Breaking Down the Barriers to Simulation

Autodesk Broadens Simulation Offerings

March 2012

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Advances in computer hardware and software over the past four decades have enabled an unprecedented capability to predict product performance during the early stages of product design and development. "Simulation-driven design" can have an immense payback in product development time, cost, and quality.

Autodesk has grown into a multinational company with product offerings far beyond AutoCAD, their original flagship mechanical design software. Their solutions span architecture, engineering, and construction; manufacturing; and media and entertainment. Their customers range from the world's largest companies to millions of individual consumers. Autodesk has made a substantial investment in acquiring and developing physics-based simulation technology and their offering now covers a range of capabilities similar to those of other major simulation solution providers.

While Autodesk fully supports the traditional product development and simulation processes, their vision to "democratize" simulation as an always-on capability for non-experts is very interesting. It derives from their understanding of their broad customer base, of societal trends, and through innovative application of available technologies.

Autodesk supports a comprehensive set of offerings and a broad strategy in simulation that indeed meets the needs of companies seeking to embrace digital product development.

Summary

The use of computers to do physics-based simulations to predict product performance began over forty years ago. Fueled by the phenomenon known as Moore's Law, the capability for technical computing has doubled every eighteen months. With digital prototypes, capable software, and almost infinite computing resources, companies are now able to apply simulation during the early phases of product development, concentrating on the concept and architecture of the product. This takes place before any detailed component design for manufacturing, and is called "simulation-driven design." This process can have an immense payback in terms of product development time, cost, and quality.

At the same time, simulation tools are being integrated into the design environment in an effort to "democratize" simulation for use by a wider audience.

These are not simplified tools that only concentrate on component analysis. They cover a full range of physics and the capability to simulate assemblies and subsystems. CIMdata believes that the integration of direct modeling CAD technology with multi-physics simulation drives a game-changing breakthrough. Simulation can now deliver a framework that provides integration in the PLM environment and access to tools, information, and computing resources.

Originally known for its flagship AutoCAD design software, Autodesk has built a multinational corporation that offers design and development software for use in architecture, engineering and construction; manufacturing; and the media and entertainment industries. Their customers range from large corporations through small and medium businesses, professionals such as architects, and millions of consumers who use apps like Autodesk SketchBook Mobile on portable devices. The breadth of their customer base gives them a deep understanding of market trends and demands.

Over the past few years, Autodesk has made substantial investments—over $500 million—to acquire and develop simulation technology. Now, they have a reasonably complete simulation offering for mechanical systems that is comparable to that available from other leading solution providers. Autodesk now delivers integrated CAE offerings to enable multi-physics simulations. The Autodesk Inventor Fusion direct modeler is included with the simulation products, offering a simulation framework with capable and easy-to-use geometry creation and modification tools. Nonetheless, the framework is open—Autodesk well understands that their customers may use tools from other vendors. As Autodesk says, their design tools are multi-CAE, while their simulation tools are multi-CAD.

Autodesk's vision for integrating design and simulation is very interesting. It derives from their understanding of market needs, their interpretation of societal trends, and their knowledge of available technologies. Carl Bass, Autodesk's CEO, describes how consumers now expect to be always connected, on mobile devices of their choice. Moore's Law continues to drive the cost of computations to near zero, while the cloud offers a way to provide always-available, on-demand resources. Bass calls this "infinite computing," and proposes to use the cloud to deliver, on demand, almost limitless computing resources.

Autodesk's vision is to democratize simulation by providing "always-on" simulation that gives feedback to product designers. They also plan to remove barriers to simulation by addressing ease of use, IT hardware and infrastructure requirements, and total cost of ownership. Their approach is extremely innovative, in that it does not derive from the historical approach of packaging and automating the simulation processes used by experts. The breadth and depth of this vision is the central theme of this paper.

Examples of this vision are already available. An Autodesk Moldflow add-on provides real-time feedback on a plastic part's manufacturability, cost, and environmental impact. Autodesk Moldflow Insight WS offloads plastic injection molding simulations to the cloud, freeing local resources.

Project Falcon is a wind tunnel simulation tool that provides feedback on flow and pressure around sculpted bodies. Autodesk TinkerBox is a physics-based mechanical simulation game that runs on an iPhone, while Autodesk ForceEffect is a mechanical statics application for the iPad.

