Enhancement of Natural Gas Combustion Characteristics on Axial Burner assisted by Plasma Discharges

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Abstract

This study focuses on increasing flame temperature and improving combustion efficiency in an axial burner through the integration of internal structures known as lateral tree rods and the application of dielectric barrier discharge (DBD) plasma. In-line and staggered lateral tree rods were installed in the air slot of the burner to serve as bluff bodies. The plasma was applied to enhance ignition and accelerate combustion reactions at the molecular level. Natural gas combustion under industrial conditions was investigated using lateral tree rods designed to induce swirling airflow within the burner. The results highlighted that the rods improved fuel–air mixing efficiency. When the bluff body was combined with plasma, charged species such as ozone (O_3) and OH radicals were generated, promoting early flame ignition, enhancing flame stability, and increasing combustion temperature. The staggered lateral tree rods with plasma discharges produced the highest average flame temperature of 1362.5 °C, representing an increase of 67.6 °C. Plasma also increased flame length, particularly when combined with bluff-body structures in both in-line and staggered configurations. This effect was attributed to ozone generation from plasma, which accelerated combustion reactions and promoted expansion of the combustion zone. Furthermore, plasma contributed to improved flame stability; when applied with staggered lateral tree rods, the flame did not blow off at equivalence ratios $\Phi \geq 0.1$. This was due to reactive plasma species, such as atomic oxygen, that enhanced oxidation reactions within the flame. In conclusion, the combination of staggered rods with plasma improved natural gas flame temperature, flame stability, and flammability limits in the axial burner.

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