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MINIATURIZATION OF ION PROPULSION THROUGH IONIZATION/ACCELERATION COUPLING - THE CORONA MODEL

Abstract

We introduce and model a way to miniaturize an ion engine type propulsion system, which are usually very resistant to miniaturization due to the size restriction of the ionization chamber. A small electric proof-of-principle thruster was built and tested preliminarily, whose mass was low (approx. 1 gram), even without any effort on our part. The new thruster relies on coupling the ionization and acceleration mechanisms, i.e. using the same electric field for both. A corona type ionization mechanism creates the propellant ions and accelerates them, producing thrust. A mathematical model describing the electric field characteristics is derived from Poisson's equation. Some predictions of the field are verified. A relationship between the potential difference and the current of propellant ions is obtained by integration, which yields insight into the ionization efficiency. A model for the thrust is derived via two different methods: The first uses energy conservation, viewing the ions as a current heating the neutrals in the plume in the direction away from the needle. A temperature can be derived for the plume, and the resulting average gas velocity estimated from molecular theory. An expression for the thrust is obtained. The second, more conventional method uses electrostatic repulsion to calculate the recoil on the needle: from the electric field computed for the system, an expression for the Coulomb forces on the ionized propellant can be derived. The recoil on the needle will experience the same force, resulting in thrust. Finally, the theoretical predictions for the various parameters are compared to some preliminary data. It is seen that the model describes the electric properties adequately, and certainly seems to encapsulate the physical mechanism to leading order. One thrust model estimates the thrust very reasonably, while the more conventional model underestimates the thrust. First investigations into a system of this type yielded some recommendations for future designs, which will be discussed.