Magnetic reconnection as a means for advanced high specific impulse plasma thrusters

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Abstract

Recent advances in the space sector have led to new improvements of propulsion capabilities for the next generation space missions. The need for propulsion systems able to deliver thousands of seconds of specific impulse has increased in the last decade along with the rising demand for space electric propulsion (EP) (1). Simultaneously, the necessity for rapid transportation of astronauts and cargo to establish the infrastructure required for sustained human presence on the moon and enabling future human exploration of Mars has accentuated the critical need for advanced in-space propulsion systems, for which the need of significant thrust density is necessitated as well.
The current (conservative) strategy to develop a thruster with higher levels of thrust and specific impulse involves the scaling up process of notable conventional electric propulsion systems such as ion and Hall thrusters. However, this strategy poses a serious problem: the scaling laws towards high power and high thrust engines depend mostly on increasing the thruster footprint. Therefore, developing a thruster for very high-power applications will impact the spacecraft overall dimensions and weight.

Recently, there has been an increased interest in developing an innovative thruster based on magnetic reconnection as main acceleration mechanism (2). Magnetic reconnection (MR) (3) involves the breaking and reconnecting of oppositely directed magnetic field lines to form a different magnetic topology and the releasing of magnetic energy, which is converted into kinetic and thermal energy.

A new concept of a plasma thruster based on MR as a mean to accelerate ions is presented in this paper. The concept features a novel thruster design where a high-current plasma is generated by multiple hollow cathodes, magnetically confined by external solenoids, and directed through a bell-shaped anode to provide thrust. Such plasma forms multiple magnetic flux ropes, which collide when kink-unstable, and the subsequent MR accelerates the ions in the axial direction. Such a thruster promises significant advantages, such as a specific impulse $>$ 10000s. In this paper, the thruster concept, as well as the experimental setup to verify the key features, are presented. This work has been performed within the Magnetic Reconnection Hollow Cathode Thruster (MaRe-HCT) project, ongoing in the framework of a Marie Sklodowska Curie Post Doctoral Fellowship at the Institute of Space Systems (IRS) of the University of Stuttgart (4).

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References

(1) Levchenko, Igor, Dan M. Goebel, and Kateryna Bazaka. "Electric propulsion of spacecraft." *Physics Today* 75.9 (2022): 38-44.

(2) Ebrahimi, F., "An Alfvenic reconnecting plasmoid thruster," *Journal of Plasma Physics*, Vol. 86, No. 6, 2020, p. 905860614. https://doi.org/10.1017/S0022377820001476.

(3) Hesse, M., & Cassak, P. A. (2020). Magnetic reconnection in the space sciences: Past, present, and future. *Journal of Geophysical Research: Space Physics*, 125(2), e2018JA025935.
(4) Becatti, G. & Herdrich, G. (2024, May). Magnetic reconnection based thruster for high specific impulses space missions. *In 9th Space Propulsion Conference* (SP2024_484).