Proceedings of the 2nd World Congress on Momentum, Heat and Mass Transfer (MHMT'17)
Barcelona, Spain – April 6 – 8, 2017
Paper No. CSP 108
ISSN: 2371-5316
DOI: 10.11159/csp17.108

Stabilizing Ammonia-Hydrogen-Air Premixed Flames Using Porous Medium Based Combustor

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Extended Abstract

The extensive use of fossil fuels has caused serious problems to environment and human welfare. As the problems became noticeably unpleasant, the search for carbon-free alternative fuels gained significant global concern. With its high hydrogen density and already existing production/distribution/storage infrastructure, ammonia (NH_3) is believed to be an excellent green fuel that can be used in energy generation and transportation systems[1]. Combustion of ammonia has certain challenges (associated with its low flame speed and fuel bond NO_x emissions) that need to be thoroughly investigated before its widespread use in practical applications. To address one of the major challenges, an experimental study has been conducted focusing on flame stability of ammonia-hydrogen-air mixtures.

At standard temperature and pressure conditions experiments were carried out for ammonia mixture fractions of 60-90%, equivalence ratios of 0.9-1.5, and mixture inlet velocities of 4-18 m/s (Reynolds number Re = 4500-25000). An inert silicon-carbide (SiC) porous medium based combustor has been designed and used in the experiments. Based on the mixture ratio and flow rate capability of the system, the heating value input of the burner can be as high as 30 kW. A schematic of the setup is presented in Fig. 1.

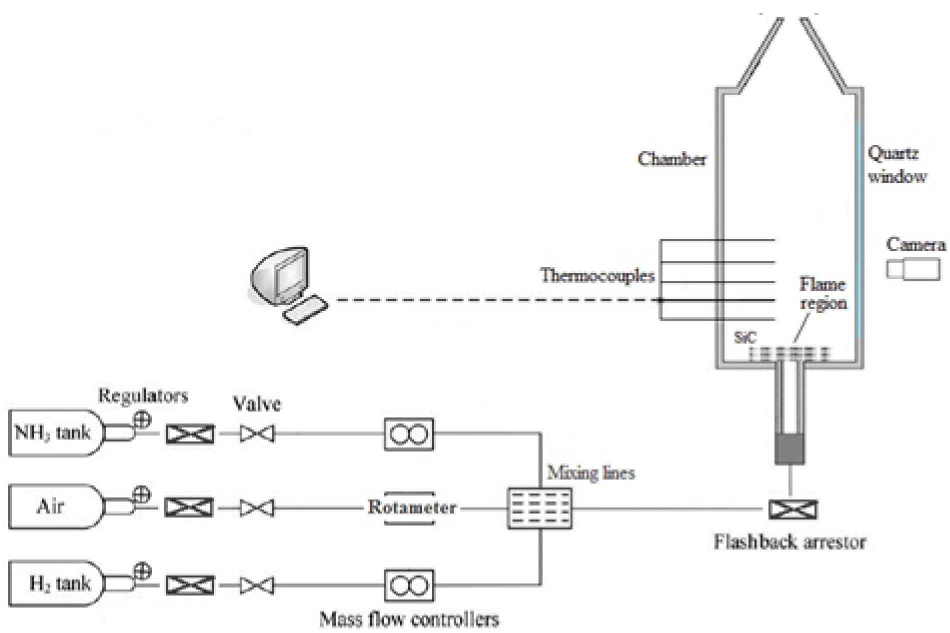

Fig. 1: Setup schematic.

The flame temperature and stability boundaries for the combustor have been identified as functions of NH_3 concentration in the fuel mixture and stoichiometry. Stability maps for the porous medium burners, which can be applied to the design of practical combustors, have been established. It is shown that using this novel combustor concept, high energy loading required for practical applications, can be achieved even at very high NH_3 concentrations in the fuel mixture. It is noteworthy that stabilizing flames with high fractions of ammonia is practically a challenging task regarding low flame speed of ammonia[2]. The porous medium based combustor has shown up to 40% better efficiency in terms of flame stabilizing capability compared to conventional combustor designs such as dump combustor (which is also tested for comparison purposes). In power output framework it is noticeable that the maximum power generation density achieved by the methane-air premixed flame in the same experimental setup with a different flame stabilizing method was 0.45 kW/cm2[3], while the power generation density in the operating range of the current porous medium burners reaches up to 1.1 kW/cm2. Also it is deduced that higher equivalence ratios provide a wider stability region by increasing the upper (blow-off) limit and decreasing the lower (flashback) limit (Fig. 2). This favourable behaviour is rooted in the excess fuel remaining unreacted in the burner which reacts with the ambient air just downstream of the burner postponing the extinction and blow-off.

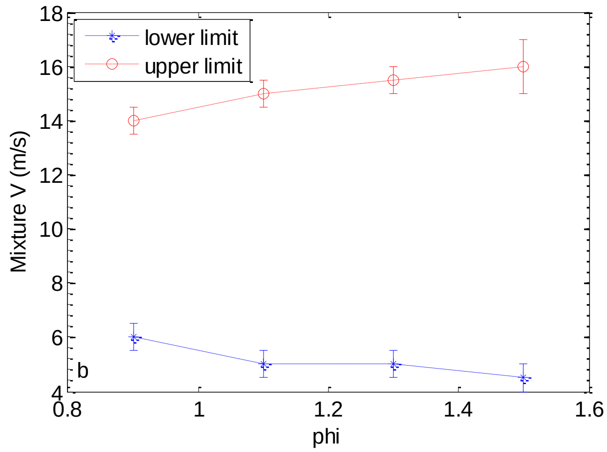

Fig. 2: Flame stability map for 70% NH3 - 30% H2.

We strongly believe that this new porous media based combustor will enable stable and efficient combustion of high NH_3 concentration (90+%) fuel mixtures in the existing power generation systems, e.g. gas turbine engines, requiring minimal modifications. Note that 10% hydrogen can easily be obtained by the partial cracking of NH_3 in the fuel supply system, eliminating the requirement to store a vigorous pilot fuel such as hydrogen or methane.

References

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