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Title
Faraday Cup design for Electrodeless Plasma Thrusters

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Abstract
Nowadays electric propulsion (EP) became a fundamental resource for in-space maneuvers or station-keeping. With the rise of large constellations thousands of satellites are already equipped with these devices and the number is constantly increasing [1]. These propulsion units involve the efficient acceleration of plasma to high speed to obtain thrust. In this context, because of their large heritage and performance, Hall effect (HT) and Gridded Ion thrusters (GIT) are still the predominant technologies [2]. An ongoing trend in the EP industry is the research on electrodeless thrusters motivated by the desire to overcome the lifetime limitations of the mention established technologies. This kind of propulsion does not involve the use of electrodes for plasma acceleration, which are the lifetime limiting factor for GIT and HT thrusters. Firstly, the electrons are heated by electromagnetic waves, then their thermal energy is converted into ion kinetic energy by the ambipolar electric field rising in a magnetic nozzle. However, these devices still show lower efficiencies respect to HT and Ion thrusters [3].
The research efforts to ameliorate the performance of these devices, involve the use of electrostatic plasma probes inserted into the plasma, to acquire information on the plasma parameters and assess indirectly for the thruster performance. This is done, by biasing an electrode immersed in the plasma and measuring the collected current, sum of the contribution of ions and electrons. Multiple electrostatic probe designs have been developed to characterize accurately different plasma quantities.
Evaluating the ion current density (J_i) in the plasma exhaust (plume) of an electric thruster is of fundamental importance since it can provide an estimation of the propellant utilization efficiency and the plume divergence.
Faraday probes are electrostatic probes designed to evaluate the J_i profile. In the simplest form, they are flat electrodes exposed to the plasma beam and biased to a large negative potential to repel the electrons and attract the ions. Alternative improved designs exist such as Guarded Faraday Probes or Faraday cups (FC) which are designed to recollect secondary electrons (SEE) emitted by ion impacts.
FCs have been extensively used to characterize HT and GIT thrusters, however the plasma of an electrodeless thruster is substantially different since it presents a higher electron temperature and typically lower ion energy. For these devices, inaccuracies between direct thrust measurements and indirect measurements suggest that J_i can be wrongly estimated by conventional FCs [5].

In this work we assess the main problematics related to the use of FCs for electrodeless thrusters, and we propose an improved probe design. The main design novelties, account for an additional escaping path for the neutrals originated from ions recombination, and the use of low SEE yield metals for the collector electrode.

The Faraday cup was tested on a helicon electrodeless plasma thruster fired at different working points. Results show that the ion current correctly saturates in the tested range and that non negligible differences in the collected current are seen if compared to conventional probe designs. This is shown to be particularly true at the higher mass flow rates tested.

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