9th International Freiberg Conference on IGCC & XtL Technologies
Closing the Carbon Cycle
3-8 June 2018
Berlin, Germany

Comparison of dynamic behaviors between crystallized and glassy slags on the wall of an entrained coal gasifier

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In an entrained coal gasifier, the molten coal ash deposits on the wall to form solid and liquid slag layers. Controlling the thickness of the slag layers plays an important role in preventing damages to the refractory lining and blockages at the slag tap. The coal ash exhibiting a sudden increase in the viscosity (critical viscosity) upon cooling by the formation of crystallized minerals is referred to crystallized slag. In contrast, glassy slag, often silica-rich, has a continuous increase in the viscosity at low temperatures. Existing slag layer models often assume the critical viscosity, typically at 25 Pa·s, as the interface value between the solid (immobilized) and liquid slag layers. However, such approach may not be valid for a glassy slag.
In this study, the transient slag layer model developed by the authors [1] was expanded to consider the behaviour of glassy slag in comparison to that of crystallized slag. The model was applied to a commercial Prenflo gasifier firing coal with either of the two slag types under simplified operating conditions of uniform gas temperature (1800 K) and uniform ash deposition flux (total 5 kg/s). The dynamic behaviours of the slag layer thickness at the slag tap (δ_{tap}) and the total heat transfer rate to the wall (Q_{wall}) were quantified using the characteristic time (τ_δ and τ_Q, respectively) for 63.2% change from the initial steady state. At the initial steady state, the glassy slag had a significantly thinner solid layer at the slag tap than the crystallized slag, while the liquid layer was slightly thicker. Due to the overall decrease in the slag thickness, the heat transfer rate to the coolant was larger for the glassy slag. When the gas temperature increases to 1900 K, decrease in δ_{tap} by the lower slag viscosity led to a larger Q_{wall} in both slag types. τ_Q was considerably shorter than τ_δ, which indicates that monitoring Q_{wall} from the inlet and outlet temperatures of the coolant can be helpful as an indirect measure for the slag thickness. Comparing the responses of the two slag types, τ_Q was influenced little, but τ_δ increased significantly for the glassy slag due to the presence of the low velocity region with high viscosity.

References

[1] Kim M, Ye I, Ryu C. Numerical analysis on transient behaviors of slag layer in an entrained-flow coal gasifier. Fuel 2017;196:532-542