3DS SIMULIA
Community News

February/March 2012
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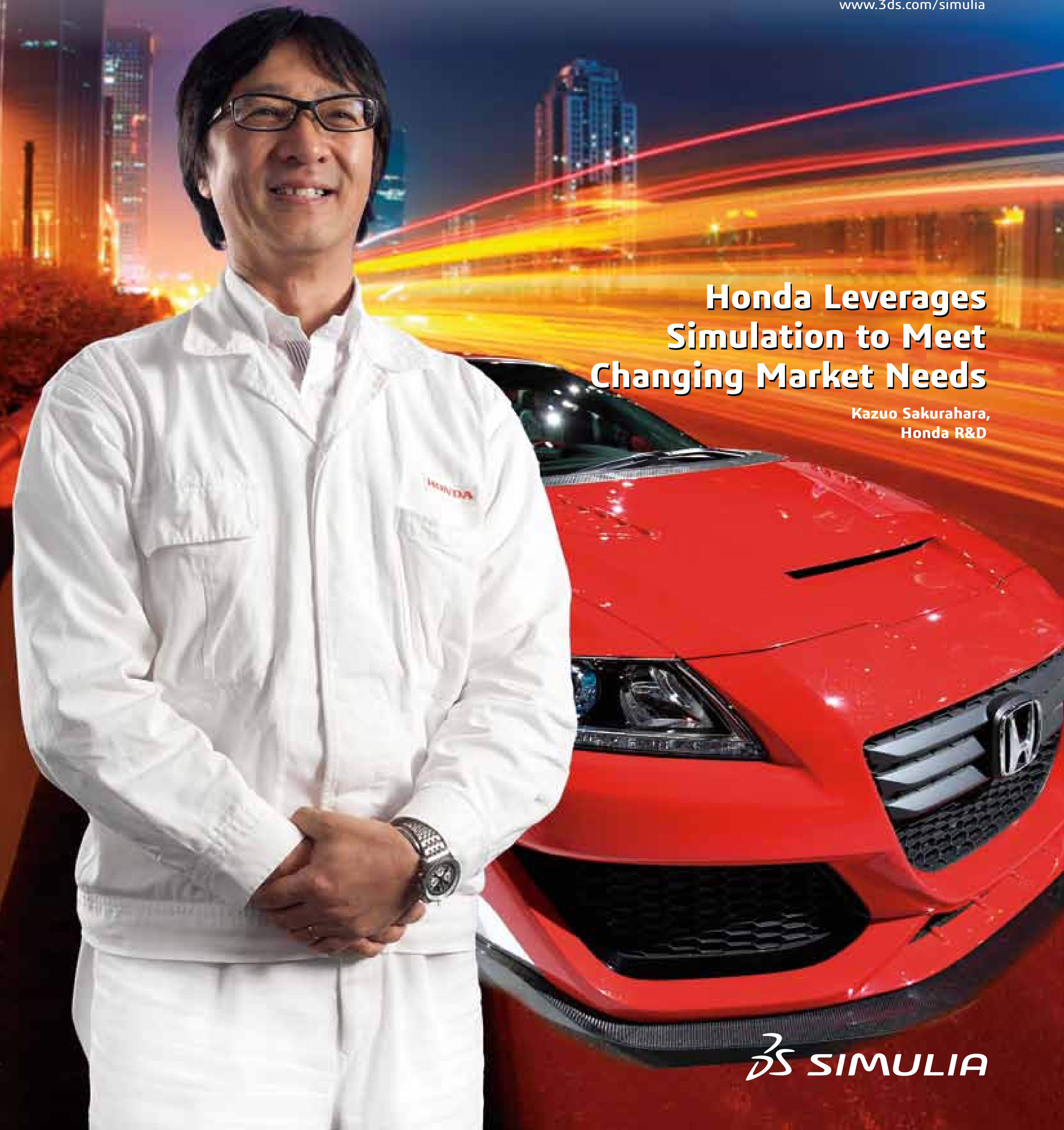

Honda Leverages Simulation to Meet Changing Market Needs

Kazuo Sakurahara, Honda R&D

DASSAULT SYSTEMES

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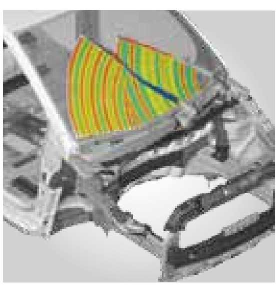

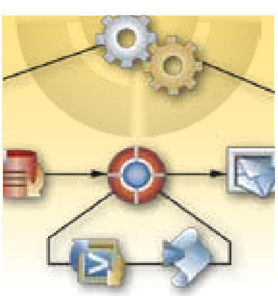

In Each Issue

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SIMULIA

3D Experience, a Catalyst for Innovation

"Twenty years from now you will be more disappointed by the things you didn't do than by the ones you did. So throw off the bowlines. Sail away from the safe harbor. Catch the trade winds in your sails. Explore. Dream. Discover."
—Mark Twain

I feel that this quote from Mark Twain captures the essence of the evolution of our 3DS SIMULIA brand promise to our user community. Since our inception in 1978, we have been committed to enhancing and expanding the technical capabilities of realistic simulation solutions so that our global user community can explore physical behavior, discover paths to innovation, and collaborate on improving product performance in life and nature. During the last 34 years, 3DS SIMULIA has expanded significantly, yet we have stayed on course with our strategy to deliver not only robust simulation technology, but equally high-quality services and support to every customer.

As part of our strategic commitment to our user community, we have changed the name of this publication to *3DS SIMULIA Community News* (SCN). This change reflects, not only our focus on interacting with our global user community, but it also recognizes the contribution of our users in pushing the boundaries of our technology to solve challenging engineering problems.

I am personally inspired by the papers and case studies provided by our community and extremely pleased to have the interview from Honda Motor Company as our cover story (page 12). Honda is a pioneer and major industry influence in utilizing 3DS SIMULIA technology. While many of the stories in this issue have an automotive focus, we are also providing real business value across a wide spectrum of industries.

We are energized by the opportunity to take the next step in our brand's journey as an integral part of Dassault Systèmes' 3D Experience platform. The 3D Experience platform transforms the way "innovators will innovate with consumers" by connecting designers, engineers, marketing managers and even consumers, in a new 'social enterprise'. The combined technology and experience of our sister brands—3DS CATIA, 3DS SolidWorks, 3DS DELMIA, 3DS ENOVIA, 3DS Exalead, 3DS 3DSwYm, 3DS 3DVIA, and 3DS Netvibes—offer significant value to you and your organizations.

We believe that the integration of our proven, robust realistic simulation technology into a 3D Experience platform will indeed be a catalyst for innovation, enabling any enterprise stakeholder to participate in simulation driven decision-making processes resulting in a competitive advantage for you and your organization.

To learn more about the evolution of 3DS SIMULIA and Dassault Systèmes' 3D Experience platform, I invite you to attend the 2012 3DS SIMULIA Community Conference (SCC). Bernard Charlès, CEO of Dassault Systèmes, will share our company's overarching vision and mission in relation to the 3DS SIMULIA community. The 2012 SCC also features more than 80 user presentations providing you with a wealth of information.

I look forward to meeting with you to learn more about your requirements and share insights into our ongoing commitment to delivering innovative simulation technology and high-quality support that will enable each of you to be a catalyst for innovation.

Scott Berkey
Chief Executive Officer

Driving Towards the Sustainable Car Engine of the Future

By Mark Stephenson, MAHLE Powertrain Ltd.

MAHLE Powertrain's 3-cylinder, 1.2 liter, extreme-downsized, demonstration engine (I3) has been installed in two VW Passats for test driving. The 50-percent downsized unit generates 160 hp, gets 49 UK-miles-per-gallon, meets EU6 CO_2 standards, has CO_2 emissions of only 135 g/km, and was designed with the aid of an extensive suite of simulation software tools.

Stricter standards for fuel consumption and emissions are leading all of us in the automotive industry to go beyond what we have done in the past. At MAHLE Powertrain Ltd., for instance, our R&D effort now includes both extreme-downsized internal combustion engines and range extenders for electric vehicles. Yet pushing the creative envelope in such new areas can bring its share of design challenges.

As a Tier 1 automotive supplier that designs and develops engines, MAHLE must always meet the expectations of our OEM customers. We do this while balancing a variety of tradeoffs such as the underlying regulatory, cost, production, and business hurdles of weight, durability, friction, emissions, and efficiency. Plus, we have to meet time-to-market demands. Our go-to toolset in balancing all of these targets efficiently is computer-aided engineering (CAE), the main design driver that underscores our entire development process.

Simulation up front

We start every product development program with a cycle simulation to determine exactly what engine configuration and technology our customers are looking for. Moving to CAD, we turn to concept-level models for information on package volume, costs, and weight. Once a concept is chosen, we manage the models using Product Lifecycle Management (PLM). For fluid studies, we utilize several 1-D tools to help avoid and reduce pressure losses in the oil and cooling systems. To guide design of the combustion chamber and related systems, we employ Computational Fluid Dynamics (CFD) for insight into very complex 3-D behavior.

We incorporate structural analysis of our conceptual ideas early on in the development process, using Abaqus Finite Element Analysis (FEA) as the main workhorse for our thermal and stress queries. These studies help us investigate ways to reduce weight and friction of components, such as the crank train, connecting rods, bearing panel, and bearings. For preprocessing, fatigue analysis, and crank train dynamics, we are able to couple other tools seamlessly with Abaqus without worrying about integration, as they can all use or generate native Abaqus data.

Each tool in our extensive library of software is hand-picked for its specific complementary capabilities, and our team of designers and analysts is cross-trained for maximum flexibility. Our design engineers are capable of using numerous CAD programs—virtually whatever our customer uses.

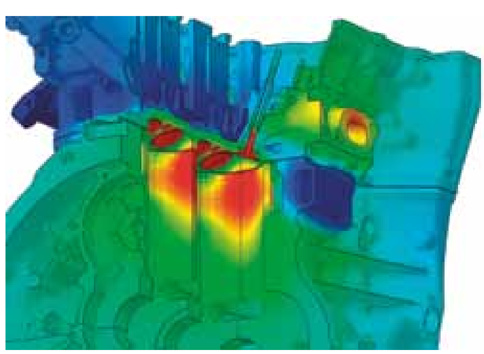


Figure 1. The 3-cylinder design for MAHLE's downsized engine (shown here in cross section on left) generates the power of a 6-cylinder engine, necessitating the need for structural and thermal optimization (right) to ensure that the engine can sustain the stresses of running at higher loads.

Meeting the performance and efficiency challenge

In our downsized engine program (which started about four years ago), if fuel efficiency had been the only engineering challenge, finding solutions would have been much simpler. But car buyers everywhere refuse to give up performance, so our team was forced to find ways to deliver both horsepower and fuel efficiency. For boosting power in a small engine, direct fuel injection and turbocharging were critical add-ons. To cut fuel consumption, both weight and friction were methodically reduced wherever possible.

