MTech Combustion CFD Research

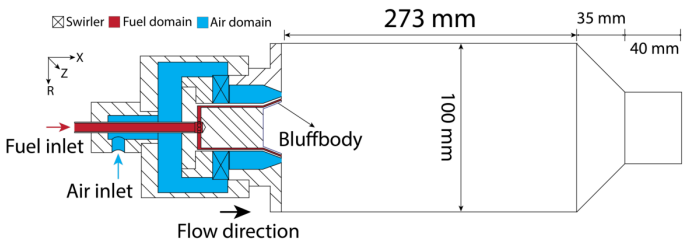
Flame stabilisation in a swirl and bluff-body burner

Ramesh M | Thermal and Propulsion, IIST | 2023-2025

Investigated how **swirl-induced recirculation, fuel-air mixing and chemical reaction** influence methane-air flame anchoring as the global mixture becomes leaner. Used reacting-flow CFD and experimental comparisons to assess the mean flow and interpret changes in flame structure.

Research question and numerical approach

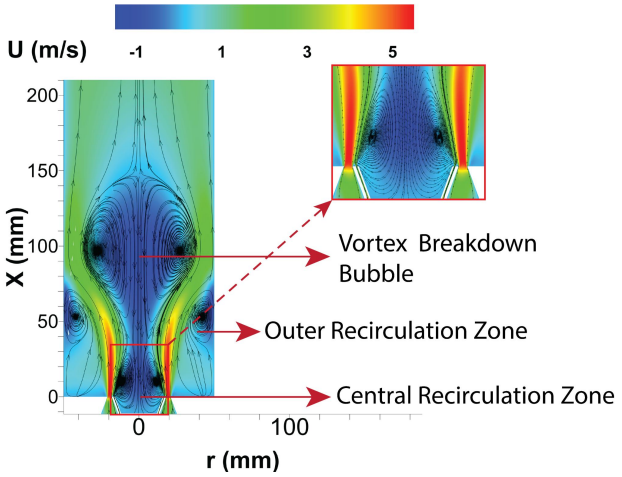
Why does the flame structure change between moderately lean and ultra-lean operation, and which flow and mixing features support stabilisation? I used **ANSYS Fluent, RANS with a modified k-epsilon model incorporating Pope's correction, and steady flamelet modelling**. The computational setup used a structured hexahedral mesh of approximately **5.4 million elements**, SIMPLE pressure-velocity coupling and a modified GRI-Mech 3.0 chemistry mechanism. [1, 2]



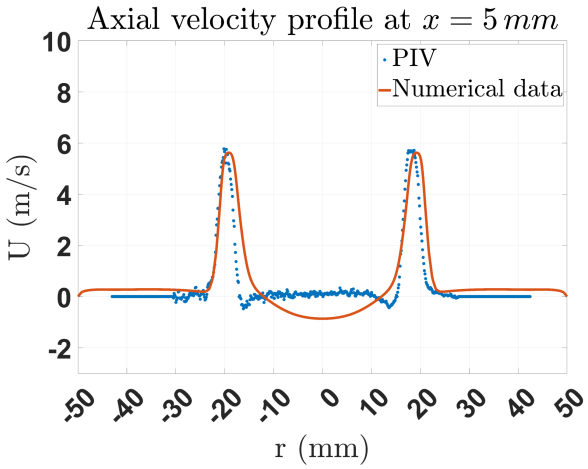
IIST-GS1 burner geometry, fuel and air passages, and flow direction. [1]

Operating conditions
Methane and air supplied through separate passages to the IIST-GS1 burner. Air flow: 100 SLPM. Selected reacting cases: global equivalence ratio **phi = 0.8 and 0.2**. Atmospheric pressure, 300 K inlet conditions and adiabatic walls in the model. [1]

Assessing the flow field before interpreting combustion



A. Mean axial velocity and recirculation. The velocity field identifies the vortex-breakdown bubble and central/outer recirculation regions that influence flame anchoring. [1]



