Iron & Steel Technology

October 2014

• Process Metallurgy and Product Applications

A Publication of the Association for Iron & Steel Technology
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**IMAGINE** seeing a power plant in operation, and training your employees on the operation of that plant, before the plant is even built. Imagine identifying the weakest spots of an overhead crane, without taking it apart at all, in order to develop a methodology that increases both reliability and cost savings. Imagine walking inside a blast furnace, where temperatures reach thousands of degrees, to see how iron ore is turned into liquid metal.

All of this and much more is now possible because of the work being done at the Center for Innovation Through Visualization and Simulation (CIVS) at Purdue University Calumet in Hammond, Ind., USA. Thanks to advanced simulation and visualization technologies, one can now “step inside” a virtual blast furnace, view a fatigue analysis of an overhead crane, and watch a virtual power plant in operation — all based on real data, real processes and real geometry. Different scenarios can be played out interactively in a 3D theater or portable virtual reality (VR) systems, on a personal computer or on a smartphone, showing how manufacturing can work better, how problems can be prevented, the immediate effects of trouble-shooting efforts, the scale-up effects of new concepts and the evaluation of new designs.
CIVS used new and emerging technologies, such as the Oculus Rift (a portable virtual reality system), at AISTech 2014 to showcase interactive virtual training in the steel industry.

BACKGROUND
In 2008, Purdue University Calumet (PUC) had an immersive 3D two-screen display which they wanted to make sure was useful. Chenn Zhou, who later founded the CIVS, was a professor of mechanical engineering at the time, and she was asked if she could use the facility for her research. “That was my dream,” Dr. Zhou told Iron & Steel Technology. “I had worked in computational fluid dynamics (CFD) simulations for decades, and I saw how the combination of simulation plus visualization could be used to solve real-world problems more effectively.”

CIVS was founded in 2009 in a single room at PUC with six computers. Starting with two pilot projects, the students and staff were quickly able to show the effectiveness of “simulation plus visualization” — the key to CIVS. More demanding projects started flowing into the center. Dr. Zhou was excited that CFD projects were no longer an anomaly, and many companies were now hiring experts in CFD.

By 2011, a state-of-the-art facility opened on the PUC campus with the help of funding from the U.S. Department of Energy. The facility includes a 70-seat 3D theater, visualization lab, including various VR systems, and a simulation lab with innumerable computers and a variety of software. The center now has five full-time staff, two Ph.D. students, and an average of 30 graduate research assistants and undergraduate student workers per semester. The center’s mission involves three facets: innovation, application and education. According to Dr. Zhou, without application, innovation is nearly meaningless, and without education, application won’t be carried forward into the future workforce, where innovation can continue.

THE CIVS DIFFERENCE
Around 12,000 people have visited CIVS since October 2011 from all over the world. Visitors to the center often ask Dr. Zhou, “What’s your secret?” She says, “Our facility may not be the best one, but our focus is different.” Her strategy includes the integration of simulation with visualization, an application-driven approach and developing partnerships.

“We developed step-by-step, section-by-section, and data-driven methodologies here at CIVS,” she explained. “We create a virtual world of a real problem. It is not just animation. It includes real data from scientific computations with real structure and real operating conditions so that it can show real application and direct impacts. We can effectively work with industrial partners to solve real-world problems by finding out what is the problem, why the problem is

“CFD MODELS developed by Purdue Calumet have helped us solve a variety of complex problems in the steel industry over the last several years. CFD is now widely accepted in the industry as a quick and economical problem-solving and design tool. The addition of virtual reality will now bring process understanding to a much higher level, as the modeler/designer can step inside the process and really get a ‘feel’ for what is going on.”

David White, Director, Process Research, ArcelorMittal R&D – East Chicago
CHENN Q. ZHOU, THE FOUNDER OF CIVS

In 1977, Chenn Q. Zhou had just graduated from high school in China. It had been 10 years since the beginning of the Cultural Revolution, and suddenly a large accumulated population had the opportunity to apply for college, and only 4.8% were admitted. The national entry exam was in either liberal arts or science and engineering, and Chenn began to prepare for her exams in liberal arts. Three weeks before the exam, one of her high school teachers paid a visit to Chenn and her parents, seeing her potential and telling her that China needed more engineers. “I switched right away,” said Chenn, “and I have enjoyed every moment since then!”

Chenn majored in power engineering and specialized in thermal fluids. In her junior year, she was engaged in undergraduate research in the area of combustion. In 1982, she started to learn computational fluid dynamics (CFD) and used CFD to study gas turbine combustion for her master’s thesis. This was cutting edge at the time. Upon completing her master’s degree, she was hired as an assistant professor, teaching combustion and power engineering.

