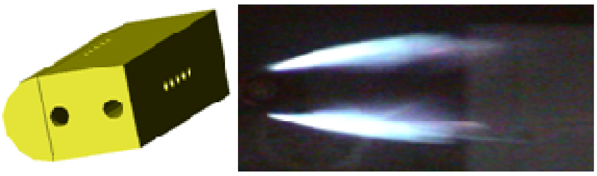
RECENT RESEARCH ACTIVITIES,

P. KOUTMOS, LAT

Hybrid/Dual Fuel multi-port Injected Combustor (HDFIC) arrangement

Driven by regulation and environmental concerns, the exploitation of ultra-lean combustion has emerged as promising technology to control emissions from practical combustion. Ultra-lean flame configurations formed by premixing of fuel and air and stabilized on a Hybrid/Dual Fuel multi-port Injected Combustor (HDFIC) arrangement are investigated both experimentally and computationally. Multiport dual fuel injection is exploited to promote flame stability and reduced emissions.

A hybrid/dual fuel injection operation is expected to achieve and maintain stable operation at limiting ultra-lean mixtures. The choice of optimum injection placement/fuel combination configurations and their verification is the core objective of the work. The emission performance of these configurations is compared against standard injection methodologies. Experiments have been performed in the medium scale combustion facility employing: a) high temperature fast response thermocouples, coupled to a DaqTemp 7A Omega card, b) exhaust gas analysis, c) CCD camera recordings of flame images and d) Laser Velocimetry to assess the momentum fields of the flames.



HDFI combustor and flame visualization

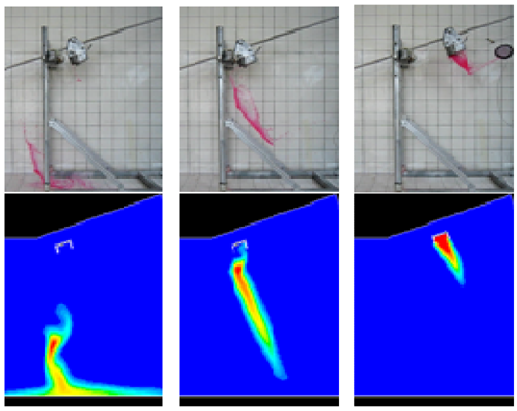
Marazioti, PE, 'Experimental and computational study of noise and emissions in jet and bluff-body flames' PhD, University of Patras, Patras, Greece, (2006).

Marazioti, P.E. and Koutmos, P. (2001) "Preliminary results from simulations of combustion roar in turbulent attached and lifted turbulent methane jet flames", 4th European Conference on Noise Control, Euronoise 2001, Patras, january 14-17, Greece.

Koutmos, P. and Marazioti, P. (2003) "Reactedness-mixture fraction presumed PDF computations of local extinction effects in piloted jet flames of methanol fuel blends", Int. Jnl. on Energy for a Clean Environment, Clean Air, 4, pp. 335-355.

Experimental and computational investigations of axisymmetric buoyant flames and fires.

The objective of these concerted efforts on buoyant flames, in cooperation with local authorities, is to improve understanding of the mechanisms that control open or enclosed fire configurations with the aim to achieve successful models to mitigate their effects. Both experiments and simulations are exploited in a series of studies related to water mist suppression of axisymmetric fires, identification of line fires base characteristics, control of the onset of fire whirls and aerial (water or chemicals) bombardment of wildland forest or spill fires.



← flight direction

Aerial water bombardment of ground fire, experiment and moving mesh 2-phase computations.
(download film)

Axisymmetric fire plume experiment and LES simulations.(download film)

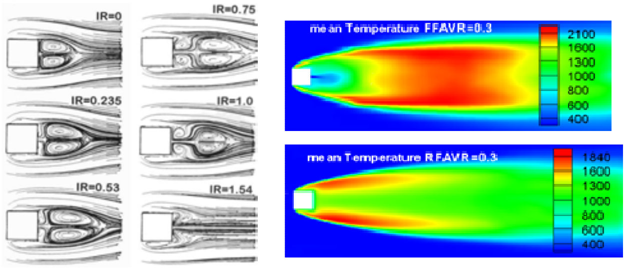
Fire whirl-experimental facility and fire vortices.
(download film)

Panagiotaras, Ch., Mprouzas, K. and Koutmos, P., 'A study of water mist suppression of buoyant fires', In Flow 2006, Patras, Greece, 2006.

