Enhanced Flame Stability of Biogas using Dielectric Barrier Discharge Plasma in Inverse Diffuse Flame Burner

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Abstract: In this study, biogas (50% CH_4, 50% CO_2) was reformed using four dielectric barrier discharge (DBD) reactors connected in series, and the resulting product gas was fed into an inverse diffuse flame (IDF) burner. The reformed biogas, containing approximately 5% hydrogen at a biogas flow rate of 1 SLPM, exhibited a flame blow-off limit at an air flow rate of 22 SLPM. In contrast, unreformed biogas at the same flow rate had a flame blow-off limit at an air flow rate of 10 SLPM.

1. Introduction

The use of biogas for combustion is considered as a net zero-carbon process. Biogas is produced by the anaerobic digestion of organic matter (animal manure, food scraps, wastewater, and sewage) by bacteria. It primarily consists of methane (CH_4) and carbon dioxide (CO_2). It offers advantages, including waste valorisation, fossil fuel substitution, and reduced carbon emissions [1].

In this study, a series of dielectric barrier discharge (DBD) reactors was employed to reform biogas into a hydrogen (H_2) enriched mixture. The reformed biogas was subsequently tested in an inverse diffuse flame (IDF) burner to evaluate its performance in comparison to unreformed biogas, with a focus on improving flame stability.

2. Methods

The DBD reactor was constructed using a coaxial steel rod with a diameter of 8 mm and a length of 400 mm as the ground electrode. A quartz tube with an inner diameter of 16 mm and a thickness of 1 mm was used to encase the steel rod, and aluminium foil, 180 mm in length, was wrapped around the quartz tube to serve as the high-voltage electrode. Four such DBD reactors were connected in series, and biogas was reformed into a hydrogen-enriched mixture. The resulting product gas was subsequently fed into an IDF burner to investigate the flame blow-off limit in comparison to unreformed biogas.

The IDF burner consisted of two coaxial concentric steel tubes. Fuel was supplied through an annular port, with the inner diameter of the outer tube measuring 20 mm and the outer diameter of the inner tube measuring 8 mm. Air (oxidizer) was introduced through a central pipe, which had an inner diameter of 6 mm.

3. Results and Discussion

Fig 1 illustrates the air flow rate (at the flame blow-off limit) as a function of the biogas flow rate for reformed biogas with plasma and without plasma reformation in the IDF burner. For plasma reformed biogas, the air flow rate decreased with increase in biogas flow rate due to reduction in H_2 concentration. This decrease in H_2 concentration occurred due to the reduced residence time in the DBD reactor. The reformed biogas, with approximately 5% hydrogen at a flow rate of 1 SLPM, showed a flame blow-off limit at an air flow rate of 22 SLPM. In comparison, the unreformed biogas at the same flow rate had a blow-off limit at 10 SLPM of air.

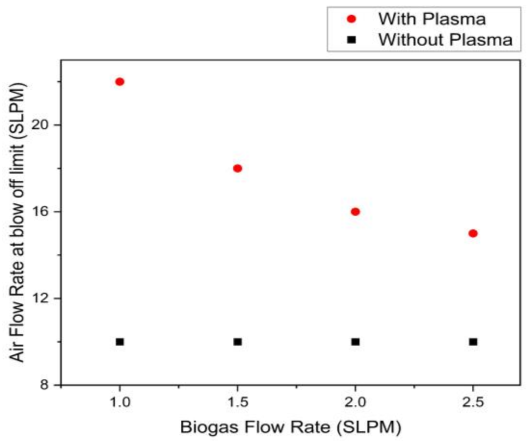

Fig. 1. Variations of air flow rate at blow off limit with biogas flow rate with and without plasma.

4. Conclusion

This study explored plasma-assisted biogas reforming using DBD reactors and evaluated its impact on combustion properties in an IDF burner. Plasma-reformed biogas, enriched with 5% H_2, significantly improved flame stability, with an air flow rate of 22 SLPM at a biogas flow rate of 1 SLPM, compared to 10 SLPM for unreformed biogas at the same flow rate. The enhanced stability is attributed to hydrogen enrichment from plasma reformation. These results demonstrate the potential of plasma-assisted reforming to optimize biogas combustion, offering a promising pathway for cleaner and more efficient energy systems.

Acknowledgement

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References

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