Coal Research Forum (CRF) and Biomass and Fossil Fuel Research Alliance (BF2RA) Research Seminar, University of Nottingham, 15 October 2013

Summary Report

Overview

This seminar organised by the CRF in cooperation with BF2RA presented the aims, objectives and progress made to date on selected BF2RA projects. The audience included BF2RA Members, potential new members, recipients of current BF2RA grants and both Industrial and Academic Members of the CRF and others.

The main purpose of this event was to demonstrate the value of the current BF2RA research programme, to identify priority research needs and to encourage proposals from the academic community that are more in line with BF2RA's requirements. It also showcased BF2RA to potential new members. Further it gave potential proposers an opportunity to hear about current BF2RA projects and to meet BF2RA Board Members.

Delegates were treated to high calibre presentations both from industrialists and BF2RA students. The number of participants at just under 40 was a little disappointing.

There follows a summary of the presentations, Q&A sessions and the Panel Discussion Session. A detailed account is not included here as all of the presentations are available on the BF2RA (www.bf2ra.org) and CRF (www.coalresearchforum.org) websites.

Introductory Session

Professor Colin Snape welcomed all to the University of Nottingham for this Research Seminar and introduced Greg Kelsall, Chairman of the BF2RA Members Board, to give the introductory presentation.

Greg Kelsall – An introduction to the BF2RA and a Overview of its Project Portfolio.

Greg described the history of BF2RA and it objectives. These include sponsoring of research in the biomass and fossil fuel areas and also organising the annual Coal Science Lecture. Greg noted that membership of BF2RA comprises 7 “world class” energy, equipment supplier and coal utilisation companies, namely, EDF Energy, E.ON New Build and Technology, EPRI, Alstom Power, Doosan Power Systems and British Sugar. Drax Group plc has confirmed as a new member for 2014.

Greg described the BF2RA funding model and presented the priority research themes for the last BF2RA Call for Proposals. He then went on to review the BF2RA project portfolio that currently comprises 11 projects with a further three starting in late 2013. Five of the current project were presented later in the programme so Greg gave details on the other 6 ongoing ones, namely:-

- **Impact of Biomass Torrefaction on Combustion Behaviour in Co-firing** – University of Nottingham (2010-2014). The aim of this research is to investigate key fundamental issues associated with the development of torrefaction technology to help to promote its more widespread use. Torrefaction of a wide range of biomasses has been undertaken. Ongoing work is looking at burnout, nitrogen partitioning, char morphology and BET analysis. Future work will include slagging and fouling studies.
- **Avoiding the Sintering of Coal-fired Fluidised Beds** – University of Nottingham (2011-2015). This research aims to investigate the causes of fluidised bed sintering in biomass co-fire to define safe operating modes to avoid sintering. A fluidised bed rig has been designed, built and commissioned and is now being used for the test programme. Future work will look at agglomerated samples, will define strategies to avoid sintering and undertake an economic appraisal.
- **Milling and Conveyance of Biomass** – University of Nottingham (2011-2015). The aim of this research is to rank and classify grinding, erosion and abrasion behaviour of biomass types to different mills. Studies are being undertaken both at the University and on site. This research has generated considerable interest amongst BF2RA Members and progress to date has been widely reported at conferences.
- **Development of a Novel Feeder for Pressurised Systems** – University of Sheffield (2012-2015). The aim of this work is to develop a novel and reliable feeder to feed continuously solid fuel into high pressure environments to enhance the commercial viability of high pressure combustion/gasification. A lock-hopper test rig has been built and operated. A key result to date is a theoretical energy saving of over 80% at 50 bar compared with a conventional lock-hopper system.
- **Development of Novel Coatings to Resist Fireside Corrosion in Biomass-fired Power Plants -** Cranfield University (2012-2015). The aim of this research is to develop the best coating composition resistant to fireside corrosion in power plants using a multi-target magnetron sputtering system. The best coating will be exposed in a specially designed furnace and the influence of elements including Co, Cr, Al, Ni and Fe will be investigated. Alternative methods for applying coatings will also be evaluated.
- **Integrity of Coated Ferritic Alloys under High Temperature Creep and Fatigue** University of Nottingham (2012-2016). The aim of this research is to investigate the mechanical and chemical integrity of coated samples subjected to high temperature exposure and steady/cyclic mechanical loadings. Specific objectives include a better understanding of currently available coatings, ranking of potential coatings based on test results and understanding of factors that limit service life.

Greg identified the three new projects that are about to start, namely:-

- **Biomass Exacerbated Cyclic Oxidation of Steels in Steam (BECOSS)** – University of Birmingham.
- **Biomass Co-firing with Low Volatile Matter Coals** – University of Nottingham.
- **Modelling Milling of Biomass** – University of Nottingham.

Finally Greg referred to the structure of the BF2RA website and illustrated the level of information that is available with the Members' areas.

Session 1: Generic and Cross-cutting Research

This Session was chaired by **Dr Will Quick**, BF2RA Board Member and CRF Executive Committee Member.

