Comprehensive analysis of gliding arc discharge in H_2/Ar and H_2/N_2 gas mixtures for plasma-induced hydrocarbon cracking

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Abstract: As plasma is proposed as one of the heat sources for the electrification of chemical processes, studying the characteristics of hydrogen plasma becomes essential to ensure effective heat transfer and suppress solid carbon formation in these processes. In this study, the role of hydrogen in arc development was analyzed by comparing the discharges of H_2/Ar and H_2/N_2 gas mixtures.

1. Introduction

As solutions to global warming, which poses a grave threat to humanity, the use of carbon-free fuels, renewable energy, and electrification of processes has been proposed. In particular, electrification supplies heat for industries via electricity, eliminating CO_2 emissions at the source[1].

Plasma-based electric heat generation provides high-temperature conditions that conventional combustion processes cannot achieve and offers higher energy density compared to traditional electric heaters[2]. However, in hydrocarbon conversion processes, the use of plasma can lead to issues such as solid carbon formation and low thermal efficiency. Hydrogen plasma, with its high heat generation and reactivity, offers a promising solution to address these challenges. In this study, the characteristics of hydrogen discharge were experimentally investigated. A 2D gliding arc reactor system was constructed to facilitate the observation of the discharge. Additionally, to analyze the role of hydrogen in the plasma, the discharge gases were compared using H_2/Ar and H_2/N_2 mixtures.

2. Methods

The gliding arc reactor was equipped with a quartz observation window, which enabled optical diagnostics such as high-speed imaging and optical emission spectroscopy. The device used to generate the gliding arc was an AC plasma power supply (ARC-6K, Dawonsys), and the arc discharge was operated at a frequency of 20 kHz. An oscilloscope system, including voltage and current probes, was configured to measure the electrical signals of the high-frequency AC arc. Additionally, it was synchronized with a high-speed camera.

3. Results and Discussion

The superimposed image in Figure 1 illustrates the arc formation process captured using a high-speed camera. This image was taken in a gas mixture composed of 50% hydrogen and 50% argon. Figure 2 presents a graph of the arc power/length(P/L) values, calculated by correlating the length of each arc image measured using high-speed imaging with the power measured at the same instant. It can be observed that the P/L values differ depending on the discharge gas, even when the arc length is the same. Additionally, the P/L variation just before the extended arc extinguishes also differs.

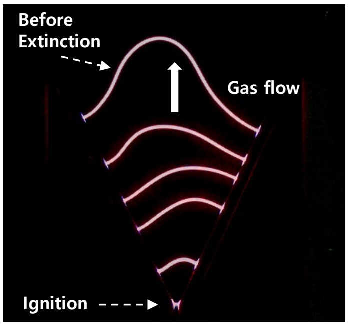

Fig. 1. Superimposed image of the gliding arcs

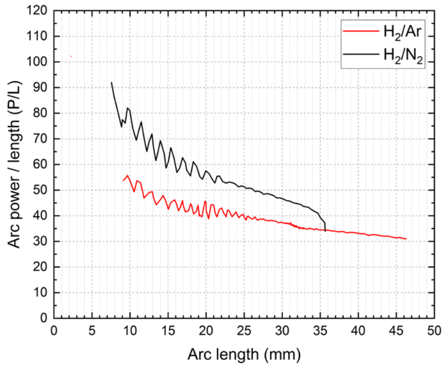

Fig. 2. Calculated P/L versus arc length for discharge gas

4. Conclusion

We compared the discharges of H_2/Ar and H_2/N_2 gas mixtures through high-speed imaging synchronized with electrical signals and OES, as well as GC analysis, to analyze the role of hydrogen in the plasma.

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