Modelling and Estimation of Momentum Desaturations for Chandrayaan-2

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All spacecrafts and interplanetary probes orbiting in space experience various disturbance forces that influence their motion in the orbits. These forces in turn, while acting on an unsymmetrical spacecraft create torques which cause disturbance to the desired orientation in space. As specific orientations are required with stringent pointing requirements for various reasons like imaging of targets of interest, pointing antenna towards ground stations during data down-links etc., the Attitude and Orbit Control System (AOCE) of spacecraft controls the attitude using reaction wheels. The continuous disturbance torques acting on spacecraft cause momentum to accumulate and make the reaction wheels to saturate. Hence a periodic unloading of reaction wheels is carried out using thruster pulses, which are known as momentum desaturations. The residual translational velocities of thruster firings during these desaturations will impact their orbits. This paper presents an analytical approach for modelling the momentum accumulation caused by the major disturbance torques acting for Chandryaan-2 (CH-2) mission. The estimation of these desaturations helps in arriving at best orientation of solar panels so as to experience minimum disturbance torque and also for precise modelling of the orbit. Theoretical predictions by the analytical model are compared against practically observed momentum build up values over the spacecraft using the onboard Telemetry (TM) data and the results are discussed.

Introduction

The design and prediction of interplanetary mission trajectories involves precise orbit determination (OD) and perturbation forces analysis. The dominant perturbation sources that cause deviations in orbital motion and attitude of spacecraft in deep space trajectory are solar radiation pressure (SRP) and gravity gradient (GG) torque and aero dynamic (AD) torque. Well-known analytical formulations are there for modelling these disturbance forces. Although, the precise modelling of these forces requires the accurate knowledge and implementation of the spacecraft structural dimensions and thermo-optical properties of surface materials. Any inaccuracies in these parameters also result errors in the orbit prediction. Thus, these predictions play an important role in OD for interplanetary missions. These forces are capable of producing torque about the center of mass of the orbiting spacecraft. The desired attitude of the spacecraft gets disturbed if these torques are not resisted the attitude control system. The main role of Attitude control system is to maintain the desired attitude. Nominally, AOCE reacts to these disturbances torques by using the reaction wheels (RWs) to producing a counter torque. As these torques are of secular nature, the continuous encountering of these torques by the reaction wheels results in the momentum accumulation in the reaction wheels according to the Euler’s moment equation. To make wheels working in their operational limits and to neutralize the accumulated momentum, thruster firings are used. These thruster pulsing operations are termed as momentum desaturation operations. As there is a small residual translational component of these thruster pulses during each firing, these cause a perturbation to the motion of the spacecraft. Although these perturbations are very small, these need to be incorporated for precise trajectory determination. Also, frequent de-saturations result in consumption of fuel. Using the modelling of these disturbance torques, an estimation of proper offset to the solar panels can be arrived so as to minimize the number desaturations. This is the motivation for the present work of modelling these torques and its effect on attitude and orbit. There are many papers dealing with the modeling of the perturbative forces acting on the spacecraft. An analytical method presented in [2] for modeling SRP torque is adopted in this paper.

Results and discussion:

The second lunar mission of the Indian Space Research Organization, Chandrayaan-2 was successfully launched on 22nd July 2019 from Satish Dhawan Space Centre, Sriharikota. A series of Earth-bound (EBN) and Lunar-bound (LBN) maneuvers were performed to get the intended orbit for orbiter, which is a 100 km science orbit around the Moon.

This final orbit was reached by the orbiter on 24th-Sep 2019.

Considering the Chandrayaan-2 spacecraft structure dimensions and optical properties of surface materials used, the disturbance torques and desaturation operations required were estimated in different phases of the mission.

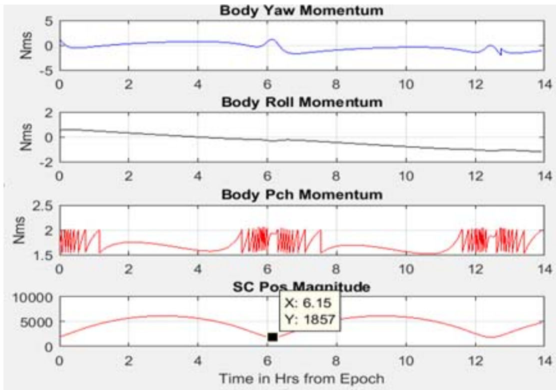

Figure-1: Estimated momentum on s/c body axes

The results for these desaturation estimations are provided for LBN phase of the mission. Figure-1 and Figure-2 show the body momentum profile during LBN#2 phase respectively for estimated values and observed values from the spacecraft Telemetry (TM). The number of desaturations predicted from the modelling are 44; one about positive Yaw axis of the body and 43 about negative pitch axis of the body. The total observed desaturations from TM are 45; one about positive Yaw axis of the body and 44 about negative pitch axis of the body.

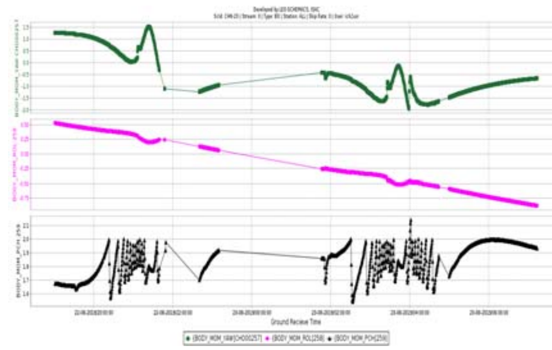

Figure-2: Observed momentum on s/c body axes

Conclusions

It can be observed from the results, that the predicted number of total desaturations are in well accordance with observed values from the Telemetry.

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