Flame- and Flow Topologies

L. Cifuentes[1], A. Kempf[1], C. Dopazo[2]
[1]Chair for Fluid Dynamics - IVG, University of Duisburg-Essen, Germany
luis.cifuentes@uni-due.de; andreas.kempf@uni-due.de
[2]University of Zaragoza and LIFTEC- CSIC, Spain
dopazo@unizar.es

Keywords: *Turbulent mixing and reacting flows, turbulent combustion modelling, local flow topologies and scalar structures.*

1. Context

Turbulent mixing of spatially segregated scalar fields is a process encompassing convection, straining and molecular diffusion. In turbulent combustion, the close contact at the molecular level is essential for reactive scalars to be chemically converted. Large eddy convection brings scalars closer together, for example, by engulfment, maintaining segregation at the smallest spatial scales, whereas entrainment by small-scales completes mixing at a molecular level [1]. Local nodal and vortical structures fold and stretch scalar fields, fostering scalar gradient enhancement and surface growth.

Recently, researchers have started to examine the (above) phenomena in turbulent combustion by studying flow and scalar topologies and how they interact with each other. The analysis of the invariants of the velocity gradient tensor [2] has been applied to study the flame-turbulence interactions using DNS data of turbulent premixed flames [3-5] and turbulent spray flames [6]. This technique allows identifying strong eddying or vortical regions, stretching zones, and stagnation points in the flow to characterize the dynamics, geometry and flow topologies that interact directly with the flame. Some suggestions [7-9] to model molecular mixing have been proposed based on the kinematic analysis of the iso-scalar surfaces. The evolution equation for the flame curvature [9-11] and the strain rates tangential and normal to iso-surfaces [12-14] have been scrutinized to demonstrate that the chemical heat release might substantially modify the statistical evolution of scalar-gradients and the turbulent micro-mixing. Several authors [15-18] have analyzed the statistics of displacement speeds and of strain rates and curvatures of iso-surfaces. The molecular diffusion rate due to the curvature of the iso-scalar surfaces (tangential diffusion) [19-22] has been examined and its relevance for modelling of turbulent flames has been identified. The importance of the pressure field on the local flame geometry [23-25] in response to hydrodynamic instability and turbulence has been demonstrated. The morphology of reaction zones and the features of flame interactions, using Minkowski functionals and shape finders, have recently been the subject of a few DNS studies [26-30]. New approaches to analyze flame-turbulence interactions are underway, but certain basic issues remain to be resolved and will be topic of the mini-symposium.

2. Content

This mini-symposium aims at contributing to fundamental understanding of the local flame behavior and its interactions with the surrounding turbulent flow field. It brings together different perspectives to the topic of interactions between scalar and flow topologies, looks for commonalities among various approaches and possible applications in modelling. The methodologies presented will contribute to the following areas of interests: turbulent mixing and reacting flows, turbulent combustion modelling, local flow topologies and scalar structures.

The following researchers have agreed to present their work in this mini-symposium:
- L. Cifuentes[1], A. Kempf[1], C. Dopazo[2]: [1]University of Duisburg-Essen, [2]University of Zaragoza.
- N. Chakraborty: University of Newcastle, UK.
- M. Klein: Universität der Bundeswehr München, Germany.
- H. Im: KAUST, Clean Combustion Research Center, Saudi Arabia.
- X.S. Bai: Lund University, Sweden.
- A. Scholtissek, W. Han, C. Hasse: Technische Universität Darmstadt, Germany.
- Y. Minamoto: Tokyo Institute of Technology, Japan.

REFERENCES

[1] S. Corrsin. Fluid Dynamics and Applied Mathematics, 105-124, 1962.
[2] M. Chong, A. Perry, B. Cantwell. Phys. Fluids 2, 765–777, 1990.
[3] L. Cifuentes, C. Dopazo, J. Martin, C. Jimenez. Phys. Fluids 26, 065108, 2014.
[4] L. Cifuentes, C. Dopazo, J. Martin, P. Domingo, L. Vervisch. J. Flow, Turb. Combust 96, 535-546, 2016.
[5] D. Wacks, N. Chakraborty, M. Klein, P. G. Arias, H. Im. Phys. Rev. Fluids. 083401, 2016.
[6] D. Wacks, N. Chakraborty. Fuel 184 (1), 922-947, 2016.
[7] C. Dopazo, L. Cifuentes, Combust. Sci. Technol. 188, 1376-1397, 2016.
[8] C. Dopazo, L. Cifuentes, J. Hierro, J. Martin. J. Flow, Turb. Combust. 96, 547-571, 2016.
[9] S.B. Pope. Int. J. Eng. Sci. 26, 445-469, 1988.
[10] S.S. Girimaji, S.B. Pope. J. Fluid Mech. 234, 247-277, 1992.
[11] C. Dopazo, J. Martin, L. Cifuentes, J. Hierro. J. Flow, Turb. Combust. (2018).
[12] C. Dopazo, L. Cifuentes, J. Martin, C. Jimenez. Combust. Flame 162, 1729-1736, 2015.
[13] R. Sankaran, E.R. Hawkes, J.H. Chen, T. Lu, C.K. Law. Proc. Combust. Inst. 31, 1291-1298, 2007.
[14] S Chaudhuri, H Kolla, E Hawkes, J Chen, C. Law. Combust. Flame 184, 273-285, 2017.
[15] T. Echekki, J.H. Chen. Combust. Flame 118, 308-311, 1999.
[16] N. Chakraborty, S. Cant. Phys. Fluids 17, 105105, 2004.
[17] H.A. Uranakara, S. Chaudhuri, H.L. Dave, P.G. Arias, H.G. Im. Combust. Flame 163, 220-240, 2016.
[18] Y. Minamoto, J. Chen. Combust. Flame 169, 38-50, 2016.
[19] C. Kortschik, S. Honnet, N. Peters. Combust. Flame 142, 140-152, 2005.
[20] L. Verhoeven, W. Ramaekers, J. van Oijen, L. de Goey. Combust. Flame 159, 230-241, 2012.
[21] D. Messig, F. Hunger, J. Keller, C. Hasse. Combust. Flame 160, 251-264, 2013.
[22] A. Scholtissek,W. Chan,H. Xu,F. Hunger,H. Kolla,J. Chen, M. Ihme, C. Hasse. Combust. Flame 162, 2015.
[23] A. Lipatnikov, J. Chomiak, V. Sabelnikov, S. Nishiki, T. Hasegawa. Combust. Flame 35, 1401-1408, 2015.
[24] F. Creta, R. Lamioni, P. Lapenna, G. Troiani. Phys. Rev. E. 94, 053102, 2016.
[25] M. Klein, H. Nachtigal, M. Hansinger, M. Pfitzner, N. Chakraborty. 10th Proc. MCS. TC16, 2017.
[26] T.D. Dunstan, N. Swaminathan, K.N.C. Bray, N.G. Kingsbury. Combust. Sci. Tech. 185, 134-159, 2013.
[27] Y. Minamoto, N. Swaminathan, Cant S.R., T. Leung. Combust. Flame 161, 2801-2814, 2014.
[28] R.A.C. Griffiths, J.H. Chen, H. Kolla, R.S. Cant, W. Kollmann. Proc. Combust. Inst. 35, 1341-1348, 2014
[29] H. Wang, E.R. Hawkes, J.H. Chen. Phys. Fluids 28, 095107, 2016.
[30] N. Doan, N. Swaminathan, Y. Minamoto. Combust. Flame, 189, 173-189, 2018.