Helicon Double Layer Thruster Concept for High Power NEP Missions

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4-month Ariadna study (25kEuro)

Background

The Helicon source is a device capable of high-efficiency plasma generation. High-density plasma is produced by the use of a helical radio frequency antenna to ionise neutral gas (e.g. argon, krypton, xenon, helium or hydrogen) in a tube closed at one end. The helical antenna excites the gas to dissociate electrons and generate highly energetic ions. Solenoid coils surrounding the tube create a magnetic field inside to confine the plasma within the tube and reach a high ion particle density.

The plasma can be heated to very high temperature by another antenna downstream (operating at the Ion-Cyclotron Resonance Frequency) and expanded through a nozzle into vacuum, as in the case of the VASIMR thruster [1]. Alternatively plasma can be accelerated to supersonic speeds by being forced through an electric double layer (a magneto-shock region with sudden drop in potential) created by a rapidly expanding magnetic field very close to the open end of the tube, as in the Helicon Double Layer Thruster [2] developed by the Australian National University. Other methods such as a “magnetic nozzle” may also be used to accelerate the plasma in the source to high exhaust velocities, thus producing a moderate thrust and a high specific impulse.

These helicon-type thruster concepts are entirely scaleable to high power (kW to MW) operations in order to potentially obtain much higher thrust levels (order of N) and even higher specific impulses (order of 10,000s or more), with the additional advantage of requiring no high-current cathode, acceleration grids or neutraliser that presently limit the operating lifetime in other electric thrusters. However, the scaling to high power is a challenging task since non-linear interactions between plasma flow, magnetic and electric fields at higher energies are difficult to predict and small-scale instabilities arising may cause a reduction in thrust efficiency. Nonetheless, some estimates of design scaling and performance are needed in order to gauge their potential for various space applications. Following this first step, detailed simulation modelling and experimental research programs must be conducted to optimise thruster geometry, radio frequency system and applied magnetic field for high-energy plasma generation efficiency, confinement and acceleration.

Rationale

Despite the significant challenges to be overcome, in principle the potential for helicon-type thrusters operating at high power levels to produce a high continuous thrust and high, variable specific impulse (compared to some other types of electric propulsion) make them an attractive choice for propelling large spacecraft requiring high delta-V and acceptable transfer times. These missions include human or cargo missions to Mars [3], and robotic missions with large science payloads to orbit planets in the outer solar system [4] or even to deflect near-Earth asteroids [5].

Study Objectives

This study shall focus on the investigation of the novel Helicon Double Layer Thruster concept and provide a means for ESA and European academia to further collaborate with the Australian National University who are leading the development of this promising technology. An existing collaboration is ongoing with ESTEC relating to the testing of a demonstration model within a thruster test facility.

The study should investigate the scaling of the helicon double layer thruster for high power interplanetary space missions. This will involve the following activities:

- Study on the scaling of the thruster design and its performance (specific power, thrust, specific impulse etc) as a function of input power (tens of kW up to MW), using theoretical methods and numerical models as necessary, and experimental data from previous tests or new data from thruster facility tests when available.

- Comparison to the performances of other types of high-power electric thruster including VASIMR and MPD thrusters.

- Proposal of a plan for further research, development & experimentation on the Helicon Double Layer Thruster to be conducted in collaboration with Australian National University.

References

[1] J.P. Squire, F.R.C. Diaz, T.W. Glover, V.T. Jacobson, D.G. Chavers, R.D. Bengtson, E.A. Bering, R.W. Boswell, R.H. Goulding And M. Light, "*Progress in experimental research of the VASIMR engine*". Fusion Science and Technology **43**, 111-117 (2003).

[2] C. Charles, R.W. Boswell, "*Laboratory evidence of a supersonic ion beam generated by a current-free "helicon" double-layer*". Phys. Plasmas **11**, 1706-1714 2004.

[3] Future Power System for Space Exploration, S54 study, ESA publication, February 2002.

[4] Report of the NASA Science Definition Team for the Jupiter Icy Moons Orbiter (JIMO), http://ossim.hq.nasa.gov/jimo/JIMO_SDT_REPORT.pdf

[5] Williams, B.G., Durda, D.D., Scheeres, D., *The B612 Mission Design*, 1st AIAA Planetary Defense Conference, Orange County, California, 2004.