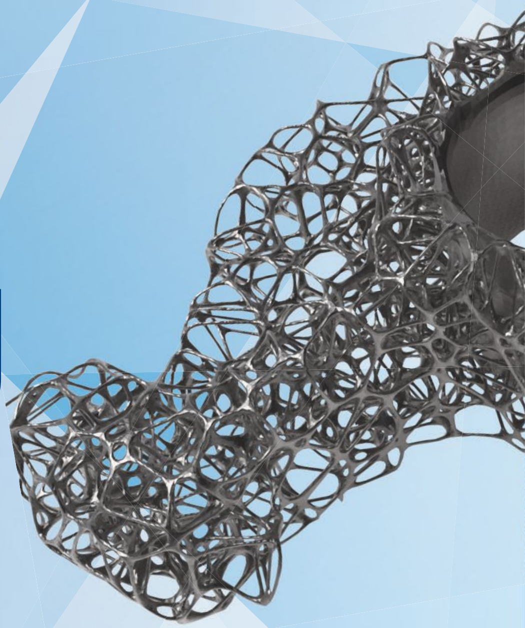
digitaleng.news //////

DE

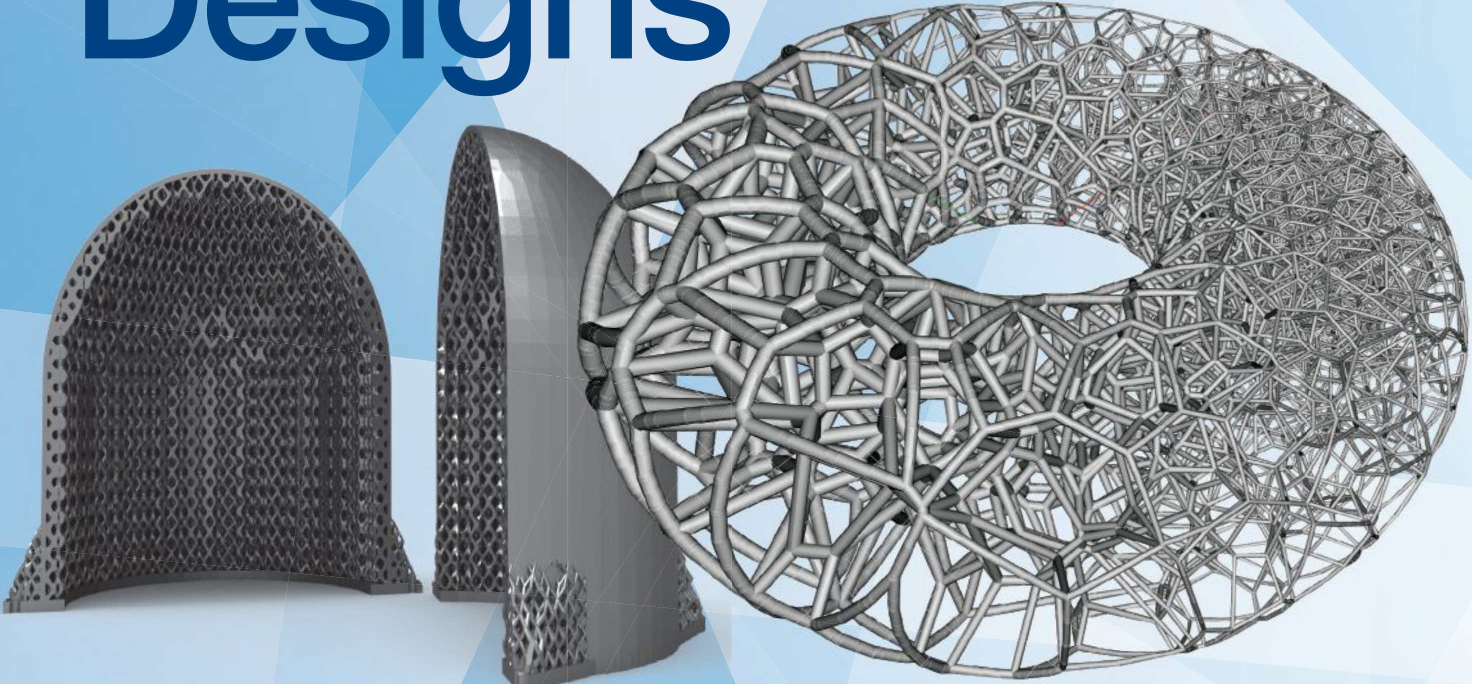
Digital Engineering

January 2017

FOCUS ON: Lightweighting P.13



3D Printing Lightweight Designs



BREAKTHROUGH
ENERGY INNOVATION

Energy systems simulation is critical for improving the way energy is produced and consumed. ANSYS solutions can help you develop efficient, sustainable energy systems that will overcome the energy challenges of today and tomorrow.

