High Performance Computing

Case Study.

Dana Holding Corporation: Optimizing Products and Processes with HPC

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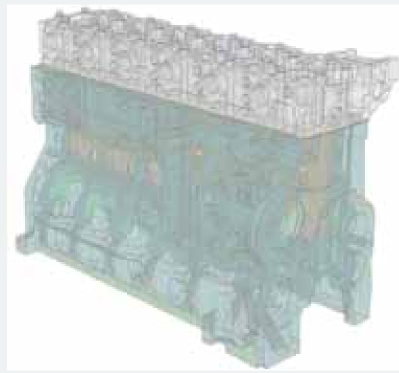
Dana Holding Corporation is a leading supplier of axles, drive shafts, sealing and thermal-management products. The company's customer base includes virtually every major vehicle manufacturer in the global automotive, commercial vehicle and off-highway markets.

http://www.dana.com/

Diesel Powertrain



Challenges

- Meet heightened competition and cope with the economic downturn in the worldwide vehicle market
- Build a broad and flexible engineering base into the company's products that includes interactions with other components in the vehicle's system during operation
- Simulate highly complex models that contain many millions of degrees of freedom
- Reduce costs and time-to-market
- Reduce dependence on physical prototyping

Solutions

- Design, develop and build products using in-house and external high performance computing (HPC) resources running computer-aided engineering (CAE) and finite element analysis (FEA) programs
- Find the optimum trade off between speeding up the simulation of a product and the computational power (the number of computer cores) required to run the job–the so-called "sweet spot"
- Instead of building a number of physical prototypes, use HPC and CAE to develop the design of a product all the way to customer sign-off

HPC's Impact—The Return on Investment

- Permits Dana's Sealing Products Group to identify the optimal configuration of layers, metals, geometries and coatings for their metal gasket products
- Permits the use of larger, more detailed models, speeding up design and analysis time
- Simulations that once took months now can be run in two or three days; other jobs that took weeks now are completed overnight
- Faster turn around time helps in incorporating experimental design techniques, allowing greater fine tuning of design aspects and contributing to more successful parts
- Physical prototyping has been substantially reduced resulting in significant savings in time and money
- Able to share design and other information directly with its customers
- By optimizing its HPC-based engineering capabilities, Dana is maintaining its leadership in world automotive and other vehicle markets

Learn more at Compete.org/hpc/darpapilots/

Dana Holding Corporation: Optimizing Products and Processes with HPC

When Frank Popielas talks about the "sweet spot," he's not referring to his tennis game. He's talking about the most efficient and cost effective way to use high performance computing (HPC) to accurately simulate the design of a specific product.

In this case, the products in question are axles, driveshafts, sealing and thermal management components that Dana Holding Corporation provides to virtually every major vehicle manufacturer in the world. Customers include the top players in the automotive, commercial vehicle and off-highway markets. The company, headquartered in Maumee, Ohio, is very good at what it does—sales for 2008 were $8.1 billion and Dana employs about 22,500 people in 26 countries.

Popielas is the manager of advanced engineering for the company. One of his charters is to keep a close eye on that sweet spot, because, as he says, "You want to get the biggest bang for your buck from your HPC investment."

Popielas points out that due to the heightened competition in Dana's marketplace—especially in the automotive industry—continuous performance advances are essential to remaining competitive. In a recent paper presented at the 2009 SIMULIA Customer Conference, Popielas and his co-authors stated, "An ineffective business will not be able to survive the drastic market challenges regarding cost, quality and performance. Computer Aided Engineering (CAE) plays a major role in achieving this effectiveness. It has been demonstrated that companies focusing heavily on CAE in a coordinated manner are facing less constraints and have a better chance of coming out of this economic down-turn with greater ease and an increased focus than companies that do not utilize CAE."

Popielas holds that to maintain leadership in the company's worldwide market means building a broad and flexible engineering base into Dana's products. This means optimizing performance in challenging and constantly changing environments. Modeling and simulating parts and their complex interactions with other vehicle components in a variety of conditions requires the use of powerful HPC systems and the latest in CAE, FEA (finite element analysis) and CFD (computational fluid dynamics) software.

"No matter how small or large the part, it has an essential role to play in one of the vehicle's critical systems," he explains. "Using simulation, we can examine a number of interrelated factors. For example, we look at the thermal properties of a part from a functional perspective to determine how we can lower heat flux in the system, or in other cases, add heat to achieve lower emissions. At the same time, we can evaluate the use of lighter materials to reduce fuel consumption while designing systems with higher combustion pressures in order to reduce emissions. Or we can investigate how to transfer torque efficiently between the front and rear of the vehicle using lightweight components while minimizing noise, vibration and harshness."