Since nearly every manufacturer is investing in downsized options—shrinking their

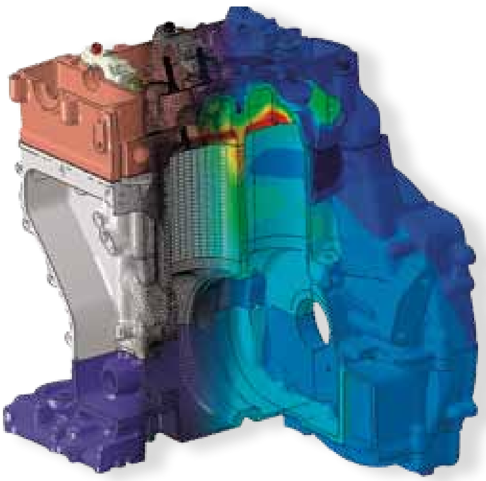
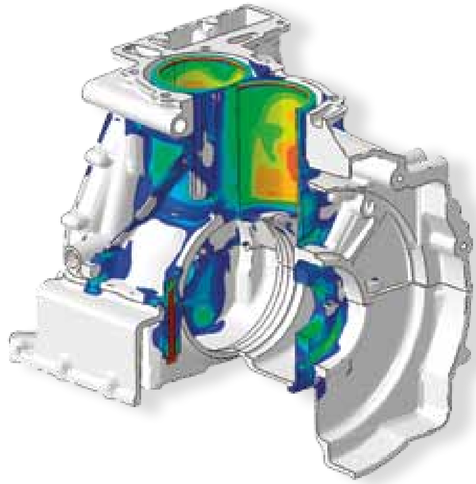
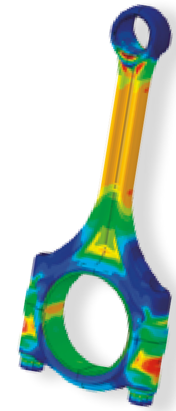




Figure 2. Abaqus FEA was employed extensively for structural and thermal analyses during the design of MAHLE's range extender (REx) engine for electric vehicles. Pictured is the engine assembly finite element model and temperature distribution (left), stresses on the engine block and crankcase (center) and connecting rod stresses due to combustion pressure (right).

engines typically about 20 to 25 percent—we decided to go to the extreme to show what's achievable. Working with Bosch-MAHLE Turbo Systems as a partner, and relying on extensive trade-off studies and design iterations, we developed a 3-cylinder (I3), heavily-boosted, 50-percent downsized engine with the same horsepower as a 6-cylinder one [see RSN, Issue No. 9, January 2010, pages 16-18.] With power gains like this, structural FEA was key for ensuring durability of components, such as the crank train and bottom end of the engine. And thermal optimization was vitally important as well for an engine running at such high specific loads (see Figure 1).

Even now with working prototypes of the I3 in demo vehicles on the road, we continue to refine our downsized concept, investigating a long list of additional friction-reducing technologies: a lower-friction valve train; improved pistons, ring packs, and bearings; a variable displacement oil pump; cooled exhaust manifolds; and enhanced boosting and intercooling. We are also looking at variable valve timing, variable valve lift, and exhaust gas recirculation. In every case, we rely on simulation to measure and evaluate the benefits of these technologies.

Extending the range of electric vehicles

A more recent design effort has involved the development of an engine for electric vehicles that addresses the common issue of insufficient range. Range extenders (REx)—in which a small gas engine is used to recharge the battery—provide a good alternative to the traditional electric hybrid model. In these designs, extender size and thermal issues (since the engine is typically positioned directly under the passengers' seats) are the crucial areas that our engineers are focusing on.

For the REx engine, the primary challenge has been one of balancing size and weight with durability and cost. Structural analysis has played a major role in this optimization (see Figure 2), with simulation helping us choose cost-sensitive, lightweight-yet-durable materials for components such as the crankshaft and block. The end result is an extremely compact, carry-on-luggage-size internal combustion unit that can be integrated into a more typical electric vehicle (see Figure 3).

Figure 3. MAHLE's REx is a gasoline-powered engine that is used to recharge the batteries of a more traditional electric-powered vehicle. To arrive at a durable, lightweight carry-on-luggage-size footprint, designers used extensive structural and thermal simulation in conjunction with optimization studies.

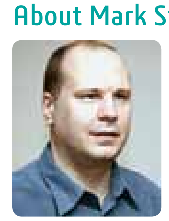
The fundamental value of simulation can be plainly seen in the specifications of our new designs. Our REx has met target performance on the test-bed with a theoretical range of 400 miles (650 km) on 8.8 UK gallons (40 liters) and promises to provide an alternative to most market-ready hybrids. The I3—currently installed in two demo VW Passats for test driving—meets EU6 legislative requirements with 49 UK-miles-per-gallon (30 percent savings), CO_2 emission of just 135 g/km, and a responsive 160 horsepower, garnering interest from customers and industry alike.

Meeting market demands

In engine R&D, technology targets are all important. However, as in most industries, so are development deadlines. For the REx, we took only 12 months from a clean-sheet-of-paper to the building of the first prototype. For the I3, it was an even more aggressive nine months. Just five years ago, before we adopted simulation, those times would easily have been almost double. If we weren't fully invested in the software tools and were trying to solve these engineering puzzles with prototypes alone, we wouldn't stay competitive.

Already, CAE and simulation are helping us push the limits of engine technology and move toward a more energy-efficient automotive fleet—with aggressive downsizing, improved fuel efficiency, and lower CO_2 emissions. In the future, standards will only get tougher, and simulation will be even more essential as engine developers work hard to stretch technology boundaries in creative and exciting ways.

About Mark Stephenson



Mark Stephenson is responsible for the analysis team at MAHLE Powertrain Ltd. (Northampton, Great Britain), one of the world's leading automotive powertrain consultancies and part of the MAHLE Group. He oversees a department of six dedicated analysis engineers that carry out structural, thermal, dynamic, and fluid flow analyses on all aspects of the engine and its components.

For More Information
www.MAHLE-powertrain.com
www.3ds.com/SCN-Feb2012

Ford Motor Company Accelerates Design for Manufacturability of Conical Joints Using Abaqus for 3DS CATIA and Isight

Developing high-quality bolted joints is an integral part of vehicle chassis design. While less understood than the design of connecting members, such as a toe-link that connects the sub frame to the knuckle, robust joints are critical to improving handling and longevity of vehicle performance. Joints that are loose tend to exacerbate quality issues such as alignment, and ultimately the durability of the joined components. A properly designed joint is more efficient and can support larger loads with smaller size fasteners without loosening.

Engineers at Ford Motor Company were tasked to deliver a robust cantilevered conical joint design for the rear suspension system of a midsize passenger car (see Figure 1). To minimize time and cost while meeting functional targets, the team developed an automated Design of Experiments (DOE) process using Abaqus for 3DS CATIA (AFC) for structural analysis and Isight for process automation and optimization.

"Our team chose AFC in order to deploy standard stress modeling and simulation practices in the form of templates to a broader group of engineers within the design organization," says Satyendra Savanur, chassis CAE engineer at Ford.

> It is estimated it would have taken approximately 70 days to complete all 35 runs, while maintaining other day-to-day work; we completed this task in about four days.
>
> **Satyendra Savanur,**
> *Chassis CAE Engineer,*
> *Ford Motor Company*

"Linking Isight with AFC enabled us to develop a powerful and automated design analysis methodology. We used response surface model, one of the approximation models, for finding optimal parameters to size the joint."

Analyzing conical joint performance

A bolted joint is the most common type of attachment method used in the suspension of a car. In this application, a conical joint is used for connecting the toe-link to the rear knuckle with a cantilevered type connection. The two mating parts of the conical joint—the bushing inner sleeve and the knuckle—each have unique manufacturing tolerances of the cone angle.

To develop a robust conical joint between a steel inner sleeve and an aluminum knuckle the following aspects were considered:

- manufacturing tolerances of each component
- contact area between the cone and seat
- angle of the cone
- torque loss after the service load is removed.

To perform virtual tests of their design, the Ford engineers used AFC to create the finite element model of the knuckle and the bushing inner sleeve with the geometry input and material properties from their model created in 3DS CATIA. AFC maintains associativity with the 3DS CATIA model to ensure that the Abaqus model updates are robust when the CAD model is changed within the usable range of design variables.

During the physical assembly process, a forged steel inner cone is forced against an aluminum knuckle seat. Due to the different manufacturing processes used to make each part, the angular tolerances of the conical design features are different on the inner sleeve and the knuckle mating surface.

"Because of the potential angular mismatch, there are variations in contact area when the two surfaces mate together and the joint is fully torqued," says Savanur. Local yielding can occur in the mating materials, leading to changes in contact area and pressure distribution during assembly of the joint. When the service load is applied, further changes to the contact area and contact pressure can occur.

"It is therefore important to simulate both the joint assembly and the loading and unloading of service loads on the joint during the analysis," he says. "Our objective was to deliver a robust conical joint design for the entire range of conical mismatch between the cone and the knuckle."

Figure 1. Close-up view, before assembly, of the toe-link (black) and the rear knuckle (silver) using a conical joint.

For a robust contact analysis and even contact pressure distribution, the mesh of the inner sleeve was constructed to align with the mesh of the knuckle seat. To facilitate mesh alignment in the contact area, a separate "domain" of the knuckle seat (shown in turquoise in Figure 2) was created to simplify meshing. This part was connected to the rest of the knuckle body with a tied contact in Abaqus.

To simulate the bolt assembly process, a virtual bolt between the inner sleeve and the knuckle joint seat was created. External service loads were applied on the sleeve center. Nonlinear stress-strain curves for aluminum and steel were imported into AFC to facilitate the nonlinear analysis. Contact pairs and bolt tension were all created inside AFC. Output of contact area (CAREA) and contact force magnitude (CFNM) were possible using AFC for postprocessing. Finally, the Abaqus analysis file was output and submitted to the high-performance computing (HPC) cluster for running the analyses.

Managing the DOE process

Ford's need to evaluate a large number of designs with different combinations of parameters prompted the engineers to create an automated DOE process. In this process, CAD geometry updates and FEA model updates are completed in the same loop thus allowing a completely automated DOE approach.

At Ford, 3DS CATIA startup is customized with an external product management system. Scripting is used to strip away the linkages to the product management system before initializing the 3DS CATIA interface.

Design parameters are then fed into 3DS CATIA with an external Excel file, a common method used to update a design table within 3DS CATIA. The input parameters from the Excel file are mapped to the DOE task of

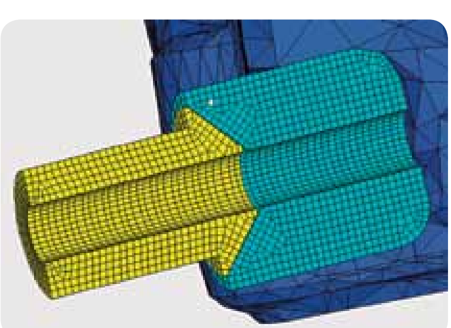


Figure 2. CAE mesh details of the conical joint.

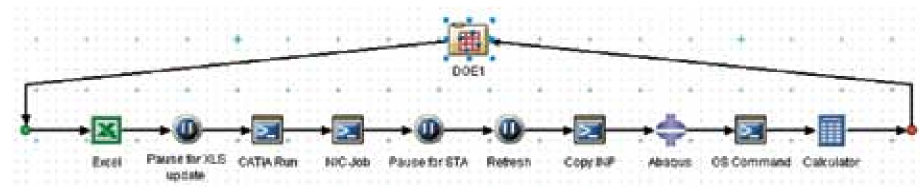


Figure 3. Integrated DOE automation loop using Isight.

the Isight manager. This enabled automatic updates of the Excel sheet for each loop. Since Excel is synchronized with the design table, this results in automatic updates of the CAD geometry inside 3DS CATIA. Within AFC, geometry and FE mesh are associated, so the resulting mesh is updated to the changed CAD data.

"By developing a single integrated process, we were able to drive automatic updates of the geometry and mesh at the same time," says Savanur. To manage and control the DOE process, Isight was used as the process automation manager. The resulting automation loop is completely integrated to run 3DS CATIA and AFC for CAD updates, create the Abaqus FE models, and submit job submission for analysis and post-process results.

The Abaqus component inside the Isight loop was used to extract outputs, including CAREA and CFNM for each run of the DOE (see Figure 3). The input parameters from the Excel file are then mapped to these output parameters to create an Isight approximation model.