CIMdata interviewed a number of customers of Autodesk's simulation products. All expressed a high degree of satisfaction, and said that strong pre-sales support was a major factor in their choice of these products. These customers stated that, without simulation, their product development cycles would be twice or three times as long. They also stressed the use of simulation as an aid in communicating and understanding design options. Overall, Autodesk supports a comprehensive set of offerings and a broad strategy in simulation that indeed meets the needs of companies seeking to embrace digital product development.

Research for this paper was partially supported by Autodesk.

Introduction

As companies drive to 3D digital prototypes for product design and manufacturing, simulation plays an increasingly important role. In this paper, "simulation" means the prediction, based on physics, of product performance. Simulation has long been used to assess the performance of completed designs, as a complement to physical testing for final product validation. Now, "simulation-driven design," where simulation is used to study physical designs early in the development process, is becoming the norm. Simulation before detailed product design has the potential to develop much more robust designs faster, and to remove many of the iterative design-prototype-test-redesign cycles of conventional product development.

At the same time, simulation is better integrated into the product design environment, and is more accessible and usable for non-experts and smaller companies.

This paper discusses these trends for simulation, and then evaluates Autodesk's offerings and strategy for simulation.

Breaking Down the Barriers to Simulation

The Rise of Simulation

The era of simulation, or Computer-Aided Engineering (CAE), began shortly before 1970, with the invention of the engineering supercomputer, the release of NASTRAN into the public domain, and the standardization of the FORTRAN programming language. For the past four decades, the capability for technical computing has doubled every eighteen months as Moore's Law has driven the price-performance curve of computing devices. The multiplying factor is in the hundreds of millions. Today, a cell phone has vastly more computing power than was available to engineers for the Apollo space program.

During the decade of the 1970s, commercial companies began to apply finite element analysis to their products. Designs were 2D drawings on paper, and 3D finite element meshes were built manually. The response time for a CAE analysis of even a simple component was measured in months. The only parts that were analyzed were those that had failed in service—simulations were used for forensics.

In the following decades, simulation response time declined dramatically. It dropped due to many factors including faster computers, better CAE software, and digital 3D designs. As the simulation response time improved, its impact was realized earlier and earlier in the product development and validation process. About a decade ago, we reached the point of automated designs: topology, shape, and material optimizations were being used to create and modify component geometry according to engineering rules and standards. By the start of the 2000s, automated design of components was indeed feasible. Simulation could be used to help lead component design with simulation-driven design.

The product development process is often described in terms of the systems engineering "V" model. The left side of the V defines the process of ideation: product concept, requirements, and architecture. The right side of the V represents program execution: component design, integration, and test. When simulation is applied on the right side of the V, it is an analog of test. It is used to assess the suitability of completed designs to meet their requirements.

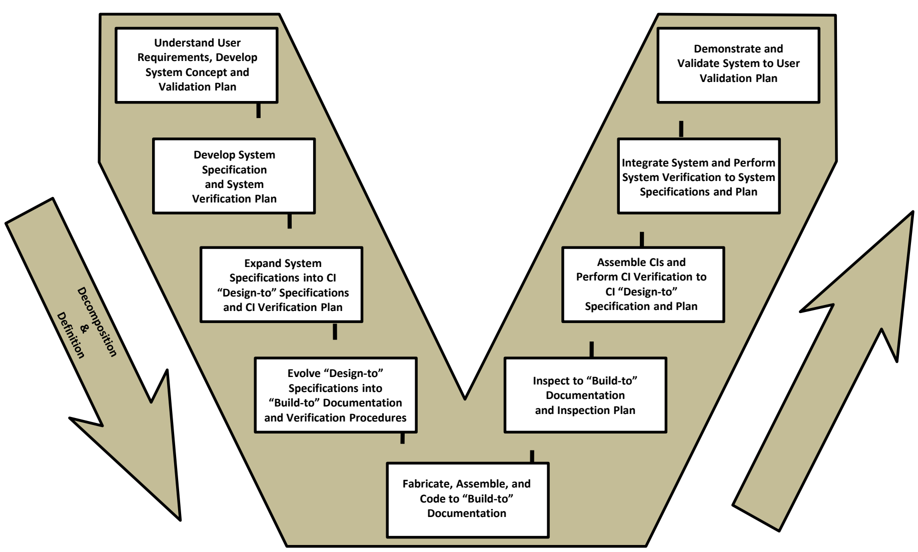

Figure 1—The Basic "V" Model

Simulation-driven design applies simulation on the left part of the systems engineering V. The challenge is to apply simulation before initiating detailed component design, during the phases of product definition and architecture. This has a number of implications:

- Tradeoffs and decisions are made on a systems level.

