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ANALYSIS OF THRUSTER EXHAUST PLUME IMPINGEMENT ON FLEXIBLE MEMBRANE OF SOLAR SAIL "IKAROS"

Abstract

This plume impingement analysis is undertaken to determine the impingement effects (thrust and torques loss) associated with the interaction of the exhaust plumes of control thrusters with the flexible membrane of a solar sail using IKAROS' flight data. The Small Solar Power Sail Demonstrator "IKAROS" was launched on May 21st, 2010 by the Japanese H2A rocket from Tanegashima Space Center with the Venus Climate Orbiter "Akatsuki" and have started accelerating by solar radiation pressure after deploying the solar sail at June 9th. As for RCS, IKAROS carries the gas-liquid equilibrium thruster system which stores propellant, HFC-134a, as liquid in the tank and exhausts it as gas from nozzles. This thruster enables the spacecraft to change its attitude and spin rate to keep communication between the Earth and the spacecraft and supply electrical power to its components.

Preliminary analysis of IKAROS' flight data shows that the plume impingement leads to considerable undesired and unexpected torques due to the characteristics the solar sail has: the flexibility in the large size of membrane and uncertainty in the shape of the membrane. This torques is compensated by additional propellant consuming maneuvers.

The impinging flow in this analysis is classified as rarefied gases because of the flow at high Knudsen number. We should hence treat the flow as a free molecule one. To determine the flux of momentum carried by molecules reflected or reemitted from the membrane surface, a specification of the interaction between the impinging particles and the surface is required. Therefore this analysis determines certain average parameters which characterize the interaction phenomena and which are known as the accommodation and reflection coefficients by comparing with available flight data and results of some additional experiments. And we propose a plume model to predict the local distribution of the momentum flux on the flexible membrane of a solar sail. The newly proposed plume model will be able to avoid or to minimize the impingement effects on the solar sail downstream of gas injection and be useful in design phase for future solar power sail missions.