Magnetically assisted effect in a warm plasma reactor for GHG reforming

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Abstract: In this work the interaction of a magnetic field in the rotation speed of a warm plasma is presented. The warm plasma is created by a high frequency electrical field; an electromagnetic field is transversally applied to produce a Lorentz force achieving a centrifugal acceleration difference between ionized spices, getting the separation of hydrogen from carbon monoxide during the greenhouse gases reforming. An analysis of the estimation of the heating value of the gas obtained and the effect of the application of the magnetic field is presented.

Keywords: warm plasma, magnetic acceleration, GEI treatment.

1. Introduction

Plasma centrifuges have been investigated for decades as a possible method for separating isotopes or chemically similar elements. This is achieved by using electromagnetic forces to accelerate the ionized gas [1]. Vacuum arc centrifuges are devices that operate with a base pressure of 10^{-5} Pa and range of kW of power. In contrast, partially ionized plasma centrifuges operate at 10^2 Pa gas pressure and a low power range (10^2 W) [2-3]. This type of centrifuges does not require expensive devices, such as lasers and high vacuum systems and can be cost effective in the separation of gaseous isotopes [4] or ions with different mass unit; therefore, the performance of a ionized plasma centrifuge can be easily predicted for various types of discharge structures or electrode geometry in the reactor.

The plasma reactor remains unmoving, only the arc column rotates by Lorentz force in a stationary discharge chamber. This can be accentuated by the presence of a transversal magnetic field (B) applied on the arc current, and it is possible to achieve extremely high rotation speeds that reach up to 2.5 km/s. Consequently, the mass separation of gaseous mixtures or isotopes of chemical elements can be carried out efficiently in a ionized arc column [4].

, Currently research in the conversion of greenhouse gases (GHG), such as carbon dioxide (CO_2) and methane (CH_4), for its recovery of *syngas* composed of hydrogen (H_2) and carbon monoxide (CO) [5-8] particularly when H_2 reaches a high concentration [9].The chemical reaction of GHG reforming is presented in Eq. (1). For this reason, it is proposed to study the effect of the magnetic field on the speed of rotation of a warm plasma discharge. The heating value of byproducts as a function of the applied magnetic field is also analyzed.

$$CO_2 + CH_2 \rightarrow H_2 + 2CO \qquad (1)$$

2. Experimental set-up

Fig. 1 presents the experimental design used to study the effect of a magnetic field B applied transversely to a warm plasma discharge. The warm plasma torch has a gas inlet vortex effect reported in [10]. A post-chamber with a central outlet and a tangential outlet is added, with the purpose of analyzing the concentration of gases in both outlets. The gas concentration was analyzed with a Cirrus MKS mass spectrometer. The magnetic field was measured with a Hall Effect Gaussmeter 5100 series of FW Bell. The electrical current and voltage signals from the plasma were recorded with an MSO2024 oscilloscope from Tektroniks ™.

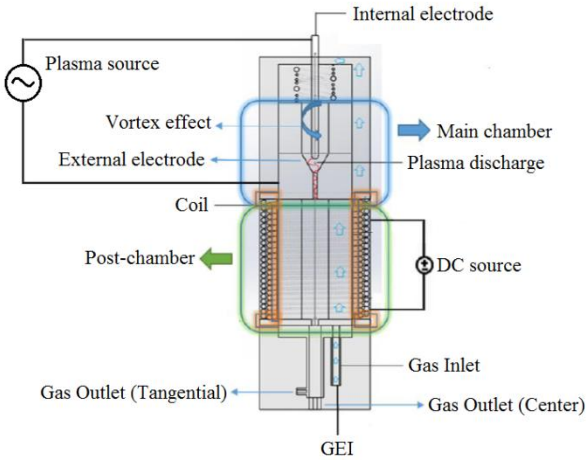

Fig. 1. Experimental set-up

3. Results and discussion

To estimate the speed of rotation of the plasma, the plasma voltage signals were recorded at high frequency as well as the voltage waveforms during gliding time of a discharge (minimum voltage) to its extinction (maximum voltage), that is, the gliding time called T_{des}. Fig. 2 illustrates these waveforms. Additionally, Fig. 3 shows the variation of T_{des} as a function of the magnetic field B. Assuming that each plasma discharge travels the same path, and considering the physical dimensions of the reactor, the angular velocity (ω) of the plasma can be estimated in function of B generated by the coil that covers the post-camera. This result is presented in Fig. 4.

