GTRC
GAS TURBINE RESEARCH CENTRE

CARDIFF UNIVERSITY
PRIFYSGOL CAERDYDD

Flashback Avoidance Analysis using Geometrical Constrictions in a Tangential Swirl Burner

Agustin Valera-Medina, Mohammed Abdulsada
Nicholas Syred, Anthony Griffiths

Centre for Research in Energy Waste and the Environment
Cardiff University, Wales

YR UNDEB EWROPEAIDD AMCAN 1
EUROPEAN UNION OBJECTIVE 1

General Introduction

- Swirling Flows are used to enhance fuel/air mixing and to generate reverse flow zones to enhance flame stability typical of gas turbines.
- Research has been focused on Greener Fuel Blends
- These blends are a mixture of hydrogen and biofuels with traditional fossil fuels such as natural gas.
- However, at low Re and high Equivalence Ratios (f) Flash-back can occur, with destructive consequences for the equipment.
- Higher flame speed of hydrogen contributes to this problem.
- Associated acoustic instabilities also aggravate the stabilization of the system.

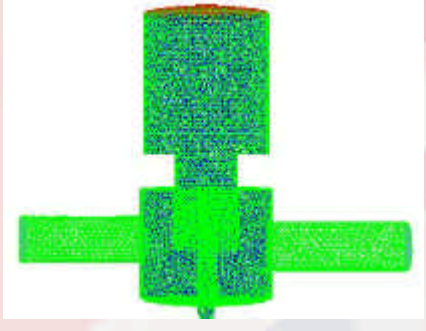
Dynamic Principles

- Swirling flows develop structures that include Precessing Vortex Core (PVC), a Recirculation Zone (RZ) and various Eddies.
- The Central Recirculation Zone (CRZ) is a region where particle growth and nucleation can occur if the flame is in contact with injection systems.
- Flashback can also occur if high contents of Hydrogen are added due to the increased flame speed.
- Negative pressure gradients produced by the Swirling Flow, can initiate flashback.

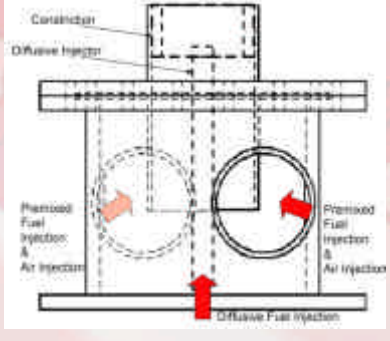
YR UNDEB EWROPEAIDD AMCAN 1
EUROPEAN UNION OBJECTIVE 1

Experimental and Numerical Procedures

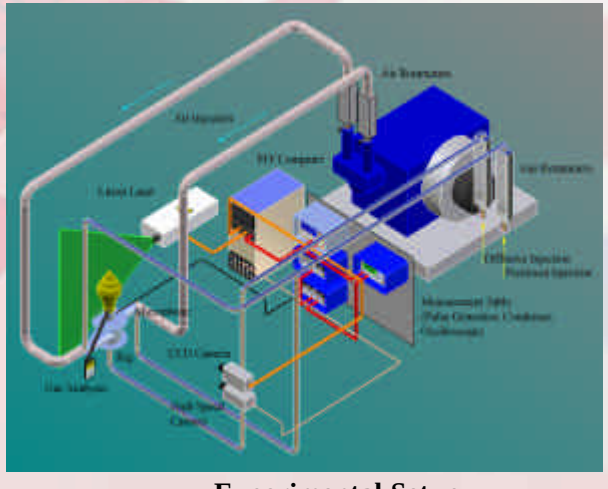
- Tangential Swirl Burner with variable S, Re and f numbers.
- Measuring Techniques used
  - Phase Locked Particle Image Velocimetry
  - High Speed Photography
- Numerical Simulation
  - FLUENT



