HELICON PLASMA THRUSTER FOR SPACE MISSIONS

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The focus of the program "Helicon Plasma Thruster for Space Missions" was to identify potential new interesting applications for the helicon technology, of which the intrinsic innovative feature of this type of propulsion system can provide substantial advantages with respect current propulsion units.

The main peculiarities of helicon technology with respect to other, more mature propulsion system are: (i) capability of operating with different propellant, (ii) no electrodes (and neutralizers) exposed to plasmas, (iii) throttability.

During the first part of the study a deep review of current and future space missions has been performed in order to identify best mission candidates. A preliminary design of helicon plasma thruster has then been performed to identify on each selected mission scenario the best helicon candidate. The helicon propulsion units resulting from this stage have been compared with existing propulsion systems (if applicable) in order to perform a detailed comparison with the current state of the art. Even if this research program has been mostly based on numerical investigation, a limited experimental campaign has been also conducted to verify codes predictions at power levels up to 400 W.

After this step we carried out a trade-off analysis in order to identify missions in which an helicon thruster could provide remarkable advantages with respect to current propulsion technologies; the results highlight that an helicon thruster of 1kW, operating with CO_2, providing a thrust of about 100 mN, could be a good candidate for missions involving long term orbiters based on the ISS, in particular orbital debris removal, since it allows the usage of ISS waste gases as propellant. This feature could provide great benefits with respect to current system, because the propellant is basically free. Moreover, in the future this unit could be applied as an atmospheric-breathing-system on planet having a CO_2-rich-atmosphere (as, for example, Mars).

This helicon thruster configuration was thus recognized as the most promising among those considered and then sized into details with respect to all subsystems: (i) structural, (ii) magnetic, (iii) radio frequency, (iv) thermal, (v) mass flow feeding, (iv) power distribution, (vii) diagnostic. The resulting thruster has a diameter of 145 mm, a length of 162 mm and a mass of 6.45 kg. The thruster performance level has been preliminarily estimated at (i) 66% efficiency (60% including the PPU), (ii) 94 mN thrust, (iii) 2139 s specific impulse , with a nominal mass flow rate of $4.47 \cdot 10^{-6}$ kg/s of CO_2 and a nominal input power of 1771 W (fed to the PPU). The thruster is equipped with permanent magnets and cooled using passive means.

The thruster has been specifically designed to minimize the impact on the spacecraft both in term of residual EM and magnetic field, and in term of thermal loads.

The impact of the helicon technology has been also assessed at system level on a reference spacecraft considered for the mission under investigation.

A detailed scaling analysis has been performed in order to identify issues related to high-power scaling. The analysis showed no intrinsic limitation of this technology at high-power, and no need of applying exotic solutions as superconductors, at least till the 50-100 kW range.

Finally a design and development plan of the engine has been drawn.