Paper ID: 3991
student

ASTRODYNAMICS SYMPOSIUM (C1)
Attitude Dynamics and Control (9)

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ATTITUDE CONTROL OF "HAYABUSA" USING ONLY ION THRUSTERS FOR THE CASE OF RWS ANOMALY

Abstract

This study attempts to construct a three-axis attitude control method for Hayabusa spacecraft where only ion thrusters are utilized, in case all reaction wheels (RWs) break down.

Asteroid probe Hayabusa was launched in May 2003, targeting on near Earth asteroid "Itokawa". It arrived at Itokawa in September 2005, and left for the Earth in April 2007. Along the way, Hayabusa has lost two of three RWs and reaction control system due to leakage of hydrazine. To cope with this situation, other studies have established three-axis attitude control method utilizing the third/last RW at z-axis as a momentum wheel in conjunction with the gimbaling of ion thruster. However, as is easily anticipated, the last RW will be possibly lost. Therefore, it is necessary to consider the way to control its attitude without using RWs. Ion thrusters are fixed on the plate which is actuated by 2 axis gimbals. The gimbals are able to shift up to 4 degrees around Y, Z axis at 0.0142deg/sec. Thereby the thruster can produce and control the torque around Y, Z axis by offsetting the gimbals angle from the position where the thrust passes through the spacecraft's center of gravity. In that manner, attitude control using only ion thrusters becomes possible.

There are two points that make this problem difficult. The first one is that the torque around X axis can not be generated. In other words, this system is two inputs - three outputs under-actuated system. The other one is that the performance of the ion thrusters is severely limited in terms of attitude control capability. To control the angle and angular rate about X-axis, the authors utilized two properties of rotational motion. One is based on the nonlinearity of dynamics due to asymmetrical nature of inertia. The other is non-holonomic property of kinematics, which is known as coning effect. Coning effect is such an effect that a series of rotation only around two axis (e.g. Y and Z axis) can generate rotation angle around the other axis (e.g. X axis) even if no angular velocity around the axis exist during the rotation.

In this study, the authors proposed a control method that can stabilize at target attitude by calculating suboptimal profile of gimbal angle that provides rest-to-rest motion. At the same time, the study evaluated the performance in terms of settling time and discussed the limitation of this approach.