A combined experimental and numerical approach for the characterization of temperature distribution in a MILD combustion furnace

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Abstract

The complexity of MILD combustion reactive structures has pushed the development of a number of different approaches for CFD simulations, which are usually validated using temperature measurements. To this end, the availability of experimental data in MILD conditions is crucial. Simplified configurations that mimic MILD conditions, such as jet in hot co-flow, make it possible to implement optical diagnostics and deliver high-fidelity experimental data crucial for model validation. However, in industrial MILD configurations, the distributed conditions result from the internal aerodynamic recirculation and the modification of the local mixing timescales. The availability of experimental data in furnace configurations operating in MILD conditions is generally limited to exhaust gas emissions due to the presence of an enclosure. The few experimental data on temperature fields are acquired with intrusive techniques such as suction pyrometers or thermocouples. Several authors have analyzed the influence of the selection of the combustion model, chemical and mixing time scales, turbulence model, and kinetic mechanism on temperature fields. Discrepancies between experimental and numerical temperatures have been found and are often attributed to limitations in the modeling approaches. Hence, the aim of this work was to implement the non-intrusive Rayleigh scattering technique to measure the temperature field in a semi-industrial MILD combustion furnace and compare the results with those obtained using an intrusive suction pyrometer. The temperature trends obtained with the two measurement techniques were consistent. However, laser-based measurements brought somewhat higher temperature values. CFD simulations were used to shed light on the disturbances induced by the suction pyrometer and their impact on the fluid dynamics and thermochemical field. It was found that the presence of the suction pyrometer disrupts the flow inside the furnace and shifts the reactive zone upstream. In addition, the probe results in a cooling effect caused by removing non-negligible amounts of the reactants from the reactive zone. The present analysis can be helpful to reconcile inconsistencies found in CFD modeling in which probe sampling measurements are used for validation.