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Entrained Flow Reactor Study of KCl Capture by Solid Additives

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Introduction – An option for abating deposition and corrosion caused by alkali species during biomass combustion, is the introduction of additives into boilers for transforming harmful gaseous alkali compounds (e.g. KCl, KOH) into less corrosive ash species with a higher melting point. Kaolin and coal fly ash have been proved to be very promising additives and have received extensive studies during the past decades. However, most previous studies were carried out in fixed-bed reactors where the reaction conditions are obviously different from that in suspension fired boilers. Detailed knowledge on the reaction between K-species and solid additives under suspension-fired conditions is still limited. In this study, a water slurry containing K-salt and solid additives was introduced into an entrained flow reactor (EFR) to study K-capture at suspension-fired conditions. A model will be developed based on experimental data and recommendations for optimal use of additives in full scale boilers will be provided.

Experimental setup

- Reactor length: 2 m
- Inner diameter: 79 mm
- Residence time: 0.8-0.9 s
- Maximum temp.: 1450 °C

K-capture quantification

- Water-soluble K
- Water-insoluble K from K-capturing reaction
- Water-insoluble K brought in by additives

K-conversion fraction $X_k$ (%) = \frac{\text{mass of K captured by 1 g solid additive}}{\text{mass of K in reactant}}

- Reaction $A + B \rightarrow C$

- K-conversion level $C_{k}(\text{g K/g additive})$

Impact of temperature

- K-capturing level of kaolin and coal ash does not change with increasing temperature (1100 - 1450 °C);
- The controlling mechanism of K-capturing at suspension-fired conditions is different from that in fixed-bed reactor.

Impact of molar ratio of K/(Al+Si) in reactants

- K-conversion decreases with increasing molar ratio of K/(Al+Si) in reactants;
- Kaolin is more effective than coal fly ash for KCl-capturing;
- Finer coal fly ash captures K more effectively;
- K-conversion in full scale boilers is around 100% using coal fly ash, while in EFR it is lower probably due to relatively shorter residence time.

Conclusions

- A method for studying additive behaviors in an entrained flow reactor has been developed;
- KCl was effectively converted into water-insoluble K-aluminosilicate by kaolin and coal ash;
- K-conversion increased with molar ratio of K/(Al+Si) in reactant decreased;
- K-capturing level does not change obviously with increasing temperature (1100 - 1450 °C), which is different from that in fixed-bed reactor, indicating different controlling mechanism;

Ongoing and future work

- EFR experiments with different alkali species, like KOH, K$_2$CO$_3$, and K$_2$SO$_4$;
- Experiments with different coal fly ash to investigate the influence of ash properties;
- Experiments with different solid additives to study the kinetics of K-capture;
- Developing a model based on experimental data for optimal utilization of solid additives in full-scale boilers.

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