- The geometry is not well defined, and there emerges the need to create geometry for simulation well before the detailed design of components for manufacturing.
- Tradeoffs and decisions need to address multiple disciplines of physics.
- Tradeoffs and decisions need to be made across multiple domains. In addition to product performance, there are considerations of cost, weight, manufacturability, and sustainability.

On the left side of the V, complex decisions about product architecture are being made. The move to simulation-driven design drives the need for early multi-disciplinary simulation with the integration of simulation and design. It also reinforces the need to apply systems engineering to mechanical design. It is well accepted that the great majority of product costs are committed very early in a product development project. The ability to make reliable predictions of product performance early in a project can have an enormous payback in terms of product cost, development time, and quality. Simulations are used as a systems engineering tool, to develop and balance requirements for subsystems and components. The capability to make better decisions early in the product development process can be an overwhelming competitive advantage, and simulation-driven design becomes a key enabler.

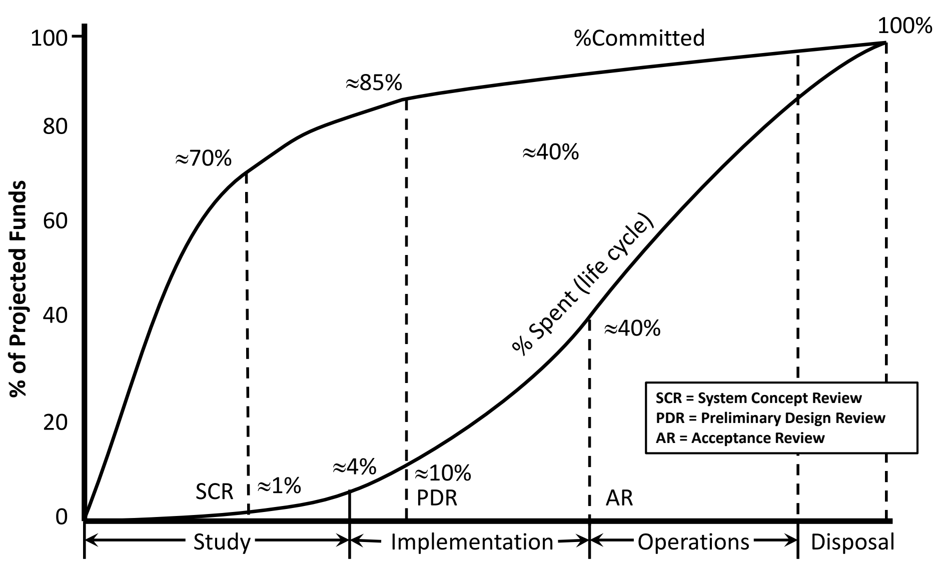

Figure 2—Typical Total Expenditure Profile

Integration of Design and Simulation

Simulation is still required on the right side of the V, for design assessment, integration, and validation. Some have the vision that simulation technology can be integrated with the design or CAD tools, and can be used by non-experts. ("Non-expert" means someone who does not understand the specific features and requirements of particular simulation applications. It does NOT imply someone who does not understand the engineering issues.)

One of the issues with simulation for mechanical design is that it is generally the province of specialists at large companies. Efforts to democratize simulation by spreading its use to non-experts have, for the most part, been less than successful.

Penetration of simulation within smaller companies is a problem, probably for the same reason that PLM has primarily been the province of large companies: it is still too complex and expensive. Smaller companies cannot afford to have full-time simulation experts, they do not have the resources to do the IT integration, and they do not have the expertise to develop simulation methods that apply to their particular products.

The idea of designers or CAD operators doing finite element analysis goes back about two decades to Rasna Mechanica, a p-element code that was promised to be easy to use and reliable for non-experts. Rasna was acquired by PTC, and other CAD companies responded with their own integrated, finite element solvers. Companies like General Motors developed the idea of a “designing engineer” who would do both design and simulation.

