Annual Report For Advanced Sustainable Iron and Steel Center (ASISC)

Mission of the Center:

ASISC was established in 2008 to conduct research that would lead to the iron and steel industry to becoming more sustainable. The iron industry shares a great deal of technology with other mineral processing and metals extraction industries, such as phosphate processing and precious metals extraction. ASISC therefore makes a particular effort to transfer applicable technologies between ironmaking and these other industries. This provides access to a broader technological base, and makes it possible to transfer solutions to problems that have already been solved in other fields.

ASISC promotes fundamental industry-sponsored research and also provides opportunities for the education of the critically-needed students to work in this area. The team assembled for this Center believes that the common perception of the iron and steel industry as being “mature” technologies, with little room for improvement, is incorrect. The overwhelming need to develop an alternative to the use of fossil fuels will force the industry to find novel approaches for producing the 130 million tons of iron and steel consumed in the U.S. annually.

The issues with sustainability cannot simply be addressed by minor tinkering with current processes. Fundamental new science and technology derived from basic research is needed to create new approaches for metal production. The Center is fostering a research and technology base that will promote synergy between academic and industrial interests, leading to a new generation of sustainable, economical iron and steelmaking technologies.

Objectives

Particular objectives of the Center are:

- Improving processing efficiency to lower energy consumption and reduce waste;
- Reducing the use of fossil fuels and replacing them with renewable energy sources;
- Utilizing mineral processing waste products;
- Capturing pollutants to prevent them from entering air or water; and
- Developing new processing methods that can provide improved performance at lower cost.

Participant Individuals:

Senior personnel(s): Peter Larsen; Timothy Eisele, Ranjit Patti, Tony Rogers, Lei Pan, Julie King

Graduate Student(s): Michael Archambo, Sriram Valluri, Victor Claremboux, Natalia Parra, Joseph Halt, Jake McDonald

Undergraduate Student(s): Sam Root, Stephanie Knudsen, Hannah Townsend, Melissa Spaulding, Rebecca Phipps, Thao Duong
Participant Detail:

Kawatra S.K. : Principal Investigator

Has worked for more than 160 hours: Yes

Contribution to project: No information

Larsen Peter: Senior personnel

Has worked more than 160 hours: No

Contribution to project: Organized the annual IAB meeting.

Eisele Timothy : Senior personnel

Has worked more than 160 hours: Yes

Contribution to the project: Project Investigator, responsible for a portion of the research projects and for technical presentation at the IAB meeting.

Lei Pan : Senior personnel

Has worked more than 160 hours: Yes

Contribution to the project: Project Investigator, responsible for a portion of the research projects and for technical presentation at the IAB meeting.

Ranjit Patti : Senior personnel

Has worked more than 160 hours: Yes

Contribution to the project: Project Investigator, responsible for a portion of the research projects and for technical presentation at the IAB meeting.

Youlian Zhou : Senior personnel

Has worked more than 160 hours: Yes

Contribution to the project: Project Investigator, responsible for a portion of the research projects and for technical presentation at the IAB meeting.
Michael Archambo: Graduate Student
Has worked more than 160 hours: Yes
Contribution to project: Conducted research. Supported by MTU and Industry membership funds

Sriram Valluri: Graduate Student
Has worked more than 160 hours: Yes
Contribution to project: Conducted research. Supported by MTU and Industry membership funds

Victor Claremboux: Graduate Student
Has worked more than 160 hours: Yes
Contribution to project: Conducted research. Supported by MTU and Industry membership funds

Natalia Parra: Graduate Student
Has worked more than 160 hours: Yes
Contribution to project: Conducted research. Supported by MTU and Industry membership funds

Sam Root: Undergraduate Student
Has worked more than 160 hours: Yes
Contribution to project: assisted graduate students in research. Supported by MTU and Industry membership funds

Stephanie Knudsen: Undergraduate Student
Has worked more than 160 hours: No
Contribution to project: assisted graduate students in research. Supported by MTU and Industry membership funds

Thao Duong: Undergraduate Student
Has worked more than 160 hours: No

Contribution to project: assisted graduate students in research. Supported by MTU and Industry membership funds

Partner Organizations:
Cliffs Natural Resources: Financial Support. Industrial member of the center
Solvay: Financial Support. Industrial member of the center
Carbontec Energy Corporation: Financial Support. Industrial member of the center
Arcelormittal: Financial Support. Industrial member of the center
MicroTrac: Financial Support. Sponsored Lunch for the meeting

Activities and Findings:

Research and Education Activities:
There have been four major research projects ongoing in the past year for the Center.

1. Bauxite Residue pH neutralization using carbon dioxide. Bauxite residue, or red mud is a caustic aluminum byproduct that must be neutralized in order to process it further. Typically red mud has a pH of 12 or higher, making it dangerous to work with and dangerous for the environment. Carbon dioxide is an effective greenhouse gas and much work has been done to find a use for it. Finding an economically viable utilization method for carbon dioxide is critical for the future. One technique for CO2 sequestration is to pump CO2 into red mud in order to neutralize the caustic sludge. In this study, CO2 was bubbled into a slurry of caustic red mud, and the pH was measured. This study found that CO2 is an effective acid gas capable of initially neutralizing the pH. Over large periods of time, experimental work has shown that CO2 can effectively reduce the pH of caustic red mud. This neutralized mud has many further uses, which are explored in this paper.