Keynote Industrial Presentation – Dr David Waldron, Alstom Power.

Dave Waldron presented generic and cross-cutting research with reference to drivers, current technologies, future requirements, the path to commercial deployment and carbon capture and storage. Drivers are increasing flexibility/reliability, lowering the environmental footprint and reducing the cost of electricity.

Dave looked at future energy demand through to 2050 and noted that CCS is needed alongside renewable energy sources. He also noted the increased flexibility required because of the intermittent nature of some renewables. For thermal power plant Dave referred to the twin track approach of increasing efficiency (including biomass co-firing) and CO_2 emission reduction via CCS. Dave summarised the scope for efficiency improvement for new and retrofit situations and noted that 60% of the projected 2030 installed capacity base is yet to be built.

Dave summarised Alstom's CCS roadmap with reference to amine scrubbing and chilled ammonia process developments. He also referred to oxy-firing and the White Rose commercial demonstration in conjunction with Drax, BOC-Linde and National Grid.

Finally Dave referred to 2nd generation technologies such as chemical and carbonate looping.

Dynamic Modelling and Simulation of Supercritical Coal-fired Power Plant with CO_2 Capture – Akeem Olaleye, University of Hull (2011-2014).

Akeem Olaleye reviewed progress on this research to date. In 2012 he undertook a literature review and did some steady state modelling work. This year has been spent on dynamic component modelling, a whole plant dynamic model and steady state validation. Future work will focus on dynamic validation, a dynamic model for CO_2 capture, model integration and evaluation for grid compliance.

Akeem presented a suite of detailed results for specific modelling activities using the gPROMS model and presented results comparisons with actual plant data.

During the ensuing Q&A session Will Quick acknowledged the importance and complexity of this research. Dave Waldron asked about the extent of breakdown of plant components. Akeem replied that individual plant components are modelled as well as interconnecting pipework, etc. Greg Kelsall commented on the use of gPROMS and asked about Matlab. Akeem justified the use of gPROMS because of the larger dynamic base.

Intelligent Flame Detection Incorporating Burner Condition Monitoring and On-Line Fuel Tracking – Danny Sun, University of Kent (2011-2014).

Danny Sun reviewed the aims of the research and summarised current progress relating to system design/implementation, testing on plant, intelligent burner condition monitoring and intelligent on-line fuel tracking.

Danny described the monitoring system used that incorporates an optical fibre bundle linked to an imaging camera and data processing system. Following commissioning in the laboratory the system has been evaluated on a large coal/biomass fired boiler in the UK and a smaller oil-fired combustion test facility (CTF) at Zhejiang University in China. Danny presented images of coal and biomass flames and also temperature distribution data within the flames. The results showed greater instability of the biomass flames.

The CTF results have enabled the use of flame parameters as a signature for a particular combustion condition. Danny compared results of different modelling approaches for estimating factors such as abnormal condition detection, NO_x formation and flame state identification.

Future research will include further field trials in the UK on both coal and coal/biomass fired power plant and oxy-firing using the University of Leeds CTF.

In the Q&A session both David Allen of E.ON and Greg Kelsall of Alstom Power focused on the commercial potential of the system and commercialisation plans. Danny responded that more testwork is required and that the system needs to be more reliable and robust.

Modelling Chemical and Micro-structural Evolution across Dissimilar Interfaces in Power Plant Alloys – John Clark, University of Nottingham (2011-2015).

John Clark described the background and need for work in this area with the move towards higher temperature and pressure operation and the requirement to join different types of materials. For lower temperature operation cheaper low-chromium steel can be used but with temperature increase there is the move to high-chromium steel and to nickel alloys.

John explained how metals are joined using multi-pass fusion welding and how this creates heat affected zones that may be subject to failure in service. He then presented modelling results that simulate steel-steel and steel-nickel interfaces and discussed the wider applicability of software methods. John presented measured data and compared with simulation using DICTRA software. To date studies have focused on ferritic-ferritic interfaces. This will now be extended to ferritic-nickel interfaces which will introduce the ferrite-austenitic problem due to the differing crystal structures.

Further research will focus on wider application in power plant technology and the extension to other industries and alloys.

During the Q&A session it was noted that the real problem relates to carbide precipitates. John acknowledged that these are caused during diffusion welding. The discussion concluded that modelling could be used to determine conditions for carbide formation and that this could be the subject of a future research project.

Session 2: Biomass Research

This Session was chaired by **Mr Karl Bindemann,** BF2RA Board Member.

Industrial Keynote Presentation – Mr Ralph Chamberlain, E.ON Energy

Whilst Ralph's presentation was on Biomass R&D from an E.ON perspective, he invited others present to interject and contribute.

Ralph provided an overview of E.ON's business before focusing on Technology and Innovation (R&D). He then introduced E.ON's biomass activities relating to fleet conversion, fleet new build and heat plant in Sweden. Ralph stated than E.ON has some 20 years experience in biomass energy and more recently has run several co-firing trials. The challenges today are scale, storage issues, pellet variability, milling, PF transport, corrosion and combustion monitoring and future emission limits. Further areas of research include sustainability, health and safety and finally ash treatment/re-use.