However, problems soon became apparent. First, CAD operators were generally not engineers, and did not have the knowledge to do engineering evaluations. Second, the easy-to-use tools were only capable of simple linear analyses on single components, and the simulation experts rejected them. The experts had a different set of tools, and were unable or unwilling to mentor the non-experts. Third, the simplified tools were misapplied, particularly for problems involving contact between components. Companies also experienced issues with parts that had passed verification with the simplified tools, had not been analyzed by the experts, and failed in final validation or in the field. Therefore, many companies adopted policies forbidding the use of simplified simulation tools.

On the other hand, some companies have had success with simplified tools, although that success was built on specific efforts. They defined standard work, and prescribed specific procedures to apply simulation. Also, they provided training and mentoring for their designers. It is not sufficient to only make the simplified tools available; the users must know how to apply them and experts must be available for support and mentoring.

With the advent of direct modeling for CAD, the process of design changes dramatically. Geometry is now being integrated within simulation rather than the old paradigm of integrating simulation into design. CIMdata believes that the integration of direct modeling with multi-physics simulation drives a game-changing breakthrough. Geometry can now be brought in as a variable in the iterative simulation and design optimization process.

Some simulation solution providers still tout the availability of simplified tools for component analysis, but this is a niche that we believe is declining. Design (CAD) tools are vastly more capable than they were a decade or more ago. Companies have developed knowledge-based engineering (KBE) tools, templates, best practices, and standard designs—they know how to design components that meet specific requirements. Often, the simulation physics are built into the design tool, and are invisible to the designer.

A Simulation Framework

Many simulation vendors, including Autodesk, are responding to the need for multi-disciplinary simulation capabilities and better integration in the PLM environment by delivering a simulation framework. This is a computer environment in which simulation engineers work, and includes:

- Access to applications
- Access to simulation-related information
- Access to high performance computing (HPC) resources
- Integration within the PLM ecosystem, to non-CAE applications, information, and resources
- Tools to manage all of this information and the related development processes

Such frameworks benefit end users, their companies, and the solution provider. The users have a more uniform and consistent interface, and integration and/or customization costs are reduced for the company. The vendors are able to leverage technology components over a range of applications and provide more complete solutions. However, even as vendors strive to offer a more complete set of solutions, the frameworks cannot be closed in terms of supporting only proprietary applications from a single vendor. They must be open to the integration and exchange of data with other tools and applications. Driving the need for openness, customers must have the flexibility to integrate their own, possibly proprietary, or competitive applications and processes. Another major issue is that any given customer usually has simulation solutions from more than one vendor.

In the remainder of this paper, we examine how Autodesk addresses these simulation requirements and issues. We will conclude that they have a comprehensive set of offerings and a broad strategy that indeed meets the needs of companies seeking to embrace digital product development.

Autodesk's strategies for simulation are rooted in their understanding of the requirements of their diverse customer base, and in the innovative application of technology across their product offerings.

Autodesk

Autodesk's roots go back almost thirty years. Originally known for its flagship AutoCAD design software, Autodesk is a multinational corporation that offers design and development software for use in the architecture, engineering, construction (AEC); manufacturing; and media and entertainment industries. Large enterprises, with 5,000 employees or more, are Autodesk's fastest growing customer segment, and account for about 30% of revenues.

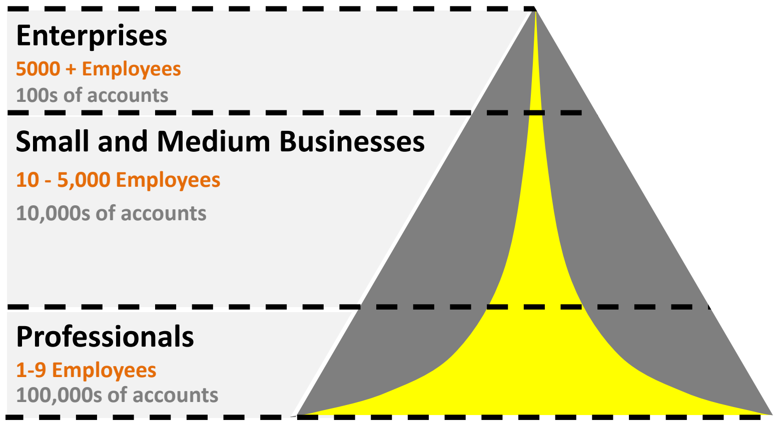

Figure 3—Autodesk Customer Segmentation

With its reseller model and even retail sales for some of its products, Autodesk has been successful at reaching small and medium-sized businesses and also professionals (organizations with fewer than 10 employees) throughout the world. Autodesk also has a line of software for consumers including SketchBook, which is available as an application for portable devices. Over 7 million copies have been downloaded.

