Plasma Arc Centrifuge for Low Capital Cost Water Plasmolysis

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Abstract: In this contribution, we investigate the dissociation of water vapor in a plasma arc centrifuge; centrifugal forces enable rapid mass-based separation of the dissociation products, preserving them even under low quenching rates. Using a prototype system, we plan to optimize the radial plasma velocity profile to improve hydrogen production efficiency and position the plasma arc centrifuge as an alternative hydrogen production method.

1. Introduction

We investigate water plasmolysis in a system with weakly-ionized plasma rotating in crossed E × B fields - a plasma arc centrifuge. Chemical dissociation is driven by the plasma arc, and strong centrifugal forces created by the rotation separate the gas species by mass. Water vapor in the system is dissociated and the resulting hydrogen and oxygen is simultaneously separated. The rapid physical separation of the reaction products can reduce recombination rates and maintain dissociation products despite low quenching rates [2]. The plasma arc centrifuge could provide a low capital cost alternative to existing hydrogen production methods, such as the electrolysis of water.

Previous studies have investigated plasma centrifuge systems [2-4]. This work aims to expand upon previous studies on the dissociation of water vapor in a plasma arc centrifuge.

2. Methods

Figure 1 shows the prototype plasma centrifuge system under development. Water vapour is fed into a vacuum chamber at a pressure of 10-20 torr. Concentric ring electrodes create a radial arc plasma and copper coils around the vacuum chamber create an axial magnetic field. Two pressure sensors measure the pressure along the central axis of the chamber and along the outer radius. A Fabry-Perot Interferometer is used to determine the rotational velocity of the neutrals in the plasma using the doppler shift of the spectral lines in the light emitted by the particles. The output gases are then analyzed by a residual gas analyzer.

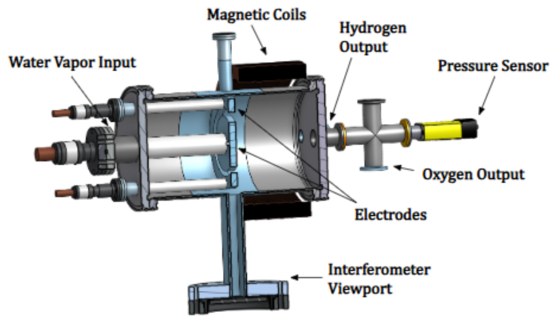

Fig. 1. Prototype plasma arc centrifuge under development for experimentation.

3. Results and Discussion

In their paper, Korobstev et al. [2] investigated water vapor dissociation in a plasma arc centrifuge. The overall energy efficiency of hydrogen production reported was 6%, with high neutral gas temperature being the main source of inefficiency. This work aims to improve this efficiency through optimization of the radial velocity profile to (1) minimize viscous heating and (2) promote shear layer collisions between water molecules to overcome the enthalpy of the water dissociation reaction (2.6 eV)[1].

A 10-20 torr plasma centrifuge system has been designed along with bitter magnetic coils capable of delivering a 0.5 T axial magnetic field. Lanthanated tungsten cathodes and graphite anodes have been machined and tested to withstand the experimental environment. Preliminary experiments are underway to validate the design and operational parameters of the system.

4. Conclusion

The plasma arc centrifuge is a promising alternative, low-capital cost method of hydrogen production for water dissociation. Korobstev et al. [2] have previously demonstrated high separation factors and high degrees of conversion despite low cooling rates, but a low hydrogen production efficiency of 6%. By optimizing the velocity profile to mitigate viscous heating and promote rotationally-driven collisional dissociation, this work seeks to improve upon this efficiency and position the plasma arc centrifuge as a commercially viable alternative to conventional hydrogen production systems.

References

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