Impact of Swirl Flow Intensity on Hydrogen Production in Rotating Gliding Arc Plasma

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Abstract: This study examines the effect of enhanced arc rotation in a Rotating Gliding Arc (RGA) reactor on hydrogen (H_2) production. The improvement is achieved by reducing the swirl hole diameter from 1.6 mm to 1 mm, enabling the destruction of methane with nitrogen as a diluent. At 5 SLPM, the 1 mm swirl hole yields higher H_2 production (4.8%) compared to 1.6 mm (4.1%) due to better mixing. However, as flow rate (Q) increases, H_2 production decreases due to reduced residence time. The percentage error in H_2 production between the two diameters is also highest at 5 SLPM.

1.Introduction

Hydrogen (H_2), a clean fuel, is widely used in fuel cells, internal combustion engines, and gas turbines [1]. Globally, 98% of H_2 is produced from fossil fuel reforming, with approximately 50% derived from steam–methane reforming coupled with water-gas shift reactors, 30% from oil/naphtha reforming, and 18% from coal gasification using oxygen and steam. Non-thermal plasma enables low temperature by generating reactive species that reduce the energy barrier is new technology for H_2 production by destructing hydrocarbons [2]. The Rotating Gliding Arc (RGA) reactor excels in efficiency and scalability for high-flow applications, using tangential gas injection to create a swirling flow [3]. This study quantifies how varying swirl hole diameter i.e., 1.6 mm and 1 mm and flow regimes influence the H_2 production using RGA with methane (CH_4) and (N_2) as diluent gas.

2. Methods

The RGA reactor consists of a quartz cylinder (40 mm ID, 80 mm height) with aluminium electrodes as shown in Figure 1, with smallest gap (δ = 3 mm) and largest gap (Δ = 14 mm) and tangential gas injection (1.6 mm and 1 mm) for vortex formation [3]. CH_4 and N_2 flow was controlled using an Alicat mass flow controller. Plasma discharge was powered by an AC supply (20 kV, 18.9 kHz) and monitored with Tektronix probes and an oscilloscope. Arc dynamics were analyzed using a synchronized high-speed camera. Gas temperature (Tg) was measured via optical emission spectroscopy, and products were quantified using a gas chromatograph with TCD and FID detectors.

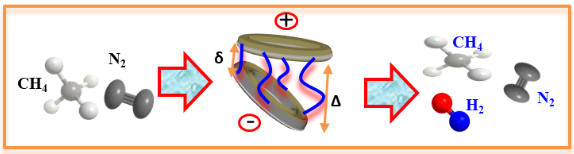

Fig.1 RGA electrode configuration.

3. Results and Discussion

Figure 2 shows H_2 production and percentage error in a RGA reactor using CH_4 and N_2 for two different swirl hole diameters of 1.6 mm and 1 mm across Q (5–50 SLPM). Hydrogen concentration decreases with increasing flow rates, with the 1mm swirl hole achieving higher H_2 production (4.8% at 5 SLPM to 2% at 50 SLPM) compared to the 1.6 mm swirl hole (4.1% to 1.8%). Compared to 1.6 mm, 1 mm have higher H_2 production due to higher mixing and higher turbulence. The higher rotational speed in 1 mm compared to 1.6 mm allows gases to spend more time within the plasma zone and promoting more efficient chemical reactions for CH_4 conversion. The right Y-axis represents the percentage error between the two swirl hole diameters, which is higher at 5 SLPM (17.1%) compared to 50 SLPM (11.1%).

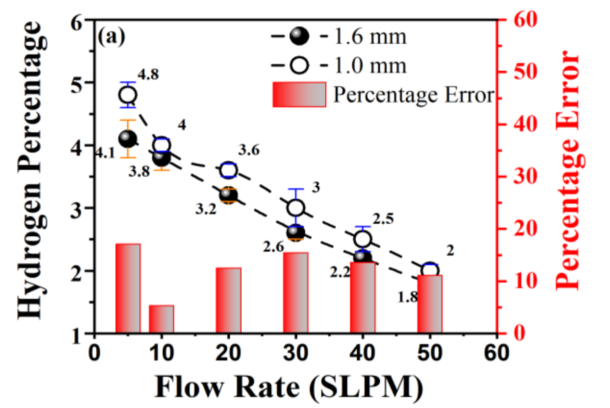

Fig.2 Variation of hydrogen percentage with flow rate for 1.6 mm and 1 mm swirl hole diameters along with their percentage error.

4. Conclusion

Investigation of H_2 production using RGA reactor with two different swirl hole diameters shows that reducing the diameter results in increased H_2 production. The smaller 1 mm diameter enables a higher rotational frequency, improving spatial homogeneity within the plasma. This enhancement fosters more consistent product quality and facilitates better interaction among species in the plasma, promoting more efficient chemical reactions.

Acknowledgement

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References

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