High Performance Computing

Case Study.

High Performance Computing Drives a "Can-Do" Attitude at Alcoa

Compete.

Council on
Competitiveness

The Council on Competitiveness is a nonprofit, 501 (c) (3) organization as recognized by the U.S. Internal Revenue Service. The Council's activities are funded by contributions from its members, foundations, and project contributions. To learn more about the Council on Competitiveness, visit us at www.compete.org.

Design: Soulellis Studio

This work was supported by The National Science Foundation under grant award #0456129.

Printed in the United States of America

High Performance Computing Drives a “Can-Do” Attitude at Alcoa

Alcoa, the world’s leading producer of aluminum products, was one of the first companies to make major use of high performance computing when it became the NSF-funded Pittsburgh Supercomputing Center’s first industrial affiliate in 1987. When aluminum faced growing competition from plastic and other composite materials, the company used the PSC supercomputer to handle the complex modeling and simulations needed to get the jump on their competitors by successfully redesigning cans for the beverage industry and a variety of components for the automotive, aerospace, building and construction industries.

Every time you pop the top of an aluminum soda can, you are holding the result of some very sophisticated design work by Alcoa researchers and engineers, much of it done with the help of high performance computing (HPC).

Alcoa, Inc., headquartered in Pittsburgh, was founded in 1888. During the 120 years of its existence, the company has grown into a giant that generated revenues of $30 billion in 2006, with 112,000 employees in 44 countries. Alcoa is the world’s leading producer of aluminum products and components for a variety of industries, such as aerospace, automotive, building and construction, and, of course, packaging. But even world leaders face competition – in this case the nemesis to Alcoa’s aluminum is plastic and other new composite materials.

Plastic in Hot Pursuit

If you’re old enough, you can remember beer and coke cans of the 1960’s. They had heavy seams down the side – a wrap-around of tin-plated steel – and the popular “pop top” tabs. These cans were ubiquitous. But, by the 1980’s, plastic was making deep inroads into the consumer packaging market, and plastic bottles were replacing the tab-top containers. In order to compete effectively, companies in the container industry needed to rethink their use of more traditional materials like aluminum. Alcoa, which developed the aluminum can designs and the technology for making them but did not manufacture the cans themselves, took a leadership role.

“The plastic bottle was gaining increasing acceptance and had the potential to take a major piece of the can market share,” recalls Andrew Trageser of Alcoa’s Growth and Marketing Strategy Group. (At the time, he was a researcher with Alcoa Laboratories.) “So we decided to explore a completely new design space and see what the possibilities were…we really needed an imaginative solution.”

For example, a 12 ounce beverage can had always been about the same height and diameter. “That’s just the way it was,” Trageser explains. “And so we thought, well, suppose we drastically change the diameter and the height and examine all the possible combinations. Just what would the right aspect ratio be? And we wanted to look at this, not just for 12 ounce cans because, at the time, the market was moving toward two liter bottles, and some of our can customers wanted to compete in that space and offer a 32 ounce, or even larger, cans.”

But Alcoa had no empirical experience designing these very large cans and did not know, for example, precisely how thick they needed to be. One option was to undertake a time consuming, costly trial and error approach to determine the design parameters. Alternatively, they could have pursued the problem computationally using mathematical models and simulations to represent new designs and physical prototypes. They chose the latter approach.

Crushing the Competition with HPC

As the competition from plastics began to intensify, Alcoa’s IT organization installed some powerful machines called super minicomputers to handle its engineering

Opposite page: (Left) This image represents one of a sequence from "dynamic snap-through" modeling of a can bottom, with color indicating pressure. From these computations, Alcoa engineers analyze whether a proposed can design will meet the internal pressure specifications of the manufacturer. Image courtesy of Alcoa, Inc., and The Pittsburgh Supercomputing Center.

(Right) Using supercomputing at the Pittsburgh Supercomputing Cener, Alcoa has developed a sophisticated approach to finite-element modeling that accurately predicts how the can will perform under the stress of manufacturing, distribution and use. This modeling reduces the number of costly prototypes and significantly cuts time-to-market for a new design. Image courtesy of Alcoa, Inc., and the Pittsburgh Supercomputing Center.

design requirements. Although they were regarded as big iron at the time, the Alcoa researchers soon exhausted their capabilities.

"The minis and workstations we had available back then just didn't have the memory capacity and the speed that we needed to solve the complex design problems we were working on," recalls Trageser.

So, in 1987, Alcoa turned to the Pittsburgh Supercomputing Center (PSC), becoming its first industrial affiliate and beginning Alcoa's long odyssey into the world of HPC.

