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BCURA Project B80

Characterising Biomass Particle Behaviour under Co-Combustion Conditions

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Introduction

Biomass, if correctly sourced, is an effective measure of controlling the intensity of CO_2 emissions from power stations.

Today we will discuss

- Government policy
- Industry requirements
- BCURA project B80
    - Progress
    - Future aims

The Renewables Obligation

“The Renewables Obligation requires licensed electricity suppliers to source a specific and annually increasing percentage of the electricity they supply from renewable sources”.

The level 2007/08 was 7.9%, rising to 15.4% by 2015/16.

At the end of 2006 generation from renewable sources eligible under the Obligation stood at 4.4%. The Obligation required 5.5%.

The buy out rate (2007/08) was £34.30/megawatt hour.

http://www.berr.gov.uk/energy/sources/renewables/policy/renewables-obligation/what-is-renewables-obligation/page15633.html

http://www.berr.gov.uk/energy/sources/renewables/policy/renewables-obligation/how-obligation-work/page15634.html

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Co-firing within the Obligation

Co-firing of biomass with coal is included within the Obligation, although the structures have recently been modified.

Latest proposal (expected to be enforced from April 2009):

- Banding of Obligation, so different technologies receive different levels of support
- Co-firing of regular biomass will receive 0.5ROCs / MWh. Additionally a supplier may not fulfil more than 10% of their ROCs from this method.
- Co-firing of energy crops will receive 1.0ROC / MWh.

This creates a buy out price difference (at the 2007/08 level) of £17.15 / MWh

BERR, 2008. Renewables Obligation Consultation, Government Response. January 2008.

Regular Biomass vs Energy Crops

Regular biomass

- Waste that is purely biomass (e.g. olive residue, waste sawdust, palm kernels*)
- Typically pre-processed or relatively easy to mill

*

Energy crop

- Either a crop planted after 31st December 1989 with primary intention to use as fuel, or one of; Miscanthus, Salix (SRCW), Populus (SRCP).
- Made up of the entire plant – more fibrous than regular biomass, and needs processing

BERR 2007, *Renewables Obligation Order 2006 (Amendment) Order 2007, Final Decisions* January 2007

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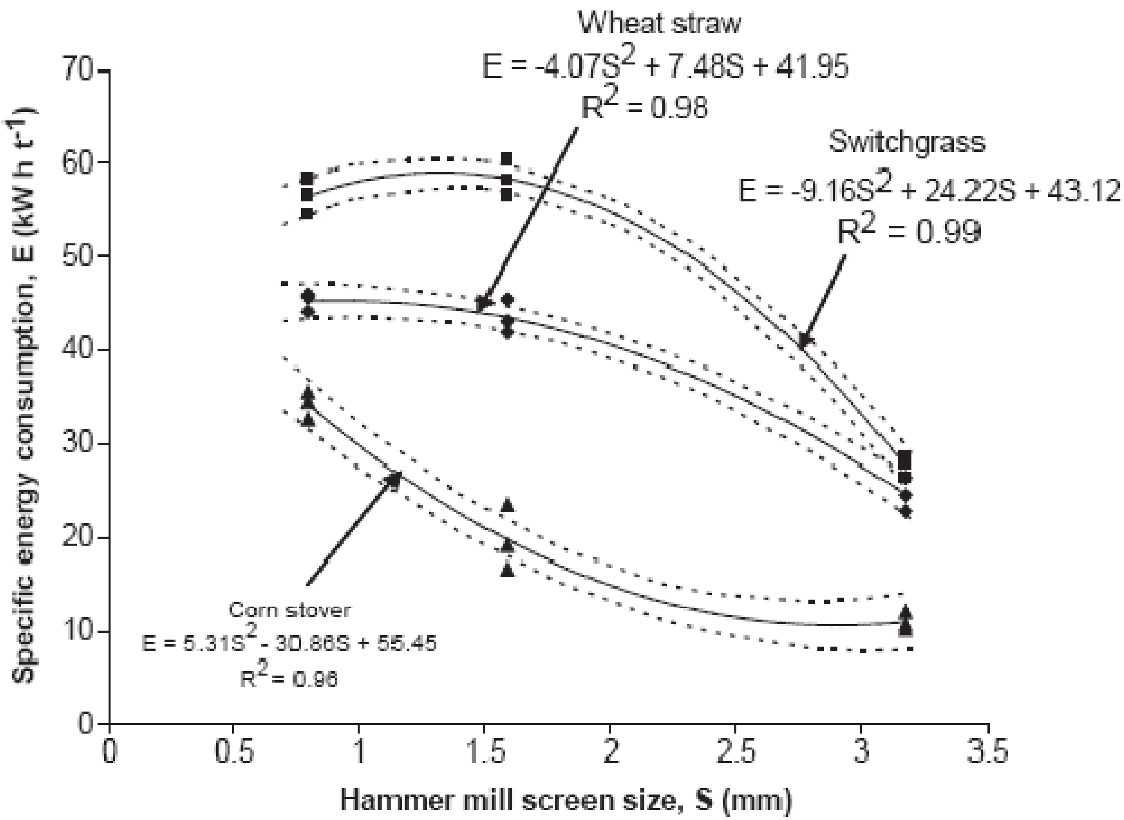
Energy demand of milling