2. Utilization of Captured CO2 from Exhaust of Steel and Coal Industry: An Electrochemical Approach for Catalytic Reduction of CO2 to Value Added Products. With increased CO2 emissions from steel and coal industry, there is great opportunity to capture CO2 and utilize the captured CO2 for economic advantage. Developing energy-efficient processes that reductively couple CO2, an abundant and renewable carbon source, for the production of value-added chemicals (methanol, ethanol, and oxalic acid) using electrochemical processes is a goal of great importance. In many cases, these chemicals can be reused elsewhere in the refining process or sold as valuable byproducts. Geological sequestration, in comparison, has no economic return. Electrochemical reduction of CO2 to hydrocarbons and other chemicals is a complex multistep reaction
with adsorbed intermediates. The exact reaction mechanisms leading to various products are not clear from the literature to date and will likely change over the range of conditions like pH, electrode potential, electrolyte medium, catalyst, etc. This paper will present different ideas and their viability to utilize CO2 as a feedstock to produce several value-added compounds.

3. In the United States, 6.6 billion metric tons of CO2 are released into the Earth’s atmosphere annually. The increasing levels of atmospheric CO2 have been linked to climate change. Carbon dioxide capturing technologies are expected to slow and even reverse the effects of climate change. Reagents used in common technologies, like amine absorption, are expensive and energy intensive to regenerate. Aiming to make carbon dioxide capture a profitable venture, researchers at Michigan Technological University have designed a packed bed scrubbing column which uses aqueous sodium carbonate rather than amines as a scrubbing medium. We have taken inspiration from mineral processing plants to add frothing agents to the alkali solution in order to increase the surface area available for CO2 transport within the packed bed. This novel enhancement of a relatively inexpensive CO2 capture-regeneration cycle shows potential to allow plants to turn a profit by sequestering a waste product.

4. Carbon Dioxide Capture from Flue Gas at Michigan Tech Steam Plant. Carbon dioxide, a byproduct of combustion reactions, is a greenhouse gas linked to climate change. At Michigan Technological University, we have studied the capture of CO2 using alkali scrubbing solutions in a pilot scale packed bed counter-current scrubbing column. To do this, we have simulated flue gas by combining streams of CO2 and compressed air. Real flue gas has impurities such as SO2 and NOx, and has lower levels of O2 than our simulated flue gas. In order to study CO2 capture from a real flue gas, the Department of Chemical Engineering is working with the Facilities department to install a pilot scale scrubbing column in the Michigan Tech steam plant. Experiments will be conducted using a sample stream of the flue gas from the boiler in the steam plant. Data collected from these experiments will be compared to the data collected from identical experiments conducted on simulated flue gas in the lab.

Mineral Processing Short Course:

This course was made available to industry and students as a course that explores the broad topic of mineral processing. This was done in order to educate those who do not participate in the field and to refresh those who have been working on specific mineral processing fields. Instructors from academia and heads of industry gave talks about a wide variety of mineral processing topics.

Student Poster Competition:

Students presented research posters on theirs projects and were judged by conference attendees. A $100 prize was awarded by Solvay to the graduate student Victor Claremboux for his poster.

Lifetime Achievement Award:
This award was presented to Todd Davis for his outstanding work in iron processing throughout his life in a number of different plants around the Midwest.

**Training and Development:**

Graduate students involved in the Center are M. Archambo, S.K. Valluri, V. Claremboux, N. Parra, and J. Halt

Undergraduate students involved in the center are S. Root, S. Knudsen, M. Spaulding, R. Phipps, H. Townsend

All students have gained valuable experience in designing and testing prototype experimental apparatus, factorial experimental design, and statistical analysis of results.

All of the graduate students in the Center are required to teach portions of courses, where they describe the results of their research to the undergraduate students.

Graduate students have also traveled to national conferences to present the results of their projects to date.

**Space and Facilities Requirements:**

**Journal Publications:**


R. Machiela, L. Zhang, T. Eisele, M. Zhang, “Regeneration of Alkali Leaching Solution through Precipitation using Calcium Hydroxide”, submitted to Hydrometallurgy May 23, 2018, accepted for publication August 30, 2018

Book(s) or other one—time publications(s):

SME 2018 conference:


Internet Dissemination:

http://www.chem.mtu.edu/asisc/

Contributions:

Our primary discipline is engineering relating to the iron and steel industries, with the specific goals of making the industry more sustainable. This ranges from reducing energy use during mineral concentration and feedstock upgrading, to reducing the dependence on coal and other fossil fuels during iron and steelmaking, to reducing waste in the production of semi-finished and finished products. This is being accomplished in direct collaboration with industry through the Industry/University Cooperative Research Center(I/UCRC) mechanism.