"In our case, we used the response surface model method of approximation," says Savanur. This approximate model of conical joint behavior can then be used to show how input affects output and quickly optimize the conical joint.

"This is the first application of an integrated DOE automation loop to morph geometry using 3DS CATIA with Abaqus at Ford," says Savanur.

Isight enables more efficient processes

The set-up and validation of the 3DS CATIA and AFC scripts, HPC job submission batch file, and the Windows batch command file took time and resources to develop, but were well worth it as they are reusable for subsequent projects with minor changes.

"Developing a comparable 3DS CATIA model with an associated Excel design table, and linked to an associated AFC model would take approximately three days to construct," says Savanur. "Modifying and debugging the previously developed scripts to run with these new models would take another day. Using Isight, it took about 3.5 hours for the process to complete 35 analysis runs."

"Typically, the manual CAE process consumes two days just to complete one run. Of course, this timing can be reduced if the project is critical, but this is the typical day-to-day turnaround time balancing several projects per engineer," says Joe Peters, chassis CAE supervisor at Ford.

Time inefficiencies typically occur in the transfer of data back and forth between CAE and CAD organizations, as people have multiple assignments and do not immediately stop their current work when new design iterations are requested; this is analogous to CPU time verses wall clock time.

"It is estimated it would have taken approximately 70 days to complete all 35 runs, while maintaining other day-to-day work; whereas, our new process eliminates the inefficiencies that were part of the manual CAD/CAE procedures," says Savanur. "By creating an integrated and automated closed-loop DOE process using Isight, we completed this task in about four days. This was the only way to help achieve the program objectives of cost and timing with a lean CAE organization."

"Using the automated DOE process, we were able to drastically cut down the time required to develop a robust conical joint with minimal resources," says Peters. "The largest amount of time savings was realized in the automated process of creating a CAE model from CAD. This is a testament to the fact that a small CAE team using new innovative technology helped Ford to achieve program objectives."

By using AFC and creating an integrated closed-loop DOE process with the help of Isight, Ford was able to deliver a robust conical joint design. This joint exhibits good contact area and retains clamp load after load removal, within the specified manufacturing tolerances.

For More Information
www.ford.com
www.3ds.com/SCN-Feb2012

Driving Automotive Innovation with Realistic Simulation

By Marc Schrank

One could argue that the new millennium has brought about one of the most challenging periods in the history of the automotive industry. For example, there are more regulations for fuel consumption, emissions and safety standards than ever before. At the same time, we know that engineers, by nature, are problem solvers. So the wide array of automotive challenges today represents a historic opportunity for automotive engineers to put their problem-solving acumen, as well as the latest computer-aided engineering technology, to the test.

Automotive challenges

Steep increases in fuel economy regulations are looming on the horizon in most major automotive markets, leading to significant powertrain technology innovations. These include not only the widely publicized industry thrusts into electric vehicle and hybrid electric vehicle technologies, but also substantially improved efficiencies for the traditional internal combustion engine.

However, powertrain technologies alone will not likely satisfy these upcoming fuel economy requirements, and so manufacturers are putting the modern automobile on a diet in order to reduce its curb weight to help achieve economy goals. High-strength steels, along with lightweight metals (such as aluminum and magnesium), and a variety of composite materials, are all receiving growing attention from OEMs and suppliers alike as they pursue the common goal of reducing weight.

Passenger and pedestrian safety standards continue to become more stringent, with various innovative technologies, such as active hoods (or bonnets) and active headrests being developed and deployed to address the standards. And meeting these tougher standards is set against the backdrop of simultaneously slashing vehicle weight.

In addition, the modern automobile is an increasingly complex design, with electronic and mechatronic systems comprising an estimated 40 percent of the vehicle sticker price. The field of systems engineering is expanding rapidly to meet these growing complexities and associated demands.

And if the engineering challenges above are not enough, global competition and consumer pressures have never been greater. While still emerging from the industry downturn that began in 2008, automotive companies today are competing for the attention of consumers who have ever-growing expectations for performance, efficiency, comfort, styling, reliability, environmental impact, affordability, connectivity, and other unique features.

Leaders in innovation

For more than thirty years, 3DS SIMULIA has been serving the automotive industry by delivering powerful realistic simulation capabilities. Our global R&D and services teams work closely with our customers to understand their problems, and then develop robust and accurate simulation solutions that help solve real-world design and engineering challenges. Since our brand's inception, merely matching our competition was not acceptable. We were, and continue to be, motivated to develop technologies and products that provide substantial added value. Both we and our customers recognize that accounting for nonlinear effects—such as contact, plasticity, and large deformations—plays an important role in the successful deployment of structural design simulation for automotive components and systems.

A lecture, by Dr. Erich Schelkle of Porsche AG, entitled *Nonlinear FE Calculations: A Progressive Trend in the Automotive Industry*, given at the very first Abaqus Users' Conference in 1988, has proved prophetic regarding what has subsequently occurred in the industry. Since then, we have been gratified by the number and breadth of presentations shared by our automotive user community from around the globe at both our user conferences and at leading industry symposiums. These presentations cover an ever-growing range of applications such as: chassis and suspension, crashworthiness and occupant safety, durability, NVH, powertrain, tires, and more. And the models for these applications have evolved considerably, from single part or component models to system-level models of the largest size and highest complexity in the industry today.

Today, automotive companies are looking to adopt simulation at an increasing pace, making it even more integral to vehicle development processes. Throughout the industry, the imperative to reduce product development costs and shorten cycle times, while also improving product quality, is pervasive. Minimizing the fabrication and testing of physical prototypes is a key driver, but that can only be achieved by adopting and utilizing simulation methods that are both robust and deliver the necessary degree of accuracy and realism. With the same passion for innovation we have had for more than three decades, we continue to collaborate closely with our customers and strive our utmost to attain these objectives.

This edition of *3DS SIMULIA Community News* highlights how a number of our automotive customers are harnessing the 3DS SIMULIA product suite to help drive their own product and process innovations. MAHLE Powertrain (page 4) is using Abaqus as a key design tool in the downsizing of new engines to be more efficient, yet still deliver high performance. To design robust windshield wiper systems, Hyundai Motor Company (page 16) is taking advantage of a wide range of Abaqus features, essentially carrying out Unified FEA with Abaqus to replace what was previously done using separate simulation tools. At Ford Motor Company (page 6), integration of simulation into the 3DS CATIA design environment is yielding substantial productivity gains through the adoption of templates for well-defined workflows. And in our cover story (page 12), you can read about Honda R&D's strategy to eliminate physical prototypes through a new development process that relies heavily on CAE.

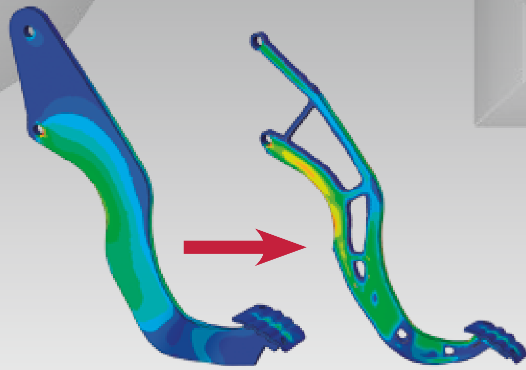
Growing portfolio of realistic simulation solutions

To support the growing demand for robust simulation solutions, 3DS SIMULIA has been working to expand our product suite beyond Abaqus. We now deliver analysis solutions integrated with leading CAD programs such as 3DS CATIA and SolidWorks. We are enhancing Isight for process automation and design optimization, and we are leveraging ENOVIA to deliver a leading solution for managing and securing the growing simulation processes and resulting data. We also continue to expand our alliances program to deliver the broadest range of integrated analysis solutions available.

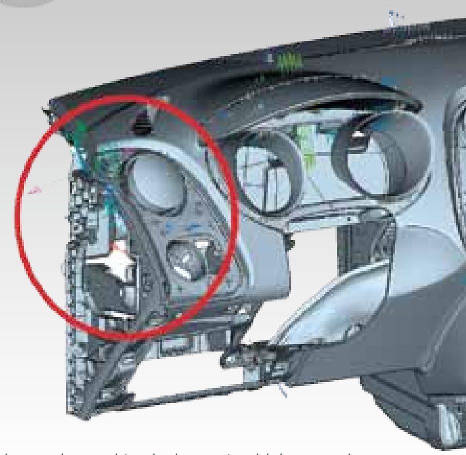
In the Abaqus product suite, we are creating new simulation technology as well as adding improvements to the existing, large foundation of sophisticated simulation capabilities. Abaqus 6.11 delivered more than 100 new features relevant to automotive applications, including: smoothed particle hydrodynamics (SPH);

Continued

Abaqus dramatically improves support for substructure modeling capabilities.



Nonlinear optimization performed on a brake pedal using ATOM.



Abaqus is used to design-out vehicle squeaks and rattles. Image courtesy of Applus IDIADA.

coupled electrical-thermal-structural procedure; electromagnetics; assembled fasteners; GPU performance acceleration; topology and shape optimization (ATOM product); and dozens more. Scheduled for release in May, Abaqus 6.12 promises to continue this long history of strong Abaqus releases enriched with customer-requested enhancements.

It is well known that manufacturers use a wide range of commercial CAD and CAE tools as well as software applications developed in-house. We are further enhancing Isight to enable our customers to integrate their tools and applications to capture repeatable processes, automate hundreds of simulations, and perform design of experiments and optimization studies. Isight 5.6 delivers several enhancements, including a reliability analysis technique, improved postprocessing, as well as enhancements to various components that are the building blocks for simulation process flows. A paper from Ford presented at the 2011 SCC in Barcelona is just one recent example where Isight is being used to bring together a wide range of design simulation tools into a cohesive framework to carry out efficient multi-disciplinary vehicle optimization.

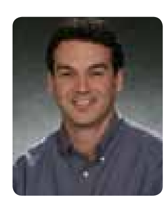
With more simulation being performed throughout the product development cycle, 3DS SIMULIA has responded by providing a solution for Simulation Lifecycle Management (SLM). Based on ENOVIA, SLM is addressing the growing need to manage simulation applications, processes, and data in much the same way as Product Lifecycle Management (PLM) in the automotive industry and elsewhere.

Looking forward

To help meet the industry demands and develop more innovative vehicles, 3DS SIMULIA is continuing to lead the market in developing robust simulation technologies and new methods with our characteristic commitment and passion for innovation.

The Version 6, 3D Experience platform from our parent company, Dassault Systèmes, provides both a foundation and an opportunity to deliver breakthrough realistic simulation solutions that will meet the exacting needs of automotive and other industries as well. Our 3DS SIMULIA V6 product suite integrates the key components that will enable simulation to become an even more vital and central aspect of product design, including: leading multiphysics capabilities; an immersive, intuitive environment for both expert and non-expert users; infrastructure for global collaboration; powerful tools for design exploration and optimization; and effective management for simulation data and IP. Of course, we are not doing this entirely alone. Along with the market's largest network of Alliance partners, we are working with key customers to define, prioritize, and implement a full range of high-value simulation workflows and methods that cover nearly every automotive engineering application.

To continue this conversation with me, I invite you to attend the upcoming worldwide 3DS SIMULIA Community Conference, being held May 15–17, 2012, in Providence, Rhode Island, the hometown of 3DS SIMULIA. This is an excellent opportunity to learn more about cutting-edge simulation applications from your colleagues in the automotive field as well as other industries. You will also be able to see firsthand some of the new features that will be available in upcoming 3DS SIMULIA product releases. Plus, you will be able to engage with 3DS SIMULIA management and R&D professionals to discuss what you need in the next generation of simulation solutions to help you meet the ever-increasing industry challenges.



