HAL
open science

Experimental two dimensional cellular flames

C. Almarcha, J. Quinard, B. Denet, E. Al-Sarraf, J. M. Laugier, E. Villermaux

To cite this version:

C. Almarcha, J. Quinard, B. Denet, E. Al-Sarraf, J. M. Laugier, et al.. Experimental two dimensional cellular flames. Physics of Fluids, 2015, 27 (9), pp.091110. 10.1063/1.4930914 . hal-01216247

HAL Id: hal-01216247

https://hal.science/hal-01216247v1

Submitted on 16 Oct 2015

HAL is a multi-disciplinary open access archive for the deposit and dissemination of scientific research documents, whether they are published or not. The documents may come from teaching and research institutions in France or abroad, or from public or private research centers.

L'archive ouverte pluridisciplinaire **HAL**, est destinée au dépôt et à la diffusion de documents scientifiques de niveau recherche, publiés ou non, émanant des établissements d'enseignement et de recherche français ou étrangers, des laboratoires publics ou privés.

AIP Physics of Fluids

Experimental two dimensional cellular flames

C. Almarcha, J. Quinard, B. Denet, E. Al-Sarraf, J. M. Laugier, and E. Villermaux

Citation: Physics of Fluids **27**, 091110 (2015); doi: 10.1063/1.4930914
View online: http://dx.doi.org/10.1063/1.4930914
View Table of Contents: http://scitation.aip.org/content/aip/journal/pof2/27/9?ver=pdfcov
Published by the AIP Publishing

Articles you may be interested in

Ignition sequence of an annular multi-injector combustor
Phys. Fluids **26**, 091106 (2014); 10.1063/1.4893452

Comparative analysis of low- and high-swirl confined flames and jets by proper orthogonal and dynamic mode decompositions
Phys. Fluids **26**, 065109 (2014); 10.1063/1.4884915

Two-dimensional direct numerical simulation evaluation of the flame-surface density model for flames developing from an ignition kernel in lean methane/air mixtures under engine conditions
Phys. Fluids **24**, 105108 (2012); 10.1063/1.4757655

Double conditioning of reactive scalar transport equations in turbulent nonpremixed flames
Phys. Fluids **16**, 2640 (2004); 10.1063/1.1758219

Diffusion flame in a two-dimensional, accelerating mixing layer
Phys. Fluids **9**, 2617 (1997); 10.1063/1.869378

Did your publisher get
18 MILLION DOWNLOADS in 2014?
AIP Publishing did.

AIP Publishing
THERE'S POWER IN NUMBERS. Reach the world with AIP Publishing.

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 147.94.56.75 On: Fri, 25 Sep 2015 13:19:38