Numerical Model



Schematics of the Rig used



Experimental Setup

YR UNDEB EWROPEAIDD AMCAN 1
EUROPEAN UNION OBJECTIVE 1

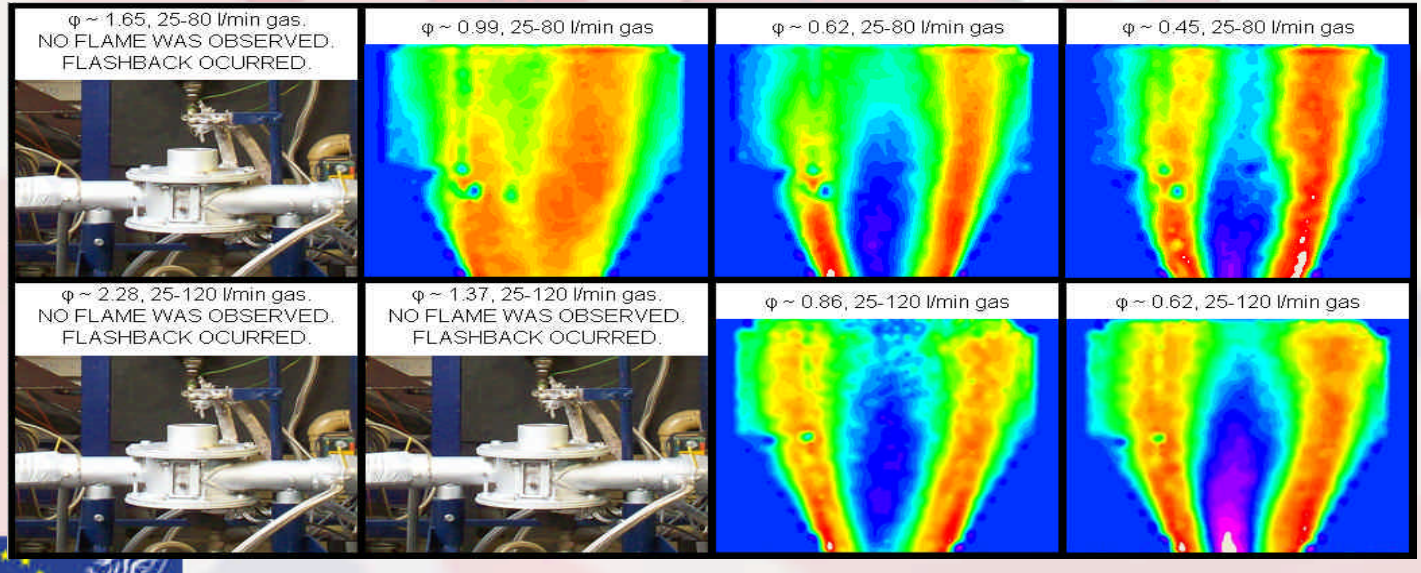
Experimental and Numerical Procedures

- Coherent Structures were analyzed with Phased Locked PIV for Structure Recognition.
- Flashback was experimentally analyzed using different 4 different constrictions at the nozzle entrance under atmospheric conditions.
- Flashback was numerically analyzed solving the transport equation by using standard k-? method.
- Fully and Partially premixed (with diffusive injection) conditions have been modelled and analyzed.

Results

- **Increasing the amount of gas develops the Central Recirculation Zone faster. This also increases the propensity to flashback at lean-stoichiometric conditions.**

