The Role of Modelling in Understanding Emissions from Biomass Combustion Plants

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Frazer-Nash Consultancy

- 9 UK, 3 Australian Offices, 700+ employees.
- Systems Engineering Approach.

**Aerospace and transport**
- Aerospace
- Automotive
- Gas turbines
- Marine
- Rail and metro

**Defence**
- Air systems
- C4ISTAR
- Defence facilities
- Land systems
- Submarines

**Nuclear**
- Decommissioning
- Defence
- Fusion
- New build
- Power generation

**Innovation and commerce**
- Design services
- Due diligence
- Expert witness
- Health
- Software development

**Security and resilience**
- Commercial
- National defence
- Organisational resilience
- Critical national infrastructure
- Insider threat

**Power and energy**
- Gas turbines
- Oil and gas
- Power generation
- Power, transmission and distribution
- Renewable energy
Directive 2010/75/EU: A Perspective

- Regulations are becoming increasingly stringent, with more scrutiny placed on compliance:
  - How do we de-risk and assure new designs?
  - How do we improve reliability, performance and emissions of ageing equipment?

- What do recent advances in numerical modelling offer?:
  - Computer power:
    - Run more complex models
    - Include more physics
  - Physics:
    - Development and validation of improved physical models

- How can this be applied in practice?
Take an example: Article 50

- What is the spirit of this article?
- How could it be assessed in a numerical environment?
- What is the scope for flexibility within it?

**Article 50**

Operating conditions

1. Waste incineration plants shall be designed, equipped, built and operated in such a way that the gas resulting from the incineration of waste is raised, after the last injection of combustion air, in a controlled and homogeneous fashion and even under the most unfavourable conditions, to a temperature of at least 850°C for at least two seconds.
Opportunities for Advancement

- How do we quantify details of plant operation?
  - Can we accurately predict performance of new designs.
  - Diagnose issues on existing plant and validate models to real life data.

- Controlled and homogeneous:
  - How homogenous is good enough?

- What is the basis for 850°C for at least two seconds:
  - On average, this can be satisfied, but could some of the flow see 850°C for much less than 2 s.
  - Should credit be able to be taken for the temperature history (>1100°C typical)?
Computational Fluid Dynamics (CFD) Analysis

- CFD is a computational simulation method to predict flow characteristics:
  - Temperature, Velocity, Pressure.
- Combustion and chemistry can be modelled.
- Heat transfer by conduction, convection and radiation is possible.
- Whole furnace models can be built, and are within reach of cost-effective computational resources.
- Can use advanced multi-physics models to assess:
  - Erosion, corrosion, fouling, slagging.
  - Flow induced vibration, fatigue loading, noise.
Heat Recovery Solutions (HRS).
Turnkey clean energy power systems.
www.hrs.energy

Tansterne Biomass Power Plant.
22MWe powered by waste wood.

Frazer-Nash have assessed:
  Fluidised bed performance.
  Radiation section performance – power take-off and WID compliance.
  Sparge tube design.
  ITA, ATEX/DSEAR, HAZOP.
Two separate CFD models

Lower:
- Fluidised bed, resolving inflow through sparge tube holes.
- Fluidisation and heat transfer to tubes.

Upper:
- Radiant section with syn-gas and secondary air.
- Combustion and heat take-off.
- Models coupled loosely by control of boundary conditions
  - Check with adiabatic flame calculations.
Controlled and Homogeneous: Radiant Section Combustion and Flow

Flow velocity (m/s)

Temperature (K)

O₂ Mole Fraction
At least 850°C for at least 2 s:
Streamlines

- Can track transport of gases through thermal and turbulence fields.
  - Can be interrogated for statistical analysis.
  - Can be progressed to include species evolution.

- Assessment against Article 50:
  - Plot streamlines
  - Interrogate temperature history (>850°C)
  - Check time-of-flight
  - Mass flow weight and plot distribution
At least 850°C for at least 2 s:
Particle Temperature History

- Evaluate temperature history of transported gas from thousands of uniformly spaced starting positions (7 example tracks shown)
- Calculate time spent above 850°C
- Cumulative probability distribution of time spent above 850°C
- Series of plant conditions and CFD model sensitivities shown
Discussion

- CFD can be used as a tool to show invisible details of furnace operation.
  - We can predict performance of new designs and diagnose issues on existing plant.
  - HRS MD Mark Wickham:
    
    “We found the work you did essential in building confidence in the design”.

- Clever application of CFD is capable of significantly more in-depth analysis than the basic requirement of Article 50.
  - Homogeneity: Quantitative metrics can be developed.
  - Can we unlock the full potential of the analysis methods?

- CFD could be used to advance the “At least 850°C for at least two seconds”:
  - Taking credit for the temperature history (>1100°C typical) could be argued?
Thank you!

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