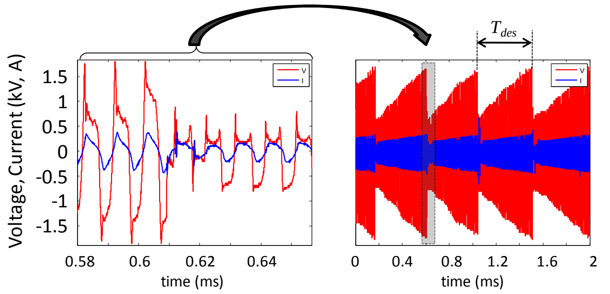

Fig. 2.Variation of plasma voltage and T_{des} measurement.

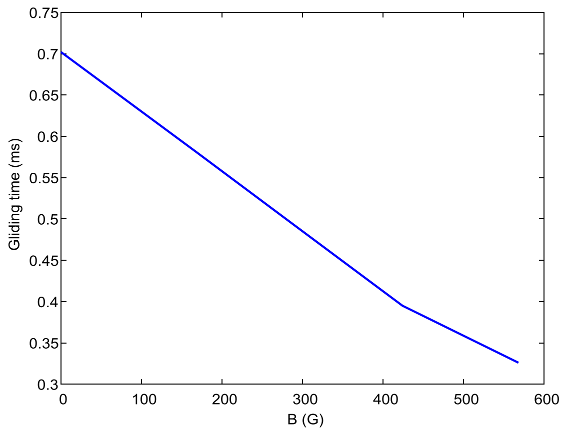

Fig. 3.T_{des} as a function of B.

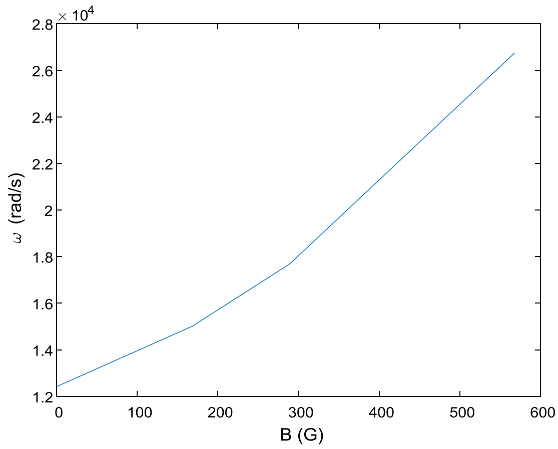

Fig. 4.Angular speedas a function of$B$.

Knowing ω, we can estimate the centrifugal force Fc of each species i with mass m by Eq. 2:

$$Fc_i = m_i \cdot \omega \cdot r \tag{2}$$

Where r is the radius of the Fc.

This means that each ion will experience a different centrifugal force due to its mass difference, thus favoring its separation in function of B.

On the other hand, for the GHG reforming analysis, a mixture of nitrogen (N_2) and GHG in a 1:1:1 ratio of N_2, CH_4 and CO_2 was applied, maintaining a constant flow of the mixture of 15 LPM and applying 700 W to the power supply of the plasma discharge.

The evolution of the species during the GHG reformation was recorded with a mass spectrometer as a function of the applied magnetic field. Applying the calculations described in [6], the values of 34.94% and 9.45% were obtained for conversion of CH_4 and CO_2, respectively. In the same way the yield of by-products was calculated, being 10.08% and 6.13% for CO and H_2, respectively.

