Profiles

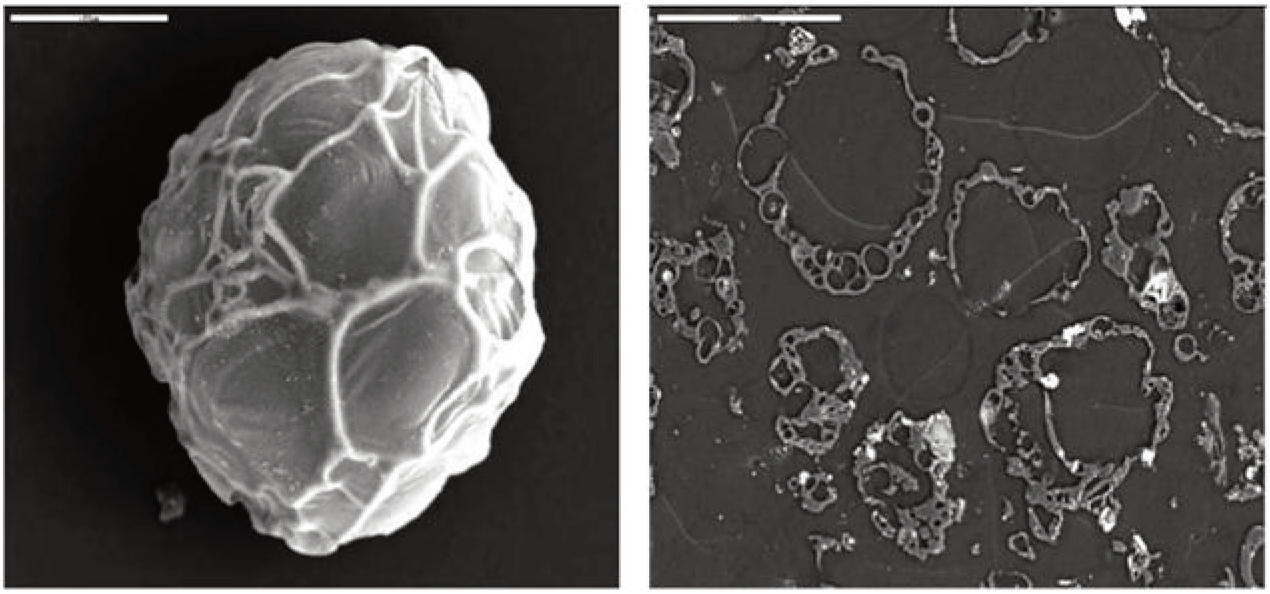
Understanding pulverised coal, biomass and waste conversion

No 12/11 September 2012

Pulverised coal firing has been the dominant technology for generating power in utility boilers for almost a century. During this period, boiler designs have evolved through an accumulating collection of knowledge that has led to many empirical relationships that still guide current and future design directions to some degree. In the late 1940s the developed nations began to undertake coal research based on scientific principles to ensure the most efficient use of the primary energy resource represented by coal. As the body of scientific knowledge on the physics and chemistry of coal combustion grew, it was used to direct the improvements to efficiency required and, later, the control of pollutants produced during the combustion of coal. This involves not only the control of emissions of particulates, SOx and oxides of nitrogen but also of trace elements, polycyclic aromatic hydrocarbons and, increasingly, CO_2.

The presence of complex carbonaceous structures in close combination with a range of mineral components subjected to an extremely aggressive temperature-time profile leads to a very large number of reaction pathways, even before interactions with boiler components are considered. Previous IEA CCC studies have collated and discussed the results of this extensive body of work on pulverised coal combustion. Individual aspects of the combustion process have been isolated by well chosen experimental techniques and characterised in detail, but others have defied clarification. In addition while these individually-focused studies were capable of giving valuable insights into pulverised coal behaviour, and could be used to guide specific aspects of the combustion process such as pollutant formation and amelioration a unified model capable of genuine predictive capacity has not emerged and many coal users continue to rely on empirical correlations to predict coal behaviour and for plant design. The overall complexity of the pulverised coal environment remains extremely challenging and a comprehensive theoretical description is considered likely to remain elusive for the immediate future.