Ralph presented examples in practice including temperature measurement in pellet piles, the fire behaviour of wood pellets and dry wood chip at the large scale and pellet quality management. The last he cited as a topic for cross-industry collaboration.

A New Classification System for Biomass and Waste Materials for Use in Combustion – Philip Jenkinson, University of Nottingham (2011-2015).

Philip Jenkinson summarised the background to the research and presented the objectives, namely, to develop a new classification system to be used as a predictive tool for combustion; to provide an effective guide to combustion characteristics of different biomasses and waste fuels and to facilitate biomass and waste utilisation.

Philip described key differences between coal and biomass structure. With coal, maceral analysis provides a guide to combustion performance and for biomass, lignin, hemicelluloses and cellulose content provides a starting point.

Philip referred to the analytical techniques used for biomass including ^{13}C NMR, elemental analysis and ICP-OES to enable an understanding of structure and TGA to determine behaviour during devolatilisation and combustion. Philip went on to discuss aromatic carbon and char yield for different biomasses and the influence of inorganic minerals.

Philip presented results of char reactivity studies that showed long burn-out times for lignin chars compared to other char material for a range of biomass types.

Results to date indicate that lignocellulosic composition impacts significantly on the combustion performance of biomass fuels. This will impact on burner design and other combustion infrastructure. Finally there is some evidence that synergistic interactions of biomass constituents during combustion could help in co-combustion with unreactive coals

Discussion reinforced the importance of this research to develop a predictive tool for biomasses alongside the established coal classification procedures. The significance of inorganic elements on biomass char combustion was also noted.

Low Temperature Ignition of Biomass – Professor Jenny Jones, University of Leeds (2012-2013).

Professor Jenny Jones presented the findings from a recently completed one-year post-doctoral study. The lead researcher was Dr Abby Saddawi, formerly of University of Leeds (now at Lincoln University).

The aims of this study were to develop laboratory methods for assessing ignition risk, to measure the ignition properties of a range of biomass fuels and to rank biomasses based on ignition risk during storage and conveying.

Jenny noted that techniques used for the research included ignition of dust layers, thermal analysis methods, FTIR and pyrolysis-GC-MS, single particle ignition and the BS method for dust accumulation. A wide range of biomass fuels were evaluated and Jenny presented the results for each technique. Based on activation energies high risk materials include wheat, miscanthus, sunflower husk and olive cake; medium risk materials include pine, red berry juniper, plane, mesquite and olive residue.

Discussion centred on the reason why dust explosion was excluded from the scope of the study. Jenny noted that a separate EngD study at the University of Leeds was looking at this.

Session 3: Panel Discussion – BF2RA's Role in Meeting Research Needs

Peter Sage, Technical Officer of BF2RA lead the panel discussion assisted by the BF2RA Board Members present who were **Greg Kelsall, Will Quick, David Gent** and **Karl Bindemann.**

Peter stated that BF2RA will hold a call for proposals in early 2014 and that the BF2RA Members Board is currently discussing the technical scope of this call. Peter referred to the current portfolio of 11 projects and the 3 new starts this year. There is the need to build on and complement current research and meet any priority research needs. Peter then presented five general themes for research that had been debated by BF2RA Members and invited suggestions for priority topics and/or specific projects. The 5 themes are:-

- Utilisation of fossil fuel and biomass
- Plant operation and control
- Materials development
- Advanced cycles for fossil fuel/biomass utilisation
- Control of emissions and products arising from fossil fuel and biomass utilisation

There then followed a lively discussion with several suggestions both from the floor and from the panel. These included:-

- Development of correlations to model corrosion
- The fundamentals of biomass corrosion – currently lacking analysis of existing information, how does industry make use of information
- Production of liquid fuels – biogas, biofuels
- Emissions from biomass as a function of plant corrosion
- Generic approach to improvement of overall performance to include materials, efficiency, flexibility and operational issues
- CFD modelling on fuel switching (coal to biomass to torrefied biomass)
- The use of kinetic parameters
- Use of torrefied fuels and benefits of using existing mills
- Combustion monitoring and control – a possible follow on to the current University of Kent research
- Expanding the fuel base to include cheaper, low quality fuels and associated safety issues

Finally there was a discussion on the mix of project timescales (3/4 year EngDs, 3 year PhDs and shorter RAs, etc.). Agreed that should identify best timescale on case by case basis. Also it was suggested that BF2RA should define specific projects based on BF2RA projects done to date (to fill gaps).

Peter thanked all for their contributions to the panel discussion and invited any further ideas to him by email before 31st October.

Concluding Remarks – Professor John Patrick, Chairman (Academe), Coal Research Forum

John thanked all the speakers and participants for their contributions towards a successful day that informed about BF2RA and its research activities and continued the discussion on research needs and priority. John also wished everyone a safe journey home.