600 l/min — 1000 l/min — 1600 l/min — 2200 l/min → Air flow

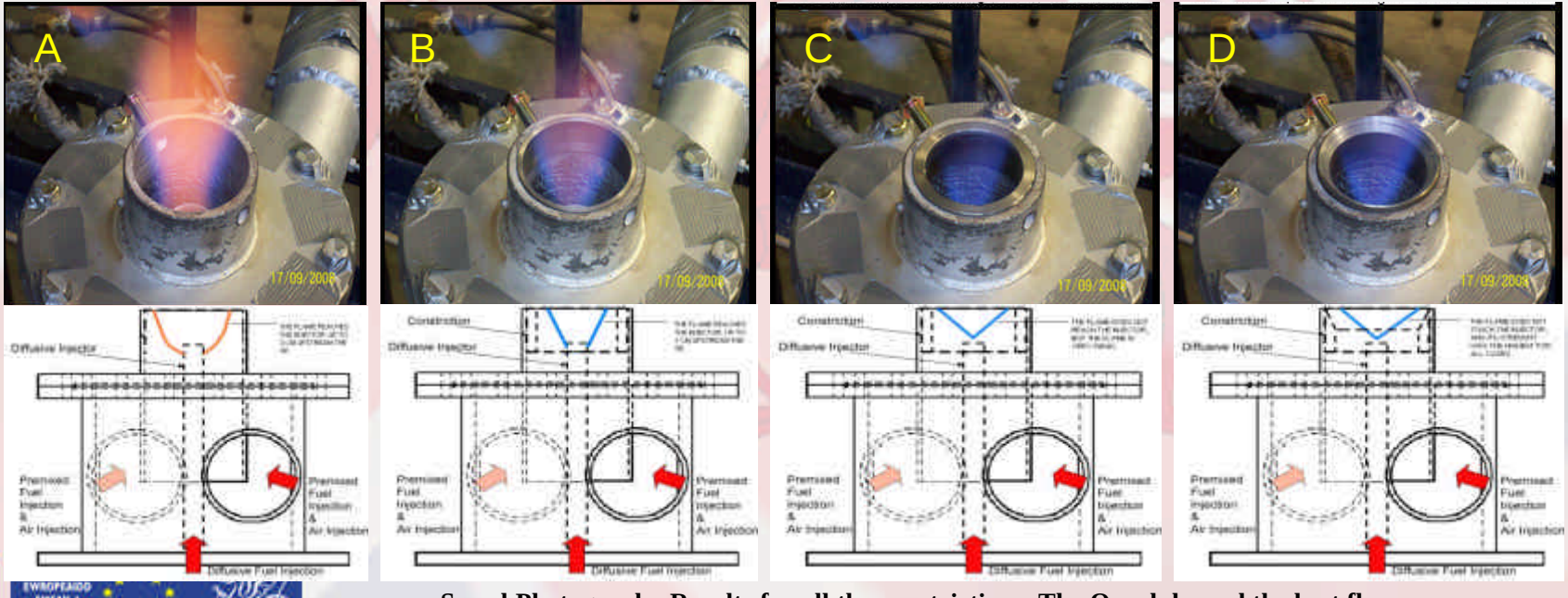


PIV Results for Diffusive-Premixed conditions. Nomenclature: X – Y l/min gas.
X: Diffusive Injection; Y: Premixed Injection.

YR UNION EWROPEAIDD AMCAN 1
EUROPEAN UNION OBJECTIVE 1

Results

- The use of different constrictions produced different flames.
- The quarl design gave the best flame and reduced axial flashback.



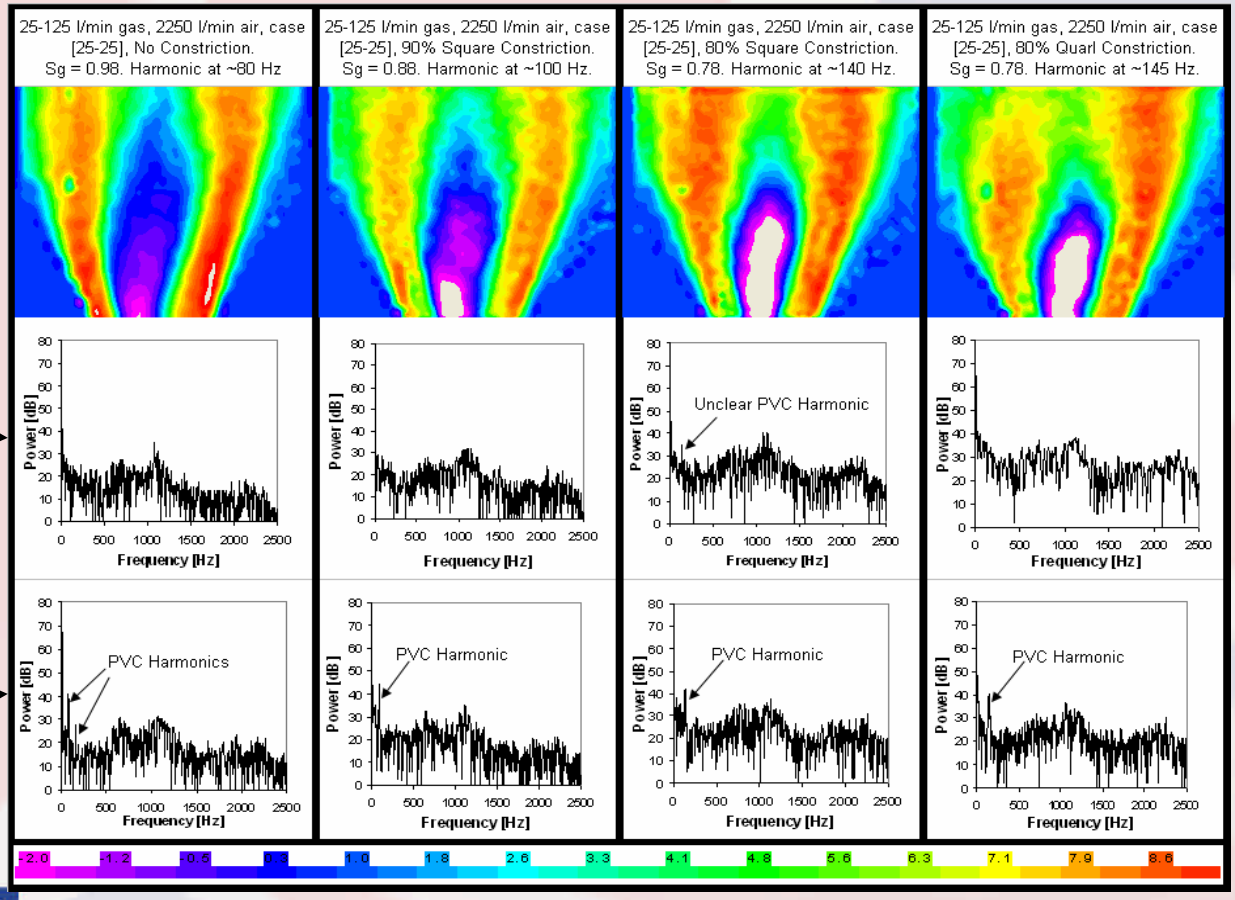
Speed Photography Results for all the constrictions. The Quarl showed the best flame. f ~ 0.27 for all cases. A) No Constriction. B) 10% Constriction. C) 20% Constriction. D) Quarl Constriction.

