High Performance Computing

Case Study.

Supercomputers and the Secret Life of Coffee

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Supercomputers and the Secret Life of Coffee

To improve the freshness of its Folgers® coffee and reduce the costs of packaging, researchers at Procter & Gamble decided to switch from a metal can to a plastic container. However, they ran into a number of problems related to gas build up inside the containers, fluctuations caused by changes in atmospheric pressure during shipment and a problem associated with the coffee cans imploding while being trucked to their destination. This latter problem almost caused the entire research project to fail. The group used high performance computing both to solve their problems in a timely fashion, and provide the company with a competitive advantage as well.

Headed for Los Angeles, the driver guided the big semi down the western slope of the Sierra Nevada mountain range. He had no idea that in the trailer behind him the shipment of Folgers® Ground coffee in two-pound containers was silently imploding.

What could have been a disaster had already been anticipated and averted by research scientists at The Procter & Gamble Company (P&G), maker of the popular brand. The solution, which had to take into account the complex behavior of gasses enclosed in a sealed plastic container, required the services of a supercomputer and some last minute problem solving that saved the day.

P&G has a strong commitment to research and development. The company, which had revenues of $76.4 billion in 2007, employs 138,000 people working in 80 countries. This total includes a talent pool of 7,500 Ph.D.s and researchers who tackle high-tech challenges and foster innovation to keep the company competitive. Its well known brands include Pampers®, Tide®, Aries®, Always®, Pantene®, Bounty®, Pringles®, Charmin®, Downy®, Crest®, Actonel®, Olay®, and, of course, Folgers®.

One of those researchers is Tom Lange, director of modeling and simulation, corporate research and development. It was Lange who corralled a group of scientists, mathematicians and engineers to fix the problem of the collapsing Folgers coffee containers.

The Problem of Pressure

"For coffee to be fresh when a consumer opens a coffee can, you have to roast it, grind it and package it very quickly," Lange explains. "But even after we seal the container at the factory, the coffee continues to give off gas. This gas build-up exerts pressure against the coffee container, and potentially could cause it to explode. A metal container can handle the pressure, but there's a problem. After the can is opened, oxygen, the oil in the coffee and the metal all interact and the grind quickly becomes stale – even if you put a plastic lid on it."

The packaging designers found they could solve the freshness problem by packaging the coffee in a plastic container. This had several advantages – not only were the plastic cans less expensive, but they kept the coffee fresher. Some of the oil is absorbed into the plastic and creates what is called an aroma headspace over the top of the coffee. This prevents loss of flavor after the can is opened, and there is no metal to act as a catalyst and cause staling.

Says Lange, "So that sounded pretty simple – we just make a plastic can, put a lid on it and we're done – right?"

Wrong. There were several problems that had to be solved, all having to do with pressure. All required inventing new and creative solutions on the part of P&G

researchers; solutions that were arrived at with the help of high performance computing (HPC). Supercomputers were used throughout the process to perform modeling and simulation of the coffee container – primarily finite element analysis, a computer simulation technique used in engineering.

HPC helped the researchers devise three inventions that met the challenges associated with pressure and staleness. Two of the inventions addressed anticipated issues. But one invention was a last minute fix to solve a problem that popped up unexpectedly just as the team was ready to claim success. The entire project was almost scuttled.

Checking the Implosion

A traditional coffee can, Lange explains, is essentially a pressure vessel that contains the gas until it is reabsorbed. To make a plastic canister that was as strong as a metal can and could withstand the build up of gases required too much material – it would be unwieldy and costly. So the first problem was finding a way to vent the pent-up gas so that a lighter weight plastic canister would not explode, but also not let oxygen back in to destroy the freshness of the coffee. Their solution was to devise a check valve that swings in one direction only – when the gas builds up, the valve swings open and releases it. After the pressure in the canister drops and the outside air tries to force its way inside, the valve swings shut.

And that led to problem number two – the collapsing coffee canisters. A shipment en route from New Orleans, where P&G packages its Folgers coffee, to, for example, a distribution center in Tennessee, is not a problem. There are no mountains to cross and therefore no dramatic changes in outside atmospheric pressure. But a shipment heading to Los Angeles or Portland, OR, has some serious elevations to contend with – 10,000 or 11,000 feet at the crest of the Sierra Nevada's, or during the trip through the Eisenhower Tunnel in Colorado and over the Cascades to reach Portland. At these elevations, the outside atmospheric pressure drops below the pressure inside the canisters, causing the canisters to vent gas through the check valve so that they won't explode.

Image courtesy of The Procter & Gamble Company.

"But," says Lange, "the problem is that when you drive down the other side of the mountain, the outside atmospheric pressure rises again, greatly exceeding the now lower pressure within the canisters. Because the air can't get back into the can to equalize the inside and outside pressure, the can crushes itself – it implodes. Imagine how an empty soda can looks after you crush it in your hand and you'll have a mental picture of what can happen."

Supermarkets do not want to stock crushed coffee canisters on their shelves, and consumers certainly don't want to buy them. So the team needed to create a design solution to prevent the implosion. Using HPC, they devised unobtrusive flat panels that fit on the side of the canister. When the canister starts to implode, the three panels shrink as well and evenly distribute the stress. "That's the tricky, cool stuff," says Lange proudly. "The bottom and top remain round, and the side panels flatten out a bit and look somewhat square. They're designed to do that, and they do it in a predictable way to avoid the crushed soda can effect." Although the canister has shrunk a bit, it retains a uniform, pleasing shape and is ready for the grocery store shelf.

