Ignition and combustion of single particles of coal and biomass under O_2/CO_2 atmospheres

Juan Riaza [1], Hannah Chalmers [1], Jon Gibbins [1,2]

[1] School of Engineering, University of Edinburgh.
The King's Buildings, Mayfield Road, Edinburgh, EH9 3JL, Scotland, UK

[2] University of Sheffield, UK

Abstract

Biomass is a renewable fuel which can be used to reduce CO_2 emissions. It is being increasingly implemented as an energy source for residential and industrial heating, electricity production in modern biomass power plants and co-firing or to replace other fuels such as coal. The use of co-fired biomass in existing pulverized coal power plants requires only minor modifications compared to the construction of new biomass-only fired power plants. This makes co-firing biomass with coal an attractive option for making effective use of biomass energy. Additionally, combining biomass combustion with carbon dioxide capture and storage (CCS) is a promising approach to achieve net removal of CO_2 from the atmosphere.

Biomass has a high volatile matter content. It also typically contains less carbon and more oxygen per unit mass and generally has a lower heating value than coal. Due to the higher reactivity of biomass, a bigger particle size range is generally used for commercial combustion of biomass fuels compared with pulverized coal. Milling of biomass fuels is inherently energy intensive. The optimization in terms of minimum particle size for efficient burn-out is still not fully established, and is one of the aims of this work. Combustion behavior of biomass fuels especially the flames of volatiles has not been studied comprehensively before. In particular, the behavior of biomass in oxy-combustion conditions has rarely been reported, and this is of special interest for future oxy-fuel power plants development. The present work aims at providing a systematic *in situ* combustion study of different biomass fuels with high speed video under both conventional (air) and oxy-fuel conditions to examine the impact of particle size on ignition, devolatilisation, char combustion, and burn-out times for different coal and biomass.

Single particle devices have been successfully used in previous studies to undertake comprehensive studies of coal combustion and pyrolysis. These studies demonstrate the ability of these low cost experimental devices to study the combustion of different fuels in a range of atmospheres. Previous studies on coals have identified the differences between coals depending mainly on their rank. However biomass shows high contrast in key parameters, such as modes of ignition and combustion, ignition temperatures, ignition delay times, and burnout times (both those encountered in the volatile and the char combustion phases). In this work, a single particle rig has been developed for rapid heating of biomass particles to study the combustion behavior with high speed camera recording. The study includes a range of sizes in order to obtain combustion test data to improve understanding of milling requirements for biomass.

Images produced by the apparatus (such as those shown in Figure 1) show the ignition and the flame surrounding the contour of the biomass particle. Biomass pyrolysis, ignition of the volatile flame and char combustion can be observed. Differences between coal and biomass combustion can be identified. For example, biomass char combustion took place for a shorter time than in the case of coal char combustion due to the lower carbon content of the biomasses with respect to coal and higher reactivity. The way the volatiles are released was also very different between coal and biomass.

Figure 1. Images during the ignition and combustion of a biomass particle.

Also, burnout times can be obtained for each particle from the video recording. The char that remains after biomass pyrolysis is enriched in carbon. Its reactivity is slower than is seen for the coals tested in this study and this an important factor for the burnout time. For example, Figure 2 shows the burnout times of "El Cerrejon" coal and a woody pelletized biomass.

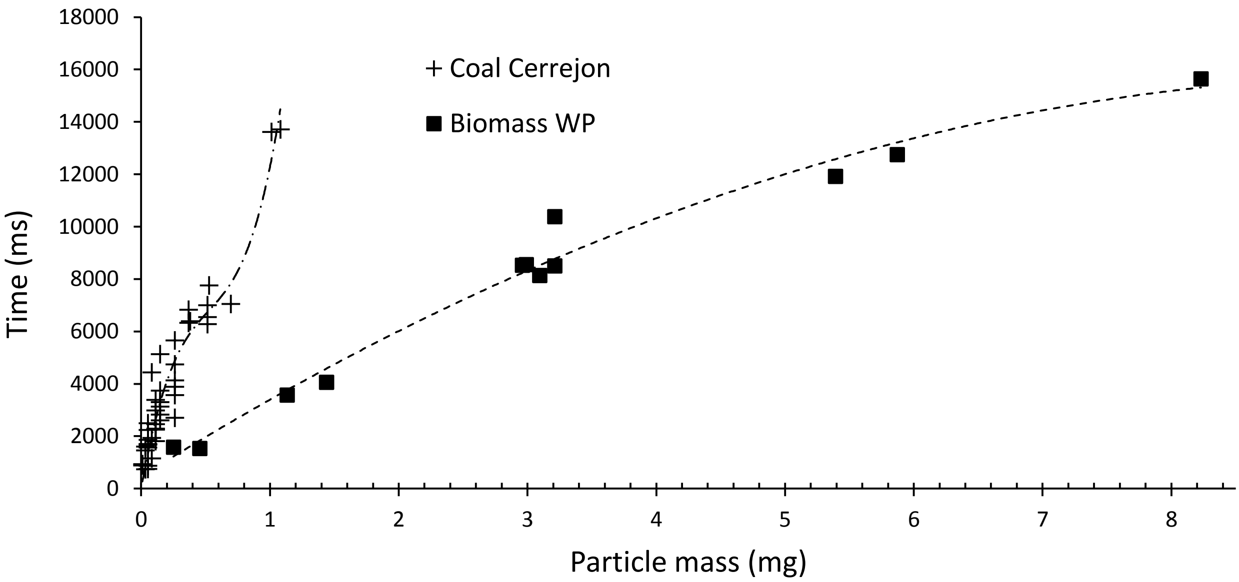

Figure 2. Burnout times vs particle mass of coal and biomass single particle combustion.

Overall, the results show the relation between particle mass and their burnout times, as well as their combustion behavior. This particle mass can be related to particle size ranges of coal and biomass and so the data obtained can be useful to understand the differences in biomass milling requirements and the overall combustion performance. In particular, a size range that would be comparable in burnout time with pulverized coal sizes for an efficient burnout can be identified providing important data for the design and operation of effective co-firing of biomass with coal in both air and oxy-fuel conditions.

Acknowledgements
The scientific work has been supported by the BIO-CAP-UK project and the Future Conventional Power research consortium supported by The Engineering and Physical Sciences Research Council (EPSRC) (www.epsrc.ac.uk) and UK CCS Research Centre (www.ukccsrc.ac.uk).