Technical Comments

Comment on "Performance of Quasi-Steady MPD Thrusters at High Powers"

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IN a recent Synoptic[1] and full paper[2] Malliaris et al. have shown that quasi-steady MPD arc performance appears to be limited by a critical value of $(J^2/\dot{m})$ such that $(J^2/\dot{m})_c = 1/b[2eN_0V_i/M]^{1/2}$; where all notation is identical to that of Ref. 1. They note that operation beyond the critical point becomes objectionable due to instabilities, sharp rise of voltage, erosion, and participation of spurious propellant. Noting that $M/N_0 = m_i$, where m_i is the mass of an ion, and $J^2/\dot{m} = v_e/b$, where v_e is the exhaust velocity, it is seen that the critical condition requires $(v_e)_c = [2eV_i/m_i]^{1/2}$ or that the exhaust velocity at the critical condition is given by the Alfvén critical velocity[3,4] (this result being equivalent to Eq. (7) of Ref. 2). A comparison of the computed Alfvén velocity and the measured exhaust velocity corresponding to $(I_{sp})_c$ of Table 2 of Ref. 1 is shown in Table 1. Since the analytic expression for $(J^2/\dot{m})_c$ is obtained by assuming a minimum power input which results in the equipartition of energy between ionization and kinetic energies,[2,4] a consequence of this model is the limiting of the exhaust velocity to the Alfvén velocity and, for a highly ionized exhaust stream, the limiting of the thrust efficiency to 50% or less. Thus from the analytic and experimental results presented in Ref. 1 it appears that the Alfvén critical velocity may have significance with regard to the performance of self-field quasi-steady arcs.

It is interesting to note that a similar critical condition accompanied by a sudden jump in voltage has also been observed in a steady applied field lithium-fueled MPD arc.[5,6] In this device, however, ion velocities more than twice as high as the Alfvén velocity have been measured at operating conditions below critical; i.e., operation at values of arc current, applied magnetic field, and input feed rate such that sudden voltage jumps are not observed. Both Doppler shift and energy analyzer techniques were used to measure ion velocities directly. The measured values agreed to within 15% with velocities deduced from thrust measurements,[6] indicating they were representative of the effective exhaust velocity. The thrust efficiency, for the fully ionized beam, varied from 25% to 45%.

It is not the purpose of this comment to define a performance limit for the quasi-steady arc, nor to compare quasi-steady and steady applied field arc performance. Its purpose is to point out that questions regarding the Alfvén critical velocity, limiting velocities, and limiting efficiencies which have been raised for applied field arcs[4] also appear relevant for self-field quasi-steady arcs.

Table 1 Comparison of Alfvén velocity and measured exhaust velocity at the critical condition

Entry no.	Propellant	$\dot{m}$, g/sec	$(v_e) \times 10^{-4}$, m/sec	$v_e = (2eV_i/m_i)^{1/2} \times 10^{-4}$, m/sec
1	Helium	0.7	2.9	3.3
2		1.5	2.5	3.3
3		4.1	2.7	3.3
4	Neon	1.6	1.2	1.4
5		4.0	1.2	1.4
6		8.5	1.3	1.4
7	Argon	1.1	0.90	0.87
8		2.2	0.92	0.87
9		5.6	0.90	0.87
10		12.0	0.88	0.87
11	Krypton	3.3	0.60	0.57
12		8.6	0.59	0.57
13		18.0	0.62	0.57
14	Xenon	4.1	0.49	0.42
15		10.4	0.49	0.42
16		22.3	0.47	0.42

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Comment on "Wind-Tunnel Magnus Testing of a Canted Fin or Self-Rotating Configuration"

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Nomenclature

A = true angle of attack
C_m = pitching moment coefficient
C_N = normal-force coefficient
C_n = yawing moment coefficient
C_{N_p} = Magnus-force derivative, $\partial C_n/\partial(pd/V)$
C_Y = side-force coefficient
d = reference length
$\{\bar{i}, \bar{j}, \bar{k}\}$ = unit vectors along $\{X, Y, Z\}$ axes
l_F = distance between Magnus force c.p. and c.g.
$\bar{l}$ = unit vector along velocity vector

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