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Effect of pulverized anthracite coal particles injection on thermal and radiative characteristics of natural gas flame: An experimental study

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HIGHLIGHTS

- Anthracite coal injection into natural gas flame considerably enhances its poor radiation.
- Anthracite particles increases the flame reaction zone and luminosity.
- The small amount of injection has an insignificant effect on flame temperature.
- The main role of small amount of injection is to improve the flame emissivity coefficient.

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ABSTRACT

Natural gas is increasingly used as a clean fuel. In many industrial combustion systems, such as industrial furnaces and boilers, a large portion of heat is transferred by radiation. The use of natural gas in such industrial systems leads to a decrease in radiative heat transfer. The addition of solid reactant particles into flame is widely proposed in the literature as a method to enhance radiation from non-luminous flames, with a preponderance of research on hydrogen flame. The present study explores how the injection of pulverized anthracite coal particles into natural gas diffusion flame, as a non-luminous one, affects the thermal and radiative properties of natural gas. A novelty of our research method is the exploitation of yellow chemiluminescence of soot particles together with infrared photography to locate radiative particles and discover their qualitative distribution. The IR filter used in our technique was tested with Thermo Nicolet Avatar 370 FTIR Spectrometer for its spectral transmittance to be determined. The results indicate that the injection of coal particles into natural gas flame leads to a rise in the soot content of flame. Having the advantage of high absorptivity and emissivity coefficients in the near IR region, the soot particles in turn increase the flame luminosity and, more importantly, its emissivity coefficient. Also, the heat released from the combustion of particles increases the average temperature of flame about 29 °C. These raise the radiative heat transfer and thermal efficiency of flame as much as 43% and 21%, respectively. It is noteworthy that the average temperature difference and emissivity coefficient, respectively, account for 17% and 83% of the enhancement of the average radiation flux.

1. Introduction

Natural gas is a major source of energy generation in combustion equipment and burns more cleanly than other fossil fuels [1]. Although natural gas is the cleanest fossil fuel, radiation heat transfer from its flame is significantly less than that of liquid and solid fuels. In combustion devices, however, radiation is a major contributor to the total heat transfer [2].

Flames are categorized as luminous or non-luminous. The luminosity of flame depends on the amount of solid particles held suspended in it. For hydrocarbon fossil fuels, the solid matter existing in the flame is soot (solid carbon). When heated, it produces a brilliant yellow or luminous flame. The rate of soot formation in flame is proportional to the carbon number (C/H) in fuel chemical structure. Thus, heavy liquid and solid hydrocarbons have luminous flames, whereas light hydrocarbon fuels such as natural gas have non-luminous flames [3].

In non-luminous flames, CO_2 and H_2O are the main products of complete combustion and the principal sources of radiation heat transfer. However, they have a weak radiation band in infrared wavelengths [3,4].

Luminous flames also contain soot particles that serve as highly emissive gray bodies in the flame and enhance the radiation heat transfer in comparison with non-luminous flames [5,6].

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