INVESTIGATION OF MAGNETOFLUIDDYNAMIC ACCELERATION OF SUBSONIC INDUCTIVELY COUPLED PLASMA

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Magnetofluiddynamics (MFD) is the interaction between the flow dynamics of electrically conductive fluids and applied electromagnetic fields. Some of the better-known research areas of MFD are on-orbit electric propulsion systems, hypersonic boundary layer flow control, heat flux reduction for re-entry vehicles, augmentation of ground test facilities and scramjet enhancements for innovative hypersonic vehicle designs. There are still unresolved issues regarding the mechanism by which conducting fluids are accelerated and about the effectiveness of the energy coupling via Lorentz forces. Some studies have indicated that acceleration may be due more to ohmic heating by electrical discharge than electromagnetic and fluid dynamic coupling. The von Karman Institute (VKI) has completed an investigation of MFD acceleration of a subsonic inductively coupled plasma (ICP) flow to provide knowledge of MFD device operation in subsonic flow for possible future applications. The goal of this investigation was to perform a fundamental analysis of the physical characteristics of the conducting fluid and MFD device performance as suitably arranged electric and magnetic fields were imposed.

One-dimensional MFD modeling was used to determine the necessary performance requirements of the MFD accelerator channel electric and magnetic field subsystems. The final design (see Figure 1) had an interaction parameter of approximately 2.25 and was designed to double an inlet velocity of 300 m/sec. The required electric field for this acceleration was a current density of 6 A/cm^2 with a magnetic field strength of 0.50 T for a channel length of 0.1 m. The most critical design constraint was the thermal management subsystem which was needed to overcome large heat fluxes while enabling the operation the MFDA channel for 10 minutes at thermally stable conditions.

The dynamic pressure measurements showed an increase of the inlet velocity of 105% for argon plasma flowing at measured mass flow of 1.01 g/s and magnetic field strength of 0.49 T (see Figure 2). This strong acceleration of the plasma was most notable near the electrodes at the outer edge of the axisymmetric channel. The central region of the plasma showed less dynamic pressure increase, corresponding to only a maximum of 15% increase in velocity at a magnetic strength of 0.49 T; it is expected that this is due to the limited penetration of the DC discharge toward the center from the annular electrodes. Experimental results showed that axial discharge voltages increased with increased magnetic field, indicating a strong Hall Effect in the accelerator as expected. Experimental force fluxes were compared to the calculated values of the one-dimensional equation of motion and momentum equation. This analysis showed clearly the need to include joule heating in the formulation of the problem. This was the first successful magnetofluiddynamic acceleration of an ICP source and validates the proof of concept.

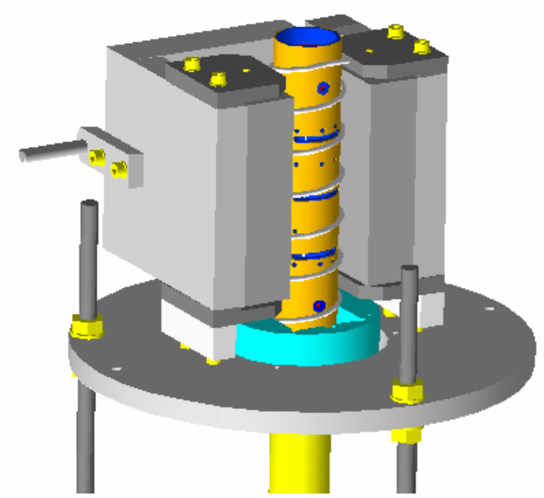

Figure 1: Drawing of the MFD accelerator channel

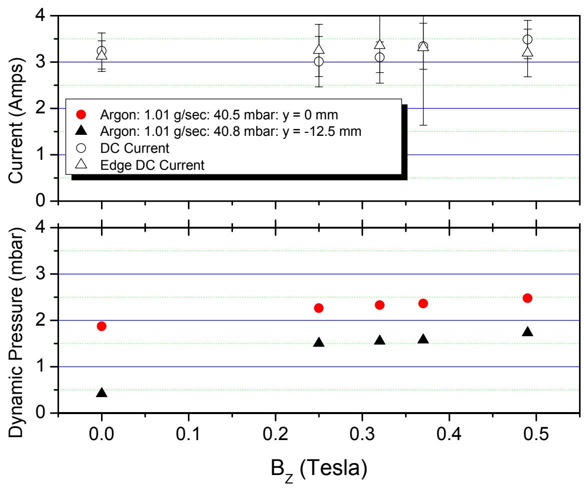

Figure 2: Dynamic pressure increase for various magnetic fields at two spatial locations