The breadth and depth of Autodesk's customer base, from individual consumers with free or low-cost applications, to the world's largest corporations, gives them a deep understanding of market trends and demands. Indeed, Carl Bass, Autodesk's CEO, recently remarked that consumer expectations for low-cost or even free software are often higher than those of corporations for their enterprise software solutions.

Autodesk is a highly innovative company. Their many acquisitions show that they are receptive to technology innovation from outside the company and there are numerous examples of how technology developed in one part of their business is applied in others. Visualization and rendering represent good examples of this successful effort.

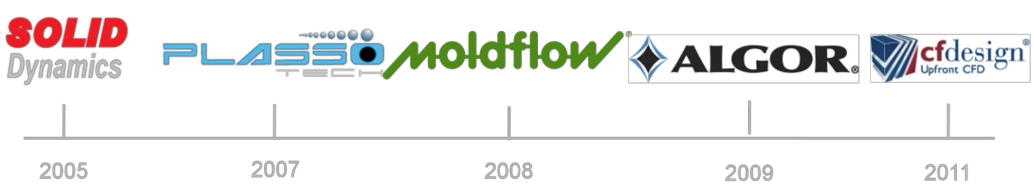

Figure 4—Autodesk Technology Investments for Simulation

One example of Autodesk's willingness to invest and innovate is in the area of simulation. In recent years, according to Scott Reese, Senior Director for digital simulation, Autodesk has invested over $500 million to develop and acquire simulation technology. Solid Dynamics (2005) and PlassoTech (2007) provided simulation technology for rigid-body kinematics and linear stress analysis that is now embedded in Autodesk Inventor Professional design software. Other major simulation-related acquisitions include:

- Moldflow, which simulates plastic injection molding (2008)

- ALGOR, a suite of multi-physics finite element software for mechanical systems (2009)
- CFdesign (Blue Ridge Numerics), for fluid flow and thermal simulation (2011)

Autodesk has established a reasonably complete set of simulation capabilities for mechanical systems that is comparable to the range of capability available from other leading solution providers.

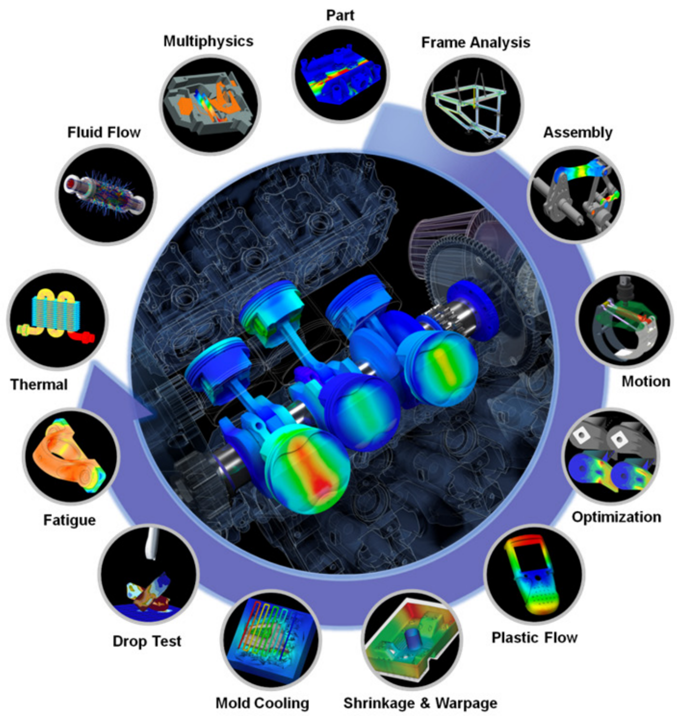

Figure 5—Autodesk Simulation Capabilities

Autodesk continues to support traditional simulation customers by integrating CAE offerings to enable multi-physics simulations, and by integrating geometry (CAD) capability with their simulation tools. However, Autodesk also provides their simulation capabilities in a stand-alone manner and many of their simulation customers do not use Autodesk tools for product design. Autodesk is also developing vertical applications for specific industries such as AEC, building design, and structural analysis.