EUROPEAID AMCAN 1
EUROPEAN UNION OBJECTIVE 1

Results

Combustion Conditions. FFT Analysis. Suppressed PVC.

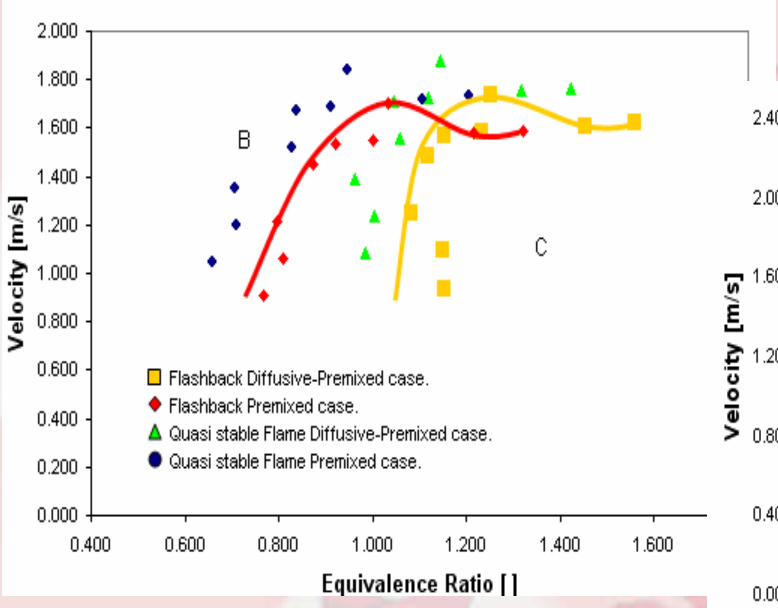
Isothermal Conditions. FFT Analysis. Strong PVC.



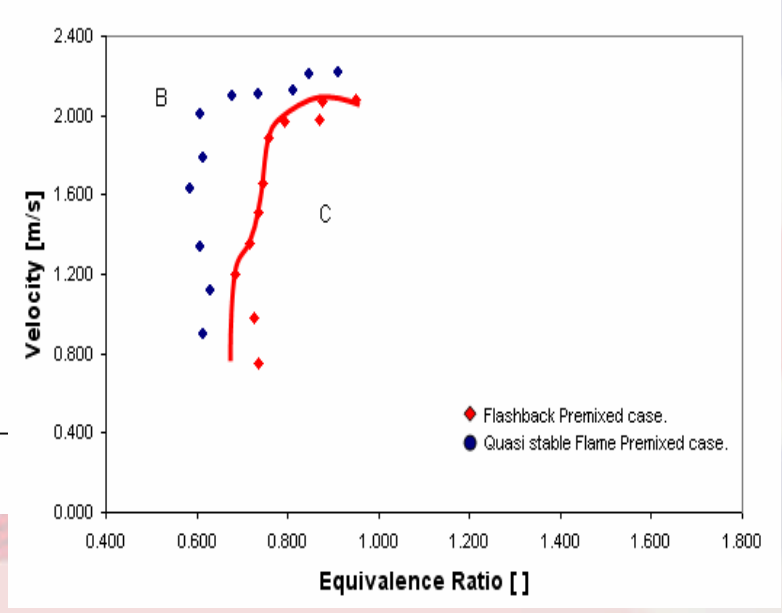
PIV Results for constricted cases, turbine conditions.