In August 1987, Chenn began studying at Carnegie Mellon University in Pittsburgh, Pa., USA, in order to obtain her Ph.D. Her research focused on experimental studies on NOx control in flue gas using ammonia plasma. Her major professor was able to secure for her a computer because she knew CFD, but this was a rarity, and CFD still was not widely accepted. For part of her Ph.D. thesis, she developed a group model to simulate sprays more efficiently and realistically. Dr. Zhou completed her Ph.D. in three and half years and began working in an air pollution control company in Pittsburgh in 1991. But her true passions were in teaching and research.

In 1994, Dr. Zhou began teaching at Purdue University Calumet. She integrated research with her teaching. Senior design projects soon incorporated CFD. When a group manager from ArcelorMittal approached her regarding a refractory erosion issue in a blast furnace hearth, she put her students to work. They delivered the results, and soon there were more and more projects coming in. Since 1995, she has focused on CFD applications in industrial problems, even when CFD was not well accepted by industry. Her team has developed several CFD software packages with an interactive user interface for specific applications, such as a blast furnace hearth model and a blast furnace shaft model, which are currently in the stage of commercialization. She has made a great deal of effort to convince industrial personnel of the practical value of CFD. Since 2009, she has found that the value of CFD applications can be easily presented because of the power of visualization. The integration of simulation and visualization not only provides a great way for researchers to understand complex data, but also makes complex problems accessible to people with all kinds of backgrounds. It opens a door that allows non-experts the opportunity to expand their knowledge and exercise their creativity.

Dr. Zhou believes that the integration of simulation and visualization is essential for providing innovative solutions to improve global competitiveness in the future.

In addition to directing CIVS, she now serves as the interim associate vice chancellor for research and graduate studies and professor of mechanical engineering at Purdue University Calumet. She is a fellow of the American Society of Mechanical Engineering. She is also a member of various boards and committees, such as the AIST Foundation board of trustees.

For Chenn Zhou’s full biography and a list of her many awards and publications, visit http://webs.purduecal.edu/civs/chenn-zhou.
U. S. Steel engineers and operators use a virtual blast furnace for training at the CIVS immersive theater as part of their Ironmaking Academy program.

there and how to solve the problem. For complex systems, we start simple, with a section of the blast furnace, for instance. Then we feed one part into the next, in a way that is sophisticated enough to represent the real problem. We can do many kinds of scientific computational simulations. And we have been lucky enough at CIVS to work with nearly 85 different organizations, developing long-term partnerships that utilize our unique capabilities as well as the industry’s know-how.” CIVS students are involved in almost all of the projects and are often hired at the companies after they graduate, and then they bring additional projects back to CIVS. It’s a “win-win-win” situation for the university, the industry and the students.

CIVS focuses on virtual design and virtual training. These two areas often overlap and have unlimited applications. As an example, CIVS built the first virtual blast furnace. It has been used for training at steel companies and in an international blast furnace short course. It has also been used for providing guidance on blast furnace operations and has saved millions of dollars. Since the founding of the CIVS, more than US$30 million has now been saved among various industries. Whether it’s by avoiding shutdowns or increasing productivity, it translates into dollars saved.

AN EVER-WIDENING SPHERE OF INFLUENCE, A FOCUS ON STEEL

CIVS projects have helped to solve issues related to energy, environment, productivity, quality, safety, training, facility planning and automation, but the scope of projects extends far outside of engineering. Other areas served include: traffic data, airport design, microbiology, logistics, supply chain, chemistry, marketing, social justice, protein structure, brain imaging, construction, flood/emergency preparation, ground water quality, hazard prevention, wind energy, French poetry, nursing, healthcare/hospitals, and much more. CIVS has worked with more than 70 faculty and staff members at Purdue University Calumet in various disciplines.

“We specialize in combining simulation and visualization for design, troubleshooting, optimization, scale-up from concept, and training/learning,” explained Dr. Zhou. “The applications are unlimited, and the only limitation is your imagination.”

The steel industry is an area of increased focus at CIVS. Recently, CIVS received a US$480,000 grant from the National Institute of Standards and Technology (NIST) to launch a national effort to ensure a leadership role
for U.S. steel manufacturing in the global market by developing innovative technical solutions using advanced simulation and visualization technologies.