12% (wet basis) moisture content

Mani et al 2004, Grinding performance and physical properties of wheat and barley straws, corn stover and switchgrass. Biomass and Bioenergy 27 (2004) 339 – 352.

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Co-firing

Biomass is currently prepared and used in a number of different ways:

- With Coal
  - Some off-site preparation, then mixed with coal fuel stream prior to mills
  - Burnt in the same burners (e.g. Didcot)
  - Lower investment, but lower co-firing levels
- Dedicated fuel path
  - Dedicated mills
  - Can be mixed with coal after mills for the same burner
  - Can be sent to dedicated burners / gasifiers (e.g. Aberthaw / Ferrybridge)
  - Capital intensive, but higher co-firing levels

Burn out rates are not guaranteed!

Improve the combustion

We want to enable industry to optimise their fuel

- Dry it out
- Mill it smaller

Project aim is to be able to compare a new fuel against other fuels (with boiler experience) enabling preparation of the new fuel such that it burns acceptably.

Our aim is to develop a test that is reliable, but rapid.

- Wire mesh apparatus has been chosen

A simple wire mesh rig

Image: http://www.widerview.com/gg9072.jpg

Past Imperial Work

Our group has a wealth of experience with past wire mesh apparatus:

High heating rates (up to 10^4 K/s)

Variable hold times (depending on rig cooling)

Very high temperatures (2000ºC is possible, but 1600ºC is more common)

Good repeatability between particles
We know that variation is due to the particle, not to errors associated with particle heating

Image: BERR 2001, Advanced Characterisation Property Database for Chinese and Indian Coals.

A new wire mesh rig

Require direct optical access

- Permits accurate time based analysis of particle combustion

Radiation controlled

- Previously sieved coal to sit in apertures of wire mesh. No longer possible.

Attempt to get rid of the pyrometer

- Drastically reduce the cost and slightly increase processing speed of the apparatus

Still wish to use high currents to permit high heating rates and high peak temperatures.

A new wire mesh rig

Three different control loops:

1. Thermocouple between mesh
   Slow to react, accurate
2. Resistance measurement
   Very fast, very cheap
3. Pyrometer
   Required to monitor mesh oxidation

All controlled by an embedded computer, synchronised to operate at 50Hz.

Control loop operation

Thermocouple is in a geometrically similar position (within the mesh) as the particle.

- Concept is that it will integrate the heat flux.

Mesh resistance reading monitors instantaneous with mesh heat flux.

- Concept is that this will maintain a consistent instantaneous heat flux.

Pyrometer corrects the resistance target value.

- Stainless steel mesh (grade 304) operates above oxidation limit.
- Oxidation causes a change in the radiation / resistance relationship.

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What we can do

Currently there is a top temperature limitation on the mesh, as such performance is constrained.

Very high heating rates are difficult – a consequence of using mains power to heat the wire mesh.