Koutmos,, P. and Giannakis, G. (2003) 'Numerical simulations of pool fires", 3rd Int. Meeting of the Greek Section of the Combustion Institute, Patras, November 26-27, pp. 33_S4.

Study of large scale vortex dynamics in square cylinder reacting wakes under co-current or counter-current fuel injection.

Current designs of industrial burners usually incorporate bluff–body nozzles to improve flame stabilization, increased efficiency and reduced pollutant emissions. A challenge in bluff-body turbulent combustion modelling is the influence of the large scale flow structures and the time-varying flow behaviour on flame characteristics such as stability, heat release and emissions. Turbulent flames stabilized by planar propane injection across the span of a slender square cylinder (discrete jets of small aspect ratio), either from its leading face against the approach cross-flow or directly within its vortex formation region are studied. Cold flow studies, turbulent temperature measurements, exhaust gas analysis and reacting Large Eddy Simulations, undertaken for two Fuel Air Velocity Ratios (FAVR) of 0.3 and 0.2 at a Re number of 8000 described the dynamic development of cold and hot wakes under counter- or co-current fuel injection.

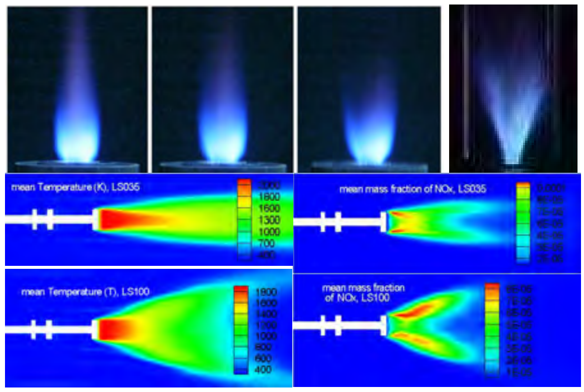


Square cylinder wake (left) and co-current (up) vs. counter-current (down) fuel injection flame topology

Bakrozis, A.G., Papailiou, D. and Koutmos, P., Combust. and Flame, 119:291-306 (1999).
Nikokavouras, N., Neofitidis, G., Koutmos, P. et al, In Flow 2010, Thessaloniki, November 12-13, 2010
Koutmos, P., Papailiou, D. and Bakrozis, A. (2000), 4th Eccomas (European Community on Comp. Methods in Applied Sciences) Conference, Barcelona, Spain, September 7-11, pp. 958-964
Koutmos P, Papailiou D, Bakrozis A (2004). Eur J Mech B Fluids 23:353–365

A study of the interaction of swirl flow with annular partially premixed propane flames.

The present project deals with the experimental and computational investigation of turbulent reacting wakes established through staged fuel-air premixing in an axisymmetric double cavity arrangement formed along three concentric disks and stabilized in the downstream vortex region of the afterbody. The innovative burner assembly is also operated with a swirling coflow, introduced upstream of the burner exit to allow for the interaction between the primary premixed recirculating afterbody flame and the swirl. The isothermal interaction of the cavity produced annular jet stabilized by the afterbody and the variable swirl is initially studied. Ultra-lean flames with strong radial mixture gradient input are measured by regulating the fuel-air ratio, while the influence of the variation of the imposed swirl is studied for constant fuel injections. Large Eddy Simulations are performed with the Fluent software using an in-house modified EDC combustion submodel and a developed 10-step propane/NOx oxidation mechanism.

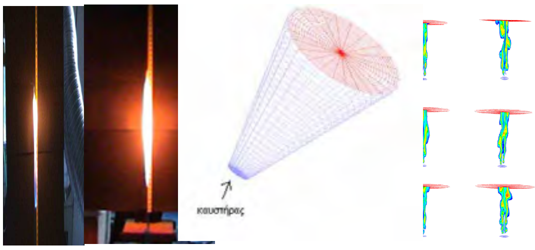


Flame images (up), Temperature distributions (left) and NOx production (right) in disk stabilized annular propane flames.

