Computational Modeling of a Hall Thruster

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Hall thrusters are space propulsion devices that convert electrical energy (typically derived from solar arrays) to kinetic energy by ionizing a propellant, such as xenon, and accelerating it through a potential gradient. First developed for spacecraft propulsion by the Russian space program in the 1960s, Hall thrusters are finding a place in Western space programs in recent years due to their high efficiency relative to chemical propellants (3-10 times as efficient) and high thrust relative to other forms of electric propulsion.

To date, Hall thruster development has been largely experimental in nature. From a scientific point of view, it is necessary to develop computational models to better understand the physical mechanisms that control the operation of these devices, including the effect of secondary electron emission and the magnetic field topology. From an engineering standpoint, the development of accurate computational models allows for the performance of virtual life tests and significantly facilitates analysis of the possible problems stemming from spacecraft-thruster interactions.

One of the primary modeling challenges posed by these devices is the need to balance physical accuracy with computational expense. Full particle simulations have been attempted with some success; however, computational times on typical desktop workstations range from multiple days to multiple weeks. Another accepted approach has been to use a hybrid code with full particle simulation for heavy particles and a fluid treatment for electrons.

It is clear that the electron physics model used in existing hybrid Hall thruster models has an enormous impact on the results produced by such simulations [1]. Consequently, the electron energy transport portion of a 2-D hybrid PIC/MCC Hall thruster code is being upgraded through the use of a more comprehensive physical model for the electron energy distribution. The existing single temperature fluid description is enhanced to account for an additional population of secondary emission electrons. In addition to improvements to the electron energy model, other changes to the model include the addition of doubly charged xenon. Results are obtained for the UM/AFRL P5 type magnetic field configuration with relevant comparisons to experimental data.

References

[1] Koo, J. W., Boyd, I. D.., "Computational Model of an SPT-100 Thruster," IEPC 03-0071, March, 2003.

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