Problems solved. Or so Lange and his team thought. But just when they were ready to declare the plastic canister design ready to go to market, they ran some additional smaller tests and simulations and uncovered what they thought at first were some minor design optimization problems that had to be addressed. The minor problems turned out to be major and could have derailed the entire project.

"There is no question that HPC has given us a competitive advantage."

Tom Lange, director of modeling and simulation, corporate research and development, The Procter & Gamble Company

Even though they had devised ways to handle the fluctuations in pressure and accommodate the resulting shrinkage with the first two inventions, they discovered through their simulations that there was still enough stress generated that an area around the canister lid would crack. The fractures propagated, and when that happened, the whole lid collapsed and came off.

"When the shipment arrived at the warehouse, you could wind up with an entire truckload of coffee canisters with no tops. It would have been a disaster," Lange says.

Keeping the Lid On With HPC

"The traditional approach to solving the fractured lid problem would be to make numerous, prototype canisters," Lange explains. "Imagine a team of engineers sitting around arguing about the thickness and shape of the canister and lid. We would eventually wind up with three or four ways to approach the problem. Then we would make three or four moulds, create several prototypes, fill them with coffee, load them in trucks, and ship them to California to see what happens. We're talking four to six months of effort. But at this late stage of the project, we could not afford to make that level of investment. And there already was a lot of concern on the part of management as to whether the entire project was worth it. We only had one shot to fix this."

Lange's engineers turned to HPC to model various canister/lid designs and try out the results in simulated environments. Within a few weeks, they had come up with some innovative manufacturing optimizations that solved the problem of the imploding, lidless coffee canisters.

The new containers not only solved the problem, but became an enormous hit with consumers. Today, the two-pound plastic canisters of Folgers Ground are on the shelves of supermarkets around the country – even in California and Oregon despite the mountain passes.

HPC Competitive Impact: Predicting the Future for Cost Savings and Market Leadership

At P&G R&D, conducting finite element analysis using HPC has become as much a routine part of their innovation process as building prototypes and conducting experiments were 20 years ago. According to Lange, every dollar spent on high performance computing – including for people, hardware and software – has been returned in savings many times over by reducing the number of physical prototypes and associated experimentation, and speeding up the entire design process. Multiple simulations can be conducted much more quickly and efficiently.

"You know, we used to use HPC modeling and simulation for autopsies – to explain why things didn't work after they failed," he says. "But now we have the computing power to get things done correctly up front rather than wait for a catastrophic failure and then try and figure out what went wrong. In other words, high performance computing has allowed P&G to be more accurate and relevant about what's going to happen in the real world. We have enough computing power to create realistic models and observe their behavior in a variety of conditions – for example, different canister designs responding to a variety of changes in atmospheric pressure. In the old days, we would make a physical prototype, allow it to fail, and then fix it. Now we can actually predict the behavior of something that we haven't built yet. This is not only great from an engineering point of view, but it also has a major impact on our competitiveness."

By speeding up the design and testing of innovations to the P&G product line, HPC has repeatedly given the company an edge on its competition. In the case of Folgers, the ongoing use of modeling and simulation resulted in new packaging and product design that propelled the brand to a leading market position over a several-year period. The plastic containers provide consumers with fresher, better tasting coffee, not to mention a pair of handles on the two-pound plastic containers that has proven to be very popular.

"There is no question that HPC has given us a competitive advantage," Lange states. "In the case of the imploding coffee cans, it allowed us to get the new packaging to market months faster without spending the massive amounts of money and time that the older methods of building and testing physical prototypes would have incurred. This is why not only the engineers and scientists in R&D, but also the company's C-suite level executives, consider high performance computing a strategic asset."

In Brief

Key Challenges

- Design a new, lightweight plastic container that would not explode from the build up of gas pressure after the coffee is packaged
- Find a way to keep the container from imploding when exposed to different atmospheric pressures while in transit
- Fix a problem that caused the lid to crack – a problem that was discovered at the last minute and could have scuttled the new plastic canister design project

Solutions

- Use HPC modeling and simulation to create a unique design that regulates pressure to prevent the canister from exploding or imploding while still preserving coffee flavor and freshness
- Enlist HPC to quickly deal with an unexpected malfunction in the canister that would cause the lid to crack and come off during transit

Web Site

- www.pg.com

Key HPC Benefits

- Allows the P&G researchers to invent three creative solutions in a fraction of the time that older methods involving physical prototyping and testing would have taken
- Enables the P&G team to respond rapidly and effectively to unanticipated, last minute design problems that, if not fixed, would have resulted in canister lids popping off and coffee spilling out
- Salvages the new packaging project in danger of being cancelled because of the lid problem
- Provides a major return on investment and total cost of ownership when compared to previous physical testing procedures
- Cuts expenses significantly by using modeling and simulation instead of physical prototyping, allowing the company to price its product competitively and increase its margins
- Allows P&G to offer convenient new packaging that enables coffee to stay fresher longer after the can is opened, boosting customer acceptance and propelling its Folgers brand to first place in market share over its rivals
- Enables the company to get new, innovative packaging to market years before its competition

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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

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