STEEL MANUFACTURING SIMULATION AND VISUALIZATION CONSORTIUM (SMSVC)

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“Where Ideas Become Reality”
CENTER FOR INNOVATION THROUGH VISUALIZATION AND SIMULATION (CIVS) (since 2009)

- **Mission**
  - Innovation
  - Application ($38++ million savings)
  - Education (1000+ students)

- **Strategies**
  - Integration of technologies
  - Application driven approach
  - Partnerships (93 organizations)

- **Background** (since 1994)
  - Built on a long history of CFD applications on various industries including aluminum, glass (R&D 100 awards), power, refinery, steel, etc.

CIVS Facility: **21,000+ local and global visitors**
(2200 169th Street, Hammond)
COMPUTER SIMULATION

**Definition:** Use a computational model to simulate behaviors of a real system or process.

- Computational Fluid Dynamics (CFD)
- Finite Element Analysis (FEA)
- GIS, ESM, etc.

**Benefits:**
- Insights
- Foresight (what if…)
- Efficiency
VISUALIZATION

- Graphics, picture, video, or web
- **3D Virtual Reality**: PC, projection, 3D TV, Oculus Rift – **not just observe**
- **Augmented Reality**: phone, tablet, smart glasses
INTEGRATION OF SIMULATION AND VISUALIZATION

- Efficient, effective, and economical
  - Better communication
  - Faster and lower risk for new ideas and scale-up
  - Integrated and interactive virtual design
  - Smart manufacturing

“A picture is worth a thousand words.” - F. Barnard, 1921
“An interactive simulation is worth a thousand pictures.”
INTERACTIVE VIRTUAL TRAINING

- Situated, work-based, real phenomena and scenarios (not just animations)
- Interactive, self-paced, engaged experience
- Authentic, immersive, emotional experience in a virtual learning environment

“Tell me and I’ll forget…
Show me and I may remember…
Involve me and I’ll understand.”

Ancient Chinese proverb
APPLICATIONS

- Reduce cost
- Short time
- Increase yield
- Improve accuracy

Scheduling Control

Design Troubleshooting Optimization Scale-up

Safety Training

Facilities Planning

Data Visualization

Marketing

- Energy
- Environment
- Productivity
- Quality
CONSORTIUM BACKGROUND

- National Institute of Standards and Technology (NIST) Advanced Manufacturing Technology (AMTech) Planning Grant in June 2014
  - To develop a technology roadmap to benefit the American steel industry across its value chain
  - To establish an industry-led sustainable Steel Manufacturing Simulation and Visualization Consortium
STEEL MANUFACTURING SIMULATION AND VISUALIZATION CONSORTIUM (SMSVC)

- **Vision:** To be the institute of choice for developing and applying advanced computer simulation and visualization technologies to ensure a competitive advantage for US steel manufacturing.

- **Mission:** To develop and implement innovative technical solutions through the integration of advanced simulation and visualization technologies.
The world’s leading steel and mining company

- ArcelorMittal is the world's leading steel and mining company, with around 210,000 employees in more than 60 countries. ArcelorMittal is the leader in all major global steel markets, including automotive, construction, household appliances and packaging, with leading R&D and technology, as well as sizeable captive supplies of raw materials and outstanding distribution networks.

- An industrial presence in 19 countries exposes the company to all major markets, from emerging to mature.

- ArcelorMittal values geographical breadth, product diversity and raw materials security. Around 38% of our steel is produced in the Americas, 47% in Europe and 15% in other countries such as Kazakhstan, South Africa and Ukraine.

- Main markets are automotive, construction and packaging.

Underpinning all our operations is a philosophy to produce safe, sustainable steel.
Why did ArcelorMittal join SMSVC?

- Familiar with CIVS, the quality of their work and capabilities
- Opportunity to solve mutual issues collectively
  - Learn from other’s past experiences
  - New ideas from the group’s interactions
- Lower cost for solving problems than doing them alone
- More projects done in a shorter period of time
- An excellent team – CIVS, major companies in the U.S. Steel Industry and key Utility Suppliers
- Sustainability
ARCELORMITTAL PROJECT EXAMPLES

- Blast Furnace (IH7) Fuel Injection Optimization
- Scheduling Model for Optimization of Slab Production
- CFD Modeling of a Ladle with Top Stirring Lance
- Lake Water Intake Study
- Blast Furnace Hearth Flow and Erosion Model
- CFD Modeling of an Anneal Furnace Inner Cover
- CFD Analysis of Blast Furnace Stave Cooling
- CFD Simulations of Solid Liquid Mixing in a Stirred Tank
- CFD Simulation of the Injection of Natural Gas & PCI
- CFD Analysis of Torpedo Car for Desulphurization
- Comparison and Optimization of Blast Furnace Tuyere Failures
- Design of Sinter Cooler Simulation Pre-Processor Software
- FEA Structural Analysis of a Vertical Edger in a Hot Rolling Mill

