Attrition Evaluation of Oxygen-Carriers in Chemical Looping Systems
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Background - CO₂ Capture
- Chemical-Looping-Combustion (CLC) is an innovative power generation technology for carbon capture at a lower cost and higher efficiency than state-of-the-art
  - Near-pure CO₂ stream produced without using oxygen from air separation
  - Solid oxygen-carrier (OC) used to provide oxygen to fuel
  - Oxygen-depleted solids regenerated separately in air
  - Solid oxygen carriers undergo attrition and loss of reactivity over time
  - Loss due to attrition and loss of reactivity creates significant operating cost burden

Project Objectives and Approach Methodology
- Objectives
  - Address critical element of CLC - loss of OC due to attrition/reactivity degradation
  - Evaluate attrition characteristics of oxygen carrier materials under high temperature, reacting conditions to establish correlations between process parameters
- Methodology
  - Basis - existing standard, (ASTM D5757), used for determining attrition characteristics of powdered catalysts by air jets
  - Incorporate modifications to attain test protocol more representative of chemical looping process conditions

Evaluation Strategy
- Evaluated multiple oxygen carriers at baseline conditions
- Ilmenite (2), Hematite, Red Mud, CaSO₄-based, MnOₓ-ore, Engineered iron oxide
- Cyclic operation between reduction and oxidation conditions
- Measured reduction/oxidation gas concentrations at reactor outlet
- Measure attrition rate by collecting and weighing attrited material
- Examine the effects of varying jet velocities on the attrition of the oxygen-carriers
- Evaluate use of coal as fuel for reduction step on performance of selected oxygen carriers

Experimental Setup

Results - Evaluation Tests
- Ilmenite and Calcium-Based oxygen carriers had lowest attrition rates.
- Iron-Based-Engineered oxygen carrier had highest rate of attrition.
- Hematite displayed a significant breakage event during testing; thereafter attrition rate decreased.
- Red Mud and Mn-Oxide-Based materials exhibited attrition rates that were slightly increasing or relatively stable over entire test period.
Manufacturing (Sintering) at higher temperature caused a decrease in reactivity.

Degree of reduction affected attrition and reactivity performance:
- Increasing CO/H<sub>2</sub> concentration resulted in better fuel utilization indicating higher reduced state of OC.
- Increasing CO/H<sub>2</sub> concentration caused agglomeration (20% - 30% concentration).
- Degree of reduction critically important.

Results – Effect of Gas Composition on OC Performance

- Fe-based carrier under coal injection

Results – OC Performance with Solid Fuel Combustion

- Fe-based carrier under coal injection

Future Work

- Effect of operating parameters on attrition and reactivity will be characterized to develop knowledge database and formulate strategies for commercial test service offerings.
- Expansion of work to study effect of cyclonic/impaction conditions on attrition and reactivity characteristics of Oxygen Carriers.

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