ON THE PREDICTION OF FLAME STABILITY: ESTIMATION OF THE CHARACTERISTIC FLAME FREQUENCY UNDER AIR AND OXY-FUEL CONDITIONS

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• Objectives
• Overview of the experimental facilities
• Methodology
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Introduction

New technologies on combustion

- Low NOx burners
- Oxy-fuel combustion
  - Coal
  - Biomass

Image 1. Representation of a retrofitted oxy-fuel combustion power plant.

Mitigate GHG

Computational Fluid Dynamics (CFD)

Combustion Efficiency/Limits/Stability

Flow, temperature, species concentrations
Objectives

• Evaluate the oscillatory nature of the flame by LES simulations
  o Instantaneous values of different scalars
  o Image and data processing

• Obtain a trend for the flame dynamics under different oxy-fuel conditions
  o Air
  o Oxy – 21, 25, 30
Overview of the experimental facilities

UKCCSRC Pilot-scale Advanced Capture Technology (PACT)

Location: South Yorkshire, UK.
Thermal input: 250 kW\textsubscript{th}
Geometry: Down-fired furnace, refractory lined cylindrical shape, which is 4 m in height with a 0.9 m internal diameter
Burner: Scaled version of a commercially available Doosan Babcock third generation low-NOx burner
Overview of the experimental facilities

PACT Pilot-Plant Tests
Overview of the experimental facilities

PACT Tests

- 250 kW pulverised fuel combustion test facility, integrated with the solvent-based post-combustion capture plant

Coal firing baselines:
- El Cerrejon coal
- air-firing with post-combustion CCS
- oxy-coal tests

Biomass firing campaigns:
- white wood pellets
- air-firing with post-combustion CCS
- oxy-biomass tests
Overview of the experimental facilities
Overview of the experimental facilities

Coal and Biomass Burners
Flame stability, Combustion performance and Emission
Experimental methodology

Camera array
Industrial CMOS RGB camera:
- $1280 \times 1024$ at $25$ fps
- $320 \times 256$ at $265$ fps

Combustion Chemiluminescence

Original video

Video sectioning and frame recovery
Methodology

Experimental methodology

**Processed grayscale image**

\[ I(t) = \sum_{i \in R_f} \sum_{j \in R_f} \frac{1}{|R_f|} A(i, j) \]

**Overall intensity calculation**

![Transient intensity graph](image)

**Transient intensity of the flame**

**Frequency spectrum construction**

\[ F = \frac{\sum_{n=1}^{N} [P_{xx}(f_n) \cdot (f_n)]}{\sum_{n=1}^{N} P_{xx}(f_n)} \]
## Methodology

### Numerical methodology

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Methodology

- Convection (turbulence)
- Radiation
- Devolutilisation
- Multistep gas combustion
- NOx, SOx kinetics
- Multistep char combustion

- Heat up and dry
- Volatile release and gas combustion
- Char combustion

- Particle aerodynamics
- Inner particle heat transfer
- Surface heat transfer
- Biomass volatiles and char

- Slagging and fouling

"Δt"
Methodology

Numerical methodology

Monitor points, lines and volumes are used in this study

Contour plots of heat of reaction

Contour plots of axial velocity
Methodology

Numerical methodology

Grayscale contour of a scalar

Overall intensity calculation

Transient intensity of the contour

Frequency spectrum construction

\[ I(t) = \sum_{i \in R_f} \sum_{j \in R_f} \frac{1}{|R_f|} A(i, j) \]

\[ F = \frac{\sum_{n=1}^{N} [P_{xx}(f_n) \cdot (f_n)]}{\sum_{n=1}^{N} P_{xx}(f_n)} \]
Methodology

Numerical methodology

\[ F = \frac{\sum_{n=1}^{N} [P_{xx}(f_n) \cdot (f_n)]}{\sum_{n=1}^{N} P_{xx}(f_n)} \]

- Transient pressure
- Axial Velocity
- Noise spectrum
- Flame rumble
- Frequency spectrum construction
- Turbulent coherent structures
- P1, P2, P3...
Results

Predicted mean temperature distribution

Experimental flame imaging

Predicted instantaneous temperature distribution
Results

Numerical estimation

Experimental estimation
Conclusions and ongoing work

Conclusions

- LES instantaneous results were successfully used to characterize the flame
- Oxy-fuel flames showed lower flicker frequencies in comparison to the air-fired case
- Obtained a trend for the flame dynamics under different oxy-fuel conditions

Ongoing and further work

- Evaluation of the turbulent coherent structures development in the furnace and their impact on the flame oscillation
- Development of the mathematical model for the propagation of pressure waves in confined spaces
- Assessment of flame stability for different fuels
Acknowledgements

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References

To Discover And Understand.