- Flood Disc Scrubber in a Sinter Plant
- Flow Analysis and Optimization of a Steel Ladle
- Interactive 3D Module for Hydraulics Education
- Minimization of Blast Furnace Fuel Rate by Optimizing Burden and Gas Distribution
- Numerical Simulation and Optimization of a Billet Reheating Furnace
- Optimization and Design of a Venturi Scrubber
- Optimization of an Industrial Boiler Firing Metallurgical Gases
- Optimization of Batch Anneal Furnace
- Preheating Furnace of an Aluminizing Line
- Simulation of a Sinter Cooler for Optimization and Design
Issue:
• Water wall tube failures

Outcome:
• Complete understanding of combustion inside the boiler
• Identified the cause of the tube failures
• Provided optimum operation conditions
• No wall tube damage since 2014

Collaborator: Al Kirk, Kurt Johnson, ArcelorMittal R&D, AMBH
Where Ideas Become Reality

VERTICAL EDGER AND STRIP
GRADE ANALYSIS

Issues:
- Gear housing failure
- Production delay
- Safety concerns

Outcomes:
- Provided valuable insight about equipment capabilities and potential cause(s) for the failure
- Practices were changed as a result of the project findings
- To date there has not been a repeat failure

Collaborator: ArcelorMittal
SCHEDULING OPTIMIZATION MODEL FOR SLAB PRODUCING

**Issue:**
- Scheduling practice have significant impact on productivity and cost of slab
- Business conditions require rapid responses to minimize cost as well as maximize throughput

**Expected Outcome:**
- A customized dynamic model providing a protocol for steel producing
- Minimize cost in slow business periods and maximize volume in high business conditions

Collaborator: ArcelorMittal
AIST STEEL WHEEL 3D VISUALIZATION

**Issues:**
- Steel-making processes are complicated and not easily understandable
- Lack of effective tools for steel-making understanding and training

**Outcomes:**
- Series of short HD videos
- Web-based interactive interface to demonstrate the iron and steel making processes
Benefits:

- Leverage internal process modeling expertise through collaborative research projects that focus on computer simulation of our critical manufacturing capabilities.

- Membership in CIVS and SMVSC provides the opportunity to develop targeted project work to support near term process and cost improvement initiatives.

- Gain access to a pool of well educated and trained engineers and scientists who have relevant industry knowledge and experience.

- Proprietary/post competitive R&D projects and partnership opportunities are frequently undertaken to support the strategic and competitive needs of individual company members.
U. S. STEEL PROJECT EXAMPLES

- Maximization of Coal Injection Rate at Gary Works No.14 Blast Furnace
- Optimization of a QBOP Vessel for Minimizing Kidney Formation
- Equipment Longevity Extrapolation
- Pulverized Coal Injection with Natural Gas Co-Injection in a Blast Furnace
- 3D USS Blast Furnace Virtual Training System
- Investigation of Tuyere Nose Failures at Great Lakes Works B2 Blast Furnace
- 3D Blast Furnace Hearth CFD Model
- Minimization of Fuel Rates by Optimizing Burden & Gas Distribution Blast Furnace
- Design of Blast Furnace Operation Stability Monitoring Program
- User Interface Software for Blast Furnace Shaft Model
3D SIMULATION AND VISUALIZATION OF BLAST FURNACE

**Issues:**
- Furnace campaign life
- Energy efficiency
- Pollutant emissions
- Furnace downtime
- Training

**Partners:**
- American Iron and Steel Institute,
  ArcelorMittal USA, ArcelorMittal Dofasco, AK Steel, U.S. Steel,
  U.S. Steel – Canada, and Union Gas
3D BLAST FURNACE CFD MODELS

Shaft Model (since 2006):
- Burden distribution
- Chemical reactions
- Cohesive zone shape and location
- Coke rate

PCI-Raceway Model (since 2004):
- Multiphase reaction turbulent flow
- Raceway shape
- Coal combustion
- Coke combustion
- Gas combustion
- P1 radiation model

Hearth Model (since 2002)
- Skull/erosion profile, liquid T, V, etc.
- Conjugate heat transfer, refractory T
- Real geometry (skulls, refractories, ram, shell…)
- Variable properties
- Liquid level
Virtual Blast Furnace
U.S. Steel Blast Furnace Ironmaking Academy
Total 20 Participants

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<thead>
<tr>
<th></th>
<th>Strongly Agree</th>
<th>Agree</th>
<th>Neutral</th>
<th>Disagree</th>
<th>Strongly Disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>The VBF simulator was <strong>beneficial</strong> as a visual learning aid in this training course.</td>
<td>95%</td>
<td>5%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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<tr>
<td>The VBF simulator enables me to <strong>better visualize</strong> the blast furnace and its equipment in a way that is difficult for me to do with presentation slides or text alone.</td>
<td>85%</td>
<td>15%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
</tr>
<tr>
<td>Training courses on <strong>other process</strong> (i.e., cokemaking, steelmaking, etc.) should develop similar simulations in the futures as a learning aid.</td>
<td>80%</td>
<td>20%</td>
<td>0%</td>
<td>0%</td>
<td>0%</td>
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- “Excellent training tool; great problem-solving capabilities.”
- "This interactive model helped me visualize the material flowing through the process. It was very helpful in understanding the flow"
ANALYSIS OF QBOP VESSEL