About Marc Schrank

Marc is the Technical Marketing Director for Transportation & Mobility at 3DS SIMULIA, closely involved in advancing 3DS SIMULIA's industry solution experiences in this field. He has held several positions within the company over the past 20 years, and accumulated 10 years of industry experience prior to joining 3DS SIMULIA. Marc holds Bachelor's and Master's Degrees in Engineering Mechanics and Mechanical Engineering from the University of Missouri and is a registered professional engineer.

For More Information
www.3ds.com/simulia/automotive

In Situ Load Measurement with True-Load® and Abaqus/CAE

Typical designs in structural applications undergo complex loading. Accurate representation of the loads is required in order to accurately predict the behavior of such complex structures. Traditional methods of obtaining loads involve specialized load transducers and modification of structures to be sensitive to specific components of loading.

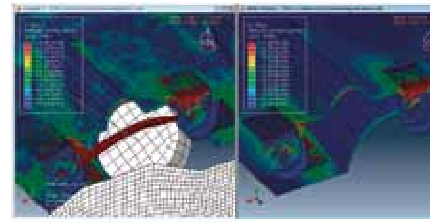
Wolf Star Technologies, a new Dassault Systèmes Simulation partner, has developed True-Load®, which provides an alternative approach to load measurement. The software leverages the finite element method in conjunction with a physical sample to produce an in situ load transducer.

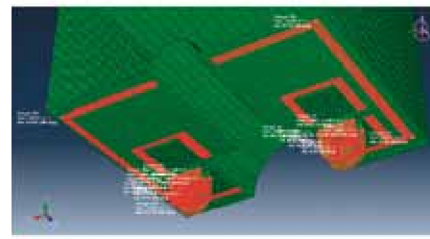
While the finite element analysis methodology has become much more sophisticated in recent years—providing greater fidelity to models in terms of geometric representation—the analyst still needs to provide the model with accurate loading information. A large amount of structural loading comes from difficult, if not impossible, to quantify external sources. Domains typical of this complex loading phenomena include vehicle (on/off road, aerospace, aquatic) loads from roads, the environment, and dynamic operation of vehicle (structure). Other structures such as buildings and bridges also undergo complex loading that typically is difficult to quantify.

Structures which behave linearly to the response of complex external loading can leverage the fact that loads are proportional to displacements and displacements are proportional to strains. Thus, strains are proportional to loads. Mathematically these relationships can be written as:

$$[F] = [K]\,[x] \quad \text{(Hooke's Law)}$$
$$[\varepsilon]\,[C] = [F]$$

Using these equations, True-Load® can easily correlate loads to measured (or calculated) strains to produce load cases for subsequent analyses—eliminating complex and expensive mounting of load transducers and modification of structures. The resulting load cases reproduce the measured strains with extreme accuracy. The load cases can then be used to calculate any field variable available in the Abaqus model through linear superposition of results. All of this—loading, correlation, and placement and orientation of strain gauges—is done through a clean





customized environment built on top of Abaqus/CAE. These loading time histories are available for design studies or fatigue analysis through fe-safe® or other fatigue software and can be used to accurately predict the behavior of complex structures and drive larger nonlinear system models.

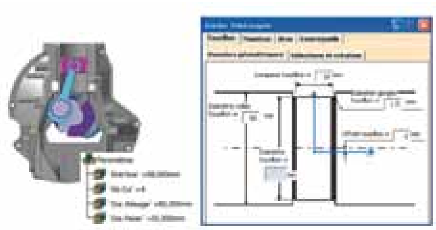
For More Information
www.wolfstartech.com

Crankshaft Development Using Integrated CAD-CAE Processes

Developing an automotive crankshaft is a very challenging process largely due to the fact that this individual component is responsible for much of the engine's final performance characteristics. Due to shorter development cycles and requirements for improved fuel efficiency, legacy development methods—including the trial-and-error approach of physical prototyping—must be improved by taking full advantage of current CAD and CAE packages.

In response to the automotive industry needs, Digital Product Simulation (DPS) based in Paris, France, and Detroit, MI, and a Dassault Systèmes Simulation partner, has successfully implemented 3DS CATIA and 3DS SIMULIA complementary solutions to accelerate development of optimized crankshafts. This work is the continuation of other advances made in CAD and CAE interoperability, as an answer to complex engineering processes.

The workflow starts with a full parametric model of the crankshaft. DPS developed a specific 3DS CATIA V5 workbench to set



Crankshaft workbench is accessible within 3DS CATIA V5 framework

up the initial baseline of the crankshaft. The designer initiates the design process by defining the crankshaft geometry with relevant parameters, including stroke, cylinders, bearing characteristics, and shapes of web. At this stage, with 3DS CATIA, it is easy for a designer to iterate on different design versions and compare them with a trade-off analysis.

In addition to 3DS CATIA workbench developments, DPS also implemented an Abaqus FEA simulation workflow with full parametric associativity to 3DS CATIA, enabling a more detailed study of some important design requirements, such as external loads or natural frequencies. Excel spreadsheets, dynamically linked with 3DS CATIA V5 models, complete the analysis package to perform mandatory static and dynamic balance analysis.

Once set up and validated, each process is automated and independently implemented with Isight as elementary subflows. At this stage, it is important to note that each subflow shares the same input based on the parametric 3DS CATIA V5 model.

As a result, not only has crankshaft development been sped up for an optimized final component, but the global design process has been captured to deliver knowledge-based engineering approaches that are, from DPS's point-of-view, a major strategic advantage for automotive product development.

For More Information
www.dps-fr.com

We are able to utilize CAE effectively for about 70% of the applications where we would like to do so.

Kazuo Sakurahara,
General Manager
Technology Development Division 0
Honda R&D Co., Ltd Automotive R&D Center

Honda Leverages Simulation to Meet Changing Market Needs

The automobile market is in a period of great change, with factors like environmental conservation and rapid market growth in developing countries now coming into play. Model-based development (MBD) is advocated as a development process that can support these changes. The previous leader of engine development for the Honda F1 Team, Kazuo Sakurahara, is currently involved in the creation of a new development process for mass-produced vehicles at the Honda R&D Co., Ltd. Automobile R&D Center. Sakurahara spoke to *3DS SIMULIA Community News* to discuss how Honda uses computer-aided engineering (CAE) and the steps it has taken toward MBD.

3DS SIMULIA Community News (SCN): What kind of effects have changes, such as environmental issues and rapid market growth in developing countries, had on the development workplace?

Kazuo Sakurahara: Speed is everything. Automobile manufacturers need to increase the rate of their development to the point that they can handle whatever changes arrive next, or they are not going to survive.

SCN: How are you increasing the pace of development?

Sakurahara: We strive for a process that makes full use of CAE, aiming to allow for optimization of functions and measurement parameters at an early stage of advanced development. We want to ensure that the development of the hardware skeleton is already complete as the vehicle goes into the development for mass production. MBD will heighten competitive power in comparison with the old experiment and experience-based process.

SCN: Why is Honda focusing so heavily on the use of simulations (CAE)?

Sakurahara: We want to avoid building prototypes. It takes an awful lot of time to build something and then test it. We want to take it to the level that you only have to build something as the final check. For this reason, we desire greater accuracy from our CAE.

SCN: In the development process, how are you making use of CAE?

Sakurahara: At the stage of the advanced development prior to the development for mass production, in the process of selection of specifications and basic design, the designer carries out CAE using 3DS CATIA Analysis in order to check and optimize the specifications. In the detailed design process, the quality of prerelease designs is evaluated using CAE. Areas that are highly integrated and require a lot of time, like nonlinearity and vibration noise, are performed by specialists using Abaqus Finite Element Analysis (FEA).

SCN: What has enabled designers to apply CAE more widely for themselves?

Sakurahara: The evolution of 3DS CATIA is largely to thank for that. The fact that the mesh in 3DS CATIA can be generated more easily than before is a really big factor. The time it takes to generate a high-quality mesh is vital when it comes to using CAE. Furthermore, using optimization tools like Isight greatly reduces the amount of work and time CAE takes, and that's another way in which we are seeking to increase the range of design CAE.

SCN: When do you use Isight?

Sakurahara: Take, for example, the engine. There are all sorts of conflicting requirements—it needs to be as light as possible but strong, to be quiet without too much vibration, yet sufficiently powerful—and you have to find a tradeoff. The existing manual process involves adjusting the model, carrying out CAE, and making a judgment, then repeating this process over and over. In the new workflow, Isight processes numerous design iterations without user intervention, changing the shape of the parametric model automatically during CAE and finding the best possible shape for us.

SCN: With the expansion of applications for CAE in the design workplace, there have been lengthy debates concerning the importance of analytical precision. What do you think about the precision of CAE evaluation?

Sakurahara: For Honda, if you include every degree to which evaluation can be performed, from complete evaluation to relative evaluation to determine a general policy, we are able to utilize CAE effectively for about 70% of the applications where we would like to do so.

SCN: What do you believe needs to be done to improve evaluation and achieve greater accuracy?

Sakurahara: What is important here is to note that Calibration & Evaluation is seen as "tests to increase the accuracy of simulations." This means that many more tests are required than if they were just being performed to evaluate simply whether or not the requirements of the design had been fulfilled. It takes a lot of work, but this is necessary in order to increase the accuracy of the physical model that is the start of development using MBD. Feeding the statistical model obtained from the results back into the physical model allows the simulations to come closer to the real world and, in turn, allows greater precision at the start of development. At the moment, the process often goes back and forth between basic design and detailed design, but we want to reduce the need to go backward by increasing the accuracy of the physical model.

SCN: How is this different from the comparison between CAE and experimental results that have been used until now?

Sakurahara: Evaluation using simulations has been about whether or not, under certain specific and limited conditions, the experimental results fit. So, no matter how accurate the results for a certain specific engine, there is no way of knowing whether the results are accurate for a new, totally different engine. In order for us to use MBD in the future, we need to work to feed the experimental results for all the vehicles we develop back into the physical model. In the initial phase, this will increase the number of experiments performed, but as accuracy continues to increase, the number of experiments required will naturally decrease. Organizing this process and building it into the development flow is vital.

For More Information
www.honda.com
www.3ds.com/SCN-Feb2012

Accelerate Design Space Exploration with Latest Release of Isight and 3DS SIMULIA Execution Engine

The release of Isight and 3DS SIMULIA Execution Engine (SEE) 5.6 delivers a number of enhancements in the areas of optimization, modeling and simulation integration, postprocessing, and process execution.

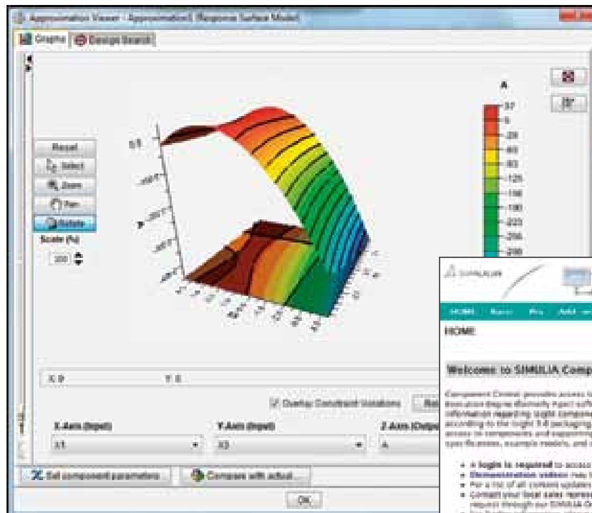
Isight – process automation and design optimization

Isight provides designers, engineers, and researchers with an open system for integrating design and simulation models—created with various CAD, CAE, and other software applications—to automate the execution of hundreds or thousands of simulations. Isight allows users to save time and improve their products by optimizing them against performance or cost metrics through statistical methods such as Design of Experiments (DOE) or Design for Six Sigma.