With support from more than 15 companies and other organizations, including AIST, CIVS will launch the Advanced Simulation and Visualization for Steel Optimization Consortium, which will work toward long-range technical solutions that steel companies and their suppliers can implement to improve and enhance workplace safety, environmental impacts, energy efficiency, reliability and maintenance, operation efficiency, workforce development, use of raw materials, and steel applications. The consortium’s initial task will be to develop an industry-led technology road map that will identify and prioritize research projects directed toward applying simulation and visualization tools that will strengthen manufacturing performance across the steel industry’s value chain in the United States.

“The NIST grant is exciting for two reasons,” Dr. Zhou said. “First, people recognize the importance of steel and the impact of advanced manufacturing on national economy and security. Second, they realize that simulation plus visualization can help. Through a team effort, simulation and visualization will be integrated to make the steel industry stronger.”

**CIVS AND AIST**

AIST has supported CIVS since its founding in 2009, and the two entities have worked together to promote 3D visualization technology for solving problems in the steel industry. As mentioned earlier, AIST is one of the organizations supporting the consortium for advancing the U.S. steel industry. CIVS also puts together a 3D video that is shown to high school and middle school students in the Materials Camps held at the annual MS&T conferences. CIVS and AIST are working to develop an online “steel flow simulation” based on AIST’s Steel Wheel. CIVS has also played a critical role in holding high school programs at the university in conjunction with the AIST Midwest Member Chapter to introduce young people to the industry. And many CIVS students have received awards from AIST, including First Place in the Undergraduate Student Project Presentation Contest at AISTech 2014 for the project titled “Roughing Mill Vertical Edger and Strip Grade Analysis Using FEA” sponsored by ArcelorMittal. Dr. Zhou also received the 2010 AIST J. Keith Brimacombe Memorial Lecture Award.
“Executive director Ron Ashburn and AIST are great supporters of CIVS,” said Dr. Zhou. “Whether it’s by serving on the AIST Foundation board of trustees or giving a demonstration to members of the Midwest Chapter and AIST Technology Committees, I want to acknowledge the great support from AIST by giving back to the industry.”

THE FUTURE OF CIVS

CIVS is fully supported by funding through grants, both federal and industry. The stability of the center as a technical resource is based on having stable staff members and a continuous pool of students at various levels. CIVS has a stacked system of leadership and skills, in which more experienced students mentor and train newcomers each year. Many of the graduate student research assistants are trained in their undergraduate years, especially during their senior design projects, and then continue to work at the center through their master’s program.

“Students are the future,” says Dr. Zhou. “I want to hire more students if possible. Through real-world projects, they learn not only technical skills, but also project management, communication and other skills, so they are well prepared for the workforce. Through mentoring and training other students, they also learn leadership skills.” One unique aspect of CIVS is that the center is actually training engineers who are also familiar with and interact with real-world industry. Students have commented that working at CIVS is even better than internship experiences because they can be involved with projects with various companies.

“Industry needs to support this kind of facility,” said one client who obtained successful, cost-effective and timely results from CIVS. Investment in the facility and the faculty members, such as through an endowment, would enable CIVS to continue to serve as a critical resource to the steel industry, not only for the unique simulation and visualization capabilities, cutting-edge technologies and cost-effective solutions, but also for the workforce of the future.

You can learn more about CIVS and its research activities by visiting www.purduecal.edu/civs.

EXAMPLES OF STEEL-RELATED PROJECTS BY CIVS

- 3D Visualization for Safety Training in the Steel Industry
- CFD Modeling of a Flooded Disc Scrubber
- CFD Modeling of a Torpedo Car for Improved Mixing Process
- CFD Modeling of Sinter Plant Venturi Scrubber
- CFD Modeling of a Ladle With Top Stirring Lance
- CFD Studies of a Bottom-Stirred Steel Ladle
- CFD Simulations and Optimization of a Batch Anneal Furnace
- Comparison and Optimization of Blast Furnace Tuyere Designs
- Developments of Blast Furnace CFD Shaft Model, PCI Model, and Hearth Model
- Development of USS Blast Furnace Virtual Training System
- Development of Blast Furnace Operation Stability Monitoring Program
- Equipment Longevity Extrapolation Based on Finite Element Analysis
- Investigation of Co-Injection of Natural Gas and PCI in Blast Furnace
- Modeling of Weld Plant Production and Logistics for Rail Products
- Numerical Simulation and Optimization of Bottom-Blow Basic Oxygen Furnace
- Numerical Optimization of a Q-BOP Vessel for Minimizing Kidney Formation
- Numerical Optimization of an Industrial Power Boiler Firing Metallurgical Gases
- Optimization of a Batch-Type Reheating Furnace and a Slab Reheating Furnace
- Simulation of a Sinter Cooler
- Vertical Edger and Strip Grade Analysis