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Unsteady propagation of premixed methane/propane flames in a mesoscale disk burner of variable-gaps

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Abstract

Unsteady flame propagation of air-premixed methane and propane flames was investigated in a new mesoscale disk burner, of which disk-gap could be precisely varied. To begin with, the quenching disk-gaps on the flammability limits were measured. In most cases, with the slight increase of the disk-gap, cellular flame structures could be generated. The initiation of such cellular structures could be explained by the thermally induced hydrodynamic instability, and it could be enhanced if the Lewis number was sufficiently small. When the disk-gap was sufficiently larger than a critical value (approximately 1.5 times the quenching distance), the cellular flame structure changed into a smooth one in the azimuthal direction. With a further increase of the disk-gap, the flame propagation velocities approached to constant values. These values were comparable to the laminar burning velocities except for the propane-rich conditions, in which much larger propagation velocities were observed. The flame stretch effects (coupled with Le-effects) within a narrow space were suspected as the reason. The structural transition of the premixed flame could be investigated successfully through various disk-gaps, from the smallest quenching-scale to the ordinary large scales via whole mesoscales including Hele–Shaw scales.

Keywords: Mesoscale combustion; Flame propagation; Cellular structure; Lewis number; Combustion instability

1. Introduction

The relationship between the length-scale and the combustion characteristics is essential for combustion studies. The ultimate phenomenon affected by the length-scale is the flame quenching on the flammability limits. In spite of a number of studies on the flame quenching, its detailed structures have not been clarified. This is because the combustion within a limited space is affected not only by the burner's configuration but also by various combustion instabilities. An early study by Ellis [1] investigated unsteady propagation of a premixed flame in a confined space, and successfully conveyed how complicated this problem is. After that, similar topics have been extensively studied under two different names. One is a 'finger flame,' which has a fast propagation speed with a long flame skirt near

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