Learn more at **ansys.com/energy**

ANSYS®

THE NEW MULTIFUNCTION SURECOLOR® T-SERIES

- Produce presentation-quality 24" x 36" color copy in under 40 seconds*
- High productivity with color scanning speeds up to 6" per second*
- Advanced image processing hardware for superb image quality
- Scan to file, email and remote SureColor T-Series multifunction printers
- Single-roll or Dual-roll models available in 36" and 44" print widths

Epson® SureColor T-Series

MFP Configuration Starting at $7,140† Single Roll

EPSON®
EXCEED YOUR VISION

Another Innovation from Epson® Business Solutions.

*Speeds are based upon print engine speed only. Total throughput times depend upon factors such as computer, file size, printer resolution, ink coverage, and networking. EPSON and SureColor are registered trademarks and EPSON Exceed Your Vision is a registered logomark of Seiko Epson Corporation. Adobe and PostScript are either registered trademarks or trademarks of Adobe Systems Incorporated in the United States and/or other countries. Copyright 2016 Epson America, Inc.
†Estimated street price after instant rebate and dealer discount. Please visit epson.com/prorebates for details. Check with an Epson Professional Imaging Authorized Reseller for actual price, as dealer prices may vary.

Adobe® PostScript® 3™

EPSON.COM/**PLOTTERINFO**

by Jamie J. Gooch

Next-Gen Engineers

IN OUR COVERAGE TO CLOSE OUT 2016 and ring in the New Year, we focused on next-gen engineering technologies available now in the December issue and in two webcasts (digitaleng.news/de/webcasts). Breakthroughs in augmented reality, artificial intelligence, simulation, optimization, 3D printing and high-performance computing are already capable of transforming the design engineer's workflow. But we left out one important factor in our look toward the future: the next generation of design engineers.

After all, the latest innovations in software and hardware don't mean much unless someone is using them. As more and more of the engineers who ushered in the age of computer-aided design and manufacturing turn their attention to the latest golf and fishing technologies they want to implement during retirement, the younger generation is facing massive technological disruption—both in the engineering tools they use and in the markets they will serve.

The word is out that engineers are in demand. Years of outreach focused on science, technology, engineering and math have more young people thinking about college majors in STEM fields.

"U.S. colleges and universities conferred 83,263 bachelor's degrees in engineering in 2012—a 37% increase over the 60,605 degrees conferred in 2002," according to the National Science Foundation. "The top four engineering subfields in 2012, in terms of the number of bachelor's degrees awarded, were mechanical, electrical, civil and chemical engineering."

But what were those undergraduates taught? Did they learn the theory and physics behind simulation? How to make use of the latest software to design for optimization or additive manufacturing? How to train software to build artificial intelligence into the products they design? All of the above? Technology is moving so quickly that it's difficult for colleges and universities to keep up.

Practical vs. Theoretical

Designing robotic-driven factories, autonomous vehicles and smart, connected products may seem like a distant goal to the college freshman in his/her Probability Theory course, but an understanding of the math and physics behind simulation is essential to effectively using modern engineering tools. On the other hand, companies want to hire students who can hit the ground running with any number of simulation and design applications and specialized pieces of hardware.

Thankfully, engineering schools, engineering hardware and software vendors, and businesses hoping to hire proficient graduates all realize a solid foundation is critical, but there is more to engineering than understanding theory. Internships and student competitions have become part of the curriculum to provide the hands-on experience that equations can't.

At *DE*, we've made a New Year's resolution to cover these practical programs and explore the debate surrounding how best to attract and prepare students for engineering careers. In each issue this year, we'll profile a new student engineering challenge—from designing race cars to submarines to planes and more—starting with this month's coverage of the World Solar Car Challenge on page 24.

Training and Experience

Ultimately, a multi-pronged approach will be required for engineering departments to keep pace with technological and market disruptions. Companies not only need to hire the best and brightest next generation of engineers, but invest in continuous training for their employees.

