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NUMERICAL AND EXPERIMENTAL STUDY OF PLUME EFFECTS FOR CHANDRAYAAN-2 MISSION

Abstract

The upcoming Chandrayaan-2 mission of ISRO is planned to deploy a lunar lander and rover on a specified lunar site. The mission objective is to ensure a safe and soft landing of lander module. The lander-craft will be released from lunar orbit, which will further undergo various lunar bound phases like de-boosting, rough and precision braking, vertical descent before finally landing on the moon surface. The thermal environment varies substantially during de-boost phase where all thrusters will operate simultaneously to decelerate the lander. The thermal control system for lander will be designed to maintain the temperatures of subsystems within the design limits during the de-boosting phase. Chandrayaan-2 mission will employ a clustered configuration of 800N thrusters, placed at the bottom of spacecraft base plate, to decelerate the spacecraft for braking and soft landing on lunar surface. The clustered engines will be operated together in the initial de-boosting phase to reduce spacecraft's velocity to move from 100 km North Pole to 18 km South Pole altitude location. Simultaneous firing of all four engines can result in possible interaction of thruster plumes and flow reversal, which will eventually lead to higher thermal loads on spacecraft structures. Plume may also impinge on the lander legs resulting in higher convective heat load on leg surfaces. In order to study plume effects and thermal load on lander craft structures during de-boost phase, numerical studies are carried out for clustered engine propulsion system in vacuum condition. Navier Stokes Solver coupled with radiative transport equation (RTE) is used to study multiple plume interactions, back flow between thrusters, and impingement over lander leg parts. Convective and radiative thermal load on lander- with and without protective heat shield configuration, are estimated. Experimental analysis is carried for single attitude control thrusters to understand radiative heat loads from plume at adjoining structures. Thruster test firing is carried out in vacuum facility with discretely placed sensors, in order to monitor radiative heating due to plume at these locations. The thruster experiment is numerically simulated and a close match between measured and simulated heat flux values is observed. A numerical methodology for RTE calculation based on validation study for single thruster is finalized and is used for estimation of heat loads in lander CFD model. The present analysis highlights plume flow fields in clustered engine propulsion system and provide input to design thermal protection system for lander to sustain harsh thermal environments.