Fuel 233 (2018) 504–512

Contents lists available at ScienceDirect

Fuel

journal homepage: www.elsevier.com/locate/fuel

Full Length Article

Study on the influence of flame inherent instabilities on crack propagation of expanding premixed flame

Yan-Huan Jiang[a,b], Guo-Xiu Li[a,b,*], Hong-Meng Li[a,b], Lei Li[a,b], Li-Li Tian[a,b]

[a] School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing 100044, China
[b] Key Laboratory of Vehicle Advanced Manufacturing, Measuring and Control Technology (Beijing Jiaotong University), Ministry of Education, Beijing 100044, China

ARTICLE INFO

Keywords:
Syngas
Hydrogen fraction
Equivalence ratio
Cracks
Flame inherent instabilities

ABSTRACT

To evaluate the effect of hydrogen fraction and equivalence ratio on the competitive relationship between flame and crack development, combustion experiments of H_2/CO/air mixtures at various equivalence ratios and hydrogen fractions were conducted in a constant volume combustion chamber. The crack length and growth rate were defined. The results indicate that the crack length and the number of the cells increase with the flame development. With the increase (decrease) in hydrogen fraction (equivalence ratio), the disturbances caused by flame inherent instabilities increases, and the crack length at the same radius increases. The appearance and generation of the new cracks dominate the cellular structure process, clear increasing the crack growth rate. The effect of hydrogen fraction on the development of cracks is more obvious at lower equivalence ratios. Flame stretch affects the competitive relationship between crack growth rate and flame propagation speed, exhibiting two completely different trends. The critical crack growth rate decreases with the increase of the equivalent ratio.

1. Introduction

With the rapid industrial development, the demand for energy continues to increase in human society. Meanwhile, the environmental pollution and ecological destruction caused by the usage of energy are becoming more and more severe, this has attracted worldwide attention [1–3]. Search for clean energy is one of the main ways to solve this problem. Syngas is a promising clean energy source; it has attracted much attention [4,5]. Syngas has been studied in the internal combustion engine as an alternative fuel [6–8]. Therefore, it is important to study the combustion characteristics of syngas/air premixed combustion.

For an expanding flame, because of the limitation of the actual combustion device, steady flame propagation and cellular structure are the two critical parts of the laminar premixed combustion. The data of the steady flame propagation stage are the key to calculate the laminar burning velocity [9–11]. The effects of initial temperature, pressure, equivalence ratio and hydrogen fraction on the laminar burning velocity have been extensively studied by scholars [12–14]. Moreover, to further evaluate the effect of initial parameters on the laminar burning velocity, the chemical kinetics analysis is a useful method [15,16].

Diffusive-thermal instability and hydrodynamic instability are two major factors for the splitting of flame front cracks and the formation of cellular structure. The cellular structure increases of the flame front area and self-acceleration of flame [17,18]. Critical radius and Peclet number are the most commonly used parameters to characterize the instability of flame [19,20]. Moreover, Jiang et al. [21] and Askari et al. [22] quantified the cellular information of flame front from its local structure. The fractal dimension can be used to characterize the overall structure of flame front to study the self-similar characteristics of flame from the perspective of fractal geometry; this can be used to estimate the flame propagation speed in the flamelet and flame inherent instabilities affecting the region [23]. For a spherical expanding flame, the flame front undergoes a considerable acceleration according to the power-law expression, Xie et al. [24] showed that when a flame reached the self-similar stage, the acceleration exponent remained constant. Furthermore, Fast Fourier transform and wavelet transformation are also effective methods to study the disturbances of different scales in the flame front caused by flame inherent instabilities, achieving the decomposition and quantification of disturbances in the flame front [25,26].

According to the aforementioned review, many valuable methods are available to study flame inherent instabilities, which provide a very important guiding significance. However, mainly two types of research on flame structure characteristics have been conducted. One type of research involves the extraction of flame profiles, followed by the use of

* Corresponding author at: School of Mechanical, Electronic and Control Engineering, Beijing Jiaotong University, Beijing 100044, China.
E-mail address: Liguoxiu@yahoo.com (G.-X. Li).

https://doi.org/10.1016/j.fuel.2018.06.088
Received 4 February 2018; Received in revised form 6 May 2018; Accepted 21 June 2018

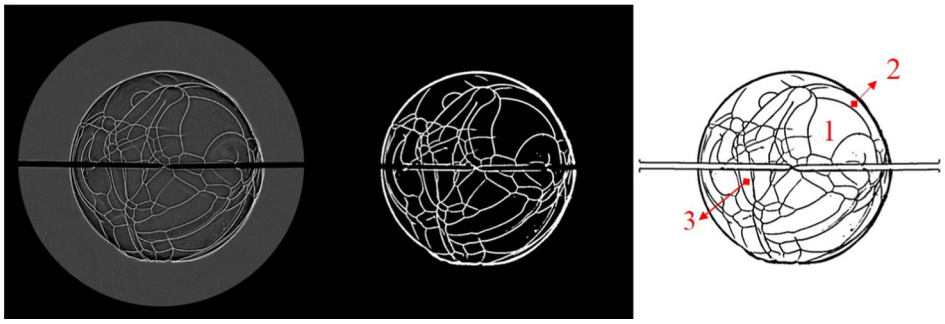

Fig. 1. Comparison between original and extracted images.