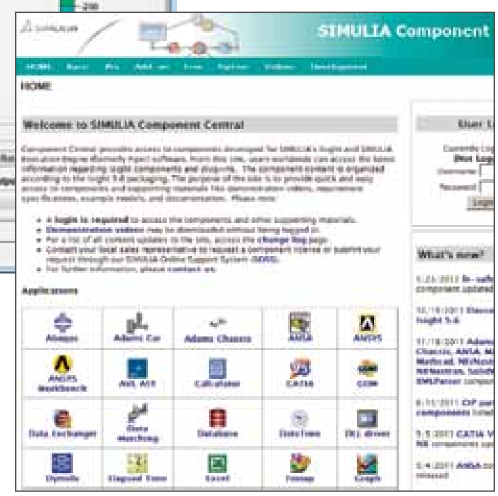
Among the new features for optimization, Isight 5.6 provides a reliability analysis technique for importance sampling that allows users to compute and sample around the most probable point of failure in a design. When compared to sampling around the mean value point, importance sampling requires orders of magnitude fewer evaluations for the same accuracy in predicting the probability of failure or success. This is especially important in the verification of high-reliability systems, such as jet turbines or automotive brakes.

Isight 5.6 also enhances several components, which are the building blocks of simulation process flows. The latest release includes updates to the Abaqus component to support multiple Abaqus/CAE cases by providing users with the option to parse all detected input files and create output parameters for multiple analyses. Improvements to the Data Matching component enable the definition and matching of multiple data sets within multiple ranges.

A number of postprocessing enhancements were also delivered in the latest Isight release, including new options in the approximation viewer for overlay constraints graphs to perform quick trade-off studies by relaxing constraints, showing or hiding constraint boundaries, and viewing constraint violations using a floor projection graph.



Isight 5.6 delivers a number of postprocessing enhancements, including a new option in the approximation viewer to examine constraint violations using a floor projection graph.



3DS SIMULIA's Component Central provides quick and easy access to the latest components and supporting materials (e.g. demonstration videos, requirement specifications, example models, and documentation) developed for Isight and the 3DS SIMULIA Execution Engine.

> Isight has features and add-ons that allow us to integrate all of the different codes and interfaces used for our physics subroutines. It played a key role in helping us to unify our processes and saved a considerable amount of time in our design optimization process.
>
> **Cosimo Chiarelli,** *Project Manager, Thales Alenia Space Italia*

SEE

The 3DS SIMULIA Execution Engine provides state-of-the-art technology for distributing and parallelizing simulation process flows in a high-performance manner that helps utilize a company's existing hardware and software investments.

By using SEE, users, administrators, and IT organizations are able to control where models are executed and the process by which they are run, allowing for optimum use of hardware and computing resources. The software integrates seamlessly with existing enterprise web application servers and databases.

SEE enables engineering groups to execute complex, multidisciplinary design processes in the most cost-effective manner to quickly deliver more competitive and profitable products to the market.

The SEE 5.6 release introduces a new "Fastflow" execution capability for executing part of a model on a single station, which reduces the 'over the wire' traffic and results in faster performance.

For More Information
www.3ds.com/isight-see

New 3DS SIMULIA Version 6 2012x Introduces ExSight for Advanced FEA and Multiphysics

The Dassault Systèmes Version 6 Product Lifecycle Management (PLM) portfolio delivers a single, open, and scalable Service-Oriented Architecture (SOA) platform that spans the complete business enterprise. It natively delivers the engineering, manufacturing, and simulation applications needed to enable users to remotely create and collaborate online. Using this global collaborative innovation, companies can maximize their intellectual assets to drive the best practices by leveraging product authoring and collaboration in real-time, concurrent work across multiple remote locations over the web.

The 3DS SIMULIA V6 portfolio provides a scalable suite of simulation and simulation data management solutions that enable designers and engineering analysts to collaborate and secure their simulation IP while performing fast, accurate performance studies on parts, components, and products in the Dassault Systèmes Version 6 environment. The 3DS SIMULIA V6 product suite includes:

3DS CATIA V6 Analysis provides the functionality of the traditional 3DS CATIA V5 analysis products in the Version 6 environment. 3DS CATIA V6 Analysis enables designers and engineering specialists to perform fast design-analysis iterations for any type of part and assembly designed with 3DS CATIA. The online platform, knowledge capture, and IP management capabilities allow design and engineering teams to perform multiple virtual tests and collaborate to make quick and accurate product performance decisions.

DesignSight provides an out-of-the-box experience for designers to perform nonlinear and thermal analysis parts and assemblies using Abaqus Finite Element Analysis (FEA) technology fully integrated with 3DS CATIA V6. DesignSight is an excellent solution for occasional users of simulation who have limited training in FEA. The user is guided through the process of performing a simulation, enabling users to study their design's behavior and to explore different design options.

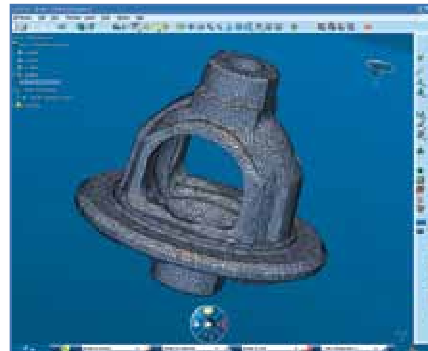
The new hyperelastic material model enables accurate simulation of rubber materials, even at very high strains. Gravity loads can now be simulated, permitting realistic deformations of models including heavy components. Also, cut-plane results postprocessing enables users to easily view results inside the model. Lastly, users can intuitively align and position loads based on existing geometry such as existing edges, axes, and coordinate systems making it easier to achieve precise load alignment.

ExSight is the first release of an expert-level product family that is being developed to provide robust and advanced FEA and multiphysics capabilities in the Version 6 environment. This initial release includes Multiphysics Model, Scenario & Results (MSK) which provides the core capabilities required by experts for meshing, property definition, multiphysics scenario definition, and results visualization of linear and nonlinear analysis. The 3DS SIMULIA ExSight product family leverages Abaqus FEA technology so that analysis experts can further explore, understand, and improve product performance, while collaborating with designers and other members of the product development organization.

3DS SIMULIA SLM enables the capture and deployment of approved simulation methods and best practices, providing guidance and improved confidence in the use of simulation results for collaborative decision making. The Version 6 Release 2012x of SLM provides a more seamless user experience with improved data sharing capabilities between the workspace folders where reference data is stored and the process flows consuming it. Additionally, the PLM behavior of the application has been enhanced to better manage owned data and the attribute group functionality is now available for documents created during the course of the execution of process flows.

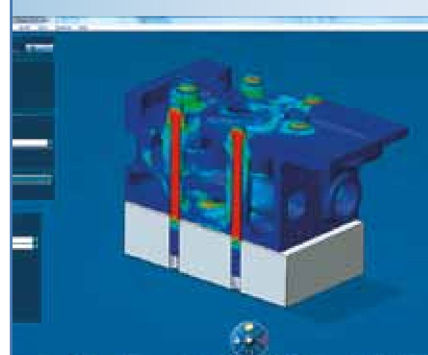
By using 3DS SIMULIA's V6 integrated design analysis and SLM solutions organizations are able to rapidly explore real-world performance of designs, make immediate design improvements, and share simulation results to accelerate making performance-based decisions.

For More Information
www.3ds.com/simuliaV6



3DS CATIA V6 Analysis

DesignSight



ExSight

3DS SIMULIA SLM

Realistic Simulation Saves on the Back-and-Forth of Windshield Wiper Design

Hyundai Motor Company uses Abaqus Unified FEA to perform faster, integrated design simulations

Quick—what's the most important safety device in your car? Did you answer seat belt or airbag? You might be correct on a sunny day. But you can't safely drive a single city block in a rainstorm or blizzard without your windshield wipers. And even when skies are clear you can't see where you're going if your windshield is streaked with mud or smeared with bugs. It's the inexpensive wiper that protects the driver's most important asset: his or her vision.

This fact first became clear when slow-moving horse-drawn carriages were replaced by faster motor vehicles—windshields quickly became necessary to protect people's faces (and hairstyles). But that simple piece of glass didn't solve everything: inventor Mary Anderson watched New York City streetcar operators struggling to see through their windshields during snowstorms and came up with a cleaning brush system, patented in 1903, that had a hand-operated lever that moved a swinging arm device.

Rubber blades soon replaced brushes, and motorized windshield wipers became standard equipment on all American cars by 1917. The current intermittent type didn't arrive until the 1960s and was featured in a 2008 movie about Robert Kearns' battle with major U.S. automakers over patent rights to his invention. Wipers have been added to rear windows and headlights and some are now activated by just the lightest touch of precipitation on the glass.

And they're not only found on cars: planes, trains, boats, off-road vehicles and even space shuttles use windshield wipers. While the blades need periodic replacement, the wiper system itself is considered one of the most reliable of vehicle devices, with a design life average of 1.5 million wipes.

Designing reliability into every vehicle component

Reliability is a key tenet of Hyundai Motor Company, ranked first in a J. D. Power vehicle dependability survey for the third consecutive year in 2010. Founded in 1967 and headquartered in Seoul, Korea, the automaker sold 3.61 million vehicles in the global market last year. Hyundai obviously keeps a very sharp eye on every detail affecting motorist safety, so it comes as no surprise that the windshield wiper has been the focus of considerable attention at the company's R&D center.

"We are looking to optimize both wiping performance and fatigue life of the windshield wipers on every vehicle Hyundai makes," says Sungjin Yoon, research engineer, Hyundai Motor Company. "To achieve that we need to consider all the critical design factors such as blade shape, material, and the structure of the wiper arm and links. Computer-aided engineering (CAE) plays a central role in that process."

Using a variety of CAE tools to evaluate the geometry, kinematics, loads, and stresses on wiper mechanisms during the initial design stages helps the Hyundai engineers meet current wiper performance guidelines. The tools also let them predict the effects of design modifications employing new materials, light-weighting, and/or innovative wiper configurations. Early identification of the most efficient design for each new vehicle concept both speeds up the product development process and reduces prototyping and manufacturing costs downstream.

Abaqus FEA sweeps through the physics of windshield wipers

At the core of the team's CAE work is realistic simulation with Abaqus Unified Finite Element Analysis (FEA). "The physics of windshield wipers are more complex than you might think," says Yoon. "Previously, we'd been performing separate analyses for wiping and durability using two different FEA programs on two different computer models, but we wanted to develop a unified analysis model with which we could study both," he says. "We found that Abaqus has a full range of simulation capabilities that allow us to analyze every aspect of the characteristics we were interested in studying within a single software package."