To make sure all of that education, training and on-the-job experience isn't lost, engineering departments should have a formal knowledge capture and retention process. Such a process may involve specialized software or be integrated into a company's product lifecycle management approach. More importantly, employees have to use it. Too often, knowledge gained by experience is hoarded and lost as engineers retire or move on to other positions. It's used as a form of job security, rather than a company resource. To get beyond that, managers have to institute a culture of job stability and incentives that reward sharing, contributing to the company's knowledge base and mentoring incoming members of the engineering team. **DE**

Jamie Gooch *is editorial director of* DE. *Contact him via de-editors@digitaleng.news.*

csimsoft™

WHICH TOOL GENERATES HIGH-QUALITY MESHES?

(IF YOU SAID A CHAINSAW, YOU WERE WRONG.)

Trelis™

THE RIGHT MESHING TOOL FOR BETTER SIMULATION.

Using the right tool for the job is important. Sometimes even critical.
Experienced engineers know the better the mesh, the better the simulation results.
That's why they use Trelis.

YOU CAN WIN THIS CHAINSAW

Try Trelis for FREE and enter to win this 14" chainsaw.
Visit csimsoft.com/chainsaw for more information.

Must enter by January 31, 2017. No purchase necessary. Visit csimsoft.com/chainsaw for more information and for official rules.

TRY TRELIS OUT FREE → csimsoft.com/chainsaw ← TRY TRELIS OUT FREE

FULLY-WORKING VERSIONS - FOR A LIMITED TIME

csimsoft™

©2017 CSIMSOFT. ALL RIGHTS RESERVED.

DE Digital Engineering

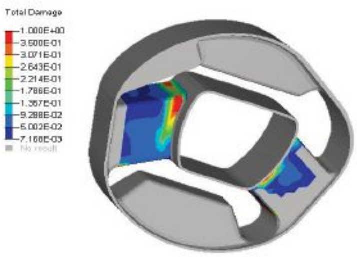
TECHNOLOGY FOR OPTIMAL ENGINEERING DESIGN

INSIDE

digitaleng.news

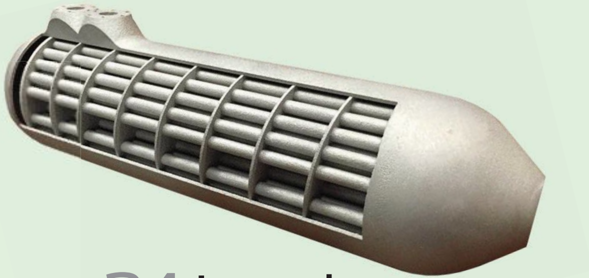
Jan/2017
Vol.22 • No.5

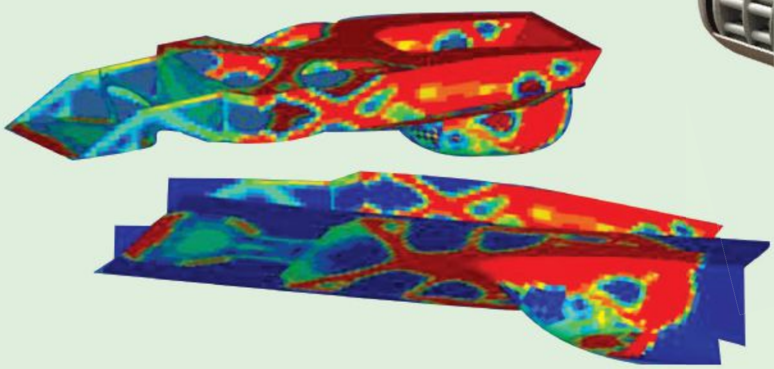
FEATURES



ON THE COVER: Images courtesy of nTolopology and Thinkstock/-strizh-

FOCUS ON LIGHTWEIGHTING





DEPARTMENTS

PUBLISHER
Tom Cooney

EDITORIAL
Jamie J. Gooch | Editorial Director
Kenneth Wong | Senior Editor
Anthony J. Lockwood | Editor at Large
Jess Lulka | Associate Editor
Sarah Petrie | Copy Editor

CONTRIBUTING EDITORS
Tony Abbey, Brian Albright, Mark Clarkson, David S. Cohn, Randall Newton, Beth Stackpole, Pamela J. Waterman

