Performance Assessment of a Flexible 2D Gliding Arc Plasmatron Technology for CO_2-free Methane Reforming into Hydrogen and Valuable By-Products

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Abstract: An atmospheric-pressure, 2D gliding arc plasmatron with diverging electrodes and argon as the carrier gas was investigated for the clean reforming of CH_4 into H_2 and valuable by-products, primarily C_2H_2 and carbon-based powders. In this work, we have evaluated the effect of several operating parameters on the performance of the process, achieving a maximum CH_4 conversion rate of 87.4% and a minimum energy cost of 14.3 kJ/L_{CH4}.

1. Introduction

The growing need for clean technologies to maintain our activities while reducing our environmental footprint calls for the adoption of CO_2-free fuels. However, this energy transition can be achieved only if the production and storage processes of said fuels become sustainable. In this context, plasma-assisted reforming processes of several hydrocarbon feedstocks, and particularly of CH_4 [1], into H_2 are currently being extensively investigated.

In this study, a DC constant-current 'warm' gliding arc discharge was tested for the reforming of CH_4 under non-oxidative, atmospheric-pressure conditions. The home-made reactor featured a planar design with two electrodes spaced by a 3 mm minimum gap, diverging at a 30° angle.

2. Methods

Our experimental window was defined (i) to account for the boundaries of the reactor, which was specifically designed with large viewports to allow further optical diagnostics, and (ii) to evaluate the effect of the fixed current intensity (I_D), the total gas flow (Φ, 5-15 L min^{-1}) and its CH_4 content (10-50% in Ar) on the process conversion rate (χ) and energy cost (EC).

These performance criteria were evaluated through the quantification of the remaining CH_4 fraction in the downstream using FTIR spectroscopy, which could also detect C_2H_2 as a by-product. Gas chromatography measurements delivered the H_2 fraction, and a wattmeter provided the total electricity consumption of the operation, allowing for an estimation of the EC.

3. Results and Discussion

The preliminary tests allowed to identify two discharge regimes differing by the plasma energy density, which may be tuned by raising I_D and/or lowering Φ (Fig. 1). A turquoise flame was typically obtained at low values of the energy density, while a brighter yellow flame appeared as the energy density increased.

The maximum χ achieved reached 87.3%, for an EC of 23.7 kJ/L_{CH4}, as the operating conditions were set to optimize the flame temperature (maximum CH_4 dilution and I_D, minimum Φ). Just by lowering I_D, the EC could be reduced to 14.3 kJ/L_{CH4} while maintaining χ above 84% (comparable to other studies using such dilutions [2]).

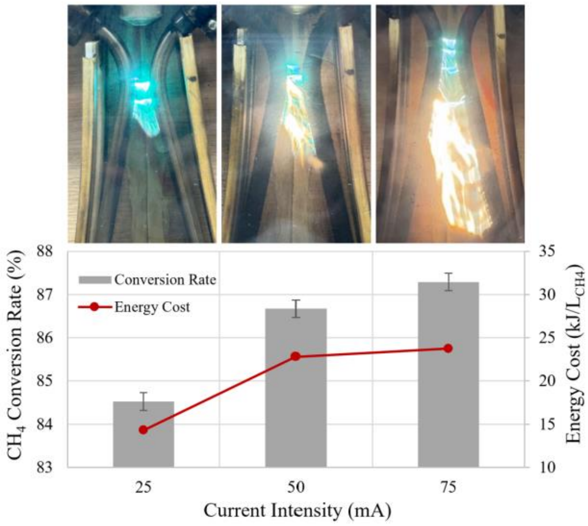

Fig. 1. Evolution of χ and EC as a function of I_D (Φ = 5 L min^{-1} and the composition is 10% CH_4 in Ar).

4. Conclusion

We show that our process can reform CH_4 at a quite high feed flow on a lab scale, with reasonably good efficiency [3]. The opportunity to tune the discharge regimes with the operating parameters hints at the possibility to develop a versatile technology that could deliver H_2 and tailored by-products.

Future works will include optical investigations of the flame temperature and key plasma species densities.

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References

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