Predicting Black Carbon Emissions from Gas Flares in the Oil and Gas Sector: Experimental Measurements to Uncouple Aerodynamic and Chemical Effects

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Abstract

Understanding the role of aerodynamic parameters and fuel chemistry effects on black carbon emissions is important for diverse reasons including quantifying soot emissions under real-world conditions and developing reliable emission factor models. Finding a suitable scaling parameter which correlates emissions and a measurable quantity in the upstream oil and gas industry is difficult, where predicting soot formation in general is considered one of the most challenging problems in the field of combustion research. Furthermore, although a few different scaling parameters have been suggested, agreement among the limited comparable data currently available is generally poor, and very few data are directly relevant to the anticipated flow regimes and fuel compositions of flares typical of the (O&G) industry.

The current work partially fills this gap by presenting simultaneous measurements of black carbon (soot), flame length, and flame regime within a range of turbulent non-premixed jet diffusion flames burning fuel mixtures representative of upstream oil and gas sector flares. Sixty-nine cases spanning ten Reynold numbers and five nozzle diameters were studied. BC yields were calculated with precisely-quantified uncertainties using thermal-optical instruments. Variability in BC yield was well-predicted by an empirical model incorporating both the aerodynamic and chemistry effects. For this narrow range of conditions, it was observed that primary independent variables (such as exit velocity and carbon-hydrogen ratio) act as reasonable surrogates for sooting propensity. Further experiments are underway to test the proposed model over a broader range of conditions. However, results to date represent a significant advance in our ability to predict black carbon emissions from flares.