 Issue:
   - Excessive slag buildup
   - Manual removal causing downtime
   - Lower yields associated with slag issues

 Outcomes:
   - Identify the cause of the metallic buildup
   - Recommendations to avoid buildup

 $450,000 per month in cost avoidances

 Collaborators: Jamie Lash, Liz Borges, Dave Runner, U.S. Steel, Gary Works
LIFE PREDICTION IN INDUSTRIAL EQUIPMENT

Issues:
- Expensive downtime for maintenance
- Identification of problem areas

Outcomes:
- General methodology to be applied to any equipment – existing or proposed
- Improved inspection planning resulted in $251,000 annual savings
- $8 million cost avoidance for a new replacement crane is estimated

Collaborators: U.S. Steel
STEEL DYNAMICS
SDI Joined Consortium

- Practical approach
- Goal-oriented group
- Technical capabilities
- New technology
- Center Leadership
To identify and prioritize research projects that will advance steel manufacturers’ and suppliers’ competitiveness to improve and enhance:

- Workplace safety
- Environmental impacts
- Operation efficiency
- Workforce development
- Energy efficiency
- Reliability & maintenance
- Use of raw materials
- Smart manufacturing
INITIAL CONSORTIUM PROJECTS

- Virtual Safety Training
- Blast Furnace
- Electric Arc Furnace
- Reheating Furnace
- Secondary Cooling Spray Heat Transfer and Stress Analysis
- Ladle
- 3D Casting SEN Simulation and Training Simulator
INTERACTIVE SAFETY TRAINING

Objectives:
- Create interactive tools for employees training to improve safety awareness
- Develop interactive 3D visualization using real scenarios

Outcomes:
- Interactive 3D environment based on real incidents in multiple technology platforms
- Allow employees to experience virtual hazardous environment
- Trace the cause of the incident
“You have been given the task to inspect a damaged area on the recuperator. The work area is in front of you highlighted in red. You will be working at height. Choose appropriate PPE from the table on the right. Once you’ve gathered the needed equipment, go to the stairs to climb to the work area.”
Project Goals:
- Optimize Raw Materials
- Optimize equipment and operational conditions
- Improve energy efficiency
- Analyze off-gases
- Develop a training simulator
PRELIMINARY RESULTS

- Flow Streamline
- Temperature Field
- Phase Interactions
- Velocity Field
Praxair in NWI

PRODUCTION FACILITIES

- East Chicago
- Burns Harbor
- Gary
- Whiting

FACTOIDS

- NWI Praxair operations date to 1911
- Separate oxygen, nitrogen, argon and rare gases from air
- 130 miles of pipelines in NWI and South Chicago area
- Store 0.5 BCF of liquid oxygen to backup pipelines
- Process and purify 50,000,000 cubic feet of air every hour
- Produce hydrogen and carbon dioxide from NG
- Over 4,000,000 miles driven per year by our NWI distribution fleet
- All products are colorless, odorless and tasteless

Roughly 75% of Praxair’s NWI production supports steel
Critical Supplier to the Steel Industry

- A Fortune 250 company with 2015 sales of $11B
- Doing business in more than 50 countries
- 26,000 employees
- One million customers worldwide
Suppliers must be an active part of the solution!

- Praxair products properly considered and accurately modeled
- Leverage collaboration of members
- Build upon CIVS’ past work and success
- Vested interest in Steel sustainability in U.S.
- Gain better understanding of Steel challenges
- Impartial science driven process
- Build closer working relationships with producers and collaborators
- Try something new building upon NWI resources and strengths
- Research projects will directly benefit both steel producers and suppliers
SLAB REHEAT FURNACE

- Developed 3D CFD furnace model and 2D slab heating model for
  - Troubleshooting to ensure uniform slab temperature
  - Maximizing the heating efficiency
  - Process planning and control
  - Training

“This project was an excellent example of collaboration between industry and a university. Together, we developed a very convenient and user-friendly tool which can be used by researchers and mill metallurgists in troubleshooting and optimizing our process.” - Mr. Rick Bodnar, Director of SSAB Americas R&D

Collaborators: SSAB North America
Slab Reheat Furnace Simulator
SUMMARY

- Global challenges require more innovations
- Advanced technologies are an essential part of innovation for our future
- Advanced simulation, visualization, and HPC provide innovative ways for efficient, effective, economic, and faster solutions to steel manufacturing related issues
Thank You!
Q & A

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