In addition to its essential back-and-forth behavior, a windshield wiper must, above all else, maintain uniform distribution of pressure between the windshield glass and the wiper blade so the driver's view remains clear (this is known in some engineering circles as "the squeegee effect"). As the blade ages, it must continue to provide

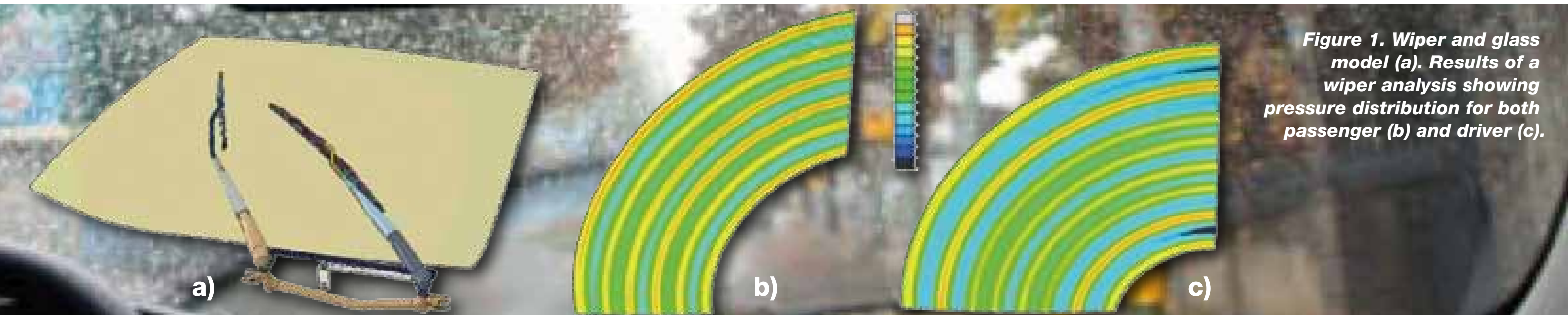


Figure 1. Wiper and glass model (a). Results of a wiper analysis showing pressure distribution for both passenger (b) and driver (c).

a certain level of cleaning ability. And the entire wiper system needs to be strong enough to withstand a variety of loading conditions, from wind-driven rain to heavy snow, and durable to last for many years of operation.

Where the rubber meets the glass

To begin their unified FEA inquiries into how wiper design affects both wiping and durability, the Hyundai team starts by looking at the rubber blade alone. Utilizing a material model that fully captures the behavior of the rubber is important in order to accurately predict wiper blade performance. The rubber material exhibits nonlinear elasticity as well as a certain amount of time-dependency in its response. Capturing both these phenomena together is accomplished with a combination of hyperelasticity and viscoelasticity material options available in Abaqus.

Next the engineers model the wiper arm system, a highly interdependent series of links and arms that combine to provide uniform pressure over the full length of the rubber blade (very important for avoiding those annoying streaks on the windshield). To facilitate their FEA modeling the group uses kinematic visualization software with a specific template for each vehicle wiper arm type. A wiper arm assembly is essentially a mechanism, the joints of which are modeled with Abaqus connector elements.

Now the team is ready to run their full Abaqus models to evaluate wiping. The first step is to properly load the wiper blade against the windshield to establish the correct initial contact pressures against the glass. The axial connector element in Abaqus is used to express the behavior of the arm spring. "It's important to establish what the preloading strain is," says Yoon, "because it needs to be taken into account as the wiper moves, when the deformation shape of the blade section on the glass will affect the results over the total wiping area."

A rotational moment is loaded at the base of the wiper arm to replicate the motor torque, at the point where the arm pivots, that causes the arm to slide across the glass with a wiping motion. The analysis can subsequently track the total strain on the blade at specific times and varying temperatures (the latter can particularly affect blade rubber). Final outputs are reported through an in-house post-program that shows the pressure distribution throughout a complete sweep of the windshield glass (see Figure 1). These results can then be compared against established design specifications to determine if the blade is performing as expected.

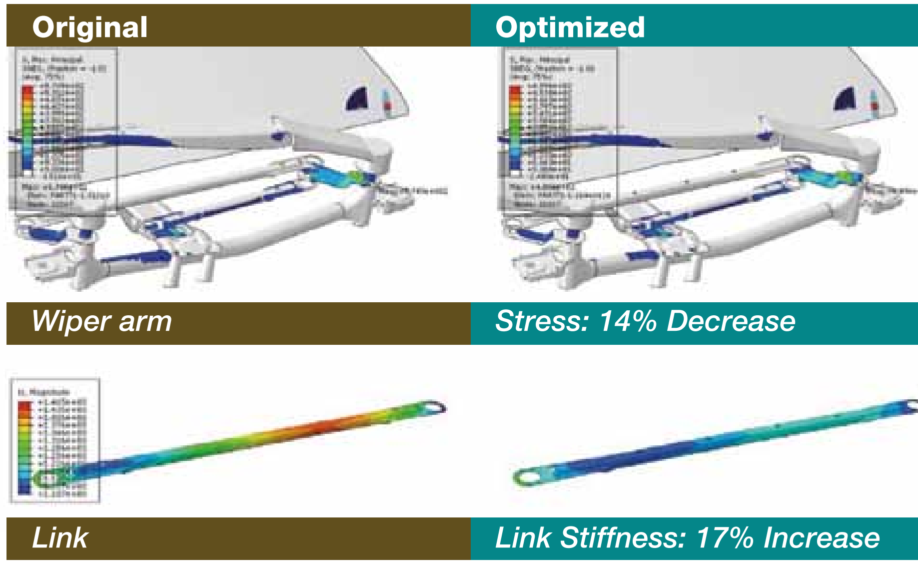


Figure 2. Comparison of FEA results for wiper arm and link before and after optimization.

Seeing multiple analysis results clearly with Abaqus Unified FEA

The second part of the analysis, for durability (fatigue life), can be performed on the same FEA model that was set up for the wiping sequence. "All we need to do is change the boundary and loading conditions in our Abaqus Unified FEA model," says Yoon.

Just as was done with the wiping analysis, a rotational moment is entered as a loading condition. But this time, stationary 'snow blocks' are mounted to halt the wiper blade before the lower and upper extremes of its sweep across the windshield glass model. As the analysis is run, the moving blade arm contacts the snow blocks and the resulting internal forces on the linkage as the blade stops can be determined. Stresses corresponding to these internal forces are used to predict fatigue life during moderate snow conditions or, in the case of heavy snow, plastic deformation or failure within the wiper assembly. These predictions are then validated under real-world conditions that include actual snow deposited on the windshield of a typical mass-produced car in Hyundai's test facilities.

Two for the road: optimizing wiping and durability

With their wiping and durability results in hand, the engineers can then optimize both by varying different design parameters and observing their effect on the overall performance of the wiper system.

"The superiority of the unified analysis model is that it enables us to consider a wide range of design factors affecting both wiping and durability," says Yoon. "With an optimized blade arm and link combination, we can achieve a lighter-weight wiper system while also increasing key link stiffness measures and reducing maximum stresses at the same time (see Figure 2)."

Hyundai's R&D group is continuing to expand their use of templates to speed the windshield wiper design workflow. Their Abaqus analyses are contributing to the buildup of a knowledge base with parameter studies that give them better insight into which design variables have the greatest effect on component operation. They will also be looking at the car-body mounting of wipers. All of which points to their customers' having a very clear view of the road ahead—in any weather.

About Sungjin Yoon

Sungjin Yoon graduated from Hanyang University in 1990 and received a graduate degree in mechanical design engineering in 1992. Since that time he has worked in the CAE department of Hyundai Motor Company. His current interests are rubber analysis and co-simulation in the automotive field.

For More Information

worldwide.hyundai.com/innovation/r-and-d-vision-and-strategy.html

www.3ds.com/SCN-Feb2012

Stow-and-Go for Space Travel

Caltech researchers use Abaqus FEA to design self-deploying composite booms for satellites

Figure 1. MARSIS satellite nearing Mars, showing one composite antenna boom already deployed and a second boom in the process of unfolding. Image courtesy of European Space Agency.

Man-made satellites have to fit a lot into a compact package. Briefly protected inside a rocket while blasted through the atmosphere, a satellite is launched into Earth's orbit, or beyond, to continue its unmanned mission alone. It uses gyroscopes, attitude thrusters and magnets to regulate sun exposure and stay pointed in the right direction. Once stable, the satellite depends on solar panels to recharge its internal batteries, mirrors and lenses for data capture, and antennas for communications with the folks back home. Whether it's a bread-loaf-sized nano, or the school-bus-proportioned Hubble Telescope, every satellite is susceptible to static electricity buildup from solar wind, the freeze of the Earth's shadow (or deep space), and tiny asteroids that pepper the route like killer bees.

In such a hazardous environment, the functional longevity of the average satellite is limited. While more than 2,000 satellites are estimated to be in Earth's orbit at any one time, the countries and private enterprises that own them must keep sending up replacements at a pretty steep price tag. As a result, aerospace engineers continually strive to come up with smaller, lighter satellites that are cheaper to make, less expensive as rocket payloads, and still capable of fulfilling their high-tech job descriptions.

Unfolding satellite hardware

The size of critical hardware like solar sails, solar concentrators, and reflector antennas is limited to some degree by the weight and stowage capacity of each satellite. But in order to function properly, much of this hardware needs to expand outside the confines of the spacecraft that carries it. The engineering solution? Design deployable structures that unfold once the satellite is in position. This way a big piece of hardware can be compacted into a small configuration for transportation, then expanded to operational size in space.

Many satellites accomplish this important task using motors and gears for mechanical deployment of their hardware, but other designs rely on self-deployment instead, using energy stored within the hardware itself during compaction. Imagine folding a plastic drinking straw repeatedly into a small, zigzagged cluster, then letting go so it springs back into a straight line. This kind of release action happens without the additional mass and power source that are required for mechanically deployed booms.

Self-deployable booms, made from flexible composites, were used for the antennas on MARSIS (the European Space Agency's Mars Express Spacecraft – see Figure 1) and are currently being designed into a number of future satellite missions. The booms are lightweight, easily folded, less expensive and fairly insensitive to friction compared to traditional motorized designs.

Modeling complex behavior in zero gravity

Structures of this type have actually been proposed for decades, but their behavior—highly nonlinear geometric deformation, buckling, dynamic snapping, etc.—was difficult to quantify and predict. As a result, earlier boom components were usually refined through repeated, costly physical experiments (including ones conducted during the 22 seconds of weightlessness generated in a plunging test aircraft).

"But now we can accurately portray these features using realistic simulation," says Chinthaka Mallikarachchi, a postdoctoral scholar working with Professor Sergio Pellegrino at the Space Structures Laboratory of the California Institute of Technology. "We can optimize the structural design of self-deployable booms through finite element simulations and conduct physical tests only on our final designs. Since ground testing on Earth of structures that are going to be deployed in the zero-gravity vacuum of space is either difficult or very expensive, such virtual testing is the answer to a lot of the challenges we face."

Mallikarachchi's work over the past several years—on the simulation of a carbon-fiber-reinforced boom that can be folded around a spacecraft—was carried out almost exclusively using Abaqus Unified Finite Element Analysis (FEA). "3DS SIMULIA's academic package has been quite helpful to us in conducting this kind of research," he says. "We used the meshing and visualization features in Abaqus/CAE a lot. The Abaqus/Explicit solver is the most important feature for us since it accurately captures all the complexities of our boom designs. And the general contact, shell general section, equation constraint and restart features were very user-friendly, as were the availability of Python scripting and keywords for input files."

The modeled boom was a one-meter long, thin-walled (0.22 mm) tube (38 mm diameter) made of two plies of plain-weave carbon fiber in an epoxy matrix. Certain regions of the tube were weakened by cutting away some of the composite material to form tape-spring hinges so the tube could be folded around the satellite ('spacecraft' in Figure 2) without causing any damage. Three possible hinge designs, with different slot parameters, were considered. The FE mesh was made finer over the hinge regions to capture the details of the complex deformation occurring in these regions.

