Evaluation of Biomass Syngas Co-firing and Reburning in a Coal Fired Boiler

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Summary

The gasification of biomass to produce synthesis gas (syngas) offers an alternative to fossil fuels for boilers in certain geographical locations. The syngas can be used as a supplemental fuel to reduce the consumption of pulverized coal and fuel oil. Furthermore, since it contains hydrocarbons and other reducing compounds such as hydrogen and carbon monoxide, it has the potential to be used as a reburning fuel to reduce NOx emissions. Using an Ahlstrom/Foster Wheeler process, the Energy & Resources Laboratories of Industrial Technology Research Institute (ERL-ITRI) in Taiwan has developed a circulating fluidized bed (CFB) gasifier to produce syngas out of paper rejects from paper mills. ERL-ITRI would like to demonstrate the feasibility of using the syngas as a supplemental fuel in a coal-fired boiler. There are several uncertainties, however. The syngas produced from the paper rejects is of low heat content, ranging from 3.99 to 6.24 MJ/kg. In addition, the syngas contains trace amounts of NH_3, HCN, HCl and H_2S. Their impacts on boiler operations and emissions should be assessed.

In order to address ITRI concerns, CFD-based combustion simulations were conducted to evaluate the technical feasibility of using this syngas as a supplemental fuel in a 70 tph-steam coal-fired boiler. Simulations were conducted with Reaction Engineering International (REI) combustion simulation software, which modeled the coal particle devolatilization and char oxidation reactions (and LOI), gas-phase chemistry (coal off-gas, syngas, and air), two-phase turbulent mixing, radiative and convective heat transfer, and finite-rate NOx reactions occurring in the combustion process. The syngas was either co-fired with coal at the burners or injected downstream as a reburning fuel under both fuel lean and conventional (fuel rich) reburning configurations. Sensitivity of syngas heat input and furnace stoichiometry were examined.

Predictions indicated co-firing syngas at the burner centerline was not beneficial as it resulted in poor combustion of the coal particles and high LOI and CO emissions. This was primarily due to the high volume of syngas required for heat replacement and resulting high syngas velocities in the burner. Results indicated that the syngas was an effective reburning fuel although it contained less than 6% hydrocarbons. Lean syngas reburning (LSR) at a reburn zone stoichiometry (RBS) of 1.30 resulted in only about 12% reduction in NOx emissions from the baseline conditions. However, as the RBS was reduced from 1.30 to 1.15, approximately 30% reduction in NOx emissions was obtained under lean reburning conditions. As the RBS was further reduced to 0.95, the NOx emission was reduced by 46% under conventional reburning conditions. More NOx reduction can be expected if more syngas is added to reduce the RBS to 0.9 ~ 0.8, the optimum for conventional reburning. In practice this might be limited by the low heating value of the syngas and its availability, however.

In order to understand the effectiveness of syngas reburning, the predicted NOx concentrations along the furnace elevations were examined. Comparing the NOx levels before and after the syngas injection for lean syngas reburning indicated that a relatively small amount of NOx reduction was achieved with syngas reburning at a RBS of 1.30. Similarly, only slightly more NOx reduction can be attributed to syngas reburning alone for a RBS of 1.15, although close to 30% reduction was observed in NOx emissions. It appears that the lower NOx produced by the coal burners accounts for a significant amount of the reduction in these lean reburning cases.

Conversely, the data from conventional reburning indicates that the large majority of NOx reduction resulted from syngas reburning chemistry. Since the syngas contains less than 6% hydrocarbons (wet basis), some of the reductions might be attributed to the hydrogen and CO contents in the syngas. Although the syngas is not as effective as natural gas as a reburning fuel, it, unlike natural gas, will not require the use of a transport medium such as flue gas or steam to provide adequate penetration and mixing in boiler applications thanks to its higher inert contents and greater mass flow.

Furnace LOI increased over baseline values for all but one reburning configuration. The highest LOI came from the top burner row in all cases. Results suggested the LOI increase due to reburning might be mitigated by biasing more air to the upper burners to enhance particle burnout. Predictions indicated co-firing syngas at the burner centerline was not beneficial as it resulted in poor combustion of the coal particles and high LOI and CO emissions. Simulation results also indicated that minor changes to the syngas composition do not significantly affect the performance of syngas reburning. The trace amounts of NH_3, HCN, HCl and H_2S in the syngas, although higher than typical fossil fuels, were predicted to not adversely affect boiler operation.