Ion-Injected MagnetoHydroDynamic Duct Drive (IIMHD-Drive): Extended Theoretical Framework (Version 2.0)

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Abstract

This document presents an extended theoretical model for the Ion-Injected MagnetoHydroDynamic Duct Drive (IIMHD-Drive), a fully electric gas-acceleration concept based on pre-ionization and Lorentz-force MHD interaction inside a duct geometry. Version 2.0 refines the mathematical derivations, adds architecture structure, and integrates a conceptual block diagram illustrating the system flow.

1 System Architecture

The IIMHD-Drive consists of four conceptual subsystems: (1) neutral gas inlet, (2) pre-ionization region to increase conductivity, (3) an MHD duct where $\mathbf{J} \times \mathbf{B}$ accelerates the gas, and (4) a nozzle or outlet section shaping the exhaust into a jet flow.

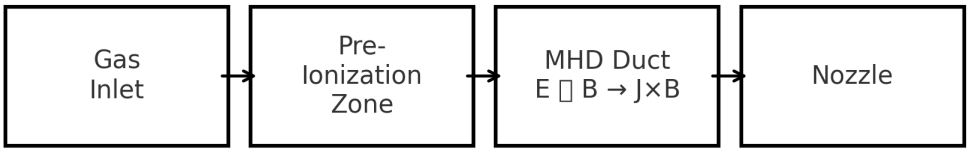

Figure 1: Conceptual block diagram of the IIMHD-Drive. Neutral gas enters, becomes weakly ionized, is accelerated electromagnetically inside the duct, and exits as a directed jet.

2 Theory

2.1 Lorentz Force

The core acceleration mechanism is the MHD Lorentz force density:

$$\mathbf{f} = \mathbf{J} \times \mathbf{B}.$$

2.2 Ohmic Approximation

Assuming an effective Ohmic response in partially ionized gas:

$$\mathbf{J} = \sigma \mathbf{E}.$$

2.3 Net Force Approximation

Integrating over the acceleration volume:

$$\mathbf{F}_{\text{total}} \approx \sigma_{\text{eff}} \left(\mathbf{E}_{\text{eff}} \times \mathbf{B}_{\text{eff}} \right) V_{\text{eff}}.$$

3 Momentum Relation

$$\mathbf{F}_{\text{total}} \approx \dot{m} \, \Delta \mathbf{v}$$

which yields the propulsion-relevant exhaust velocity increase:

$$\Delta v \approx \frac{\sigma_{\text{eff}} (\mathbf{E}_{\text{eff}} \times \mathbf{B}_{\text{eff}}) V_{\text{eff}}}{\dot{m}}.$$

4 Exhaust Kinetic Power

$$P_{\text{kin}} = \frac{1}{2} \dot{m} (\Delta v)^2.$$

5 Conclusion

This Version 2.0 document provides a structured theoretical framework for the IIMHD-Drive, including simplified governing equations and a conceptual diagram. It is intended as an Open Science reference and prior-art description for future numerical and experimental investigations.