250 kW Oxy-fuel Combustion Test Facility

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Objectives

• Investigate the combustion of pulverised coal and biomass under oxy-fuel conditions in the 250 kW state of the art combustion test facility

• Provide a comprehensive and detailed characterisation of pulverised oxy-coal flames, keeping the needs of CFD modellers in mind

• Novel 3D flame imaging predicts flame characteristics such as flicker leading to possible LES validation
PACT Core Facility: Overview
250 kW oxy-fuel rig layout
The Furnace
Oxidiser feed system
Fuels used

Experimental campaigns:

- 100% coal firing
- Biomass co-firing
- 100% biomass firing

Fuels tested:

- El Cerrejon high volatile bituminous coal
- Biomasses used by power generators
  - milled wood
  - straw
  - torrefied biomass

Williams, A. Dr J. M. Jones, Professor M. Pourkashanian. 2007. Co-firing Coal/Biomass and the Estimation of Burnout and NOx Formation. BCURA Agreement Number B 79.

Jones JM, Williams A, Waldron DJ. An investigation of the grindability of two torrefied energy crops. Fuel (89); 3911–18
1. Baseline studies
- air-firing
- oxy-firing

2. Parametric studies
- $O_2$ concentrations (21-35 %),
- recycle ratios,
- optimal $O_2$ distribution between annuli
- impact of impurities ($SO_x$, $NO_x$) - dry/wet synthetic flue gas

Conventional measurements
- temperature (suction pyrometry)
- in furnace heat flux profiles
- species profiles ($O_2$, $CO$, $CO_2$, $SO_2$, $NO_x$)
- unburnt carbon
- ash analysis
- deposition studies

Visualisation*
- 2D/3D imaging
  e.g. flame shape, luminosity, non-intrusive flame temperature
- LDV
  non-intrusive velocity measurements
- LIF
  in flame NO and possibly OH

* collaboration with other universities
Boundary conditions and output

Fuel Characteristics
✓ type, proximate and ultimate analysis
✓ size distribution

Boundary conditions
✓ oxidiser flow rates, temperature, composition
✓ well defined geometry

Output data
✓ temperature, heat flux profiles
✓ species profiles
✓ flame characteristics (flame shape, luminosity, frequency etc.)
  including direct photographs/videos of the flame
✓ burnout
✓ ash characterisation
✓ laser diagnostics (non-reactive and reactive results)
Flame Characterization via 2D & 3D Imaging

Flame images → Flame characteristics
- Size/shape, Ignition point
- Luminous intensity, Uniformity
- Temperature
- Oscillation frequency

→ Flame assessment

→ Computational modelling

Recommendation to Combustion optimisation
The 3D flame imaging system consists of eight optical image fibre bundles protected by water jackets, two CCD cameras and a PC with associated application software, capable of acquiring eight 2D flame images simultaneously from eight equiangular directions.

Specifications of each fibre bundle:

- 30k fibres;
- 650-700mm length;
- 92° angle of view;
- operating temp: 70°C (max);
- mini band radius: 50mm

Video of 225kW PF flame

PACT:
Pulverised Fuel Rig - 250kW
DPS PF burner
2-D imaging
Video of 225kW PF flame

**PACT:**
Pulverised Fuel Rig - 250kW
DPS PF burner
2-D imaging
Flame Temperature Distribution

Averaged flame image
(from 46 instantaneous images captured during 26/07/2013 14:52~14:53)

Temperature distribution
A new tomographic algorithm that combines the logical filtered back-projection (LFBP) and the simultaneous algebraic reconstruction technique (SART) is used to reconstruct the flame sections.

Eight image projections assumed here as symmetric.
• Digital imaging provides a viable approach to online monitoring and characterization of coal flames
• Flame flickering frequencies from digital imaging and Large Eddy Simulations (LES) can be calculated
• The work presented demonstrates the potential importance of using measured data for validation of LES turbulence models for coal combustion.
Thank you

Questions?

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