ADVERTISING SALES
Tim Kasperovich | East Coast Sales
440-434-2629
Jim Philbin | Midwest/West Coast Sales
773-332-6870

ART & PRODUCTION
Darlene Sweeney | Director
darlene@digitaleng.news

A PEERLESS MEDIA, LLC PUBLICATION
Brian Ceraolo | President and Group Publisher

ADVERTISING, BUSINESS, & EDITORIAL OFFICES
Digital Engineering® magazine

Peerless MEDIA, LLC

Peerless Media, LLC
111 Speen St., Suite 200,
Framingham, MA 01701
Phone: 508-663-1500
E-mail: de-editors@digitaleng.news
www.digitaleng.news

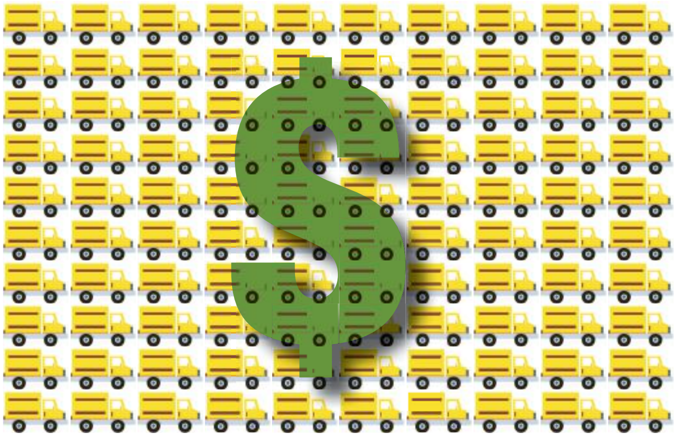
Kenneth Moyes | President and CEO, EH Media

SUBSCRIBER CUSTOMER SERVICE
Digital Engineering® magazine
PO Box 677 • Northbrook, IL 60065-0677
Phone: 847-559-7581
Fax: 847-564-9453
E-mail: den@omeda.com

BPA WORLDWIDE

Digital Engineering® (ISSN 1085-0422) is published monthly by Peerless Media, LLC, a division of EH Media, 111 Speen St., Suite 200 Framingham, MA 01701. Periodicals postage paid at Framingham, MA and additional mailing offices. *Digital Engineering®* is distributed free to qualified U.S. subscribers. **SUBSCRIPTION RATES:** for non-qualified; U.S. $108 one year; Canada and Mexico $126 one year; all other countries $195 one year. Send all subscription inquiries to MeritDirect, *Digital Engineering®*, PO Box 677, Northbrook, IL 60065-0677***Postmaster:*** Send all address changes to MeritDirect, *Digital Engineering*, PO Box 677, Northbrook, IL 60065-0677. Reproduction of this magazine in whole or part without written permission of the publisher is prohibited. All rights reserved ©2016 Peerless Media, LLC.Address all editorial correspondence to the Editor, *Digital Engineering*. Opinions expressed by the authors are not necessarily those of *Digital Engineering*. Unaccepted manuscripts will be returned if accompanied by a self-addressed envelope with sufficient first-class postage. Not responsible for lost manuscripts or photos.

Lighter Transportation = Better Fuel Economy



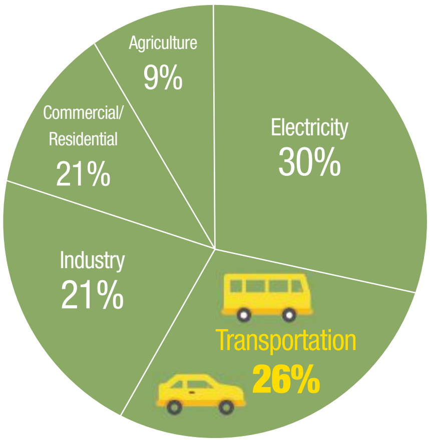
An "aluminum-intensive" Class 8 commercial tractor trailer can reduce vehicle weight by 3,300 lbs. For every 10% of weight reduction, up to a 5.5% improvement in fuel economy is possible.

— Ricardo Consulting Engineers via the Aluminum Association

A typical 100-truck fleet would save almost $100,000 per year in diesel costs with 2,500 lbs. of weight saved per truck.

— The Aluminum Association

Lighten Up on Pollution



More than a fourth of U.S. greenhouse gas emissions come from our transportation system.

