OXY-FUEL COMBUSTION ASH FORMATION MECHANISMS

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Oxidation-fuel combustion is a process of burning coal in O2/CO2 instead of air to generate a CO2-rich flue gas which has the potential to be directly sequestered and/or stored with minimal further treatment (Buhre et al., 2005). Due to the different physical properties of CO2 relative to N2, a variety of distinct phenomena relating to coal combustion performance and gaseous emissions in O2/CO2 have been observed in both field and laboratory studies (Buhre et al. 2005; Pathnam et al 2009; Molina and Shaddix 2007). Elucidation of the ash formation mechanisms in oxy-fuel combustion is also imperative, as minerals in coal links with corrosion and erosion problems in furnace as well as the release of inhalable, potentially toxic airborne particulates.

A variety of variables could be significantly changed with gas shifting from air to a mixture of O2 and flue gas. Depending on where the flue gas is re-circulated and if it is cleaned and/or dehydrated, the gas environment in an oxy-fired boiler could be very different. As illustrated in figure 1, in the case 1 where flue gas is completely cleaned and dehydrated, the flue gas re-circulated back into the boiler can be regarded as a nearly pure CO2. Therefore, oxy-fuel combustion only refers to a substitution of CO2 for N2 and a higher O2 content in the boiler. However, in the other cases 2-4 where flue gas is less cleaned and/or dehydrated to avoid the loss of the heat in the flue gas, the gas environment in a boiler will be greatly different from air. Plausibly, the gas impurities including steam, SO2, HCl and even a portion of fine ash particles can become dominant in an oxy-fuel boiler, which are vital to ash formation. A detailed understanding on these issues is essential for managing the ash-related furnace troubles and environmental impacts. It is also important for managing the CO2 quality for the downstream carbon capture and storage (CCS).

For the case 1 with a mixture of pure O2 and CO2 for coal combustion, the char temperature, local gas environment on char surface, and the char reaction rate could differ considerably from that in air combustion. In a given O2 content, coal combustion
possesses lower temperatures for both flame and char in O2/CO2 than in O2/N2, due to the larger specific heat capacity of CO2. As the diffusivity of O2 in bulk CO2 is 20% less than in N2 with a same content of O2 (Shaddix and Murphy 2003), replacing N2 by CO2 bulk gas could reduce the content of local O2 while increase the content of CO2 on char surface. The potential CO2-gasification reaction on char surface could also increase the CO/CO2 ratio. These factors have the potential to affect the vaporization and melting propensities of the mineral grains embedded in char matrix. Figure 2 for the mass loss of individual metals during Victorian brown coal combustion supports this hypothesis. As can be seen, the mass loss of Na is higher in two O2/CO2 mixtures than in air, due to the preferential vaporization of Na as NaCl in O2/CO2 (Zhang et al, 2010). In addition, the consumption rate of char in O2/CO2 would differ from that in O2/N2, it is referable that the collision/agglomeration frequency among the included minerals in char would be distinct in O2/CO2, as evidenced by the results in figure 3 for the particle-size distribution (PSD) of ash formed from combustion of a bituminous coal in air versus two O2/CO2 mixtures (21/79 and 27/73) at 1273 K (Zhang et al., 2010).

The gas impurities including steam, SO2 and HCl in flue gas are influential on ash vaporization, as evidenced in figure 4 for the overall brown coal ash mass loss as a function of the contents of SO2 or HCl in O2/CO2 at 1273 K. This is because of the formation of gaseous chlorides and liquidus sulfates which preferentially condense into ultra-fine particulates that are difficult to capture. Introducing steam into the reactor however inhibits the ash vaporization/loss, due to the preferential formation of solid/molten alumino-silicates which rarely vaporize. Recirculation of fine ash particles into a boiler is also one influential issue which greatly affects the ash formation.

REFERENCES