Maximum temperature	900°C
Heating rate	2000K/s
Maximum particle size	40mg

Video of particle burning

21-05-08_16-56

This is a particle of White Ash wood.

It is approximately 1.5x4.5x6.2mm

Stills

We can then break the video down into stills for analysis

0.00s

0.36s

0.76s

1.04s

1.56s

2.36s

3.16s

3.48s

3.60s

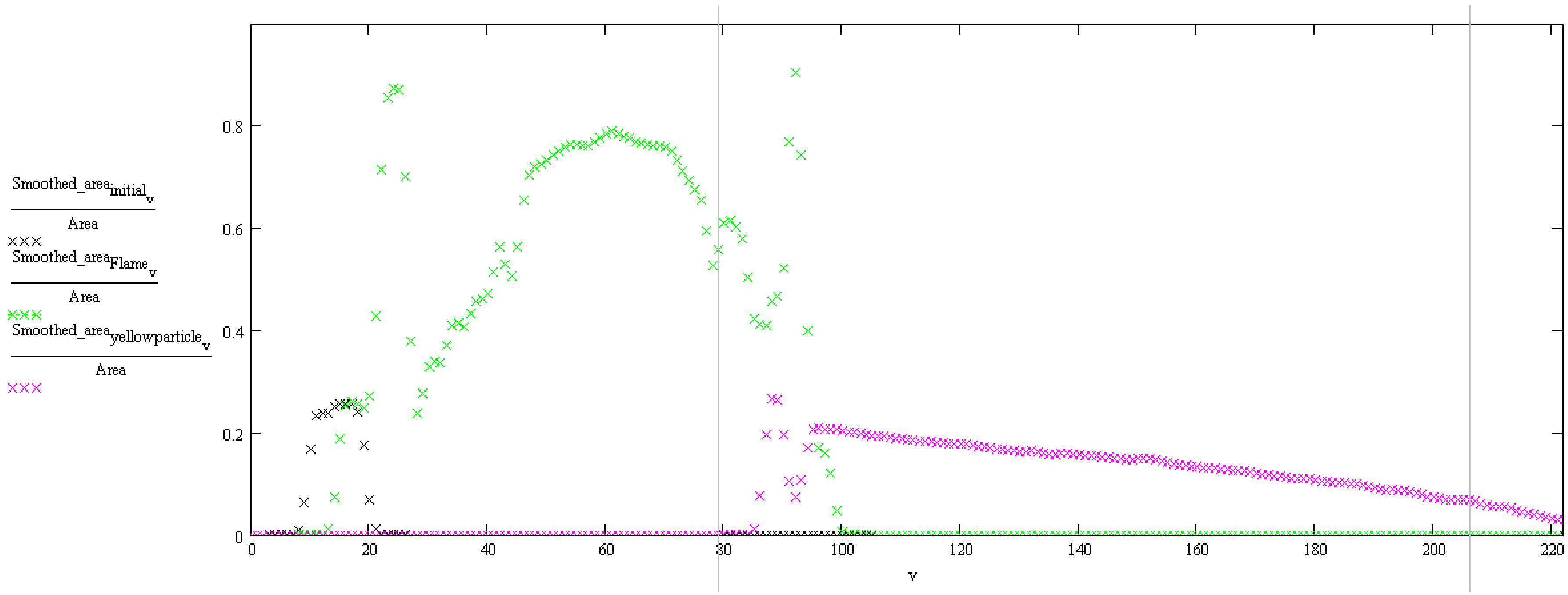
3.88s

7.56s

8.88s

MathCAD analysis

MathCAD image analysis on each frame gives us a flame area



We can then compare characteristic combustion points of different particles

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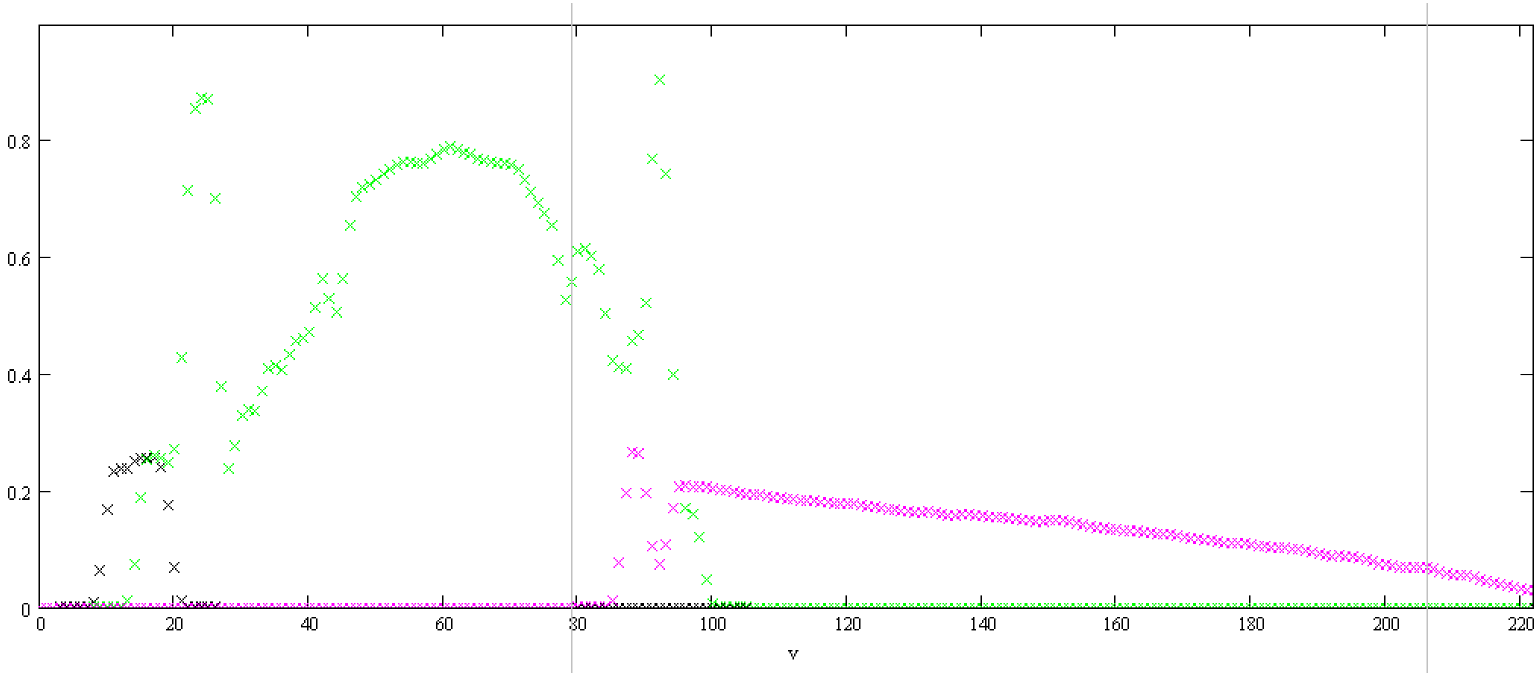
Characteristic points