— U.S. Environmental Protection Agency, 2014

Substituting the nation's fleet of Class 8 tractor-trailers with aluminum-intensive models would save 9.3 million tons of CO_2 annually.

— Ricardo Consulting Engineers via the Aluminum Association

Fly Light

In aviation, lightweight materials already make up about 80% of all materials.

— "Lightweight, Heavy Impact," February 2012, McKinsey & Co.

A **5%** increase in fuel efficiency could mean **132 million gallons** of jet fuel saved every day.

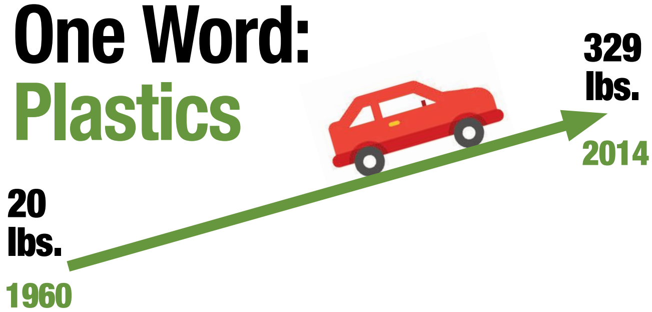
— "Lightweight structures and 'smart skin' make aviation more sustainable," Tyler Irving, University of Toronto, March 23, 2016

Great Weight, Less Filling

Lightweighting technology has cut the average weight of a 330ml (11.2 oz.) beer bottle in half over the past 20 years.

— Beveragedaily.com, Rebecca Cocking, Friends of Glass, Dec. 8, 2016

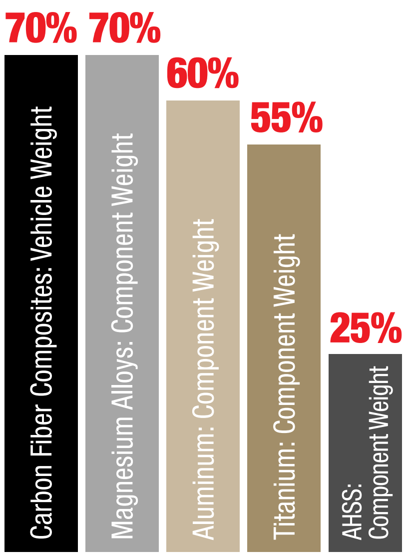
One Word: Plastics



Use of plastic and polymer composites in light vehicles increased from less than 20 lbs. per car in 1960 to 329 lbs. in 2014.

— "Plastics and Polymer Composites in Light Vehicles," Economics & Statistics Department, American Chemistry Council, October 2015

Automotive Weight Reduction Potential



- Carbon Fiber composites are half the weight and 4X stronger than traditional steel.
- Magnesium has the lowest density of all structural metals.
- Aluminum is being used for hoods, trunk lids and doors.
- Titanium is a high temperature metal used in powertrain systems.
- Advanced High Strength Steels (AHSS) are particularly useful in strength-limited designs such as pillars and door rings.

— U.S. Department of Energy

Top 5 Lightweighting Barriers

1	Capital Investment
2	Manufacturing Capacity
3	Design
4	Qualification
5	Supply Base Competitiveness

— Center for Automotive Research, "Assessing the Fleet-wide Material Technology and Costs to Lightweight Vehicles," Jay Baron, Ph.D., and Shashank Modi, September 2016

| CONSULTANT'S CORNER |

DESIGN

by Monica Schnitger

A Look at Lightweighting

IF WE'RE SO CONCERNED WITH WEIGHT, why don't we just make everything out of carbon fiber? Or aluminum?

The aerospace and automotive industries have been working hard to reduce weight for decades. The main goal has been to lightweight so that cars and planes need less fuel to cover the same distance. Besides meeting regulatory targets, lightweighting a car means that a smaller engine can meet performance criteria—and that has all sorts of other implications like less load on the brakes, a slimmed-down suspension, smaller tires, different handling. It becomes, perhaps, a completely different car than the original specs detailed.

Most car chassis are made of low carbon steel, the choice for over a century. Steel is relatively inexpensive and so established that its material characteristics led to the welding and other manufacturing processes that prevail in the automotive industry. But it is heavy and therefore not ideal to meet tomorrow's fuel economy standards.

