Aerospace Europe Conference 2023
Joint 10th EUCASS – 9th CEAS Conference

Abstract #XXX *(to be filled by the organizers)*
Preferred Topics: PROPHY
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Type: Oral
Status of corresponding author: Student
For student corresponding author: student member of one of the following:

Title

An Experimental Setup for the Performance Analysis of Low-Power Hollow Cathodes at High Applied Magnetic Field Strengths

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Abstract

As demand for cheaper and more efficient space access increases, applied-field magnetoplasmadynamic thrusters (AF-MPDTs) operating in a low-discharge current regime enabled by high applied magnetic field strengths promise to become a viable technology for future LEO and deep-space missions [1]. A research project in New Zealand funded by the New Zealand Ministry of Business, Innovation and Employment (MBIE) aims to design and build such a low-power AF-MPD thruster utilizing high-temperature superconducting (HTS) magnets with applied magnetic field strengths greater than 500 mT [2].

As a vital component of an AF-MPD thruster, the cathode acts as the source of the electrons needed to ionize the propellant gas and turn it into plasma. Where conventionally, a solid rod is used in AF-MPDTs, hollow cathodes (HCs) with a thermionic emitter are a more promising source of electrons at lower current levels. While hollow cathodes have been investigated extensively for propellant ionization and beam neutralization of both Hall effect and ion thrusters [3], little to no research has been conducted on their utilization as an on-axis electron source for an AF-MPDT. As a result, it is unclear how a HC performs when subjected to an axially applied magnetic field.

To investigate this, an experimental setup to test hollow cathodes at high applied magnetic fields in a space environment has been designed and commissioned at the University of Auckland Space Institute. The setup consists of a vacuum chamber and turbopump that can reach pressure levels down to 10^{-7} Torr. Three power supplies connected to a high voltage power feedthrough allow testing of the cathode in both a 'diode' standalone mode and a 'triode' mode with an anode to simulate the thruster environment. The cathode is placed on axis of a magnetic coil that can reach field strengths of up to 600 mT. Type C thermocouples are used to measure high temperatures of up to 2000 °C at various points of the cathode. Different plasma diagnostic tools find application in determining relevant plasma parameters of the plume, such as electron density and temperature.

In this paper, we will present the results of initial experiments involving a parametric study using a commercial HC to quantify the impact of different parameters on its operation. From there, scaling laws for the cathode performance in dependence on the magnetic field strength are derived and presented. In the future, experimental results will also be used to validate simulation data. This will allow to design and test a novel hollow cathode optimized for usage at high applied magnetic fields. Furthermore, the impact of the magnetic field strength on the erosion and degradation of the cathode will be analyzed. The outcome of these experiments will give insight into the feasibility of utilizing a hollow cathode in a high applied-field MPD thruster with HTS magnets for future space missions.

References

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