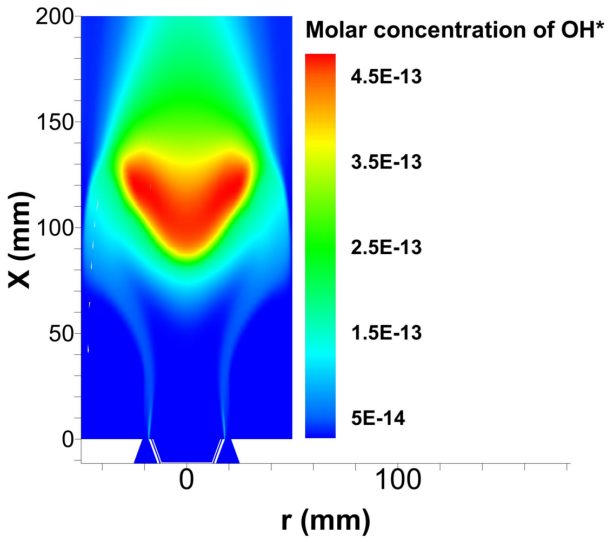
B. Numerical-to-PIV comparison. Predicted axial velocity at x = 5 mm is compared with laboratory PIV measurements to assess the mean-flow prediction. [1]

Model assessment. I assessed the modelling approach against Sydney burner benchmark data before applying it to IIST-GS1. Comparisons with laboratory measurements captured the main recirculation structure, with discrepancies in near-field velocity peaks and turbulent mixing. These checks informed interpretation of the reacting cases. [1-3]

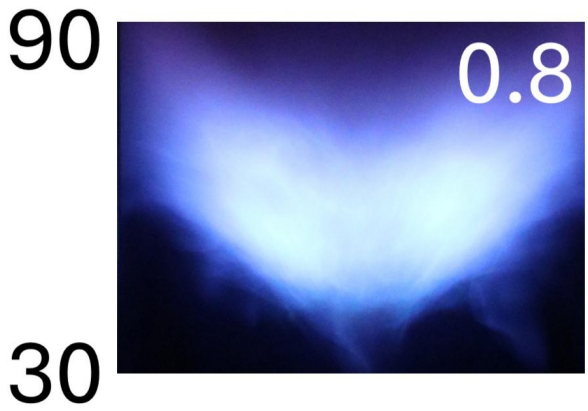
Flame Structure and Interpretation

Methane-air combustion in the IIST-GS1 swirl and bluff-body burner

Qualitative flame-shape comparison at phi = 0.8



C. CFD reaction-zone contour, phi = 0.8. The heart-shaped OH* molar-concentration field indicates the predicted reaction-zone structure within the swirling flow. [1]



D. Experimental flame photograph, phi = 0.8. The luminous V-shaped flame provides a qualitative comparison with the predicted structure. The photograph and CFD show different quantities and fields of view. [1]

What the study showed

Recirculation provides a stabilising environment. Vortex breakdown creates low-velocity regions and recirculates hot products, helping sustain reaction near the burner exit.

Global equivalence ratio does not describe the local mixture. The phi = 0.8 case showed a central/V-shaped structure, while the phi = 0.2 case showed an annular structure concentrated in the shear layers. Experimental flame photographs provide a qualitative comparison. [1, 2]

Mixing and chemistry must be considered together. Flame anchoring was associated with locally favourable mixture fraction and moderate-to-low scalar dissipation, highlighting the balance between mixing and reaction rates. [1, 2]

My contribution and relevance

My work focused on the numerical investigation, model assessment, post-processing and interpretation of the results against benchmark and experimental data. I also helped with **rig setup and camera arrangement**. The laboratory team's PIV and flame measurements are distinguished from my CFD work.

This project developed my skills in **combustion aerodynamics, turbulence-chemistry interaction and CFD-to-test comparison**. The reported results concern mean-flow RANS analysis of a laboratory burner. LES, alternative fuels and wall heat-transfer effects were identified as directions for further study. [1-3]

Sources and attribution

[1] Ramesh Murugesan, Rajesh Sadanandan and Manoj T Nair. *Numerical Investigation of Flame Stabilization in a Non-Premixed Swirl and Bluff Body Stabilized Burner.* ASPACC 2025 work-in-progress poster. Figure source and presentation of this research.
[2] Corresponding ASPACC 2025 WiPP abstract, 15th Asia-Pacific Conference on Combustion, Singapore, 18-22 May 2025.
[3] Ramesh M. MTech thesis, IIST, May 2025, Sections 7.3-7.4 and 8.1-8.2.