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Emissions from ethanol-blended fossil fuel flames

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ABSTRACT

A fundamental study to investigate the emission characteristics of ethanol-blended fossil fuels is presented. Employing a heterogeneous experimental setup, emissions are measured from diffusion flames around spherical porous particles. Using an infusion pump, ethanol–fossil fuel blend is transpired into a porous sphere kept in an upward flowing air stream. A typical probe of portable digital exhaust gas analyzer is placed in and around the flame with the help of a multi-direction traversing mechanism to measure emissions such as un-burnt hydrocarbons, carbon monoxide and carbon dioxide. Since ethanol readily mixes with water, emission characteristics of ethanol–water blends are also studied. For comparison purpose, emissions from pure ethanol diffusion flames are also presented. A simplified theoretical analysis has been carried out to determine equilibrium surface temperature, composition of the fuel components in vapor-phase and heat of reaction of each blend. These theoretical predictions are used in explaining the emission characteristics of flames from ethanol blends.

1. Introduction

Pollutant emissions from fossil fuels are higher when compared to alternative and renewable alcohol fuels. Ethanol (C_2H_5OH) is a fast developing renewable bio-fuel, which is employed in automobile engines in various proportions along with gasoline and diesel. Ethanol can be produced from crops such as sugarcane and corn. Currently, there is a lot of interest in ethanol production from renewable feed stocks to minimize the emissions of carbon dioxide, a greenhouse gas which contributes to global warming. Alcohols, especially ethanol, have been blended with gasoline and diesel in various proportions for use in IC engines [1]. He et al. [2] studied the emission characteristics of spark-ignition engine with an electronic fuel injection system employing ethanol blended gasoline fuels. Emissions from an automotive diesel engine employing conventional diesel and bio-ethanol have been measured by Lapuerta et al. [3]. Their results proved that the use of ethanol with diesel provided a significant reduction in particulate emissions, with no substantial increase in other gaseous emissions. The effect of using ethanol and unleaded gasoline blends on burning characteristics and emissions has been investigated by Ceviz and Yuksel [4] and Al-Hasan [5]. The results showed that CO and HC emission concentrations in the engine exhaust decrease, while CO_2 concentration increases. A 20% ethanol by volume in fuel blend gave the best results for all measured parameters at all engine speeds [5]. Huang et al. [6] carried out experimental tests with ethanol blends and diesel. They found that smoke emissions from the engine fuelled with blends were much lower than that fuelled with diesel. Also, CO emissions from engine fuelled with blends were lower than those fuelled with diesel when engine ran above half loads and when engine ran under full loads, the CO emissions of blends were higher than those of diesel.

Ethanol blended with fossil fuels is multi-component in nature. Several researchers have studied the evaporation and combustion of multi-component droplets [7–12]. Heterogeneous combustion of multi-component fuels was studied by Wood et al. [7]. Alternative liquid fuels were mixed with some fuel oils and the combustion of the blend was studied by Braide et al. [8]. Law and Law [9,10] have worked on gasification mechanisms for multi-component droplets. Evaporation of multi-component arrays was studied by Annamalai et al. [11]. A model for evaporation of multi-component droplet was reported in Newbold and Amundson [12].

From the above studies, it is clear that the emissions from the exhaust of engines employing ethanol blended fuels have been studied widely. Studies on mechanisms of evaporation and combustion of multi-component droplets are also available. However, the formation and distribution of the emissions such as CO, CO_2 and un-burnt hydrocarbons produced during the burning of ethanol blended fuels in the flame zone, which is of more fundamental academic interest, have not been studied in detail in the past. In this study, an analysis of emissions from simple diffusion flames established over spherical particles of blended ethanol fuels is carried out. A base-line case of pure ethanol has also been studied. A porous sphere of 10 mm diameter is supplied with a blended fuel at a rate at which the fuel is consumed. The porous sphere is kept

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