YR UNDEB EWROPEAIDD AMCAN 1
EUROPEAN UNION OBJECTIVE 1

Results

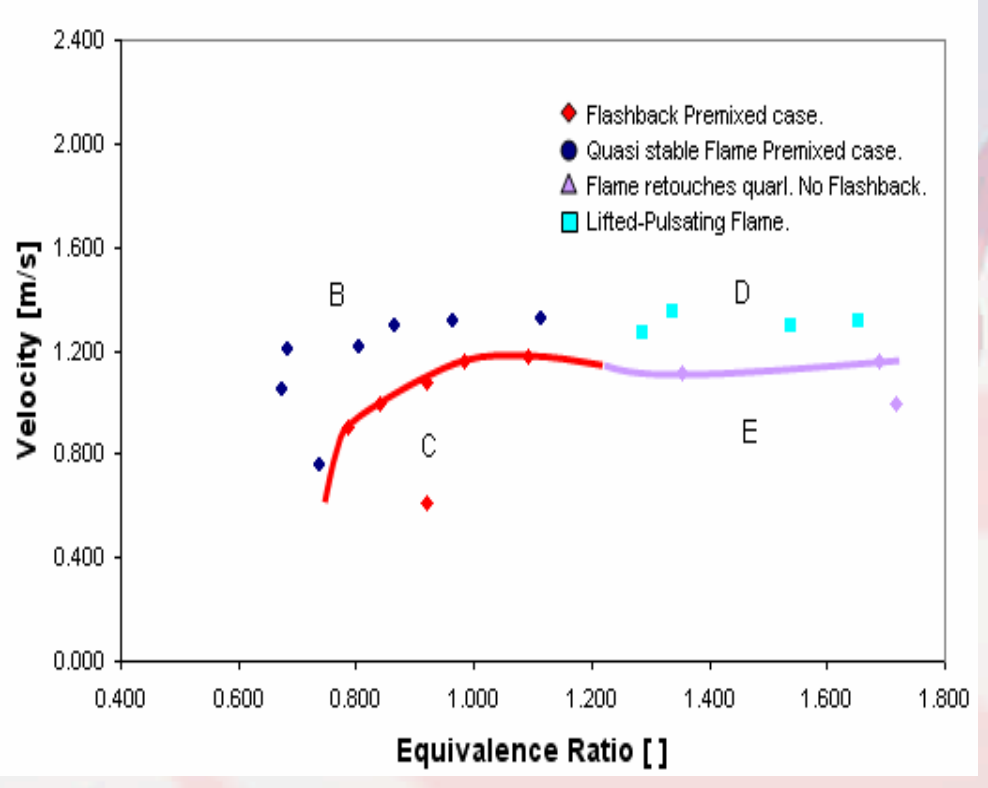


Flashback Results. Open Case with Wide Injector. B) Quasi Stability; C) Flashback.



Flashback Results. Quarl Case without Injector. B) Quasi Stability; C) Flashback. The Quarl without Injector presents lower resistance to Flashback.

