Assessment of RANS Model Predictions of Mixing of Natural Gas in Model Premixers

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OVERVIEW

Combustion performance of lean premixed systems is sensitive to the mixing level of fuel to air at the exit of the premixer. Due to the increasing capabilities of computational systems, reliable CFD approaches can be used as design tools in practical applications. In the present work, predictions of time efficient RANS models, including k-epsilon and RSM turbulence models with four different turbulent Schmidt numbers, are assessed based on the experimental measurements and statistical analysis for both axial and radial injection of natural gas into non-swirling and swirling air flows.

GOALS

•Establish the general capabilities of time-efficient CFD models to provide reliable predictions of mixing of natural gas in model premixers with complex 3D geometries

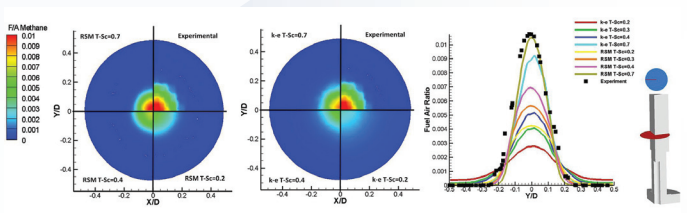
•Identify the most effective numerical approaches for the design of premixers in lean combustion applications

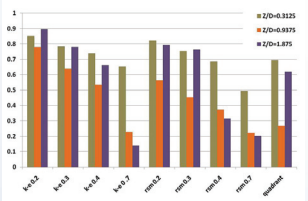
RESULTS

•Numerical cases have been generated through several steps including testing alternative geometries, imposing the coefficient of discharge for injectors, and extensive grid independency study.

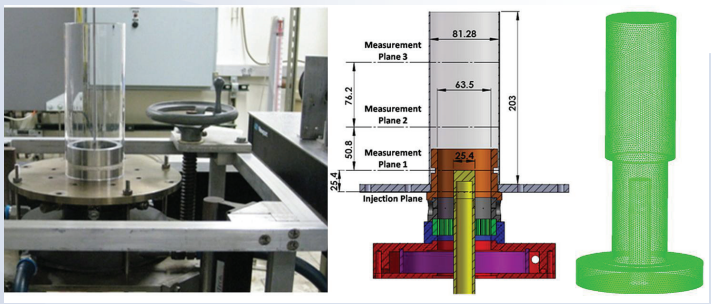
•Fuel concentration measurements are conducted utilizing an extractive probe in conjunction with gas chromatograph analyzer. Velocity field measurement is obtained by pitot probe and particle image velocimetry.

•Quantitative and qualitative comparisons between numerical and experimental results for velocity and fuel concentration distributions have been made to evaluate different simulations strategies for various 3D complex premixer configurations.





Examples of quantitative and qualitative comparison between numerical and experimental results, and also statistical analysis based on differences between them.



Experimental hardware, schematic figure, and numerical model

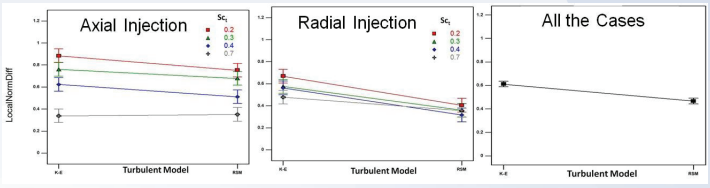
RESULTS (continued)

•ANOVA (ANalysis Of VAriance) is carried out based on numerical and experimental studies to present more quantitative information about capabilities of different turbulence models.

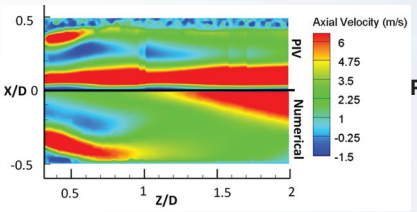
•For axial injection of fuel into a non-swirling main flow, the numerical results are sensitive to Sc_t values but fairly insensitive to turbulence model selection.

•For radial injection of fuel into a non-swirling main flow, the numerical results are sensitive to turbulence model. However, low sensitivity of numerical results to Sct value is evident

•The results show that the overall agreement for the non-swirling cases is reasonable. For swirling flows, however, common CFD approaches used in this work produce results that are substantially different from experimental measurements.



ANOVA Results



PIV results versus numerical predictions of velocity flow field for swirling cases

RECENT PUBLICATIONS/PAPERS

•A.Akbari, S.Hill, V.McDonell, S.Samuelsen, "Experimental and Computational Analyses of Methane and Hydrogen Mixing in a Model Premixer", 2010, Journal of Engineering for Gas Turbines and Power.

•A.Akbari, V.McDonell, S.Samuelsen, "Statistical Evaluation of CFD Predictions of Mixing Properties of Hydrogen and Methane for Lean Premixed Combustion", 2011, Paper GT2011-46126, Proceedings of ASME Turbo Expo 2011, Vancouver, Canada

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