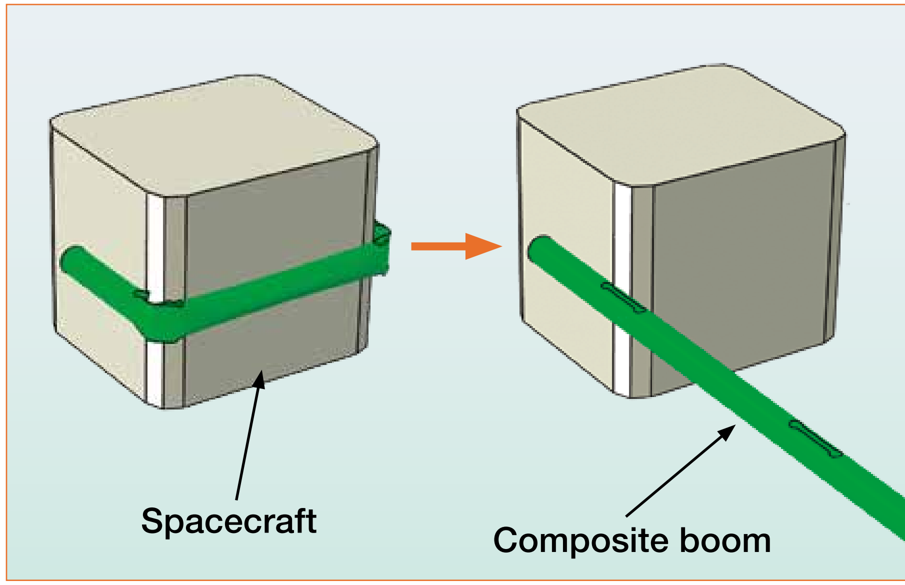


Figure 2. The boom design challenge: fold it around a satellite, then release it and have it fully extend.

Abaqus supports years of research challenges

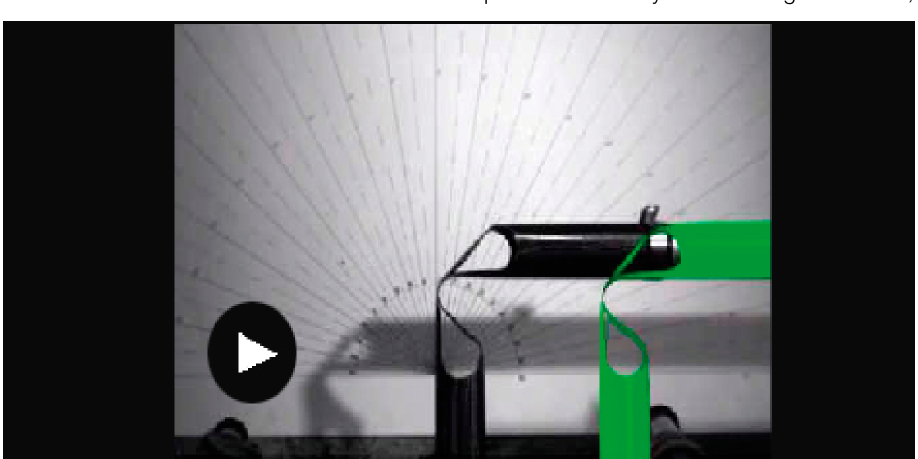
Early research used micromechanical modeling to capture the behavior of the boom's thin laminate material through homogenization of a periodic unit cell (with Abaqus/Standard). From this, the material stiffness was computed in the form of a matrix and used to define the shell elements in the Abaqus/Explicit simulations of the quasi-static folding and dynamic deployment. The numerical simulations were then integrated with a material failure criterion. The combination of these tools allowed an analysis of the detailed effects of hinge design changes on three different boom models. This led to identifying the design that could be most safely folded and deployed.

Modeling the boom deployment involved first pinching the hinges to fold the boom around the spacecraft, then releasing all constraints so the boom dynamically deployed and self latched. "This behavior needed to be fully understood and optimized since overshooting at the end of deployment could damage the boom, the spacecraft or other equipment attached to it," says Mallikarachchi. "Alternatively, a too-slow, highly damped deployment might never achieve the fully expanded configuration that's needed."

Project test launch: simulation versus reality

During the FEA simulations, the first boom design overshot the fully deployed configuration and was rejected. When the failure analysis and hinge angle were optimized against the time response (full deployment occurred in about 0.3 seconds), Design III performed better than Design II. With their simulation data in hand, Mallikarachchi's team then built and tested a boom according to Design III specs, filming the results from two different camera angles. Side-by-side motion comparisons of Abaqus FEA and boom deployment confirmed that the real boom also deployed in 0.3 seconds, became fully latched, then oscillated around the deployed configuration in excellent agreement with the simulation.

"Our studies showed that the most critical points are the fully folded configuration and, during deployment, the point at which the second hinge latches, affecting the load on the root hinge," says Mallikarachchi. "The hinge transition region between the straight and curved part of the slot experiences the most stress/strain, so special care should be given to this area during fabrication of this kind of boom."



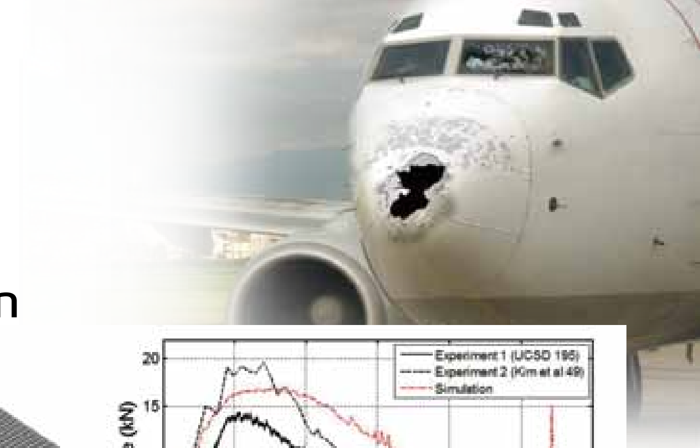
The Caltech team's validation of their boom design paves the way for further exploration of satellite hardware deployment. "Our simulation techniques can be used to design deployable booms with multiple hinges and optimized boom geometry to meet specific mission requirements," says Mallikarachchi. "Future work could consider alternate laminates and thermal and viscoelastic effects in different materials."

About Chinthaka Mallikarachchi

Chinthaka Mallikarachchi has a Ph.D. from the University of Cambridge, U.K., and a B.Sc. in civil engineering from the University of Moratuwa, Sri Lanka. Now a postdoctoral scholar at the Space Structures Laboratory of the California Institute of Technology (Caltech), he has been interested in space structures since childhood and was inspired by the deployable structures work of his thesis advisor, Professor Sergio Pellegrino. The son of an electrical engineer, Chinthaka has brothers studying mortar mechanics and computer science. He plays cricket and badminton and is interested in photography.

For More Information

http://pellegrino.caltech.edu
www.3ds.com/SCN-Feb2012



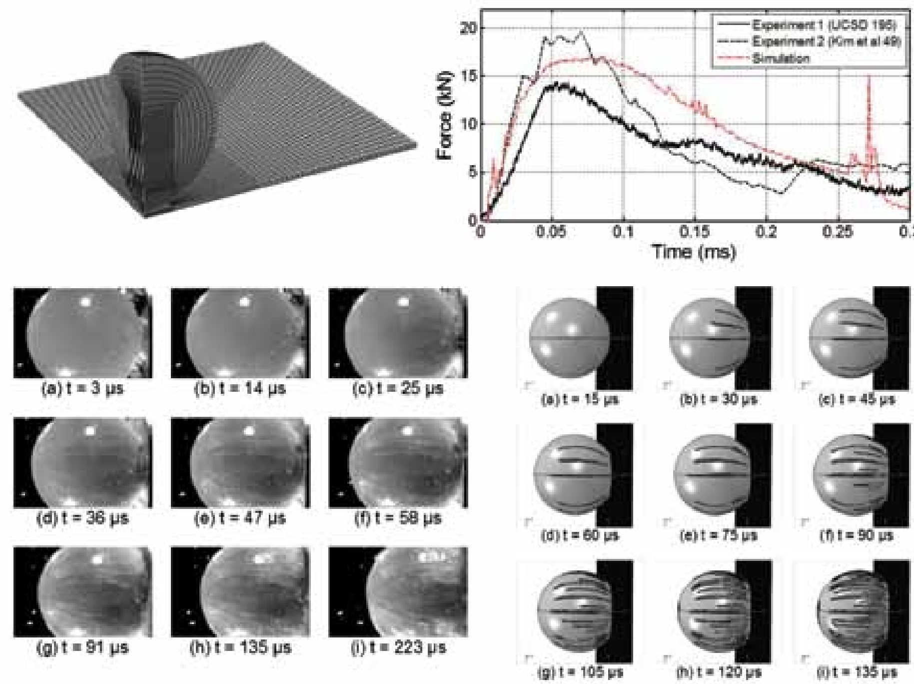
Strain Rate Sensitive Ice Material Model for Hail Ice Impact Simulation

Ice impacts and the ensuing dynamic loading are significant issues in many fields, such as ship building, arctic researchers, aviation, and interplanetary space missions. Hail impacts have always been of interest to aviation, particularly in engine structures. Within the last decade this threat has become of greater importance in aviation due to the significant use of composite materials, such as carbon fiber reinforced plastics, in exposed primary structural components. Because new aircraft are using complex composite laminates, numerical simulations can provide information about internal stress states, damage initiation, and growth, which can be difficult to directly measure via experiments.

In order to produce accurate predictions of a composite structure impacted by hail, the ice projectile properties must first be accurately modeled. In this case, the projectile properties modeled are of hail ice spheres. An improved strain rate dependent model was developed for use in Abaqus by University of California at San Diego graduate student Jeff Tippmann, under the guidance of Professor Hyonny Kim of the Structural Engineering Department and with assistance from graduate student Jennifer Rhymer, and partially funded by the FAA.

The ice material model included elastic properties, strain rate dependent yield strength, and a tensile-pressure failure criterion. The strain rate dependent yield strength was the main improvement from past models developed by previous researchers in academia. The newly developed model uses strength data at impact strain rates measured by previous researchers. All previously developed models required the tuning of various material parameters for different impact speeds and projectile sizes. With the added strain rate dependent yield strength in Abaqus, the new material model does not require any adjustments.

During development, the simulation results were compared to experimental measurements of dynamic forces generated during an ice sphere impact onto a force measurement bar. Several parametric studies were performed to study the material parameters, as well as the mesh density. Because there was a considerable scatter in the experimentally measured ice strength data, the final material model incorporates the ability to use a lower bound, average, or upper bound strength curves.



(Top-left) Quarter-symmetric model of ice sphere and rigid target (Top-right) Force history comparison of simulation results (red) with experimental data (black) (Bottom-left) High speed video frames of 50.8 mm diameter ice sphere impact at 60.6 m/s (Bottom-right) Cylindrically patterned view of quarter-symmetric model and deformation with elements failed by tensile failure pressure criterion removed from viewport

The Abaqus simulation results show a strong agreement with the experimental results, with the lower bound and upper strength curves bounding the peak forces observed. Additionally, using high-speed video images of the ice sphere impact, the cracking was observed to propagate along the projectile in a direction away from the initial impact side and continue growing as the impact force increases (up to 0.05 ms). Once the peak force occurred, transverse cracks also formed and the ice sphere began to fragment into many pieces. Thus, the forces created by high-velocity ice impact can be defined by two major phases: (i) elastic-dominated structural response during initial time following first contact in which cracks develop and the impact force is increasing, and (ii) fragmentation and cracking, which imparts mainly a momentum-based loading that corresponds with the decreasing force trend following the peak force.

The cracking can also be observed visually in the simulation by removing the failed elements from view. As with the visual experimental observations of the ice sphere impact, the cracks propogate from the impact side of the projectile and reach their maximum length when the peak impact force is reached. However, the simulation does not predict the fragmentation of the projectile after the peak force. Therefore it is important to distinguish that the model is particularly suited for predicting early time-scale events loading up to peak force and initial localized failures in the structures impacted by high-velocity hail ice, and not the spray pattern and debris flow of ice well after it strikes a surface.

