UEDGE Simulations of a Direct Fusion Drive FRC Rocket
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OBJECTIVES
- Evaluate the field-reversed configuration (FRC) for use as a direct fusion drive rocket engine. Determine the expected values for thrust, specific impulse, and propulsion efficiency as a function of gas and power inputs.
- Develop an understanding of plasma parameters and determine what value of gas input will maximize thrust for a given power input.

BACKGROUND: FRC AS A ROCKET
- An FRC rocket could be used for manned or unmanned space exploration within the solar system, beyond the range of chemical rockets.
- Chemical rockets are not fast enough to reach a comet and change its trajectory. An FRC used as a rocket could do so.

BACKGROUND: SCRAPE-OFF LAYER (SOL)
- Pictured below is a schematic of an FRC with an asymmetric SOL used for direct-fusion drive.
- Propellant gas (Deuterium) is injected into a gas box, as shown on the left. Plasma formed in the gas box is heated by fusion products from the FRC core as it flows along the SOL. The heated plasma is then ejected out a magnetic nozzle at the opposite end, generating thrust.

GAS BOX PARAMETERS
- 1MW, 0.05 grams/sec
- 1MW, 0.08 grams/sec

ROCKET PERFORMANCE
- \( T \) is the specific impulse
- \( \eta \) is the specific exhaust
- \( \eta \) increases with \( G \)
- \( \text{Specific Impulse decreases with } G \)

SIMULATION METHOD
- This work was done using UEDGE, a 2-dimensional transport code. The code was written by Tom Rognlien et al. at LLNL. A magnetic field geometry created by Bruce Cohen was used to simulate an FRC SOL
- The code solves multi-fluid equations for plasma variables, as well as the Braginskii transport equations. The code produces steady state solutions.

ANALYSIS
- As the gas input \( G \) increases, the plasma in the gas box transitions from an attached state to an detached state.
- In a detached state, high recombination rates in the gas box create a cold gas blanket on the gas box surfaces and hence lower power flow to the material surfaces (gas box and wall) of the FRC.
- If less power flows to material surfaces, more power must flow out of the open end of the FRC. Thus, detachment and the associated decrease in power to the gas box is the mechanism for increasing \( \eta \).

HIGHER GAS INPUT TO THE GAS BOX IMPROVES PERFORMANCE
- Higher gas input is associated with higher thrust, higher efficiency, and less power to material surfaces.
- There is a tradeoff between thrust and specific impulse.
- A direct fusion drive FRC rocket could expect 5-10N of thrust per MW of SOL heating power.

REFERENCES AND ACKNOWLEDGEMENTS

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