Materials Change Everything

Reducing a product's weight sounds simple—just replace everything heavy with something light—but requires complex engineering and manufacturing techniques that are made possible by advances in material science, manufacturing processes and cheaper, faster simulation.

Today's lightweight materials include high-strength steel, magnesium and aluminum alloys, and carbon fiber plastics. They typically cost more than the materials they are replacing, in part because they're harder to produce but also because they're not as widely used. This leads designers to make a trade-off between cost and weight, resulting in hybrid designs that optimize the system as a whole. The resulting mix of steel and other materials can cause significant disruption in long-held manufacturing processes. To look at only one aspect: Steel has a melting point of around 2600°F, while aluminum and magnesium melt at around 1200°F. Welding steel to aluminum, therefore, requires new techniques that are still being developed.

3D Printing and Simulation

New techniques, such as additive manufacturing, make it possible to fabricate completely new part concepts and offer an opportunity to rethink traditional designs. For example, car makers are developing aluminum alloy castings that—with one assembly—can replace dozens of smaller parts that had to be hand assembled. In addition to saving weight, this redesign decreases manufacturing complexity, saves production time and leads to a higher level of repeatable quality. This can't happen without consciously thinking about a part and reframing its design objectives to include weight, manufacturability, quality and other criteria—and spending the time to get the design right.

Simulation is of tremendous help in lightweighting. Engineers can cycle through many combinations of part geometries, materials and use cases to discover the best combination. Finite element analysis (FEA) of 3D-printed or additively manufactured parts is still evolving because there are so many parameters unique to each manufacturing process, but analysts making cautious assumptions about part quality, for example, can evaluate the lighter part's performance and fitness for purpose before producing a part. Iterating through so many alternatives takes time, even with massive cloud CPU capacity, but is typically worth the effort and cost because of savings in other parts of the product's lifecycle.

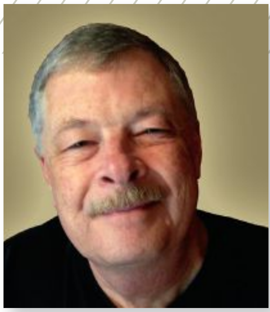
The lessons learned in aerospace and automotive are being applied across industries because the economics are impressive. Anything that has to be transported from the point of manufacture to the final customer can be redesigned to weigh less while still meeting performance criteria. And this opportunity to reconsider many aspects of the design can open the door to all sorts of other improvements, too. Lighter flat packs of DIY furniture can lead to more unit sales because it's easier for a consumer to get the box up the stairs. Redesigned industrial equipment might not need the same kind of foundations, saving on install costs. Lower transportation costs can be passed along to customers—or not, and can be used to increase profit. Laundry detergent can be recast as environmentally friendly and fetch a premium price.

Engineers, regardless of industry, need to create part-specific materials strategies that take into account function, formability, strength, temperature profile and so on, and weigh that against the cost of each material. Often "light" means "light enough"—there is, as yet, no perfect material that is the single, ultimate answer for every situation. DE

Monica Schnitger *is president of Schnitger Corporation (schnitgercorp.com). Send email about this commentary to de-editors@digitaleng.news.*

ADCs

by Tom Kevan



Not All ADCs Are Created Equal

NEARLY EVERY ELECTRONIC PRODUCT on the market contains an analog-to-digital converter (ADC). With all the wiz-bang features that some of these devices sport, the importance of ADCs can be overlooked. But one of the first decisions a designer must make is the type of ADC best suited for the application. The real challenge becomes sorting through the various types of ADCs and choosing the most appropriate converter. This decision is critical because it often determines the overall performance of the product and the success of the design.

To make the best decision, the design engineer must make tradeoffs, juggling resolution, sampling rate, accuracy and power dissipation to achieve the optimum balance to meet the application's requirements. This calls for a solid understanding of the strengths and weaknesses of each type of ADC. To help with that, let's look at the three main types of ADCs: The successive approximation register (SAR), sigma-delta and pipeline.

SAR Converters

The SAR converter is one of the oldest and most widely used ADC architectures on the market. Designers often pick it for medium-to-high-resolution applications, such as motor control, vibration analysis and system monitoring.

The architecture offers significant operational flexibility. Resolutions range from 6 to 18 bits, and the SAR typically operates between a few kilosamples per second to as high as 10 megasamples per second. While they are not as fast as pipeline converters, SAR ADCs are typically faster than sigma-delta converters. The high throughput rate of a SAR converter enables oversampling, which improves anti-aliasing and noise reduction.