Jeff Tippmann and Hyonny Kim, Department of Structural Engineering, University of California San Diego

For More Information

structures.ucsd.edu
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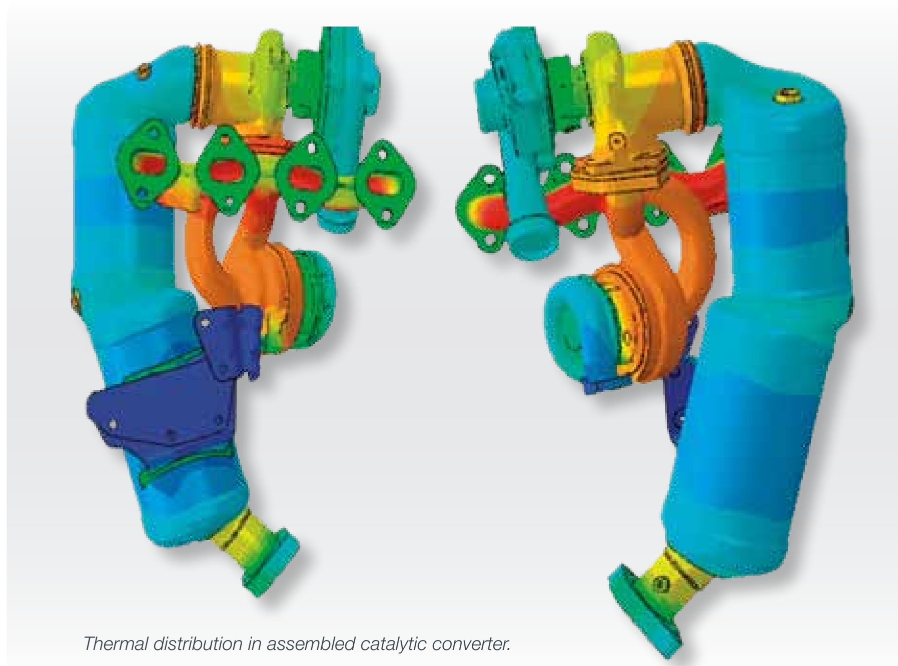
Universidad Autonoma de Nuevo Leon Successfully Simulates Vibrations in a Catalytic Converter for Diesel Engines

Automotive manufacturers are faced with many challenges to meet industry standards and satisfy customer demands. One common requirement is to produce greener automobiles by reducing toxic emissions. Since the first emissions standards were passed in the 1970s, manufacturers have strived to develop technologies to detoxify the exhaust, which are an essential part of emissions control. To study the complex thermal and mechanical phenomena of these components, engineers are leveraging realistic simulation to improve designs and select the best materials for optimum performance.

A good example is the catalytic converter, a device installed in the exhaust system to reduce the toxicity of exhaust gases generated by the combustion process. Car manufacturers assess the noise control of the exhaust pipe, the amount of the emissions after treatment, the reliability of achieving heat transfer, the surrounding components that can be damaged by temperature, and exhaust fumes that create discomfort to passengers or pedestrians.

There are many important mechanical and thermal aspects to assure the catalytic converter meets its required operating performance. It is critical to understand the different modes of heat transfer involved in and around the exhaust system to be able to improve the design of components. A high-quality design and a proper material selection are the key to preventing damage early in the life of the catalytic converter components.

Thermo-mechanical stresses in the system are caused by thermal cycles or thermal shocks. The resulting high temperature gradients can cause thermal fatigue in the components. These same thermal gradients can radically alter the dynamic response of the components themselves (through contact, thermal strains, and thermal softening). Finally, at high temperatures the exhaust system components could experience degradation by corrosion as they regularly reach up to 1000° C. Some of the mechanical aspects that influence the catalytic converter performance are related to the structural vibration from the engine and road profile. The stresses caused by the vibration inputs into the catalytic converter must be correctly distributed to avoid the nucleation of cracks that could lead to an early fracture.



Thermal distribution in assembled catalytic converter.

Table 1. Cold and Hot Modal Results (Hz)

Modal	Mode 1	Mode 2	Mode 3	Mode 4	Mode 5	Mode 6	Mode 7	Mode 8
Cold modal	156.95	233.83	254.68	267.45	323.84	341.36	398.35	448.46
Hot modal	131.55	174.10	186.34	210.02	234.87	271.25	318.73	353.24

To properly simulate the operating conditions of the catalytic converter, a full 3D model was created in Abaqus. Geometries were imported, assembled, meshed, and material properties were assigned to them. A thermal analysis using the output from a CFD code was created, then cold and hot modal analysis were run using Abaqus. For the thermal analysis, a heat transfer step was created at steady state. Convection and radiation boundary conditions were imposed, as well as temperatures of the gas and components. In order to obtain the frequencies of the assembly, a frequency step was set up. For the frequency, the Lanczos Eigensolver was used to calculate the first 10 modes (see Table 1). It is readily seen that the component response dramatically varies when different thermal conditions are considered—these differences in turn can impact both the system-level performance and the resultant fatigue life.

The obtained results could be utilized for further optimization of the design to meet the automotive manufacturer's requirements, and various operational and thermal scenarios. This may affect the materials used, the geometries of the different components or the location of the supports. Also, it is possible to accurately predict the catalytic converter performance and to gain deeper understanding and even simulate the fatigue life and noise of the system.

This article is based on a paper presented at the 2011 3DS SIMULIA Customer Conference by Nestor Martinez, Miguel Amado, and Martha P. Guerrero, Universidad Autonoma de Nuevo Leon.

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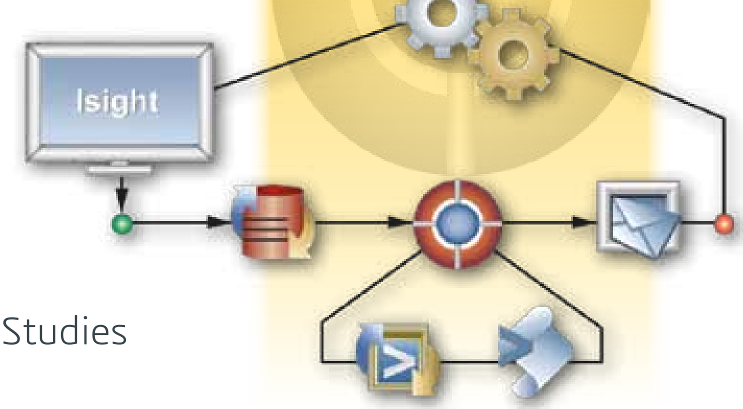


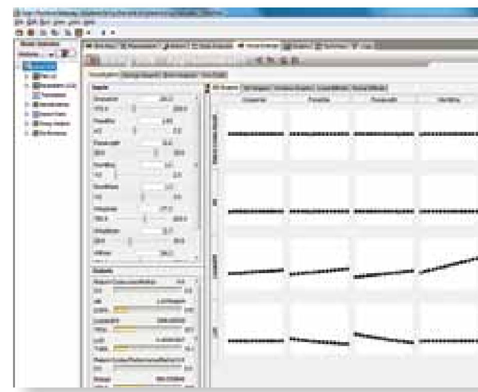
Isight

How to Perform Simple and Quick Design Studies Using Execution History Data in Isight

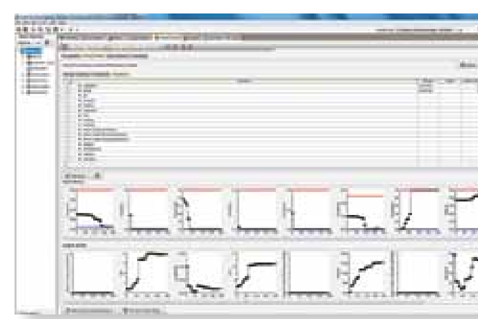
The approximations capability in Isight can be used to generate a mathematical model of previously analyzed data, which can then be used for quick and efficient design studies or optimization. The Approximation Viewer tool, also known as the Visual Design Driver, allows you to interact with the model and observe, graphically, how changing the input values affects the output values and the shape of the output function.

Here's What You Do:

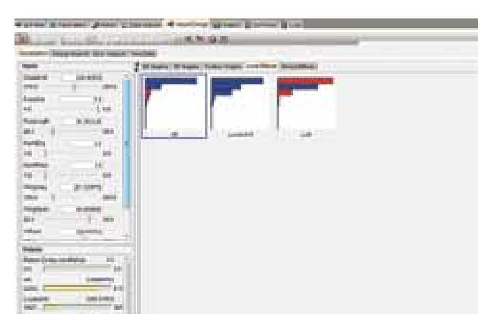
1. Go to the **History** tab in the **Isight Runtime Gateway** for the component of interest and make sure that the input and output parameter values provide an adequate representation of the design space.
2. Go to the **Visual Design** tab in the **Isight Runtime Gateway** and click on the **Create Approximation** button.
3. Isight will use the available sets of input and output data from existing results to create an approximation model of the workflow. The **Visual Design** tab is updated to show the approximation information.
4. The **Visualization** subtab presents the inputs and outputs of the approximation with their corresponding values and also displays graphs for visualizing the approximation.
5. Move the sliders for one or more input parameters to change the input values. The output values will change based on the inputs and the graphs will also get updated in real time.
6. If necessary, click on the **Modify Range** button to change the upper and lower limits of the input range.
7. The **Design Search** subtab assists users in finding a design that meets specified criteria.
8. Choose the **Design Variables**, specify any constraints and select the objectives for design search and click on **Search** option. A design search is performed and the interface is updated to show the results of the search.
9. Update the constraints and objectives to refine the search. The graphs are color coded and show the bounds of the sampling range.
10. Click **Set Component Parameters** to transfer the updated parameter values to their corresponding parameters in the model and click **Compare with Actual** to see how the approximate design compares with the actual design.
11. The visual graphs and metrics in the **Error Analysis** subtab can be used to gauge the quality of the approximation model.
12. Note that it is possible to configure the approximation model created and also to export the computed approximation data using the icons available in the **Visual Design** tab.



DOE Visual Design 2-D Graphs



DOE Visual Design Inputs/Outputs History



DOE Visual Design Local Effects

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2012 SCC

New Technology Brief

Fluid-Structure Interaction Analysis of a Prosthetic Aortic Valve Using Abaqus/Explicit Smoothed Particle Hydrodynamics

Prosthetic Aortic Valve Analysis

Assessment of a prosthetic heart valve's fatigue life requires accurate estimates of the stresses induced during the cardiac cycle. To ensure durability of prosthetic heart valve function, the smoothed particle hydrodynamic analysis method in Abaqus/Explicit is used to determine the fluid-structure interaction response of a generic prosthetic heart valve.

Download the Tech Brief: www.3ds.com/SCN-Feb2012

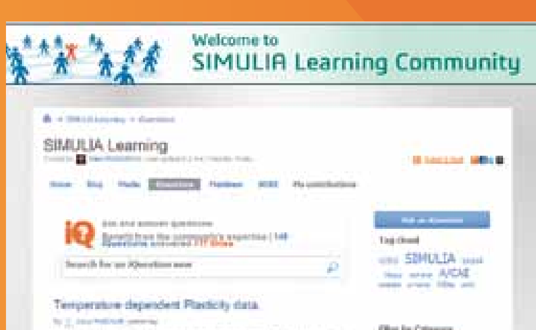
New Technology Brief

Isight Optimization of Material Parameters Used in the Abaqus Worldwide Side Impact Dummy

Isight optimization workflows are used to analyze the response of the various parts of a crash dummy during crash-testing, a critical element of vehicle safety. Abaqus Worldwide Side Impact Dummy (WorldSID) offers a greater biofidelity than existing side impact dummies and allows engineers to validate one of the calibrated material parameters by comparing the response of several dummy responses.

Download the Tech Brief: www.3ds.com/SCN-Feb2012

Abaqus WorldSID



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