Inevitable Rise in Complexity

In past years, Dana engineers would analyze a single joint or engine cylinder. Those days are gone—now an entire power train, axle assembly, or the dynamic and thermal properties of fluids flowing through the system must be considered simultaneously.

These requirements are highly demanding from a computational standpoint. Dana engineers are dealing with models that are becoming increasingly detailed, incorporating increasing numbers of degrees of freedom

Figure 1. Sealing system components for powertrain, exhaust and aftertreatment applications

that must be taken into account during the simulation. Degrees of freedom are the set of independent displacements and/or rotations that specify completely the displaced or deformed position and orientation of the body or system (specifically of an element in a FEA model). Ten years ago, Popielas recalls, they were working with one or two million degrees of freedom. Today that number has reached five or six million, and in a few years they will be simulating models featuring significantly above 10 million degrees of freedom.

For example, he cites the evolution of simulating a critical engine component—the cylinder head gasket. Ten years ago using the high-powered workstations available at the time, Dana engineers were only able to model and simulate the performance of one engine cylinder operating at room temperature. Also, cylinder head gaskets are composed of multiple layers, but in early simulations could be represented by just a combined single layer, using so-called gasket elements. And even these crude simulations would take several days to run. Much of a product's testing and analysis at this time relied on complex, time consuming and costly physical prototyping.

As HPC clusters became more powerful and affordable, the engineers were able to run larger, more complex models that simulated not just one component—for example, the single cylinder—but an entire engine. They could apply thermal information to the model and explore the dynamic motion between parts and the distortion of those parts under different operating conditions. Only five or six years ago, because of the model's high degree of complexity, including a major ramp up in the number of degrees of freedom being studied, a simulation could take a month or longer to run. And here is where the sweet spot comes in.