PSC is a joint effort of Carnegie Mellon University and the University of Pittsburgh together with Westinghouse Electric Company. Established in 1986, PSC is supported by several federal agencies, the Commonwealth of Pennsylvania and private industry, and is a leading partner in the TeraGrid, the National Science Foundation's (NSF) cyberinfrastructure program. It is one of several NSF High Performance Computing Centers located throughout the United States.

"We used the Pittsburgh Supercomputing Center to analyze the design space for very large can sizes. This was invaluable in helping us determine the optimum can geometry," Trageser says. "A design space with just two variables – height and diameter – provides you with a wide variety of possible heights and diameters that could be manufactured. In our space, we actually had about 15 different dimensions."

Using PSC's supercomputing system and working with its experts, Trageser and Ken Lippert, a mathematician with the Alcoa Technical Center, were able to examine these dimensions using complex, non-symmetric modeling techniques called Monte Carlo simulations. Running a Monte Carlo simulation on Alcoa's internal computers would have taken weeks. On the HPC system at PSC, each can design took just two or three minutes to evaluate, so a full Monte Carlo simulation containing 1000 designs took just a day or two. Answers started arriving. As a result, the Alcoa team was able to offer their manufacturing customers a wide variety of options in order to compete with plastic and glass containers.

For example, Trageser, Lippert and their research colleagues could now determine the can's optimum thickness and the maximum velocity cans could travel down the assembly line before dents started to occur. Cans can get dented during manufacturing or they may be dropped off a truck during delivery. Consumers don't want dinged drink cans.

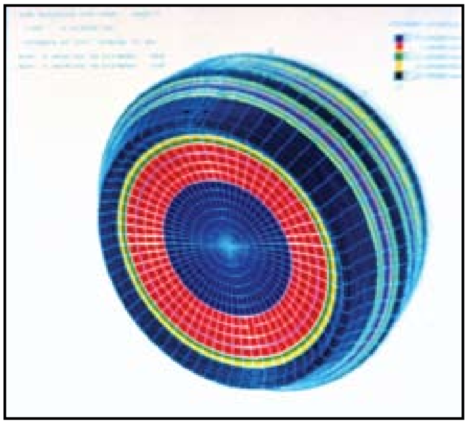
They also conducted "dynamic snap-through" modeling of can bottoms to analyze whether a proposed design would meet the internal pressure specifications of a manufacturer. "The bottom of the can has a very complex geometry," Lippert explains. "It has to withstand internal pressures and stacking loads, and it also needs to be as thin as possible to minimize the amount of metal used. There are many curves in the bottom of the can that have to interact to meet these physical requirements. We speculated that if we could make the radius of the bottom rim of the can very small – almost a sharp edge – the can might be able to withstand greater internal pressure. To determine this, we needed the power of high performance computers to run the analysis and see how it would perform mechanically.

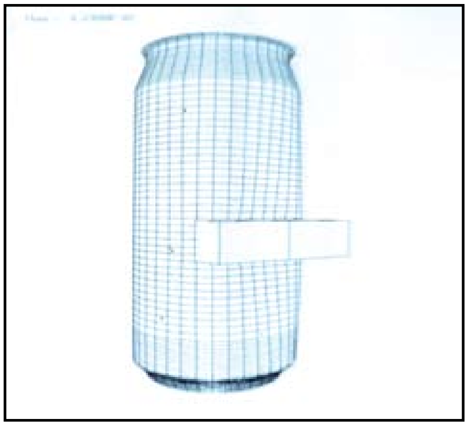
Use of the PSC supercomputers resulted in faster design turnaround – simulations that would take weeks using in-house workstations were completed in minutes on HPC.

"In addition to the bottom of the can, the top of the beverage can has become smaller to save on weight," Trageser adds. "Over time, what the can makers have attempted to do is continue to make the top smaller, actually approaching the configuration of a bottle, while retaining a reasonable thickness that allows consumers to easily open the tab-tops."

The Alcoa researchers found that not only were they getting the answers they needed to solve complicated design problems, but, using the PSC supercomputer, they could cut the $100,000 price tag for developing a can design in the laboratory to $2,000.

"Lightweighting", or designing cans with the thinnest aluminum possible within the constraints of strength and appearance, also was a major priority at the time (and





still is 20 years later). Lightweighting saves the industry about $200 million annually in the manufacture of cans and helps aluminum cans stay competitive. This is a huge market – more than 100 billion cans are produced a year, which averages out to one can per person per day in the North American market.

