NO_x reaction analysis of ammonia flame burner with hydrogen stabilizer

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Ⅰ. Abstract

Ammonia is considered ideal fuel that does not emit greenhouse gases (i.e., CO_2, CH_4 etc.). However, if ammonia is forcibly combusted, a large amount of NO_x (toxic substance) will be generated. For fuel utilization of ammonia, the low-NO_x combustion is required (Kobayashi, 2019, pp.109-133). In this study, NO_x formation/reduction area formed in flame and the rate of reaction are especially identified by using numerical simulation. This study aims to develop a turbulent burner that can simultaneously achieve NO_x reduction.

Ⅱ. Equipment & Calculation method

The burner has a structure of triple tube (Figure 1). In an experiment, a stable flame was obtained by separately supplying ammonia, hydrogen, and air in central, duplex, and triple tubes, respectively (Figure 1). The burner developed in this study can supply a high-velocity airflow (<10 m/s), the velocity could be changed. For the coaxial diffusion flame, another coaxial high-velocity airflow was added to the space between the central fuel jet flow and the surrounding airflow. This additional airflow produced strong turbulence to the flame front area.

Turbulent flows were investigated using Reynolds-averaged Navier-Stokes (RANS) and the Chen model, which was suitable for determining the rapid changes in turbulent flow energy (k) and its dissipation factor (ε). CRECK mechanism (31 species, 203 reactions) (Stagni, 2020, pp. 696-711) is employed to calculate oxidation of ammonia and hydrogen.

Ⅲ. Result & Discussion

Figure 2 shows profiles of temperature and rate of reactions by numerical simulation. The maximum temperature of flame is approximately 2200 K and the low-temperature area formed at inner flame where fuels are not combusted. Figure 2 (c) shows the distribution of NO_x reduction rates reacting with N, NH, or NH_2 radicals. Simultaneously, Figure 2 (b) shows the reaction rates of NO_x formation. When the right and left phenomena are simultaneously examined, the reduction reaction of NO_x is found to intensely generate on the slightly inner side of the high temperature region (i.e., NH_3-fuel rich region), thus inhibiting NO_x increase. NO_x formed by the NH_3 combustion is decreased in the reduction region and the net NO_x formation is prevented since NO_x reduction area

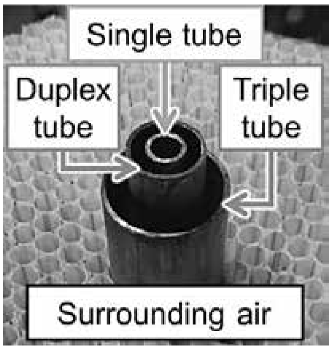

Figure 1. Burner structure (center tube: NH_3, duplex tube: H_2, triple tube: air with high velocity).

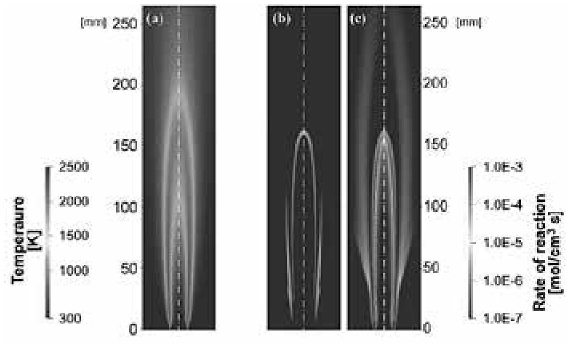

Figure 2. Calculation results. ((a) temperature, (b) rate of NO_x formation, (c) rate of NO_x reduction)

Ⅳ. Conclusion

(1) NO_x formation/reduction areas in flame of ammonia burner with hydrogen stabilizer are identified by numerical simulation.

(2) NO_x formed by the NH_3 combustion is decreased in the reduction region and the net NO_x formation is prevented since NO_x reduction area locates on NO_x formation area. A reduce mechanism by which NO_x is reacted with NH_3 works simultaneously to inhibit increase in NO_x formation.

Ⅴ. References

Kobayashi, H. et al. (2019). Science and technology of ammonia combustion, Proceedings of the Combustion Institute, vol. 37, pp. 109-133.

Stagni, A. et al. (2020). An experimental, theoretical and kinetic-modeling study of the gas-phase oxidation of ammonia, Reaction Chemistry & Engineering, vol. 5, pp. 696-711.