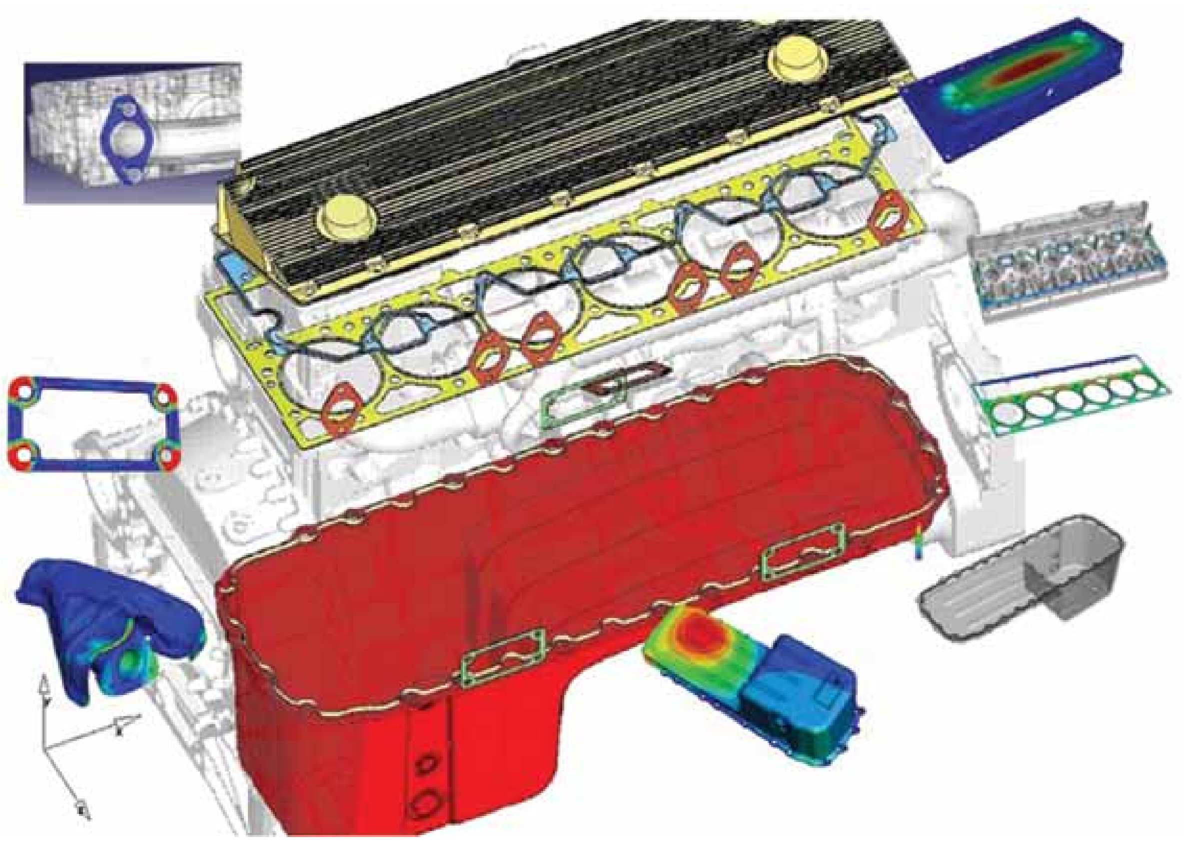


Figure 2. Sealing components in a diesel powertrain

The older multicore and multiprocessor HPC systems that the Dana engineers were using relied on a shared memory processing (SMP) architecture in which every CPU shared memory with its fellow processing units. Popielas' solution was to move to the newer distributed memory processing (DMP) architecture where each CPU or node has its own non-shared memory space. DMP systems can operate at much higher speeds. But raw speed is not enough. To really be effective, there is a cost/benefit ratio that has to be investigated and implemented.

To optimize the simulation of a highly engineered system with millions of degrees of freedom, the engineers look for the sweet spot. This represents the optimum relationship between the speed of the simulation and the cost per unit of the computing cores required to run the job. Ideally, the speed of the run increases linearly with the addition of cores to the simulation. However, the reality is that not all software is capable of using the hardware to maximum effectiveness—even some of the most widely used CAE solvers have their eccentricities. This is why Dana's engineers have to benchmark each new hardware and software configuration to identify its unique sweet spot before releasing it into production.

Boosting Dana's Competitiveness Worldwide

Popielas says that his team's approach to HPC gives them the flexibility they need to handle a wide variety of jobs with a broad range of computational and time requirements. In order to meet a tight deadline, for example, the sweet spot for a simulation of an axle might require 24 cores, whereas a power train simula-

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Frank Popielas
Manager of Advanced Engineering, Dana Holding Corporation

tion might call for 32. When a particularly complex job on a tight time schedule is called for, the Dana team will enlist the aid of supercomputing capabilities from third party vendors or institutions like the National Center for Supercomputer Applications at the University of Illinois.

"Our use of HPC has had a major impact on Dana's ability to compete in the world markets," Popielas notes. "Before we optimized our HPC environment, the simulation of a product, such as a powertrain which has a huge number of degrees of freedom, could take months–and that's not even taking into account the time required to set up the model. Today, with our optimized system, we can run the equivalent simulation in two or three days. Jobs that were taking a month, can be handled overnight. And, given the advances in HPC price/performance and CAE capabilities, in 2010 we anticipate running simulations even faster."

Not only does this speed-up in operations make Dana more competitive, it is also helping the company realize significant savings in time and money. Popielas says that 10 years ago, very little CAE was used prior to constructing a physical prototype for test, analysis and design modification. This was expensive. For instance, a simple dynamometer test can cost in the neighborhood of $100,000. And often three or more iterations were necessary.

Today the situation is totally reversed. A typical example is the design of cylinder head gaskets–90 percent of all new releases are developed using CAE to create the final design and obtain customer sign-off. The old trial and error technique of building and testing multiple physical prototypes is a thing of the past.

Says Popielas, "With each successive generation of new HPC systems, we are looking at efficiency improvements of at least 25 percent every year. In addition, we are beginning to exchange product development information on a real-time basis with our major customers that use HPC along with CAE and FEA technology. In fact, we are collaborating with those customers to develop new simulation technologies and standards.

"In addition, remote visualization tools, available today, provide an efficient way for engineers to interact graphically with their simulations at locations other than a directly connected terminal monitor," he says. "We are rapidly moving toward a time when there will be a direct link between our customers and Dana that will allow us to freely exchange simulation models and resources. Without HPC, none of this would be possible."

About the Project

This case study was produced as part of a project that was created to demonstrate the business and competitive value of modeling, simulation and analysis with HPC in the U.S. private sector, motivate usage of this innovation-accelerating technology throughout the DoD's supply chain, and identify technologies and partners that can help support an HPC infrastructure for the DoD supply chain base. It was led by the University of Southern California's Information Sciences Institute (ISI) and supported by funding from the Defense Advanced Research Projects Agency (DARPA) under contract number FA8750-08-C-0184. DARPA is the central research and development office for the U.S. Department of Defense. DARPA's mission is to maintain the technological superiority of the U.S. military and prevent technological surprise from harming our national security. For more information, see http://www.darpa.mil.

Complete information about the other case studies and pilot programs associated with this project is available at http://www.compete.org/hpc/darpapilots/.

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