Another strength of the SAR architecture is its ability to take a high-speed snapshot of an analog input signal. SAR converters sample one moment in time. This is useful when a designer must measure multiple signals simultaneously, which can be achieved by simultaneously sampling with multiple SAR ADCs.

This type of converter also brings key features to wearable, mobile and other low-power applications. SAR converters scale power dissipation directly with the sample rate. Because of their low power consumption, high resolution and small form factor, these ADCs can often be integrated with other larger functions. The architecture's main limitation is its lower sampling rate.

Sigma-Delta ADCs

Sigma-delta converters entered the marketplace when digital signal processing became practical. While complex, this signal conversion architecture offers the greatest resolution of any ADC, complemented with noise mitigation.

The analog portion of the architecture is simple. The digital side, on the other hand, is more complex. Essentially, these converters consist of an oversampling modulator and a digital/decimation filter that together produce a high-resolution output. The converter's low-pass filter eliminates most of the high-frequency noise generated by the sampling process.

Sigma-delta ADCs are ideal for converting analog signals over a broad spectrum of frequencies, ranging from DC to several megahertz. The downside of the design is that it is slower than other types of ADCs, so designers typically use sigma-delta converters only in applications with DC and audio frequencies.

Sigma-delta ADCs are well suited for low-noise, precision applications. When speed is not an issue, the oversampling of a sigma-delta converter provides very high precision. This makes them a good fit for communications systems, precision measurements and audio applications.

Pipeline ADCs

Pipeline ADCs deliver speed at the expense of power and latency. These converters use a parallel structure in which each stage processes one to a few bits of successive samples simultaneously. For optimum performance, these converters require accurate amplification in the ADC and interstage amplifiers. Pipeline ADCs offer speeds of 100 megasamples per second at 8- to 14-bit resolutions. With these sampling rates, the interface becomes critical. Parallel digital has long been the interface of choice, but new interfaces have begun to appear on the market.

With these resolutions and sampling rates, pipeline converters can serve a broad spectrum of applications. These range from RF and software-defined radios to CCD (charge-coupled device) imaging and ultrasonic medical imaging.

If you are looking for cut-and-dry guidelines for choosing an ADC, you're going to be disappointed. The selection process is a balancing act in which the designer and the application determine the importance of speed, accuracy and power. DE

Tom Kevan *is a freelance writer/editor specializing in engineering and communications technology. Contact him via de-editors@digitaleng.news.*

AU2016: Software Should be Less Like Spock, More Like Captain Kirk

BY KENNETH WONG

At AU 2016 (Nov. 14-17, The Venetian, Las Vegas), vocal percussionist Butterscotch performed the Gershwin classic "Summertime" to open one of the keynotes. The lithe, spunky singer produced a symphonic mix of electronics, drumbeats and saxophone melodies with nothing but her mouth. In short, Butterscotch is a human sound-machine.

Taking his turn onstage, Autodesk CTO Jeff Kowalski discussed machines that are on the verge of acquiring human characteristics.

"Computers have always been a little bit like Mr. Spock [the epitome of logical thinking, as personified on "Star Trek"]. Today, they're becoming more like Captain Kirk," Kowalski said. "Spock is logical and brilliant, but as we saw on the show, that was never enough to save the day. It's usually Captain Kirk who came up with the ultimate solution … something driven by hunch, intuition and creativity."

Coding Intuition into Design

Over the past two years, Autodesk began developing algorithm-driven design or generative design technologies. "It's a way of collaborating with the computer," Kowalski said. "We don't tell it what to do; we tell it what we need."

The company's endeavors resulted in Autodesk Within, Autodesk Inventor Shape Generator and Project Dreamcatcher. The company employed Autodesk Within, a topology optimization software, in its Bionic Partition project, jointly undertaken with Airbus and APWorks. Shape Generator is a feature in the company's mechanical CAD product Autodesk Inventor. Autodesk Dreamcatcher is still branded as a technology preview, not a commercial product.

Autodesk CTO Jeff Kowalski on the big screens during the AU 2016 opening keynote. *Image courtesy of Autodesk*.

Can a piece of software develop the intuition for what makes a sturdy, comfortable chair? If so, what would such a chair look like? Brittany Presten, an Autodesk intern, and Arthur Harsuvanakit, a technical assistant to Autodesk CEO Carl Bass, discovered the answer when they decided to design a chair using Dreamcatcher.

