Oxy-Gas Combustion for Efficient CO_2 Capture: Effect of Near Burner Mixing on Velocity and Composition Fields

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Abstract

While there is growing concern in the U.S. about the long-term effects of CO_2 emissions from fossil fuel combustion on global climate, there is also an awareness that fossil fuel usage will not disappear overnight. One option for controlling emissions from large, stationary sources of CO_2 involves CO_2 capture and subsequent storage. Cost effective retrofit capture technologies that could be quickly adopted in both the power generation and the upgrading/refining industries have great appeal. One proposed retrofit technology is that of oxy-gas combustion. Despite its advantage of providing an effluent stream of concentrated CO_2, questions remain about heat transfer, pollutant formation, and flame stability in a process heater retrofitted with an oxy-gas burner. The objective of this research is to produce the simulation tools needed for efficient CO_2 capture from process equipment used in the upgrading/refining of unconventional fuels. The specific focus of this phase of the research is to create a Large Eddy Simulation (LES) tool for demonstrating practical oxy-gas combustion in process heaters and then to use that technology to produce predictive capability with quantified uncertainty bounds for a pilot-scale oxy-gas process heater. To achieve predictive capability, a validation/uncertainty quantification (V/UQ) analysis is required. We employ the Data Collaboration methods of Michael Frenklach and coworkers at the University of California-Berkeley in our V/UQ analysis [1,2].

Data Collaboration requires consistency between simulation results and experimental data. For our Data Collaboration analysis, we employ the ARCHES simulation tool, a three-dimensional, Large Eddy Simulation (LES) code developed by Professor Philip J. Smith and his research group at the University of Utah. ARCHES uses a low-Mach number ($M < 0.3$), variable density formulation to simulate heat and mass transfer in reacting flows [3]. The selected experimental data are from the International Flame Research Foundation's (IFRF) oxy-gas experiments, also known as the OXYFLAM experiments [4]. To perform the V/UQ analysis, an experimental design must be proposed and completed. The purpose of the experimental design is to probe the parameter space that has the greatest effect on the response quantity of interest. In the case of the IFRF data, the following measurements were taken: wall temperature, gas temperature, gas composition, soot concentration, total radiance, total radiative flux at the wall, furnace heat extraction, axial velocity, and turbulence intensity. In oxy-gas combustion systems, the questions most often asked relate to how oxy-gas firing changes the local temperature, the local gas composition, and the radiant heat transfer. However, before choosing these data as the response quantities of interest, one must consider the reported experimental error for the various types of measurements taken. The authors in

the IFRF report expressed most confidence in the accuracy of the velocity data. The gas temperature data were off by several hundred degrees but could be corrected with some confidence using a calibration curve given in the report. The gas composition data may have been affected by recombination reactions in the sampling probe, particularly the H_2 concentration. Radiation measurements were hampered by the lack of a blackbody at a calibration temperature high enough (1650°C) for the refractory-lined furnace. For these reasons, the V/UQ analysis focuses first on the velocity data and second on the composition data. Based on prior experience, the three parameters we probe with our experimental design are burner design (high, medium, and low momentum burners), chemistry/mixing model, and domain resolution.

References

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