Autodesk states that their design tools are multi-CAE, and their simulation solutions are multi-CAD. Even as Autodesk integrates their own offerings, they have committed to support customers who may, in part, use a competitor's offerings. Even so, their framework includes offerings from the Autodesk technology toolbox that may add significant value for their customers. Inventor Fusion is a direct modeling CAD tool used to simplify and modify geometry for simulation that is now bundled with all Autodesk Simulation offerings. With it, simulation engineers may be freed from reliance on their CAD department to provide modified CAD models for simulation.

By delivering an open simulation framework, Autodesk is clearly committed to supporting the traditional simulation community and the CAE experts, while also democratizing simulation for design and product development engineers.

External Driving Forces

Carl Bass, Autodesk's CEO, provides a fascinating look into Autodesk's emerging technology, and their response to perceived trends. Among design and simulation vendors, Autodesk is unique. Their penetration to small and medium businesses is better than most, but their reach extends to hundreds of thousands of professionals, and millions of consumers with applications like SketchBook.

The major force is consumer expectations. Consumers now expect to be always connected, on mobile devices of their choice. Moore's Law continues to drive the cost of computations to near zero, while the cloud offers a way to provide always-available, on-demand resources. Autodesk calls this infinite computing. They propose that essentially unlimited computing resources can be made available, on demand, via the cloud.

Some believe that these trends are not relevant for mechanical product development at large companies. They believe that companies will not submit to end-user anarchy with personal mobile devices, nor will they place product design and engineering data outside their corporate firewalls.

Autodesk clearly does not agree. They fully embrace the cloud to provide access to resources like high performance compute cycles, access to applications, and data storage. CIMdata agrees: the mobility revolution and the provisioning of cloud-based resources are unstoppable trends. Consumers demand them, and every employee is also a consumer. The security concerns will likely be resolved over time, as they have been for e-commerce.

Of course, Autodesk continues to support traditional product development environments as well, such as desktop software products.

Democratizing Simulation – Autodesk's Strategy

Scott Reese has described Autodesk's vision to remove the barriers to simulation. It is built on the factors affecting ease of use, IT hardware and infrastructure requirements, and total cost of ownership. Autodesk is investing in simulation offerings that exploit the cloud and infinite computing as well as always-on simulation tools that give real-time feedback to a product designer. The goal of such unified simulation tools is to provide design guidance, not to replace end-of-design simulation for verification.

Part of this vision is already available with the Autodesk Moldflow solutions. For Autodesk Inventor, Pro/ENGINEER, and SolidWorks environments, a Moldflow add-on (formerly Project Krypton) provides early stage design advice to plastic part designers. It gives real-time feedback on a plastic part's manufacturability, cost, and environmental impact.

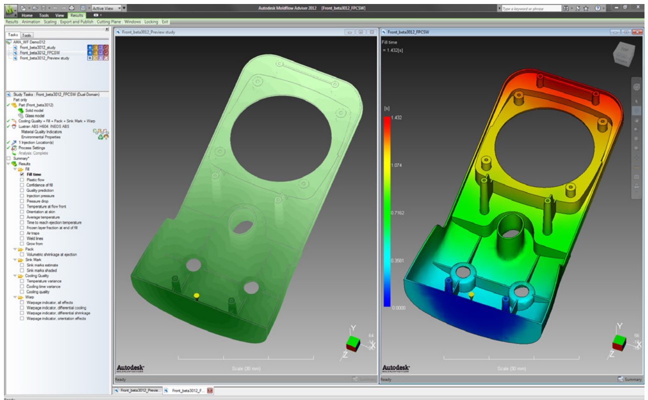

Figure 6—Real-Time Plastic Injection Molding Simulation

Moldflow provides simulation tools for validating and optimizing plastic parts, injection molds, and the injection molding process. Moldflow Insight WS (formerly Project Cumulus) offloads plastic injection molding simulations to the cloud, freeing local resources.