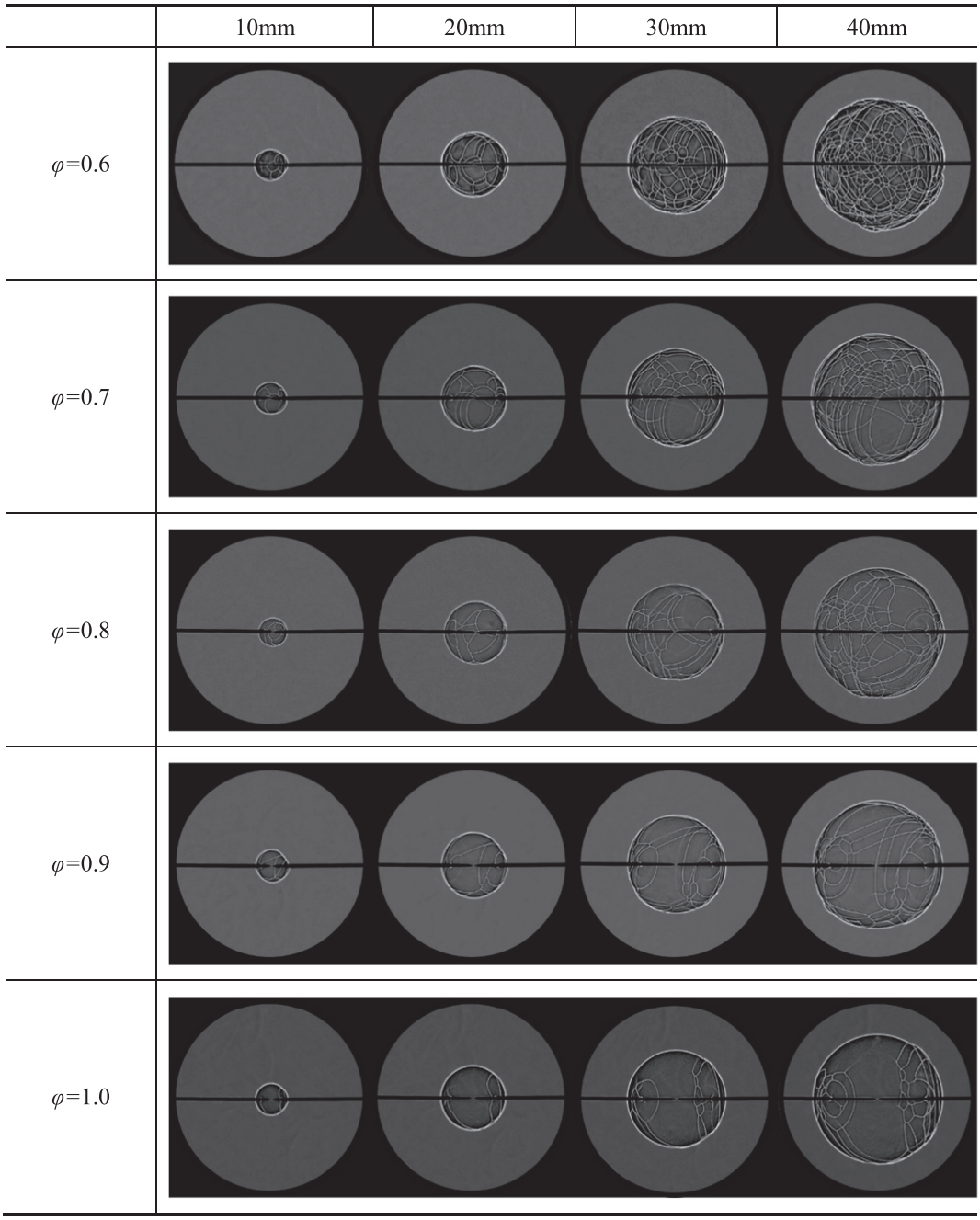

Fig. 2. Effect of equivalence ratio on the flame evolution of 70% H_2/30% CO/air mixtures.