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IMPACT OF CO_2 ON BIOMASS DEVOLATILISATION, NITROGEN PARTITIONING AND CHAR COMBUSTION; A DROP TUBE FURNACE ANALYSIS

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Summary

Biomass oxy-combustion is attracting considerable attention in recent times because it can achieve negative CO_2 emission. While different fundamental issues of oxy-coal combustion are being tackled and pilot demonstrations have been conducted at various scales, little is known about the behaviour of biomass under oxy-fuel combustion. This paper investigates and presents the results of the devolatilisation and combustion behaviour of sawdust in CO_2 in a drop tube furnace (DTF) compared to conventional air fired conditions. The effect of devolatilisation temperature and residence time on volatile yield and char burnout was investigated. Also, the influence of CO_2 on nitrogen partitioning between volatiles and residual char was considered. From the results, it was observed that higher volatile yields were obtained in oxy conditions. More nitrogen was transformed into the volatile phase in CO_2 than in nitrogen, suggesting that less nitrogen will be retained in the char residue and hence less NOx will be formed under oxy-fuel firing conditions. Scanning electron microscope (SEM) images revealed higher porosities of the DTF CO_2 chars than

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those of N_2, being consistent with the higher BET surface areas as measured for the CO_2 chars. In DTF re-firing tests, the sawdust char was observed to burn off faster in oxy-fuel than in air firing conditions.

Background

The EU's energy policy target to increase renewable energy use by 20% in 2020 (Tous et al., 2011), 45 % by 2030 (EREC, May, 2011) and a commitment towards 100% renewables energy systems by 2050 (EREC, April, 2010), has resulted in increasing research being carried out in this sector. Biomass is one of the renewable energy options and has received significant attentions in the power sector as a renewable fuel (Demirbas, 2005, Domenichini et al., 2011) to achieve this target. Most importantly, the EU's Large Combustion Plant Directive (LCPD) requires coal-fired power plants without flue gas desulphurisation and low NOx technology to retire before January 2016, and this means that such power plants will operate on either dedicated biomass or high levels of biomass co-firing. Few studies have investigated the devolatilisation and combustion behaviour of biomass under oxy-fuel conditions using TGA. These studies revealed that oxygen concentrations of 30% produced matching temperature profiles of air firing condition (Lai et al., 2012) and increase CO_2 reactivity (Yuzbasi and Selçuk, 2011). However, these studies did not produce reactions that mimic the conditions prevailing in practical industrial systems because TGA has low heating rates and temperatures are far away from reality. On the other hand, investigations on biomass devolatilisation in high temperature domains have been carried out under air-fired conditions in entrained flow reactor (Shuangning et al., 2006), and free flow reactor (Commandré et al., 2011), but little is known about the devolatilisation and char burnout behaviour of biomass in such high temperature under oxy-fuel conditions. Also, it has shown that nitrogen was preferentially transformed into the volatiles phase (Jones et al., 2012) during biomass devolatilisation but this was also carried out in TGA. Therefore, fundamental high temperature combustion data, in terms of devolatilisation, nitrogen partitioning and char combustion which will be useful for oxy-biomass combustion modeling will be required.

Experimental

Devolatilisation of sawdust biomass (120-250 µm) was conducted in a DTF at temperatures of 900, 1100 and 1300°C and residence times of 200, 400 and 600 ms in both CO_2 and N_2 atmospheres all containing 1% oxygen. The chars from devolatilisation at 1300°C at different resident times were then re-fired into the DTF in CO_2 and N_2 with 5% oxygen. A silica tracer method was developed, validated and used to calculate the volatile yields because it is more accurate for biomass than the normal ash tracer method. Chars were characterised using SEM for surface morphology and BET for surface area measurements.

Results and Discussion

In both CO_2 and N_2, the volatile yields depended not only on devolatilisation temperature but also the residence time. Higher yields of volatiles were generated from the devolatilisation in oxy-fuel conditions, and this appears to be attributable to the contribution of CO_2-char gasification reactions, due to the high CO_2 reactivity at high temperatures. However, the difference in volatile yields between oxy and air fired conditions became smaller as residence time increased from 200 to 600 ms. This could be due to the decreasing quantities of char left in the solid residue with increasing residence times. The release of fuel-N into the volatile phase under CO_2 condition was found to be higher than in N_2 condition, consistent with other findings (Borrego et al., 2009). SEM images of the chars showed that chars produced under CO_2 were more porous than nitrogen chars. BET surface areas of the CO_2 chars are higher than the nitrogen chars for all temperatures and all the residence times investigated. The higher surface areas of the chars from devolatilisation under oxy-fuel conditions arise from the activation by the CO_2-char gasification reaction. Compared to air firing conditions, improved char burnout performance was observed in oxy-fuel firing conditions at all temperatures and residence times examined.

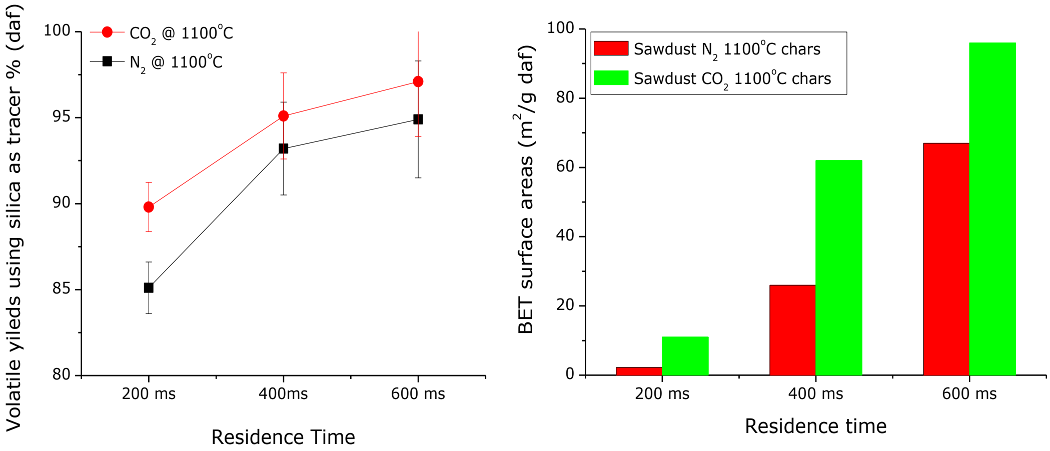

Fig 1 (a) Sawdust DTF volatile yields at 1100°C, (b) BET surface areas of the chars

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