Autodesk Inventor optimization technology allows a user to specify material choices and acceptable ranges for parametric dimensions of a component, as well as the resulting analysis that drives design optimization performed in the cloud. The results are filtered to highlight the design options that best meet the optimization criteria, and standard reports make comparisons easy.

Similarly, Project Storm from Autodesk provides cloud-based tools for structural analysis of Autodesk Revit Structure models.

The cloud-based offerings are potentially very significant, for they can greatly lower the entry barrier for these types of simulations. No investment in local IT infrastructure for high performance computing is required to gain this capability. Also, the end user's workflow is basically unchanged.

Autodesk likens their cloud offerings to having a gym membership rather than owning home exercise equipment. They contend that customers want access, not ownership. Prepaid "cloud units" will give access to the full range of offerings without the need for specific licenses. This should reduce the hassle, if not the price, of entry for customers to evaluate the benefits of new simulation capabilities.

Another illustration of always-on simulation is Project Falcon, which is a plugin for Autodesk Alias surfacing software. Falcon is a wind tunnel simulation tool. In Autodesk's words, "Industrial designers can get intuitive simulation results for their designs in seconds, with no specialist knowledge required. Flow and wind pressure results update almost in real-time in response to changes in wind direction and speed." Project Falcon is likely to outrage some CFD experts, who will regard it as a dangerous and possibly misleading oversimplification of a complex problem. However, Autodesk's point is well taken. In the current process, the designer has no feedback on aerodynamic performance. To get such feedback, the designer has to consult a simulation expert, often waiting days or weeks for a response.

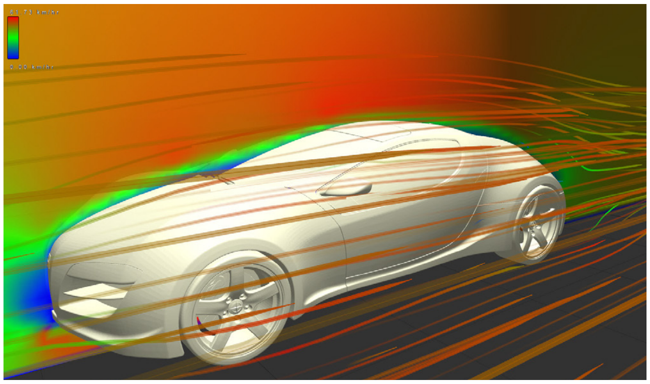

Figure 7—Project Falcon

Autodesk's vision for democratizing simulation is interesting because it does not impose the experts' processes on non-experts. Rather, according to Mr. Reese, it provides guidance to designers where none was available before. It reduces the need for full-blown simulation studies during product design, though it does not replace the need for proper design validation.

Further demonstrating Autodesk's effort to democratize simulation, even for consumers, is TinkerBox, a physics-based mechanical simulation game that runs on an iPhone; and ForceEffect, a mechanical statics application for the iPad.

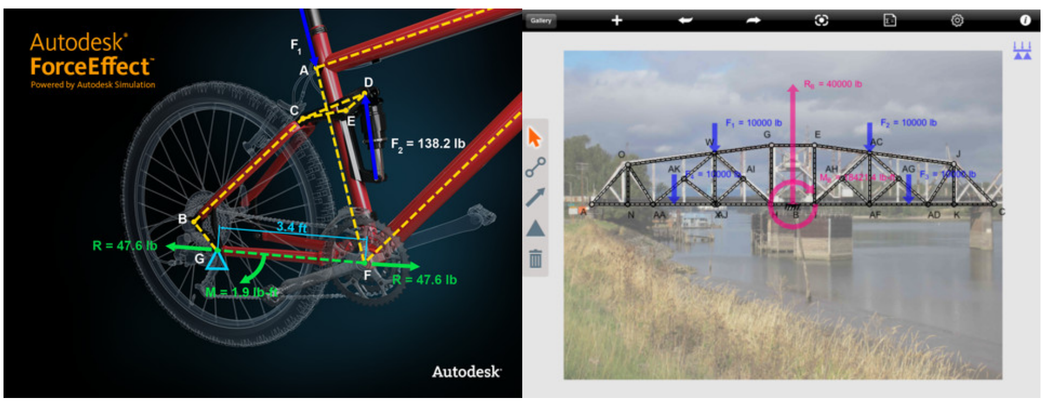

Figure 8—ForceEffect

Customer Testimonials

John Evans (of John Evans Design), a consultant and blogger, has been a user of Autodesk products since 1992 and of Inventor since the V4 release. He was also a beta tester for the Autodesk 2012 suites. He talked about the rigid-body kinematics and linear stress analysis capabilities within Inventor; and of the integration to the more extensive capabilities of Autodesk Simulation: "It works superbly well," he says, "and, this year, the integration is even better."

