Experimental Study of a Co-flow Steam-assisted Flare: Emissions and Hydrodynamics

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Abstract

In the oil and gas industry, burning waste or unwanted flammable gases in an atmospheric diffusion flame is a regular procedure, known as *flaring*. The radiation field, emissions of smoke and gaseous pollutants, and the completeness of combustion in flares are highly influenced by parameters, such as fuel composition, crosswind, and flare exit geometry. Globally, flaring is an essential contributor to carbon dioxide emissions and other pollutants, such as black carbon and oxides of nitrogen.

Introducing a separate assisting fluid, such as air or steam, near the base of the flame, known as *assisted flare*, changes the hydrodynamics, thermodynamics, and chemistry, which in turn affects the efficiency and emissions. As illustrated in the combustion literature, with increasing the steam co-flow in turbulent jet diffusion flames, the emissions of black carbon and oxides of nitrogen are significantly reduced until the carbon conversion efficiency collapses and the main flame blows off. It is also shown that there is a range of assisting fluid flow rates, where the carbon conversion efficiency is ~100%, while the emission of black carbon and oxides of nitrogen are highly suppressed. This range is not known in assisted flares, especially the effects of a low assisting fluid flow rate on emission suppression in flares are not well explored in the combustion literature. Hence, this study aims to gain a deeper knowledge of the effects that steam has on the emission of selected compounds, such as black carbon, oxides of nitrogen, and carbon dioxide. In addition, this study will focus on the black carbon size distribution as well as the formation characteristics of black carbon aggregates, *i.e.*, elemental versus organic, as a result of steam addition. In this study, a lab-scale co-flow burner constructed of a concentric tube and a contoured nozzle is used, where different fuels (methane or propane) flow through the annular space, and steam, as the assisting co-flow, flows through the center tube.

Furthermore, to study the hydrodynamics of assisted-flares, this study aims at developing laser diagnostic techniques and image processing tools for detailed velocity field and flame structure measurements in assisted flares using particle image velocimetry (PIV). These techniques will be used to quantify the velocity field, burning rates, mixing characteristics, and flame structure in flares, to characterize the effects of assisting fluid co-flow on emissions control in flaring during refining and upgrading.