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PLUME FLOW FIELD ANALYSIS FOR LANDER PROPULSION SYSTEM OF 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 on the lunar surface. The lander-craft will be released from lunar orbit, which will further undergo various lunar bound phases like de-boosting, rough and precision braking, and vertical descent. Chandrayaan-2 lander will employ a clustered configuration of four 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 different phases to reduce spacecraft's velocity to move from 100km North Pole to 18 km South Pole altitude location. Thermal environment in periphery of 800N engines will vary substantially during a phase, where all thrusters will be operated simultaneously to decelerate the lander. The thermal control system for lander will be designed to maintain the temperature of lander-craft systems within the safe limits during this phase. The 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 this phase, numerical studies are carried out for clustered engine propulsion system configuration in near vacuum condition. Navier Stokes Solver coupled with radiative transport equation (RTE) is used to study multiple plume interactions, reverse flow between thrusters, and flow impingement over lander leg. Convective and radiative thermal load on lander with and without protective heat shield configuration, are estimated. Analysis also carried out for sea level multiple thruster test to determine heat loads from thruster and plume on adjoining structures. Radiative heating is monitored at discretely placed sensors during test and is numerically simulated. Numerical methodology finalized based on validation studies is used for estimation of heat loads in lander flight model. The study highlights the plume flow fields in clustered engine configuration for Chandrayaan-2 lunar lander and provides input to design thermal protection system for lander to sustain harsh thermal environments due to multiple thruster firing.