HPC Supports other Alcoa Lines of Business

“The lessons we learned from working on the beverage can design with PSC – such as optimizing the computational processes and applying Monte Carol simulations – were widely applicable to design development for other areas of the company’s business, such as aerospace and automotive,” notes Trageser. “When compared with designing an aircraft landing gear, a wing part or a truck wheel, modeling a beverage can was a relatively simple problem.”

For example, using the PSC facilities, Alcoa helped develop the Plymouth Prowler, the first U.S. car engineered from the ground up to exploit aluminum technology, and the Audi A8, a German-produced aluminum vehicle. The company’s ability to do computer simulations that predict how aluminum structures and body sheets will perform reduced costly prototyping and trial-and-error processes.

According to Alcoa automotive engineer Edmund Chu, the company’s partnership with PSC allowed it to refine its model of how the microstructure of the metal behaves when formed into a manufactured product. It also allowed the Alcoa engineers to look at multiple design possibilities. “With high performance computing,” says Chu, “we could look at five or six scenarios at once. The turnaround is six times faster than our own workstations, and this is critical in the design stage, where you need to make changes quickly.”

Trageser points out that some of Alcoa’s key competitors in the automotive and aircraft industries are the manufacturers of carbon fiber composites. This drives Alcoa to design parts that are lighter and stronger.

“Another major benefit of working with PSC goes beyond the computer cycles that we purchased,” he adds. “It was the technology transfer that really put us ahead of similar sized organizations in the computing technology arena. It was not only our ability to go to the center and bounce ideas off very smart people, but also the on-the-job training and classroom work provided by PSC that made the difference.”

Alcoa’s Evolving Journey with HPC

During the years, Alcoa’s approach to high performance computing has changed and evolved. In the early 1980s, researchers relied on the in-house processing power of the era’s super minicomputers to explore new design parameters. When more processing power and memory was needed, Trageser and his colleagues began using the supercomputer at the Pittsburgh Supercomputing Center some 20 miles down the road. Next they automated the links between the PSC system and their own internal systems. As PSC stepped up their technology transfer efforts, the Alcoa teams became increasingly adept at devising and running new models and simulations.

Today, thanks to that expanded knowledge base, the tremendous increase in power of commercial workstations, and the ability to create HPC clusters from inexpensive, off-the-shelf computers running the Linux operating system, much of the modeling and simulation work that was once done at PSC is back inside the Alcoa Laboratory.

But that’s for now. Supercomputers and the NSF centers that house them will continue to become more powerful and flexible. And Alcoa will continue to be driven by competitive pressures and the need to find innovative, new ways to design aluminum products. One way or another, it’s a safe bet that the company’s long association with HPC is far from over.

In Brief

Key Challenges

- Compete effectively against providers of plastic, glass, carbon fiber composite and other materials used in Alcoa's major markets with dramatically new, lower cost aluminum designs, faster prototype turnaround and faster testing cycles
- Move past the limitations of Alcoa Laboratory's in-house computer systems to solve the complex design challenges posed by its core line of products
- Build Alcoa's in-house design expertise

Solutions

- Take advantage of the immense power of high performance computing at the Pittsburgh Supercomputing Center, along with the expertise of the center's personnel, to create new, competitive designs through computational modeling and simulation
- Engage PSC to provide technology transfer in HPC to the Alcoa researchers through on-the-job training and classroom sessions

Key HPC Benefits

- Allows Alcoa to accelerate its innovation by tackling new design problems that required massive amounts of computational capabilities – e.g. exploring the complex geometries of beverage cans to design lighter, stronger products and the behavior of aluminum at the molecular level for automotive and aerospace applications
- Cuts the $100,000 required for designing a can in the laboratory to $2,000 using the PSC system
- Saves about $200 million annually by reducing the metal required for the manufacture of cans
- Positions the company to successfully compete against new materials and products and to enter new markets
- Builds in-house high performance computing expertise through technology transfer, enabling Alcoa to handle more product modeling and simulation in-house

Web Site

- www.alcoa.com

FSC
Mixed Sources
Product group from well-managed forests, controlled sources and recycled wood or fiber
www.fsc.org Cert no. SW-COC-002557
30%

Instead of using 100% virgin paper, we used paper that has been 30% Post-Consumer Recycled and made with 100% wind-generated electricty. We saved:

5 trees preserved for the future
1667 gal of water flow saved
276 lbs of solid waste not generated
509 lbs of greenhouse gasses prevented
3 million BTUs of energy not consumed

Environmental impact statements were made using the Environmental Defense Fund Paper Calculator.

Council on Competitiveness
1500 K Street NW, Suite 850, Washington, D.C. 20005 T 202 682 4292
Compete.org

Compete.
Council on
Competitiveness