Effects of Staged Ammonia Injection on Emissions in Methane-Ammonia Co-Combustion

Hsin-Yi Wu[1], Fang-Hsien Wu[1], Ming-Hsun Wu[1*], Jun Hayashi[2]
[1]Department of Mechanical Engineering, National Cheng Kung University, Tainan, Taiwan
[2]Graduate School of Energy Science, Kyoto University, Kyoto, Japan

Abstracts

Co-firing ammonia with methane in industrial heating furnaces offers a promising approach to reduce carbon emissions but often results in elevated NO_X and CO emissions. Inspired by prior success with hydrogen lancing for NO_X mitigation, this study explores staged ammonia injection as a strategy to reduce pollutant formation in methane–ammonia co-combustion. Experiments were performed in a 100 kW furnace (3 m × 0.9 m × 0.9 m) using a commercial burner (Tajun TJ-20) for methane supply. Ammonia was injected via a pair of 45°-angled tubes positioned at the burner port rim, directed toward the furnace centerline. The volumetric blending ratio of ammonia, defined as ammonia to total fuel, including pilot, varied from 0 to 0.56. The global equivalence ratio was maintained at 0.90, with a total heat release of 76 kW, 70 kW from co-fired fuel and 6 kW from a methane pilot flame. Injection velocity was adjusted by tube diameter, and emissions were monitored using a multi-channel NDIR analyzer (MRU Prime).

When 5 vol.% ammonia was introduced, NO_x emissions spiked to over 900 ppm in the premixed case, compared to approximately 400 ppm under the staged injection configuration. NO_X emissions initially increased with ammonia content, peaking at a blending ratio of approximately 0.2, then declined. In contrast, the staged injection configuration achieved substantially lower NO_X emissions across the tested range, with a reduction of nearly two-thirds at a blending ratio of 0.2. While NO_X levels gradually rose with increasing ammonia content under staged injection, they remained significantly lower than in premixed operation up to a blending ratio of 0.36. Moreover, the staged injection effectively mitigated the sharp increase in CO observed at higher ammonia fractions. At a blending ratio of 0.46, NO_X levels in staged injection approached those of premixed combustion, indicating a crossover point in the NO_X–CO trade-off. Flame-zone temperatures were slightly higher with staged injection, but no significant differences were observed in furnace centerline, exit, or wall temperatures in the furnace with water-cooled bottom wall. Further optimization of injection velocity and spatial positioning is underway, alongside the development of reactor network models to elucidate the underlying chemical and fluid dynamic mechanisms responsible for the observed trends.

Correspondence to: minghwu@ncku.edu.tw