Temperature field investigation of hydrogen/air and syngas/air axisymmetric laminar flames using Mach–Zehnder interferometry

Sadrollah Karaminejad, Mohammad Hossein Askari,* and Mehdi Ashjaee

School of Mechanical Engineering, College of Engineering, University of Tehran, Tehran, Iran
*Corresponding author: mhossein.askari@ut.ac.ir

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In this study, the optical method of Mach–Zehnder interferometry (MZI) is utilized in order to explore the flame structure and temperature field of syngas/air and hydrogen/air flames. Two axisymmetric burners with inner diameters of 4 mm and 6 mm are used for temperature field measurement of hydrogen and syngas, respectively. The effects of fuel composition, equivalence ratio, and Reynolds number (Re) are investigated at ambient condition (P = 0.87 bar, T = 300 K). Three different H$_2$/CO fuel compositions with hydrogen fractions of 30%, 50%, and 100% are studied. Temperature profiles are reported at four different sections above the burner tip. Measured temperatures using the interferometry method are compared with thermocouple data and good agreement between them is observed. The results obtained in this investigation indicated that the MZI can be applied for accurate determination of flame front and temperature field, especially for high-temperature flames where other methods cannot be properly utilized. Analyses of the data reduction method revealed that the exact determination of the refractive index distribution and reference temperature is critical for accurate determination of the temperature field. The results indicated that by increasing the Re, the maximum flame temperature is enhanced. Increasing the equivalence ratio leads to expansion of the flame radial distribution (at the same distance from the burner tip). At higher distances from the burner tip, temperature increases uniformly from the flame boundary toward the flame axis, while at lower heights it shows reduction at the burner axis. By increasing the CO content of fuel, the maximum flame temperature increases at all equivalence ratios except at the stoichiometric condition, where SH100 illustrates the highest maximum flame temperature. © 2018 Optical Society of America

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1. INTRODUCTION

NOMENCLATURE

Diameter

Focal length

Fringe number

frame per second

Liter

Mach–Zehnder

Mach–Zehnder interferometry

Non-premixed flame

Partially premixed flame

Reynolds number

As a result of increasing in the world energy expenditure and worries about environmental emissions, investigations are focused on renewable, clean alternative fuels. Among alternative fuels, syngas and H$_2$ have definite advantages due to their plentiful available resources and easy production. Syngas is a biological fuel, which is mainly comprised of CO and H$_2$. Premixed burners are one of the main potential users of syngas and H$_2$ fuels. These burners are regularly used in light industries and domestic applications.

Fundamental investigation of the temperature field of a premixed flame is indispensable for designing efficient burners. Furthermore, temperature field data of the premixed flames are vital in demonstrating the heat transfer rate of the combustion to a receiving medium. There are various techniques to demonstrate the temperature field of a flame. Measuring temperature by utilizing thermocouples is one regular way, which has considerable defects. High temperature measurement limitations, inability of simultaneous temperature field determination, flow pattern disruption, and radiation coefficient interference are all counted as main thermocouple defects [1] which led to the invention of optical methods. On the other