Total Combustion time

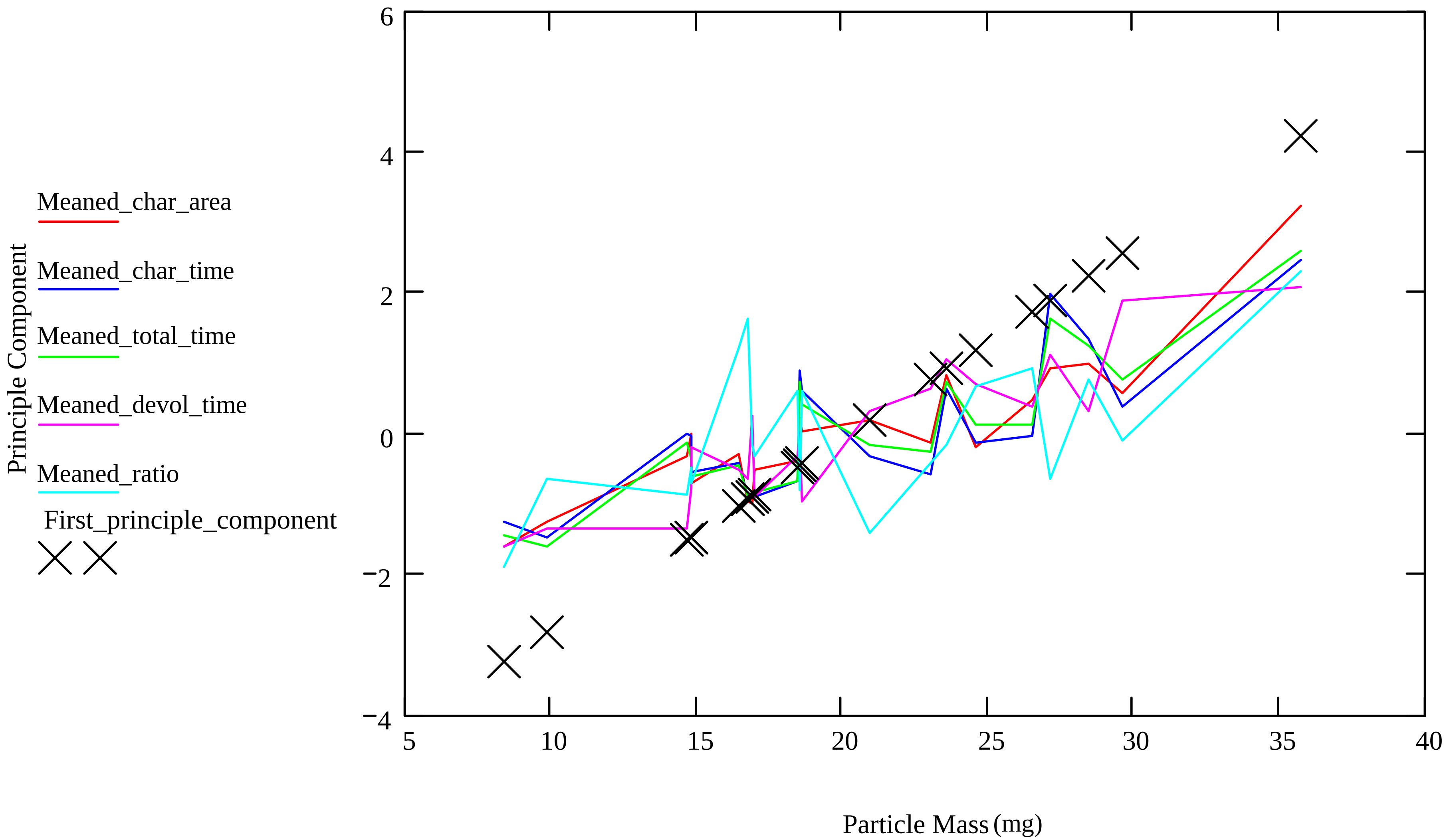
Char Combustion time

‘Devolatilisation’ time

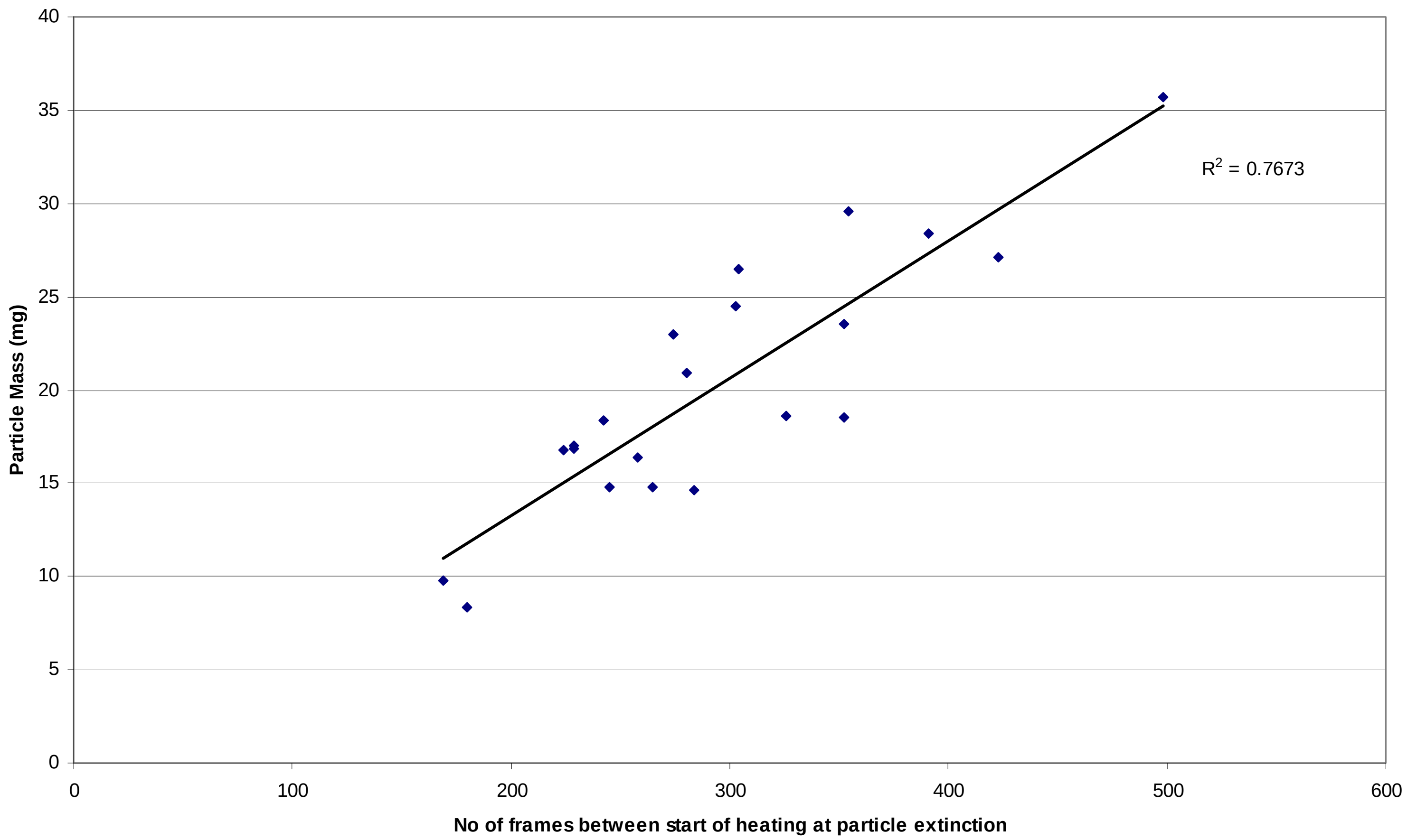
Area under char curve

Ratio between particle size before and after devolatilisation

Principle Component Analysis



Combustion times for 21 particles



Today

Think that we have a valid measure of particle combustibility

- Shown on only one fuel with one moisture content

Looking at shape of particle

- Different aspect ratio’s known to affect combustion times
- Much modelling work has been completed in the literature

Particle moisture content

- Moving to burn fuels with different moisture levels

Different fuels

Shape factor

Common measure is the ratio of surface area of equivalent sphere to particle surface area used.

Suggests a flake 4x4x0.63mm is identical to a bar of 1x1x10mm

- Same volume, same surface area

Currently evaluated by using three orthogonal cameras, and processing results in MathCAD

- Only valid for rectangular particles

Moisture

Fuel moisture content is changed by drying particles at different constant relative humidity's.

Method has been verified with wood maintained at 50% RH.

Long term changes in moisture content as the ambient temperature changes (which has not been controlled) have not been evaluated.

