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# Premixed flame propagation of $CH_4$ and $C_3H_8$ in a narrow-gap disk burner using constant-volume processes at elevated-pressure

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ABSTRACT

Premixed flame propagation within a narrow combustion space has been an important issue in combustion studies. Recently, it was found that flame-induced instabilities are very sensitive to the length-scale of the combustion space. However, experimental results obtained at higher pressures have not been sufficient. In this study, the propagation characteristics of methane and propane premixed flames were investigated using a new narrow-gap disk burner, of which the disk gap and the initial pressure could be varied precisely while the volume was kept constant. Quenching distances were measured during increase of the initial pressure to 4 bar. Flame propagation characteristics were compared with variation of the disk gap, the equivalence ratio, and the initial pressure. Significant changes were found in the trends of the flame propagation velocity and flame shape. Cellular flame structures were observed when the disk gap was slightly larger than the quenching distance regardless of the Lewis number. In contrast, smooth flames could form when the disk gap was sufficiently larger than the quenching distance. The elevated pressure enhanced flame oscillation and cellular structures (if they could be generated) regardless of Lewis number of mixtures. The relationship between the pressure and the flame propagation was evaluated, and a mechanism for the flame instability is discussed herein.

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## 1. Introduction

Premixed flame propagation within a finite combustion space has been of great interest in combustion studies. Flame propagation behavior was first visualized in a closed tube by Ellis [1], and various complicated combustion phenomena have been reported within a variety of combustion spaces [2–8]. Some specific phenomena, including “finger flame” (having a long flame skirt near the wall) and “tulip flame” (having a cusped flame shape at the center), have been studied [2–4]. These flame structures were thought to be mainly concerned with variation of the flow direction, which is affected by the flame location and the boundary conditions of the combustion space. The finger-flame shape forms at the initial stage, mostly when the flow moves to the unburned-mixture side, and the tulip-flame shape forms mostly when the flow velocity is decelerated or changes its direction toward the burned mixture. Such studies have been conducted consistently regarding the flame morphology [5] and regarding different configurations of the combustion space [6]. Besides, within such confined combustion space, flame oscillation have been observed and investigated. Gonzalez derived a scenario of flame oscillation in a tube from the aspect of acoustic instability [7]. In addition, it was reported that the oscillation became stronger with increase of the length scale of the combustion space [8].

It is now understood that such combustion phenomena in narrow spaces are concerned not only with the performance of small combustion devices (such as micro-combustors) but also with the initial flame propagation in internal spark-ignition engines. In particular, the flame propagation characteristics in a narrow flat channel, namely a Hele-Shaw burner, have been studied by many researchers. The effects of heat loss and friction on the hydrodynamic instability of a large wavelength were introduced theoretically based on a quasi-2D assumption [9]. Since then, numerical studies have been conducted, and the effects of various instabilities have been considered [10–14]. In particular, it was found that the effect of Saffman–Taylor instability becomes larger in the case of smaller Peclet numbers [10]. The effects of heat and momentum losses on flame instabilities were investigated [11,12]. Overall, it has been reported that the development of cellular flame structures is affected by a variety of instabilities, including such as hydrodynamic, Rayleigh–Taylor, Saffman–Taylor, and diffusive-thermal (or Lewis number effects) [13].

Recently, these complicated flame behaviors and intrinsic flame instabilities were investigated in relation to flame oscillations [15,16]. It was found that there are two acoustic instability modes

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