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Model of Gas Flow Inside a Plasma Thruster

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Stationary Plasma Thrusters (SPT) are high-efficiency electric rocket engines that are ideally suited to spacecraft orbit transfer and positioning missions. By harnessing the power resources available on-board to accelerate a plasma, these engines allow substantial savings on the propellant mass in comparison with chemical rocket engines. The dynamic of neutral particles (non-ionized propellant) is a key element in numerical simulations of SPT discharges. Yet, some important kinetic phenomena are often overlooked in the common macroscopic descriptions of such a collisionless flow, namely: i) the fact that the ionization probability of slow neutrals is higher due to their longer transit time in the channel, ii) the flow deceleration due to friction on the walls. Using a specific property of the distribution function of a collisionless flow in the presence of ionization, an assumption on the velocity dispersion of a free flow is proposed. Distinguishing then between a primary free flow and a secondary flow in thermal equilibrium with the walls, simplified one-dimensional macroscopic equations are obtained. Stationary and transient test-cases highlight an excellent consistency between the results of the macroscopic model and exact kinetic solutions.

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