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High Power Hall Thruster Design at SITAEL

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The increase of available power on board of modern spacecraft is paving the way to the use of very high power electric propulsion systems for a variety of deep space exploration missions to cislunar space, asteroids and planets of the inner solar system, as well as private commercial space missions. Hall thruster technology offers a favourable combination of performance, reliability, and lifetime for such applications. For these reasons, the attention of the electric propulsion community to the development of high power Hall Effect Thrusters (HETs) has been gradually increasing.

SITAEL is currently engaged in carrying out preparatory activities in the field of very high power HET-based electric propulsion. In the frame of the ESA TRP "Very High-Power Hall-Effect Thruster for Exploration", SITAEL has developed and tested a new 20kW class Hall Thruster, the HT20k, together with the associated high current cathode, the HC60.

The HT20k Hall Effect thruster is designed to operate at a nominal discharge power of 20kW. The thruster design is based on the extensive experimental and theoretical heritage of SITAEL in this field. A theoretical scaling methodology developed in past years, along with detailed numerical analyses conducted with a dedicated model have been used to size the HT20k and to estimate its performance envelope. The HT20k was expected to perform thrust levels of 1 N with efficiencies of about 60%. This prediction has been confirmed by the experimental characterization carried out in SITAEL's IV10 Vacuum Facility.

In the usual design of a HET, channel dimensions (in terms of length and height) are scaled so as to keep the involved physical processes unchanged with respect to the reference thruster (e.g. the Russian SPT 100). However, in the frame of the present project it was decided to opt for a different approach resulting in higher densities. This choice permitted to reduce the overall dimensions by about 20% with respect to a conventional-design thruster of the same power level. [figure 1]

The development of the HT20k also includes the assessment of non-standard magnetic field topologies aimed at drastically increasing the thruster lifetime. In its "magnetically shielded"variant which presents chamfered channel ceramics, the magnetic field is shaped to be almost tangent to the chamber edges. A preliminary numerical and experimental assessment of the magnetically shielded thruster showed that the erosion can be effectively reduced by more than two orders of magnitude, whereas performance, even though affected, remain close to those of the standard configuration.

The HT20k Hall thruster features an internally mounted hollow cathode, the HC60, located inside the inner pole of the magnetic circuit. Based on past experience with lower current applications, the thermionic hollow cathode configuration with a lanthanum hexaboride (LaB6) emitter was selected as the baseline configuration of the HT20k Hall effect thruster. The design was carried out through a dedicated numerical model previously developed at SITAEL and validated against experimental data of lower current class devices (from 1 to 20 A of discharge currents).

In the characterization campaign, systematic investigations aiming at optimizing thruster performance over an extended operating envelope were carried out. The HT20k was tested from 10 to 20kW on Xe, demonstrating a peak of anodic efficiency of 67% at 800V of discharge voltage and 12.5kW of discharge power. At power levels of 20kW, a maximum anodic efficiency of 64% was reached at 800V. The HT20k demonstrated anodic specific impulses greater than 2000s even at low voltages (300-350V).

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