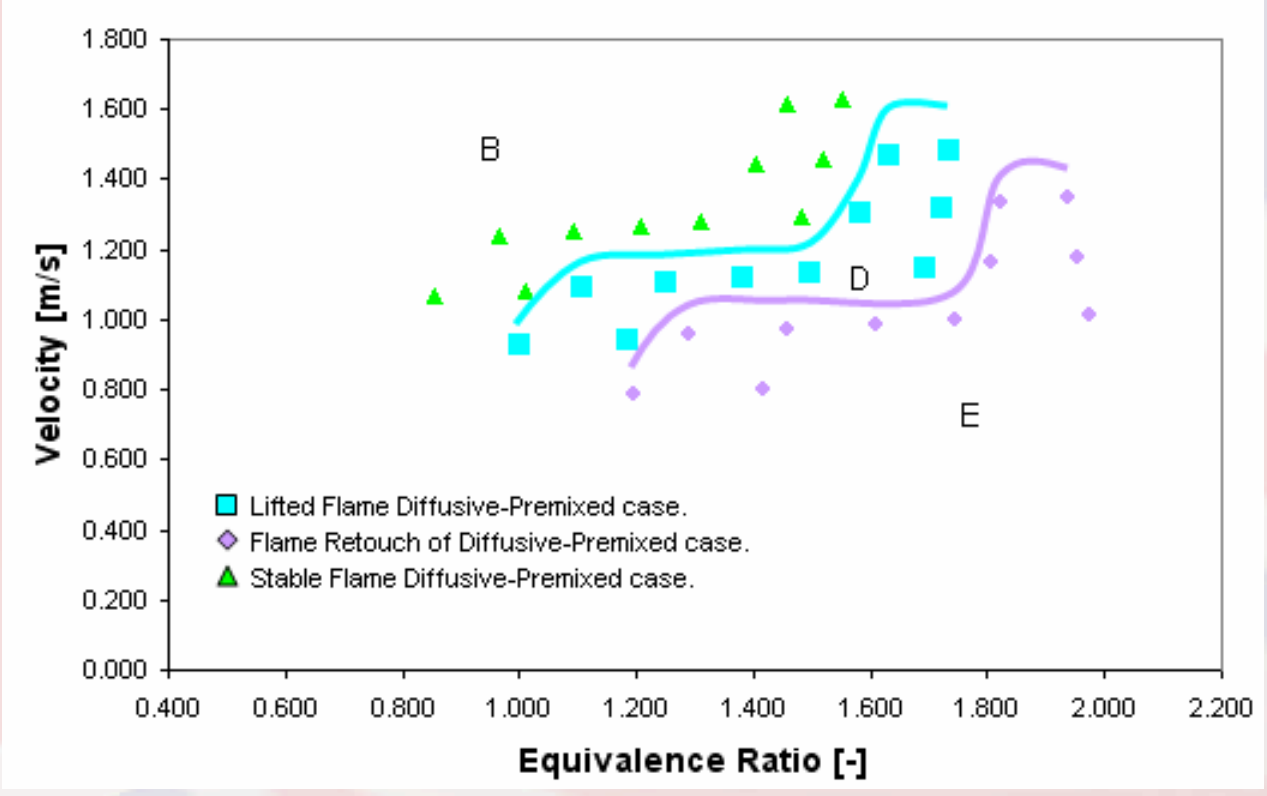
Results



Experimental Flashback with Quarl and Injector. The resistance has increased by 25% compared to the Open Case. B) region of quasi stability for the flame, with different shapes and emissions. C) Flashback region. D) Lifted flame. E) The flame retouches the quarl.

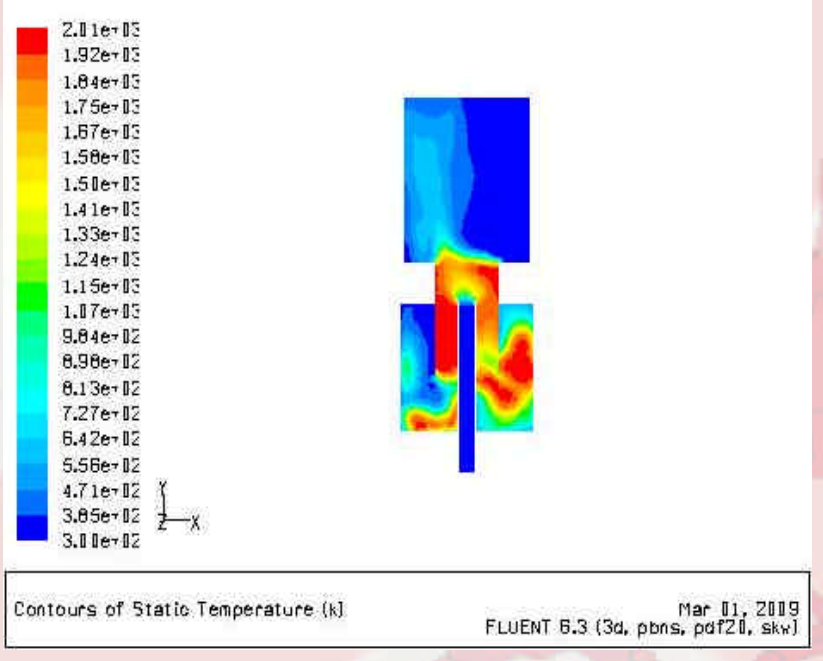
YR UNDEB EWROPEAIDD AMCAN I
EUROPEAN UNION OBJECTIVE 1

Results



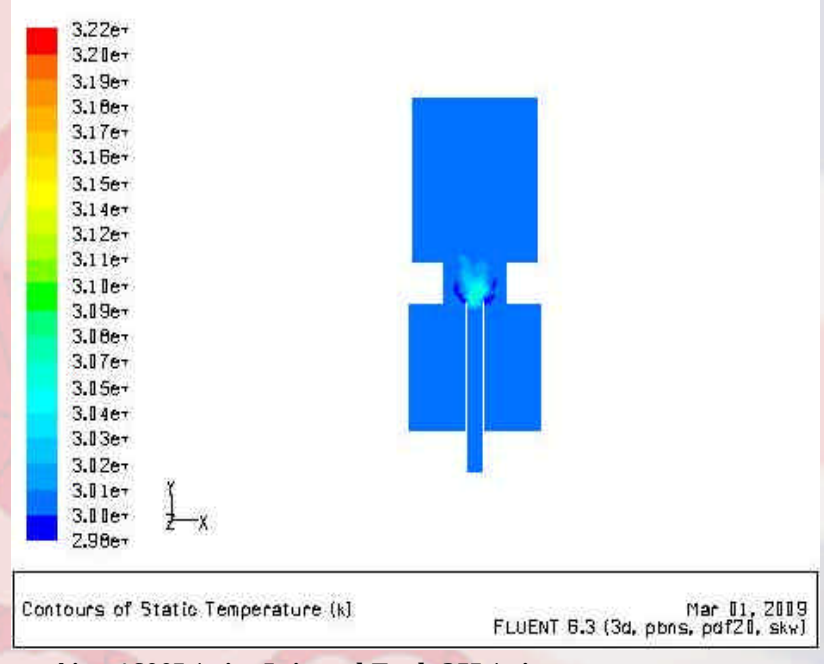
Diffusion caused a phenomenon of reattachment with the quarl, but no flashback was observed. B) region of quasi stability for the flame, with different shapes and emissions. D) Lifted flame. E) The flame retouches the quarl.

