EFFECTS OF OXIDANT MASS FLOW RATE ON POLLUTANTS PRODUCED FROM AN INVERSE DIFFUSION FLAME

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ABSTRACT

Although non-premixed flames generate copious amounts of environmental pollutants such as NOx, soot in comparison to premixed flames, it’s relevance in gas turbine engines, rocket motors and furnaces has been linked to the stability of the flame. To curtail the effects of pollutants to the environment, researchers have developed means to improve the performance of non-premixed flames in these application areas. One of these approaches involves changing the configuration of the non-premixed flames - Inverse Diffusion Flames (IDF) and Double Inverse Diffusion Flames (DIDF).

INTRODUCTION

Flame luminosity, soot production and soot emission have been found to increase with oxygen enhancement in both Normal Diffusion Flame (NDF) and Inverse Diffusion Flame (IDF) experimentally in a coflowing non-premixed flame of ethane. This indicates that soot emission from a non-premixed flame is dependent on the amount of oxygen available for the combustion process. However, the amount of soot produced in IDF was found to be less than that produced in NDF. Also, inverse diffusion flame length increases with increase in air flow rate as measured from experiments conducted on methane and ethylene. Although the flame height measurements obtained from the visible images were overestimated, soot, which was located closer to the reaction zone than Polycyclic Aromatic Hydrocarbons (PAH’s), was found in the fuel rich region of the flame and the measurements correlated properly with an OH Planar Laser Induced Fluorescence (PLIF).

Also, experimental measurements of the flame structure and soot characteristics in diluted Ethene inverse diffusion flames found that ethene inverse diffusion flames (IDFs) are more stable than methane inverse diffusion at low flow rates. Moreover, soot inception occurred in the lower region of the diluted ethene IDF with a temperature range of 1550 - 1600K and the fuel dilution has a weak influence on the inception of soot. To further understand the effect of the fuel - air velocity ratio on soot production, Kaplan and Kailasanath conducted a numerical study on a normal diffusion flame and inverse diffusion flame of a co-flowing methane – air. Based on the results obtained from the computation, soot production increases with increase in fuel to oxidizer velocity ratio for both NDF and IDF. According to this work, this is due to the increased residence time for the reactions, which gives preferences to the growth of soot particles. However, the amount of soot produced by NDF was found to be higher than that produced in IDF, which confirmed the experimental measurements.

According to Blevins, et al., the soot particles in IDF are large, stacked, plate-like particles, which are lumped together and surrounded by liquid-like material while exiting the flame. Based on these results, IDFs produce lesser soot than NDFs for the same flow condition. This has been attributed to the fact that the produced soot particles in IDF do not pass...
through the high temperature reaction zone, which promotes the coagulation and surface growth of soot precursors — (C₂H₂ and PAH), unlike those produced in NDF which pass through the high temperature reaction zone, thus promoting the coagulation and surface growth of soot precursors 11, 10. Previous researchers have confirmed that the amount of soot produced in an Inverse non-premixed flame is lower than that produced in a normal non-premixed flame. Although soot produced in IDF is lower than that produced in NDF, the amount of soot produced in an IDF can be minimized by considering the diameter of the oxidant flow. The goal of this paper is to confirm the need for optimizing the dimension of an IDF for a given oxidant mass flow rate.

MODEL AND ASSUMPTIONS

The model used in the computational study of the effect of air flow diameter on the pollutants produced is shown below in figure 1. In this model, the conservation laws of reacting flow was solved using Ansys Fluent with the reduced 32 species of the San Diego research group 2. The assumptions of the computations are: Steady state flow, temperature dependent specific heat, constant viscosity, temperature dependent species diffusivity, and a constant mixture thermal conductivity.

RESULTS AND DISCUSSION

From the computations performed, the maximum mass fraction of soot produced for a given mass oxidant mass flowrate decreases with increase in diameter of the oxidant flow, but increases after a given diameter as shown in figure for two mass flowrates of the oxidant. Further work is required to further explore this finding.

REFERENCES