Mr. Evans was quite positive on the prospects for design technicians using these simulation tools, so long as they understand the underlying engineering issues. He estimated the learning curve to be less than a few weeks. He is also adopting Autodesk Simulation Mechanical (formerly ALGOR) for nonlinear analysis and more complex loading scenarios; he estimated that learning curve to be about six months for a seasoned engineer and estimates that the use of these simulation tools cuts development time in half. Mr. Evans selected Autodesk Simulation software based on capability and price, and found the pre-sales customer support to be much better than that provided by other prospective vendors.

CIMdata interviewed Bruce Jahnke, Director for Testing at K2 Sports, a leading maker of outdoor sports equipment. His department is responsible for product validation, including simulation and physical testing. At K2, the primary CAD tool is Pro/ENGINEER, with some SolidWorks. Mr. Jahnke characterized the interface to Autodesk Simulation as “very seamless, and somewhat parametric.” In other words, Pro/ENGINEER design changes can easily be associated with a simulation study.

K2 adopted the ALGOR tools before ALGOR was acquired by Autodesk. They had the need to simulate large nonlinear deflections, and also materials like plastics and non-isotropic composites. ALGOR sales support and recommendations from colleagues at other companies were major factors in their choice.

K2 produces new products for each calendar year. The payback from using simulation tools is meeting product development schedules. Mr. Jahnke said that their current three- to four-month development cycle could easily double or triple without simulation. At K2, simulation is done by experts, and designers generally do not use simulation.

John Samson is a Senior Mechanical Engineer at SmithGroupJJR, a multi-discipline design firm. His firm uses Autodesk Simulation CFD (formerly CFdesign) in conjunction with Autodesk Revit, Autodesk’s solution for building design and architecture. He and other users say the software is easy to use; there are no meshing issues; and that post-processing, including the ability to create videos, is good.

Mr. Samson stated that, at his company, CFD simulations are conducted by experts in modeling and sustainable building design. A primary benefit is the assessment of design performance, but they also engage clients in virtual reviews of design alternatives.

Conclusion

Over the last decade, Autodesk has moved beyond their AutoCAD roots to become a broad-based software company, now with a significant capability for physics-based simulations to predict product performance. Their $500+ million investment in simulation and analysis is making them a major player and their commitment to simulation is clear. In that space, Autodesk’s plans for always-on simulation and their use of the cloud to bring their offerings to their broad range of customers is an innovative approach to the democratization concept.

About CIMdata

CIMdata, a leading independent worldwide firm, provides strategic management consulting to maximize an enterprise’s ability to design and deliver innovative products and services through the application of Product Lifecycle Management (PLM) solutions. Since its founding nearly thirty years ago, CIMdata has delivered world-class knowledge, expertise, and best-practice methods on PLM solutions. These solutions incorporate both business processes and a wide-ranging set of PLM enabling technologies.

CIMdata works with both industrial organizations and providers of technologies and services seeking competitive advantage in the global economy. CIMdata helps industrial organizations establish effective PLM strategies, assists in the identification of requirements and selection of PLM technologies, helps organizations optimize their operational structure and processes to implement solutions, and assists in the deployment of these solutions. For PLM solution providers, CIMdata helps define business and market strategies, delivers worldwide market information and analyses, provides education and support for internal sales and marketing teams, as well as overall support at all stages of business and product programs to make them optimally effective in their markets.

In addition to consulting, CIMdata conducts research, provides PLM-focused subscription services, and produces several commercial publications. The company also provides industry education through PLM certification programs, seminars, and conferences worldwide. CIMdata serves clients around the world from offices in North America, Europe, and Asia-Pacific.

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