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Combustion Characteristics of Ammonia as a Promising Renewable Fuel

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Extended Abstract

Introduced as a renewable energy source in many studies, ammonia (NH3) is known as a potential fuel to be combusted in power engines. With its high hydrogen density and already existing infrastructure, it is believed to be an excellent green fuel that can be used in energy generation and transportation systems. Combustion of ammonia has certain challenges (associated with its low flame speed and fuel bond NOx emissions) that need to be addressed before its widespread use in practical systems. A comprehensive numerical study [1] is accomplished focusing on the major combustion characteristics of ammonia and ammonia-hydrogen flames in a wide range of conditions.

In the first section of the study we investigate the combustion characteristics of ammonia-air and ammonia-hydrogen-air mixtures at elevated pressure and lean conditions which are encountered in gas turbine combustors. Laminar premixed freely propagating flame and homogenous reactor models are used to calculate the combustion properties. The improvement by hydrogen addition to the fuel mixture in the key combustion characteristics such as laminar flame speed and ignition delay time is noticeable. Based on ammonia decomposition sensitivity analysis, it is found that the OH radicals have a leading role in controlling the fuel mole conversion and the laminar flame speed.

The complex chemistry of NO_x formation is highly dependent on the fuel mixture composition which controls the contribution of fuel NO_x and thermal NO_x levels. This could lead to a trade-off situation in choosing the optimum fuel composition for engine applications. The results of sensitivity study of total NO formation with respect to the equivalence ratio reveal the possibility of localized rich combustion as an effective way to reduce the NO concentration down to levels that are the same order as the modern gas turbine engines (Figure 1). In the second part of the study, by considering a wide range of conditions in terms of pressure, fuel mixture, and equivalence ratio we develop two reduced mechanisms [2] based on the Konnov mechanism [3]. The reduced mechanisms are capable of predicting total NO_x emission level and laminar flame speed in an acceptable accuracy under wide range of conditions (Figure 2). Evaluating performance of the reduced mechanisms with respect to the full mechanism and experimental data shows that the mechanisms are able to predict the combustion properties with almost the same accuracy as the full Konnov mechanism and with nearly five times less CPU time expense (Figure 3). As another important section of the study, by using our reduced mechanisms we have performed CFD simulations to investigate the flame characteristics in a basic axis-symmetric burner configuration. As the most critical parameter in practical systems, NO_x formation is carefully taken into account. The effects of mixing and bypass air dilution level on the exhaust emission are investigated. The results are to be compared with experimental data which will be obtained in near future.

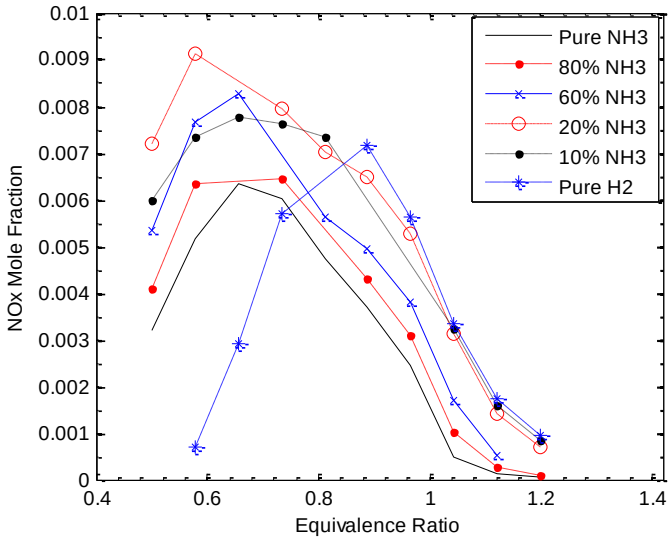

Fig. 1: Total NO_x mole fraction as function of equivalence ratio, P=17 bar, T=673 K.

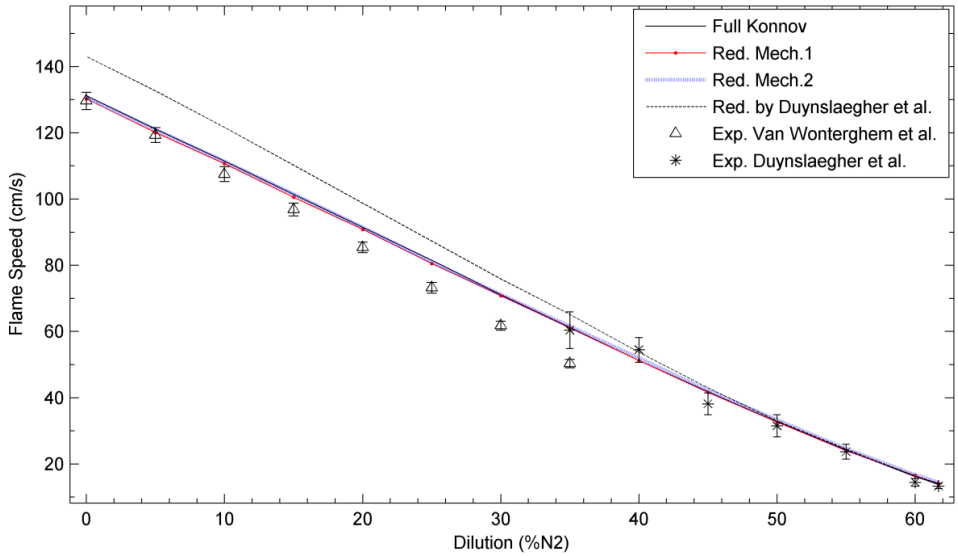

Fig. 2: Flame speed variation with respect to dilution level; numerical predictions and experimental results at STP condition.

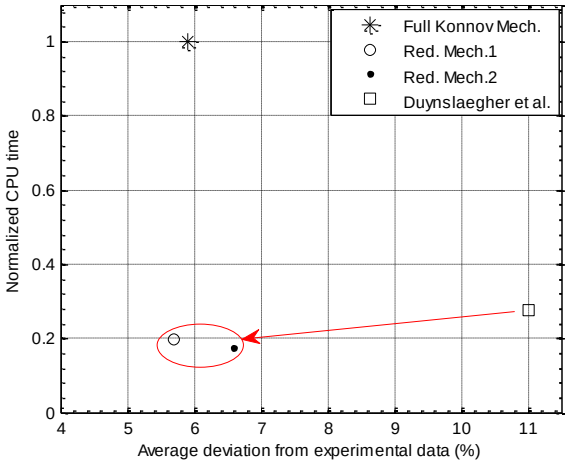

Fig. 3: Efficiency chart for reduced mechanisms.

References

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