The last twenty years have seen some very significant changes in the power generation sector that affect the way

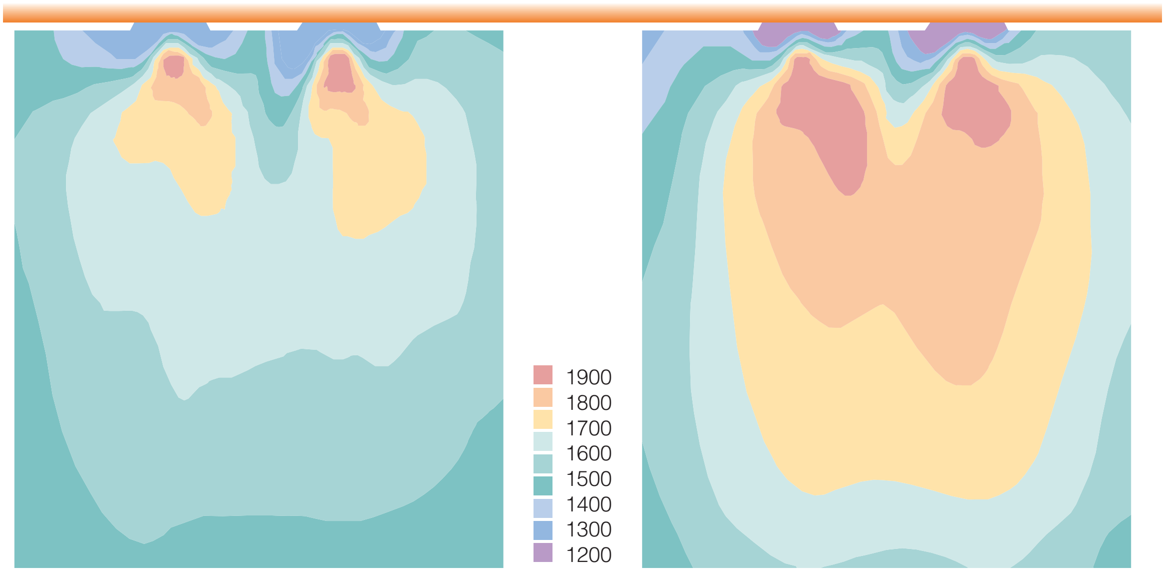


SEM micrograph showing morphology (left) and cross section characteristics (right) of coal char particles in which coal is burned to generate power. In addition to the way in which plant is operated, a new tranche of co-fuels have been introduced into the pulverised coal combustion environment, further complicating an already challenging picture of the fundamental transformation occurring during combustion. Many of these new fuels are themselves highly variable in composition and exhibit behaviour during combustion that can be significantly different to coal. They may also contain high concentrations of species that can interact with coal combustion products, sometimes with deleterious results. The most recent changes to pulverised coal fired boiler plant include modifications to the gaseous atmosphere within the boiler during oxycombustion which are highly likely to produce concomitant changes in reaction mechanisms and pathways that are only just beginning to be explored by research workers. An understanding of the ways in which oxycombustion affects combustion is currently a major driving force in coal research and development.

The traditional coal characterisation techniques (for example density, proximate and ultimate analysis, ash fusion temperatures, ash chemical composition) have served coal users well for several decades and remain important 'first step' tools in assessing coal behaviour under pulverised coal combustion conditions. These techniques have been joined by an impressive array of developments that give detailed information on coal properties, often under dynamic (combustion) conditions in real time. The ability to observe and measure coal reactions as they occur is a valuable step forward as coal behaviour under the demanding temperature-time history in a boiler can be markedly different to that observed in a laboratory under different conditions.

Perhaps the most significant development is the emergence of computer modelling which allows the prediction of fluid and entrained particle flows through a burner and subsequently the boiler to be predicted with a high degree of accuracy. By incorporating sub-models of coal behaviour an understanding of 'real time' coal behaviour is becoming increasingly possible with the benefits of true predictive capability.

Research efforts on coal combustion are now largely focused on important developments like cofiring and oxyfuel combustion and how these affect conditions and reaction pathways within the boiler. Despite the wide variability of cofiring fuels, and the radically different environment in an oxyfuel configured boiler, impressive progress has been made in understanding these new systems. In particular, CFD-based approaches that bring together the detailed understanding of basic coal transformations are being used to give a deeper understanding of the new environments and to drive the development of more efficient and less polluting plant.



Predicted horizontal burner plane for air-combustion (left) compared to the oxycombustion (right) for a 3 MWe furnace

Each issue of *Profiles* is based on a detailed study undertaken by IEA Clean Coal Centre, the full report of which is available separately. This particular issue of *Profiles* is based on the report:

Understanding pulverised coal, biomass and waste conversion
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CCC/205, ISBN 978-92-9029-525-9,
55 pp, September 2012, £255*/£85†/£42.50‡

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