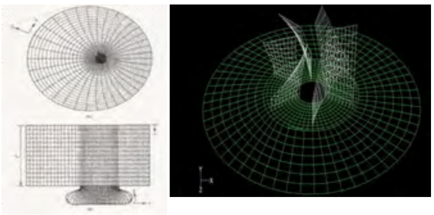
Xiouris, Ch. and Koutmos, P., 'A study of the interaction of swirl flow with annular partially premixed propane flames', in Flow 2010, Thessaloniki, 12-13 November, Greece, 2010.

Large Scale Computations of reacting flows with reduced multi-step chemistry and higher order models.
Hydrocarbons combustion is an important phenomenon in energy production. In Internal Combustion Systems, combustion usually takes place within and strongly interacts with a turbulent flow and the adequate description of the process requires consideration of large number of fluid and chemical parameters. Direct or Semi-Direct Numerical Simulations (e.g. DNS, LES) of turbulent reacting flows offer a promising tool toward the understanding of these complex flows. The full potential of these techniques can best be realized when sufficiently complex and realistic but flexible combustion, chemistry and transport models are exploited. Turbulent combustion submodels and tractable chemical schemes for the oxidation of CH_4 (natural gas), C_3H_8 (LPG) or higher hydrocarbons or mixtures (Diesel, surrogates etc) including NO_X and soot production modules are therefore derived and tested in laminar and turbulent protype flows and then applied to practical industrial configurations such as knock prevention and end gas ignition in Internal Combustion Engines.

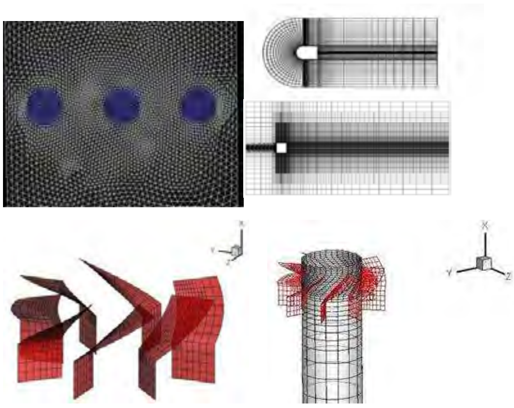
<u>Example - Reduced C_3H_8 mechanism for use in IC Engines</u>
$C_3H_8{}^{\alpha} + O_2 + H_2O + H_2 \rightarrow 3CO + 6\,H_2$,
$CO^{\beta} + H_2O^{\gamma} \leftrightarrow CO_2 + H_2$,
$3H_2{}^{\delta} + O_2{}^{\varepsilon} \leftrightarrow 2H_2O + 2H$,
$2H + M \rightarrow H_2$,
$C_3H_8 + 3H_2O + 4H \rightarrow 3CO + 9H_2$,
$0C_3H_8{}^{\zeta} + 2CO^{\eta} + H_2{}^{\theta} \leftrightarrow C_2H_2 + O_2$,
$0.5\,N_2 + 2O^{\iota} \leftrightarrow NO + O$,
$2O + M \rightarrow O_2$,
$2O + 0H_2O \leftrightarrow O_2 + 0H_2$,
$0C_3H_8{}^{\kappa} + N_2{}^{\lambda} + O_2{}^{\mu} + 0H_2O^{\nu} + 0O^{\xi} \leftrightarrow 0C_3H_8 + 2NO$



Laminar and turbulent multistep chemistry
Large Scale Simulations of laboratory flames



Internal Combustion Engine Computations,
Diesel engine in-cylinder simulations using a
mesh with pre-chamber and swirl.



Typical mesh arrangements in industrial reacting
flow computations.

Marazioti, P., Koutmos, P and Giannakis, G. (2007) "A global oxidation scheme for propane-air combustion suitable for use into complex reacting flow computations" Journal of Engineering Transactions, CAMES, Vol.55 No 4, pp 293-316.
Marazioti, P. and Koutmos, P. (2010) "Simulations of combustion roar in turbulent attached and lifted turbulent methane jet flames" In Review , Journal of Engineering Transactions
Nikokavouras, N., 'Bluff-body premixed swirl stabilized propane flames', Dissertation thesis, U. of Patras, June 2010.