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DESIGNING AND TESTING A MICRONEWTON THRUST BALANCE FOR AN AUTONOMOUS ARCJET DEVELOPMENT TEST BENCH

Abstract

The Institute of Space Systems (IRS) has been doing research on arcjets as deorbit systems under ESA Clean Space initiative. Due to its high values of specific impulse, electric space propulsion (EP), in particular, thermal arcjets are a promising propulsion technology with low-cost applications for end-of-life scenarios due to their higher thrust densities and simplicity in working principle compared to the other EP devices.

Space debris, whether natural or artificial, around our planet is a growing safety concern for the ongoing & upcoming space missions. Probable solutions to overcome this problem are either passive or active removal and mitigation of debris, by deorbiting it into the atmosphere and burn naturally; the latter is the focus of this paper.

The arcjet development at the IRS is intended to deorbit satellites at appreciably lower power levels. To characterize an arcjet thruster, the IRS has been developing an inverted pendulum thrust stand with an expected thrust resolution lower than 0.1 mN. Therefore, the thrust stand needs to be highly sensitive to measure thrust variations in 0.1 mN range. Hence, it is equipped with an inverted pendulum to host the thruster, an inductive displacement sensor, an in-situ calibration system, and other components supporting a good performance of the apparatus. Furthermore, the novelty of the stand is to perform thrust measurements and plasma diagnostics, simultaneously, thus, supporting a fully autonomous test bench. The stand utilizes a parallel linkage with four highly slender stainless-steel flexures between the thruster-mount (moving) plate and the stationary base that hosts the other aforementioned components to allow the motion as smooth and horizontal as possible.

The design comprises of two methods of thrust measurement: 1) thrust-displacement mode and 2) zero-displacement mode. During the first method, the mount's displacement due to thrust will be sensed by a displacement sensor and the output determines the instantaneous thrust. During the second method, a known, equal & opposite force to that of the thrust is applied by a controlled actuator to bring the balance back to its neutral position, and a load cell determines the thrust produced.

Consideration of every possible error source and uncertainty in the thrust measurements are presented in the paper along with the related mitigation techniques. With multiple tests and simultaneous calibration, the results will be reviewed, and the design will be refined for its maximum performance.

Keywords: Electric Propulsion, Thrust Balance, Thermal Arcjets, Zero-Displacement Balance, Inverted Pendulum