Dynamic Model of a Smart Refractory Brick for Gasifier Applications

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The operating temperature is the most important variable in an entrained-flow gasifier. A lower temperature results in lower carbon conversion and can lead to disruption in the flow of molten slag. A higher temperature can result in reduced life of the refractory leading to significant capital cost and undesired downtime. However, the current state of the art in measurement technology is not adequate for measuring the temperature profile inside the entrained flow gasifiers reliably mainly because of very high temperature and extreme harsh conditions. As a result, the thermocouples that are inserted into the gasifier through open access ports within the refractory survive for only a few weeks. To circumvent this problem, a novel smart refractory is being developed at West Virginia University. This refractory contains embedded sensors throughout the volume of high-chromia refractory brick. Since these sensors are embedded, they do not negatively impact the intrinsic properties of the refractory. However, in course of operation, the slag will penetrate into the smart refractory. When the slag penetrates into a location, the material properties will be that of a mixture of slag and refractory and are expected to change considerably as the material properties of the refractory and the slag are very different in terms of thermal and electrical characteristics. Therefore, characterization of these sensors by considering the data from the pristine bricks would not be sufficient for satisfactory estimation of the variables of interest. A model-based approach can be very useful for satisfactory estimation. Other than estimating the temperature profile, the model-based approach can be used for estimating the change in the material properties and can therefore be used for estimating the extent of slag penetration.

With this motivation, a rigorous, first-principles, dynamic model of the smart refractory brick has been developed. The thermal model has been developed by considering properties of the pristine smart refractory bricks as well as that of the slag-infiltrated brick. Using in-house experimental data and data from the open literature, correlations have been developed for thermal conductivity, heat capacity, and emissivity for the pristine and the slag-infiltrated brick. Models of the interdigitated capacitors as well as the thermistors have been developed by considering the location and the geometries of the embedded sensors. Finally, the raw, temporal measurements from the embedded sensors are used in a model-based estimation framework to obtain the satisfactory estimate of the variables of interest.

The dynamic, distributed model including the electrical systems model is developed in Aspen Custom Modeler for easy integration with other Aspen Engineering Suite models while the estimator algorithms are developed in MATLAB. The co-simulation using Aspen Plus Dynamics and MATLAB is accomplished by using the available commercial link.