Proceedings of the 10th World Congress on Momentum, Heat and Mass Transfer (MHMT 2025)
Barcelona, Spain – April, 2025
Paper No. CSP 128
DOI: 10.11159/csp25.128

An Experimental Study on NO_X Emission of Hydrogen MILD Flames

GIHYEON LEE[1], KEEMAN LEE[1†]
[1]School of Mechanical and Aerospace Engineering/Center for Aerospace Eng. Research, Sunchon National University, 255 Jungang-ro, Sunchon 57922, Jeollanam-do, South Korea
vrlgus1234@naver.com; kmlee@scnu.ac.kr

Extended Abstract

Due to the rapid increase in global temperatures caused by climate change, efforts toward achieving carbon neutrality have been actively pursued worldwide following the Paris Agreement in 2016 [1]. Most conventional energy sources are hydrocarbon-based, offering high cost-effectiveness but inevitably accompanied by greenhouse gas (CO_2) emissions—the primary driver of global warming. As a solution, hydrogen has gained attention as a promising alternative to conventional hydrocarbon fuels. However, hydrogen fuel poses various risks, including a wide flammability range, high reactivity, and elevated flame temperatures [2], thereby necessitating the development of new combustion techniques that can accommodate these challenges.

MILD (Moderate or Intense Low Oxygen Dilution) combustion, defined by Joannon et al. [3], is known to be highly effective in mitigating nitrogen oxide (NO_X) emissions. By employing a high-temperature, low-oxygen oxidizer, the reaction zone becomes more uniform, eliminating local temperature peaks within the flame and transitioning to a volumetric combustion mode, thereby suppressing thermal NO_X. Despite its effectiveness, there is still a lack of research on the application of MILD combustion to hydrogen fuel. Consequently, this study focuses on adapting hydrogen fuel for MILD combustion, which is characterized by relatively low-temperature operation.

By employing a low-oxygen oxidizer to achieve MILD combustion, the NO_X emission characteristics of hydrogen were investigated. To measure NO_X in the MILD regime, a method from a previous study [4] was referenced, defining delta NO_X as the difference between the NO_X value measured when two zones combust simultaneously and the NO_X value generated in the gas generation zone. In addition, the Emission Index (EI) [5], which is useful for indicating the amount of pollutant produced per unit mass of fuel consumed, was also presented.

As the oxidizer's oxygen concentration decreased, the system approached MILD combustion conditions and delta NO_X decreased. This phenomenon occurs because lowering the oxygen concentration expands the flame reaction zone, transitions it into a more volumetric combustion mode, and thus leads to a more uniform flame temperature distribution, suppressing thermal NO_X formation typically induced by high temperature peaks. Both delta NO_X and $EINO_X$ showed the same trend: NO_X emissions decreased as the oxidizer's oxygen concentration was reduced.

References

[1] UN Climate Change Conference (UNFCCC), "The Paris Agreement", UNFCCC, 2015.
[2] A. Parente, C. Galletti, and L. Tognotti, "Effect of the combustion model and kinetic mechanism on the MILD combustion in an industrial burner fed with hydrogen enriched fuels", International Journal of Hydrogen Energy, Vol. 33, No. 24, 2008, pp. 7553-7564.
[3] A. Cavaliere and M. de Joannon, "Mild combustion", Progress in Energy and Combustion Science, Vol. 30, No. 4, 2004, pp. 329-366.
[4] X. Zheng, Y. Xiong, Y. Liu, F. Lei, and Y. Xiao, "Emission characteristics and visualization of an axial-fuel-staged MILD combustor", Combustion Science and Technology, Vol. 193, No. 15, 2021, pp. 2588-2609.
[5] M. D. Rumminger, "Numerical and experimental investigation of heat transfer and pollutant formation in porous direct-fired radiant burners [Doctoral dissertation]", Berkeley (CA): University of California, Berkeley, 1996.