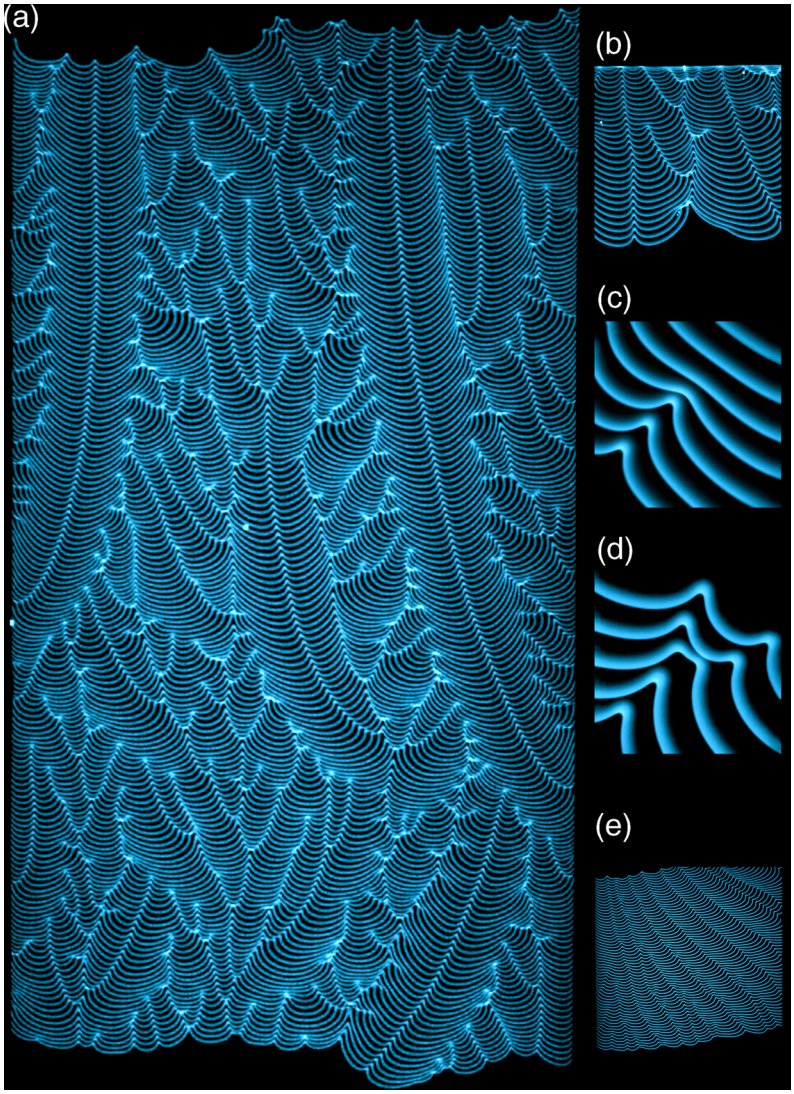

FIG. 1. (a) Downward propagation of a stoichiometric premixed propane air flame in a vertically oriented Hele-Shaw cell. (b) Destabilization of a flat initial condition. (c) Cusp creation. (d) Cusps merging. (e) Lean flame close to the stability threshold. http://dx.doi.org/10.1103/APS.DFD.2014.GFM.P0036.

Experimental two dimensional cellular flames

C. Almarcha,[1] J. Quinard,[1] B. Denet,[1] E. Al-Sarraf,[1] J. M. Laugier,[2] and E. Villermaux[1,3]
[1]*Aix Marseille Université, CNRS, Centrale Marseille, IRPHE UMR 7342, 13384 Marseille, France*
[2]*Aix Marseille Université, CNRS, PIIM UMR 7345, 13397 Marseille, France*
[3]*Institut Universitaire de France, Paris, France*

(Received 24 August 2015; published online 24 September 2015)
[http://dx.doi.org/10.1063/1.4930914]

Premixed flames, where fuel and oxidizer are mixed prior to combustion, are widely used in gas turbines or internal combustion engines like spark ignition engines since they provide a practical

 © Author(s) 2015

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 147.94.56.75 On: Fri, 25 Sep 2015 13:19:38

mean to control the rate of combustion and lead generally to lower pollutant emissions, particularly for lean flames. However, thermal and hydrodynamical effects distort inherently the flame front, which generically presents a collection of cells, separated by cusps, merging and birthing at random and having a broad distribution of sizes. Studying this wrinkling in the flamelet regime, for low turbulent velocities not influencing the inner structure of the flame, is of prime importance as it rules the global velocity of the flame, an information also useful for calibrating numerical simulations.[1]

The description of the flame propagation and its dynamics is difficult in usual cases, such as propagation in cylindrical tubes[2] and deserves a dedicated experimental facility allowing for quantitative imaging. For this purpose, a vertically oriented Hele-Shaw cell (two glass plates separated by a thin gap of 5 mm, 50 cm wide, and 150 cm in height) has been used. It is filled with a mixture of propane and air which is ignited at the top of the cell. The propagation of the flame along the cell in a quasi two-dimensional fashion allows for the precise analysis of its corrugations from the wrinkling of an initially flat flame front (Fig. 1(b)) to the steady wrinkled regime (Fig. 1(a)). The corresponding space-time diagrams illustrating the cusps dynamics have been obtained for stoichiometric propane air flames, diluted with nitrogen in the second case. They are constructed by superimposing the pictures of the front taken with a high speed camera at successive instants of times. The fields of view are, respectively, 12 cm wide and 50 cm wide. The frame rates are, respectively, 100 images/s and 60 images/s.

The key elements for understanding the statistical features of the front are the formation (Fig. 1(c)) and merging (Fig. 1(d)) of the cusps. These two concomitant and competing processes rule the distribution of the sizes of the cells, a distribution which appears to be identical for a large variety of gas mixture provided that the flame is unstable enough, i.e., not too close from the stability threshold. In that later case, most of the cells have the same size, as seen in Fig. 1(e) (equivalence ratio 0.66, field of view 43 cm wide, and recorded at 25 fps).

This research is supported by Agence Nationale pour la Recherche (No. ANR-14-CE05-0006).

[1] M. Philip, M. Boileau, R. Vicquelin, T. Schmitt, D. Durox, J. F. Bourgoin, and A. Candel, "Ignition sequence of an annular multi-injector combustor," Phys. Fluids **26**, 091106 (2014).
[2] C. Almarcha, B. Denet, and J. Quinard, "Premixed flames propagating freely in tubes," Combust. Flame **162**, 1225-1233 (2015).

This article is copyrighted as indicated in the article. Reuse of AIP content is subject to the terms at: http://scitation.aip.org/termsconditions. Downloaded to IP: 147.94.56.75 On: Fri, 25 Sep 2015 13:19:38