Performance of a Cylindrical Hall-Effect Thruster Using Permanent Magnets

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While annular Hall thrusters can operate at high efficiency at kW power levels, it is difficult to construct one that operates over a broad envelope from ∼1 kW down to ∼100 W while maintaining an efficiency of 45-55%. Scaling to low power while holding the main dimensionless parameters constant requires a decrease in the thruster channel size and an increase in the magnetic field strength. Increasing the magnetic field becomes technically challenging since the field can saturate the miniaturized inner components of the magnetic circuit and scaling down the magnetic circuit leaves very little room for magnetic pole pieces and heat shields. In addition, the central magnetic pole piece defining the interior wall of the annular channel can experience excessive heat loads in a miniaturized Hall thruster, with the temperature eventually exceeding the Curie temperature of the material and in extreme circumstances leading to accelerated erosion of the channel wall.

An alternative approach is to employ a cylindrical Hall thruster (CHT) geometry. Laboratory model CHTs have operated at power levels ranging from ∼50 W up to ∼1 kW. These thrusters exhibit performance characteristics that are comparable to conventional, annular Hall thrusters of similar size. Compared to the annular Hall thruster, the CHTs insulator surface area to discharge chamber volume ratio is lower. Consequently, there is the potential for reduced wall losses in the channel of a CHT, and any reduction in wall losses should translate into lower channel heating rates and reduced erosion, making the CHT geometry promising for low-power applications. This potential for high performance in the low-power regime has served as the impetus for research and development efforts aimed at understanding and improving CHT performance.

Recently, a 2.6 cm channel diameter permanent magnet CHT (shown in Fig. 1) was tested. This thruster has the promise of reduced power consumption over previous CHT iterations that employed electromagnets. Data are presented to expose the effect different controllable parameters have on the discharge and to summarize performance measurements (thrust, Isp, efficiency) obtained using a thrust stand. In addition, beam current data are presented to show the effect of the magnetic field topology on the plume profile and current utilization and to gain insight into the thruster's operation. These data extend and improve upon the results previously presented by the authors in Ref. [1].

References

[1] K.A. Polzin, Y. Raitses, E. Merino, and N.J. Fisch, "Prliminary results of performance measurements on a cylindrical Hall-effect thruster with magnetic field generated by permanent magnets," *3rd Spacecraft Propulsion Subcommittee Meeting of the JANNAF Interagency Propulsion Committee*, Orlando, FL, Dec. 2008. JANNAF Paper #43.

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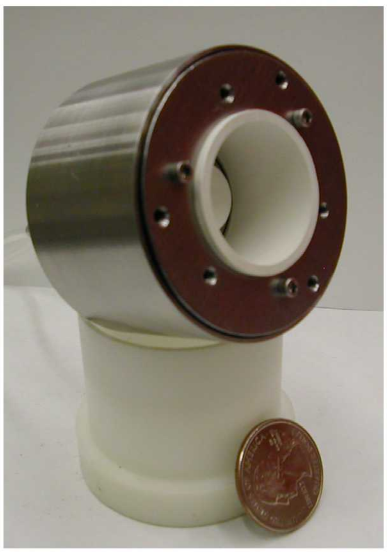

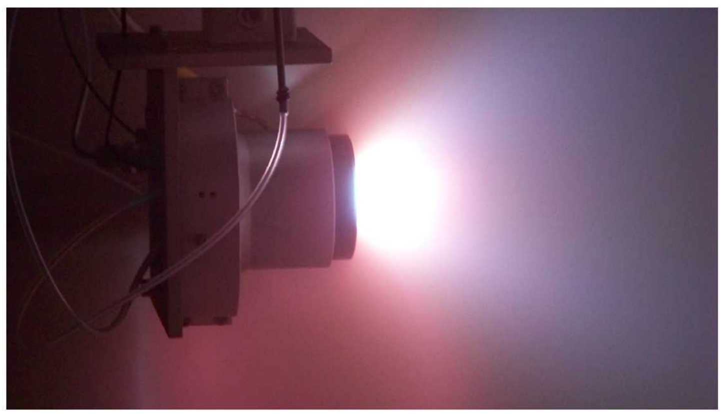

Figure 1. (Left) Laboratory model 2.6 cm CHT with Sm-Co permanent magnets (with US quarter for scale). (Right) Permanent magnet CHT in operation.