIGN AND THERMAL ANALYSIS OF A SOLAR THERMAL MICROTHRUSTER FOR A LUNAR MISSION

Abstract

Lately, an area of research that has received significant attention is the miniaturisation and standardisation of satellites. The need for miniaturised propulsion sub-systems to perform orbital transfers, formation flying and attitude control emerge as the demand to broaden the mission capabilities of micro-satellites grows. Besides miniaturisation, there is a growing need for clean and safe propulsion systems along with the inclination to reduce the launch and operational costs for micro-satellites. Solar thermal propulsion (STP) is a possible candidate that offers intermediate performance between chemical and electric propulsion using green propellants. STP utilises solar energy to heat the propellant which in turn is expanded in a thruster. The paper investigates the performance of a micro-scale STP thruster design that fits within a 1U CubeSat volume and offers proper integration for an inflatable concentrator. A feasibility study of the design is analysed for a lunar mission from low lunar orbit to a halo orbit at Earth-Moon L2 that is capable of providing a minimum velocity increment of 160 m/s for station keeping, orbital transfer, and end-of-life disposal. The STP system distinctively employs an optical fiber bundle to concentrate the solar energy onto a receiver. Water was selected as the propellant for this system as it is green and provides a specific impulse range of 138 to 213 s depending on the nozzle throat width and receiver temperature between 0.5 to 0.7 mm and 500 to 1200 K respectively. As the design is inclined towards miniaturisation, geometries, and material suitable for microelectromechanical system manufacturing methods are considered such as etchable micro-channels and rectangular receiver. The design process for the STP thruster involves a thruster performance model that is integrated with an optical and thermal model that defines the geometrical parameters and determines the stored energy and the associated heat loss with the design. Simultaneously, a ray tracing model in COMSOL is included in the iterative design process to investigate the intensity and power deposited on the receiver surface and its variation with the number of optical fibers. The paper presents a suitable STP thruster design that fits within 1U of CubeSat volume while implementing 8 optical fibers for the transmission of heat energy, resulting in a propellant temperature of 1000 K. The final design of the STP thruster offers a thruster efficiency of 50 % with a thrust of 0.4 mN for the lunar mission.