With the concentration values obtained, the heat value was calculated as a function of B, both for the gases in the center outlet and in the tangential outlet of the reactor post-chamber. The results are presented in Fig. 5, where it is observed that in the central outlet, the heat value of the exhaust gas mixture is greater with respect to the tangential outlet. This is due to the fact that particles with a greater atomic mass have a higher centrifugal acceleration and therefore are greater in the tangential output, while particles with a lower atomic mass, such as H_2, have a lower centrifugal acceleration and therefore remain with greater proportion at the center outlet, H_2 being a gas with a higher heat value than other species.

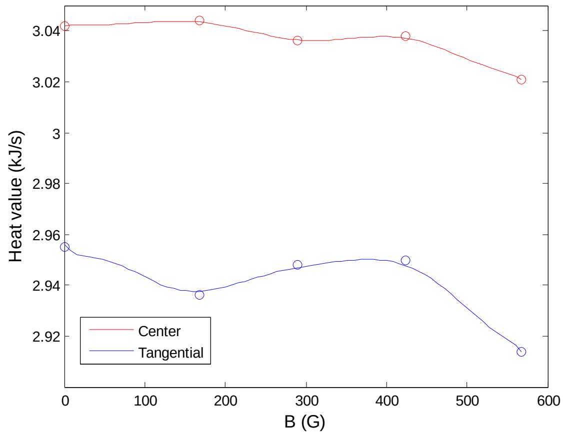

Fig. 5.Heat value as a function of B for both outlet, center and tangential.

Additionally, the ratio between the heat value of the center outlet and the heat value of the tangential outlet was calculated. The result is presented in Fig. 6. In this figure it is observed that without applying magnetic field (B=0 G), with the vortex effect of the reactor a 2.9% increase in the heat value of the center outlet with respect to the tangent output. When the magnetic field is applied, it is observed that an increase of up to 3.7% is obtained in values of 150 and 580 G for B. This indicates an increase of approximately 0.8% of the heat value of the reactor center outlet when the magnetic field is applied to increase the centrifugal force of the ionized particles.The values in the range of 200 to 500 G for B, where the ratio of the calorific value is low, indicate that there are lapses where the synchrony between the magnetic field and the electric field of the plasma is not optimal.

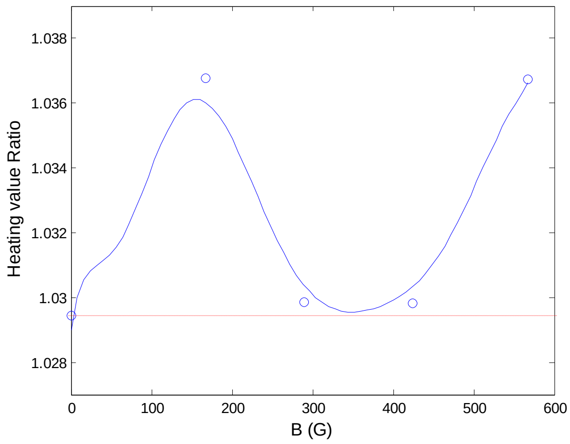

Fig. 5.Heat value ratio as a function of *B*.

4. Conclusions

The GHG reformation was carried out using warm plasma. By means of a vortex effect in the reactor and two gas outlets (one central and one tangential) it was demonstrated that the separation of species by mass difference is possible, achieving an increase in the total heat value of 2.9% in the outlet center with respect to the tangential outlet (considering all the species in each gas outlet).

By applying a magnetic field perpendicular to the electric field of the plasma, Lorentz forces are generated to accelerate the ionized particles and further promote their separation by mass difference. With the applied magnetic field an additional increase of 0.8% in the calorific value was obtained at the central outlet of the reactor.

For optimal results it is suggested to synchronize the plasma power supply with the coil power supply in order to increase the Lorentz force and, therefore, also the centrifugal acceleration.

5. References

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