Flashback occurs during diffusive-premixed conditions with no nozzle constriction.



Air =600L/min, Injected Fuel=25L/min
Premixed Fuel =40L/min,Φ =1.15

Flame Blow-OFF appears at Lean Diffusive-Premixed conditions.

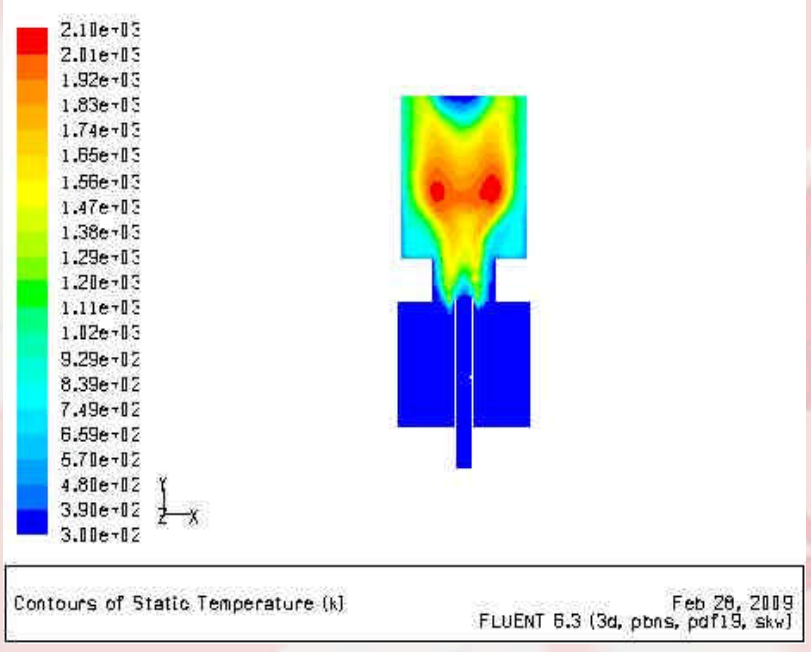


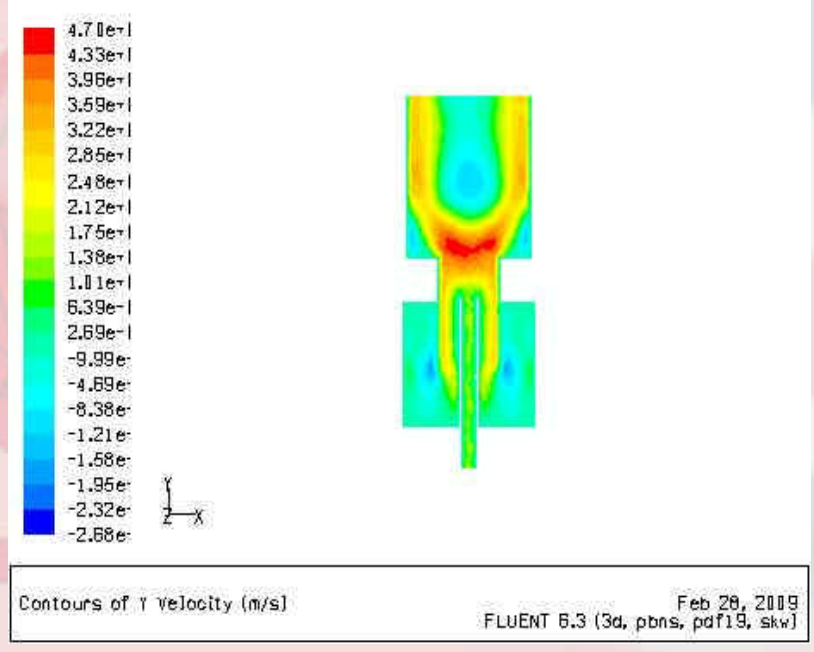
Air =1600L/min, Injected Fuel=25L/min
Premixed Fuel =40L/min,Φ =0.43

YR UNDEB EWROPEAIDD AMCAN I
EUROPEAN UNION OBJECTIVE 1

Results

Numerical Simulation proved that there is No Flashback during fully diffusive injection, similar to Experimental Results



