Charge Exchange Ions on the Hump of Hall Thruster Plume

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Using the Semi-Onion Model[1] an expression for the velocity of plume's particles along the plume-center line was obtained as written below:

$$v_{plz}(z) = \left(\frac{v_{exz}}{\sqrt{1+\left(\frac{\partial \rho(z)}{\partial z}\right)}} \right) \tag{1}$$

where the plume-center line is taken to be along z-axis and $\rho(z)$ is the radius of plume at any position z with respect to the plume-center line. For $q_i = q_{pl}$ this expression was utilized to derive the equation for the corresponding acceleration potential $\mathbf{V_{plz}}(\boldsymbol{z})$ along the plume-center line in the following :

$$\mathrm{V_{plz}}(z) = \left[\frac{\mathbf{1}}{\mathbf{1}+\left(\frac{\partial \rho}{\partial z}\right)^{\mathbf{2}}} \right] \mathrm{V_b} \tag{2}$$

q_i: ionization order of exhausted particles

q_{pl}: ionization order of plume's particles

$\mathrm{V_b}$ **:** acceleration voltage of primary plume particles

At the location of At charge exchange ions, $\boldsymbol{z = z_{CEX}}$, we took $\mathbf{V_{plz}}(\boldsymbol{z_{CEX}}) = \mathbf{V_{CEX}}$ [2,3]. Hence,

$$\left(\frac{\mathbf{q_i}}{\mathbf{q_{CEX}}}\right) = \left[\frac{\mathbf{1}}{\mathbf{1}+\left(\frac{\partial \rho}{\partial z}\right)^{\mathbf{2}}} \right]_{\boldsymbol{z=z_{CEX}}} \tag{3}$$

From the Eqn.(3) the locations of the low-voltage CEX ions with the average number densities of the plume's particles (see Figure 1(b)) were determined in the three regions of the plume's hump (see Table 1). The Eqn.(2) was used to obtain the voltage distribuition for the plume's hump along the plume center line (see Figure 1(a)). by taking $\mathrm{V_b} = 300V$. Also, by referring to the related equations of the semi-onion model[1] thrust values and the curvatures corresponding to the plume's hump along the plume center line as seen in Figure 2(a) and (b). Here the thrust value for the primary particles was taken T=180 [mN].

In conclusion, the drops in the thrust values (see Figure 2(a)) while the rises in the curvatures (see Figure 2(b)) were seen to happen in these three regions of the plume's hump corresponding to the locations of the low-voltage CEX ions.

References

[1] Yilmaz, A., "Semi-onion Model for Hall Thruster Plume," 47th AIAA/ASME/SAE/ASEE Joint Propulsion Conference, AIAA Paper 2011-6078, July31-August03, San Diego,CA, 2011.

[2] King, L. B., and Gallimore, A.D., "Identifying Charge Exchange Collision Products within the Ion Energy Distribution of Electrostatically-Accelerated Plasmas", Physics of Plasmas, 6,7,p.??,July 1999.

[3] Brown, D.L., and Gallimore, A.D., "Evaluation of Facility Effects on Ion Migration in a Hall Thruster Plume",Journal of Propulsion and Power, 22, 3, 577-585, May3-June 20 2011.

Table 1: Positions of CEX ions on the plume's surface.

$\left(\frac{q_i}{q_{CEX}}\right)$	z [cm]		
(3/4)	1.0714	2.9843	7.0503
(2/4)	0.81422	3.3611	6. 0633
(2/3)	0.98140	3. 103	6. 6927
(1/2)	0.81422	3.3611	6. 0633
(1/3)	0.6338	3.7683	5.3286,
(1/4)	0.52453	-	-

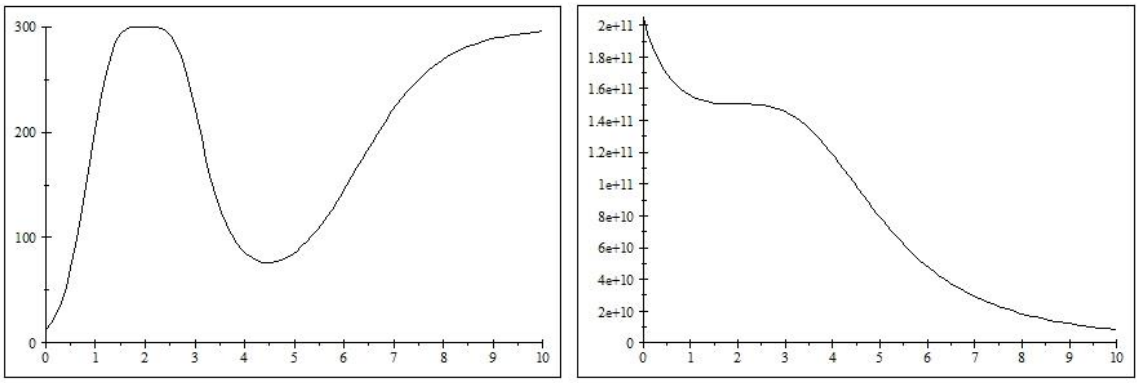

Figure 1: **(a)** Voltage distribution and **(b)** average number density of plume's particles [cm^{-3}] corresponding to the hump of the plume along the plume center line [1].

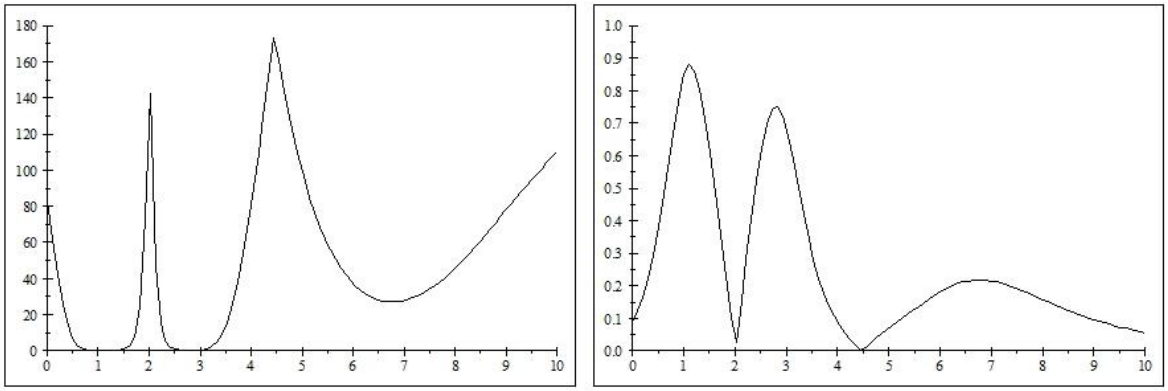

Figure 2 (a) Thrust [mN] values and **(b)** the curvatures corresponding to the plume's hump along the plume centre line[1]