An Investigation on Combustion Properties of Nitrogen-Enriched Hydrogen-Air Mixtures

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Currently, new concepts for power generation are discussed, as a response to combat global warming due to CO_2 emissions stemming from the combustion of fossil fuels. These concepts include new, low-carbon fuels as well as centralized and decentralized solutions. Thus, a more diverse range of fuel supplies will be used, with (biogenic) low-caloric gases such as syngas, vent gas, and coke oven gas (COG) among them [1-4]. Typical for theses low-caloric gases is the amount of hydrogen, with a share of 50% and even higher. The composition of alternative fuel mixtures differs considerably compared to natural gas (NG). For example, natural gas consists mainly of methane, besides ethane and other lower hydrocarbons; biogenic gas mixtures consist of relatively high amounts of H_2, CO, besides methane, and inert species such as CO_2 and N_2. In particular, hydrogen mixtures have a higher reactivity than natural gas (NG) mixtures, burned mostly in today's gas turbine combustors.

Reliable data of major combustion characteristics like laminar flame speeds are needed, under a wide range of relevant parameters, in order to enable a reliable operation as well as the numerical simulation of the combustion process itself as part of combustor design.

Therefore, in the present work, a combined experimental and modeling study of nitrogen-enriched hydrogen-air mixtures, some of them with a share of methane, to be representative for COG, will be discussed focusing on laminar flame speed data as one of the major combustion properties. Measurements were performed in a burner test rig at ambient pressure and at a preheat temperature T_0 of 373 K. Flames were stabilized at fuel-air ratios between about φ = 0.5 - 2.1, depending on the specific fuel-air mixture.

This experimental database was used for the validation of four chemical kinetic reaction models, including an in-house one, and by comparing to hydrogen-enriched natural gas mixtures [5]. Calculations were performed by using Chemical Workbench [6]. The results will be analyzed and discussed, also with respect to combustion of natural gas in air.

The measured laminar flame speed data of nitrogen-enriched methane-hydrogen-air mixtures are much smaller than the ones of nitrogen-enriched hydrogen-air mixtures. The grade of agreement between measured and predicted data depends on the type of flames and the type of reaction model as well as on the fuel-air ratio: Good agreement was found in the fuel lean and slightly fuel rich regime; a large underprediction of the measured data exists at very fuel-rich conditions (φ > 1.4).

References

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