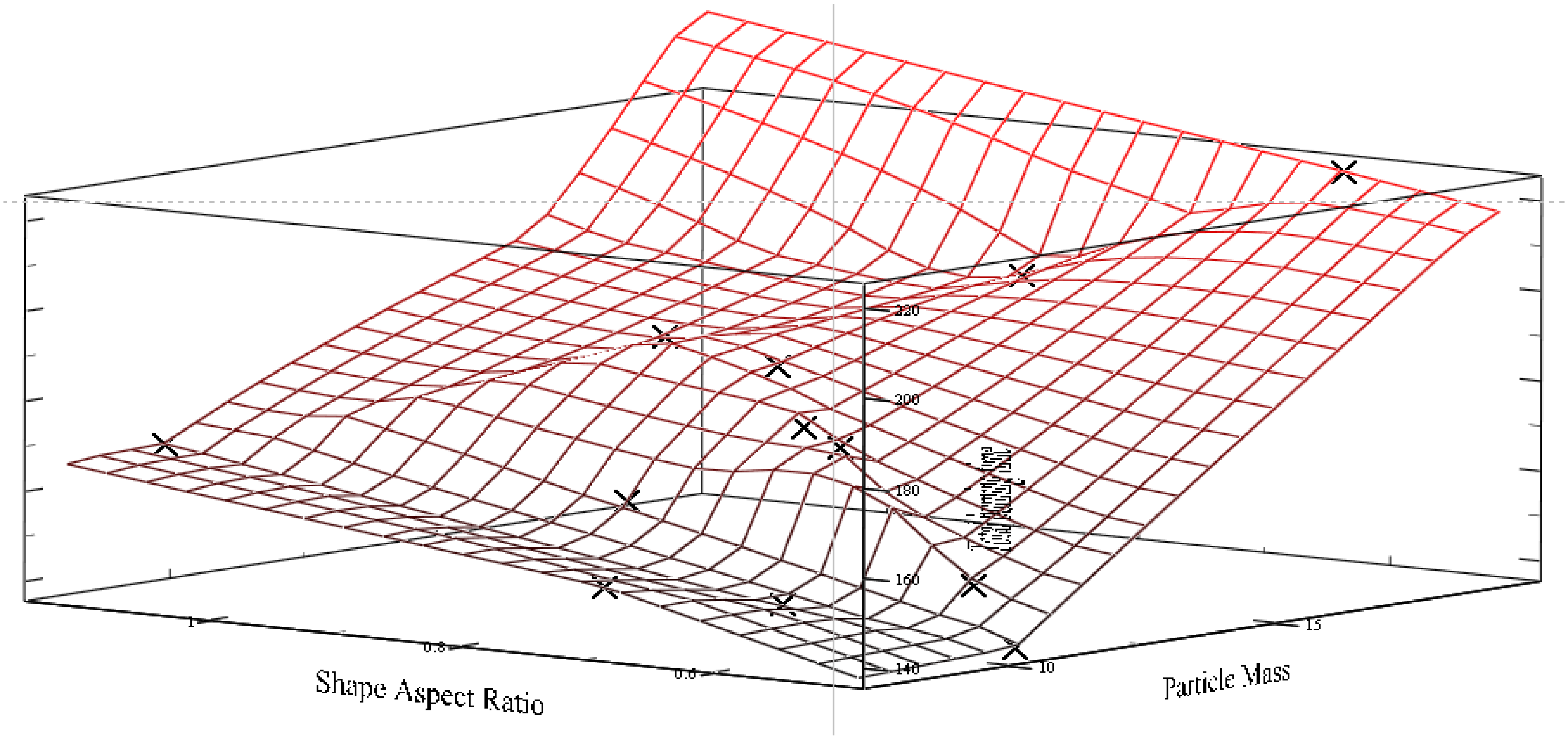
Different fuels

To date two different fuels (olive residue and white ash) have been burnt within the rig.

The olive residue trials were completed at a different stage in the rig design, and as such the results are not comparable.

At this stage we are not seeking characterise many new fuels, rather to burn a new one to ensure that the system works.

Goal



Goal is a plot similar to the above (one surface per fuel) with metrics such as;

Combustibility, shape factor, moisture content.

Conclusion

We have discussed:

- The push from government
- The pull from industry
- Rig operation and development
- Interim results
- Direction of project

Now looking to rapidly acquire experimental data sets by burning different particle shapes with different moisture contents.

Any Questions?

BCURA project B80

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