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Analytical Study of Structure of Laminar Diffusion Flame in Hydrogen-Enriched Methane-Air Mixture

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ABSTRACT

The present study focuses on modeling a CH_4/H_2 diffusion flame using the laminar flamelet model. The investigation aims to explore the effect of hydrogen enrichment on temperature evolution, as well as on the emissions of CO, NO, OH. The results indicate an increase in the flame temperature due to hydrogen enrichment. Furthermore, nitric oxide (NO) exhibits a similar trend to temperature evolution, with NO emissions primarily arising thermally during combustion. Ultimately, this study underscores the significant role of hydrogen enrichment in stabilizing non-premixed flames.

Keywords: Diffusion flame; flamelet approach, hydrogen enrichment, NG-H2 hybrid fuel

1. Introduction

Nowadays, the primary focus of research and development in the automotive industry revolves around minimizing fuel consumption and reducing pollutants emissions from vehicles. Methane and hydrogen emerge as the predominant alternative gaseous fuels under consideration for engine applications. Notably, hydrogen-enriched natural gas has garnered significant attention in the past decade, leading to extensive research in this domain. The NG-H2 hybrid fuel, presents numerous advantages in terms of combustion performance and pollutant emissions when utilized in internal combustion engines [1-3]. Various experimental and numerical studies have been conducted to enhance the understanding of its combustion characteristics [4,5]. In pursuit of this objective, the concept of laminar flames had been embraced, which can reliably predict the characteristics of a diffusion flame for a methane-hydrogen mixture [6-9]. The structure of diffusion flames is significantly influenced by the mixing fraction and scalar dissipation, crucial parameters that describe the mixture's quality.

2. Experimental

The present analysis adopts a physical model involving a laminar diffusion flame configured in an opposed jet arrangement. This specific geometry holds significance, enabling an in-depth exploration of the laminar flame's structure while simplifying the flow equations.

3. Results and Discussion

Figures 1 to 4 depict the temperature distribution of the methane-hydrogen mixture and the mass fractions relative to the mixing fraction, z. Throughout this investigation, a constant pressure of 1 atm and a scalar dissipation rate of 27 $^{s-1}$ are assumed, maintaining consistency across varying proportions of hydrogen.

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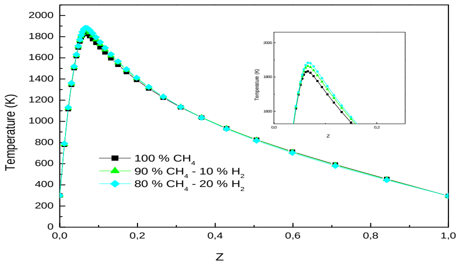


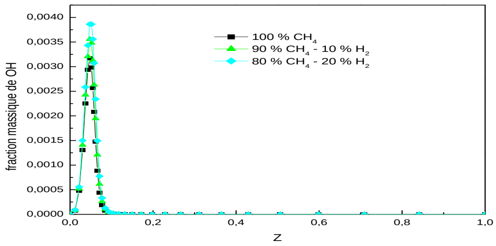
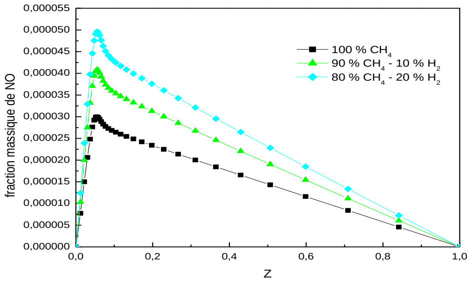


Figure 1: Temperature flamelet profiles as a function of Z. **Figure 2**: Flamelet profiles for mass fraction of OH



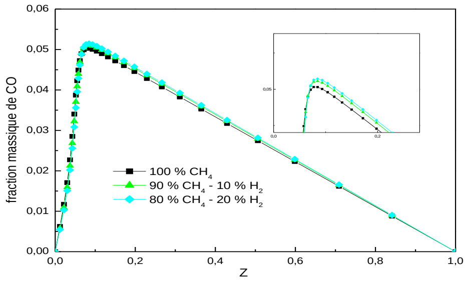


Figure 3: Flamelet profiles for mass fraction of NO **Figure 4**: Flamelet profiles for mass fraction of CO

4. Conclusions

The acquired results yield the following insights:

- The introduction of hydrogen leads to an elevation in flame temperature surpassing 1750 K, resulting in the generation of thermal NO.
- The impact of hydrogen doping on carbon monoxide (CO) is minimal, as CO primarily arises from the incomplete combustion of carbon compounds.
- Ultimately, we have demonstrated that employing the flammelet concept proves effective in comprehending the CH4/H2 flame's structure. Furthermore, the mixing fraction Z emerges as a suitable descriptor for characterizing the mixture's quality.

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