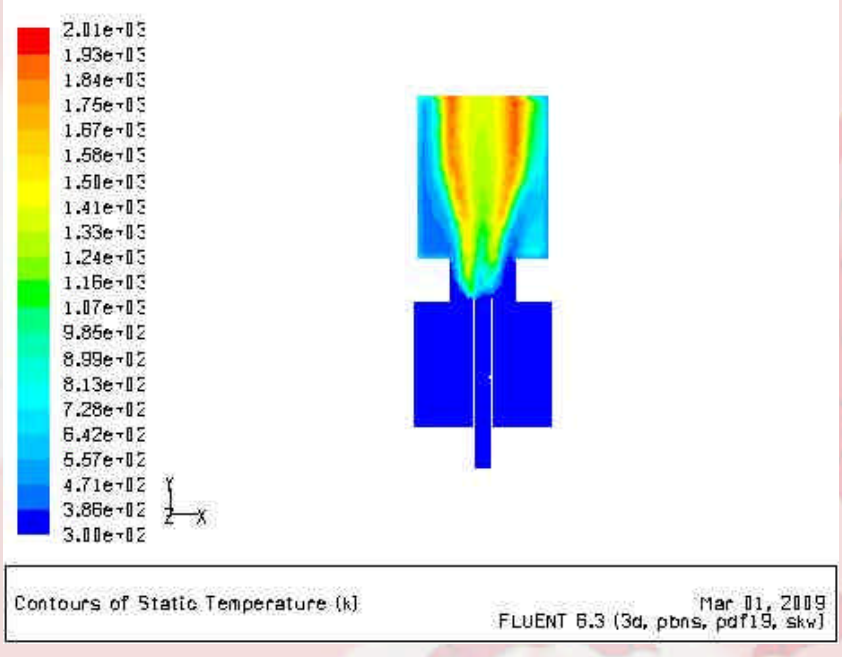


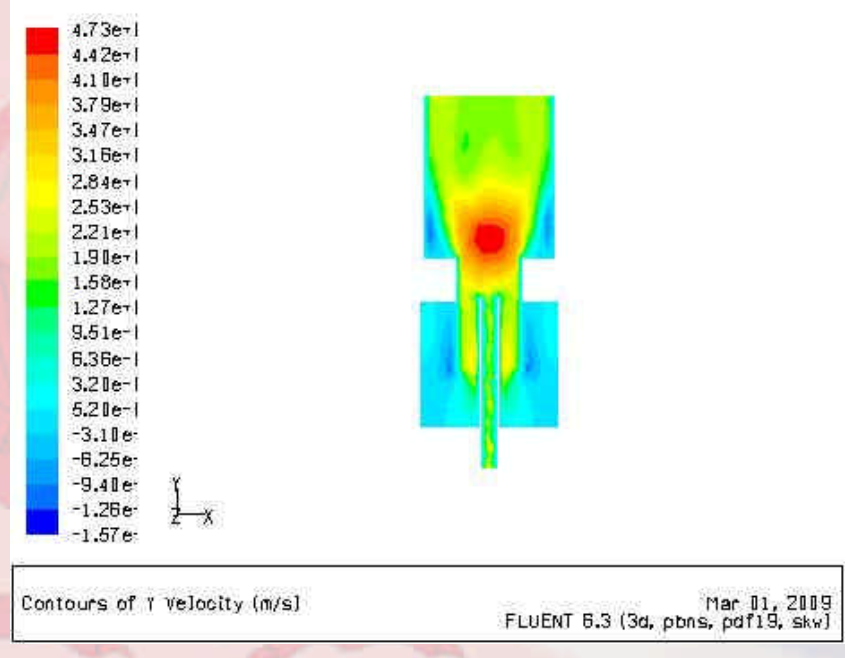
Air Flow Rate =600 l/min, Fuel Rate=25 l/min (diffusive injection).

Lean Mixture Φ =0.717

Results

Diffusive Rich Mixture without Flashback





Air Flow Rate =600L/min, Fuel Flow Rate=25L/min
Rich Mixture F =1.15

Conclusions

- Small quantities of diffusive fuel injection are useful in extending the limits of premixed flames with no nozzle constriction.
- Small exit quarls fitted to the swirl burner are useful in making the CRZ boundary and the main reaction zone in premixed flames match. This geometrical changes can push up the flame in order to avoid flashback at high Re which are capable of reattaching the injector.
- CFD studies showed that diffusive-premixed flames with no nozzle constriction suffer flashback. Moreover, fully diffusive injection avoids the flame to propagate inside of the burner.

Conclusions

- The use of injector increases the flow drag and avoids the appearance of the Combustion Induced Vortex Breakdown, increasing the resistance to flashback at low Re inside of the burner.
- The use of injection with the Quarl showed no flashback inside of the burner.
- The research into flashback is on going:
  - the effect of pressure
  - the effect of gas mixtures that include CO_2
  - The effect on burner design