"The software doesn't understand what a chair is supposed to be," explained Harsuvanakit in his talk with *DE* in the AU exhibit hall. "All we did was to give the software the loads on the backrest and the sitting surface."

The general shape—the design space for the software to explore—was created in Autodesk Fusion 360, then fed into Dreamcatcher with the desired constraints. The optimal design proposed by the software, Harsuvanakit noted, "has 18% less volume and decreases the max displacement by 90.4% as well as decreases the max von Mises stress by 78.6%."

MORE → digitaleng.news/virtual_desktop/?p=12409

Formnext 2016: 3D Printing's Reality Check

BY RANDALL S. NEWTON

3D printing industry titans, startups and every company in-between gathered in Frankfurt in November for formnext, the conference and trade show from TCT. It may be remembered as the time 3D printing paused for a reality check.

Three themes emerged:
1. Thank God the hype train left the station;
2. Software needs to eat 3D printing;
3. Joy's Law of Innovation is alive and well in 3D printing.

We'll tackle them in order.

Getting off the Hype Train

Research firm Gartner coined the phrase "hype cycle" to explain how most tech innovations go from invention to mainstream use. There are five stages:
1. Technology Trigger,
2. Peak of Inflated Expectations,
3. Trough of Disillusionment,
4. Slope of Enlightenment, and
5. Plateau of Productivity.

Casual observers of the 3D printing industry may think the industry is plummeting down from the Peak of Inflated Expectations and will soon hit bottom in the Trough of Disillusionment. But the insiders gathered at formnext 2016 know better, and will tell you the climb up the Slope of Enlightenment is underway.

"The hype of 2012 and 2013 drove up share prices and created unrealistic expectations that every home would have a 3D printer," said Terry Wohlers, the dean among analysts in the 3D printing industry. "But what was good [about that time] was opening the subject to a lot of people."

He said from 2012 to 2015, the indus-

The 3D Systems ProX DMP 320 is aimed at high volume users of metal printing. *Image courtesy of Randall Newton.*

try averaged 31% annual growth.

Industry analyst Bernhard Langefeld of Roland Berger said the Peak of Inflated Expectations turned downward in December 2013. But if the 3D printing industry wallowed in the Trough of Disillusionment, it didn't last long.

Software is Hungry

When the founder of Netscape wrote "software is eating the world" in a *Wall Street Journal* opinion piece in 2011, it instantly became the best summary of what software does to any value chain it touches. One common theme that emerged from formnext 2016 was the need for some of that eating to hit 3D printing.

"The value chain for printing a simple part must be as efficient as possible," said Langefeld. From CAD to simulation/analysis to topology optimization to lattice structures to printing, there are just too many steps. And we are oversimplifying it.

Following Joy's Law of Innovation

When Bill Joy was famous for his work at Sun Microsystems, he once quipped, "No matter who you are, most of the smartest people work for someone else."

Several key patents related to 3D printing have expired, so now there are many young companies experimenting with new ways to tweak the old technologies. A walk down the aisles at formnext revealed clever bits of innovation in all directions.

Langefeld sees a lot of interesting work happening in amorphous materials and the reordering of properties at the atomic scale. Right now, state-of-the-art can only make very thin prints, but Langefeld said thickness is coming "soon."

MORE → rapidreadytech.com/?p=11013

SC16 Hints at What Supercomputing Means for Manufacturing

BY JAMIE J. GOOCH

Each year, the top talents and technologies in computing converge at the SC supercomputing conference to focus attention on how computing power can be used to solve some of mankind's greatest challenges. SC16 was no exception, as more than 11,100 registered attendees from 26 countries took in 349 exhibits and hundreds of sessions in Salt Lake City Nov. 13-18.

Supercomputing's role in precision medicine took center stage during a panel discussion at SC16.

Precision medicine took center stage both during a panel discussion on the topic and during Katharine Frase's keynote on how cognitive computing is evolving. Frase recently led strategy and business development for IBM's Watson Education unit. "Now more than ever, visionary thinking will drive an endless and transformative array of applications for Watson and cognitive computing in general, along with whatever comes next," she said.

Some of that visionary thinking is coming from the manufacturing sector as well, according to NVIDIA. During a press briefing at SC16, NVIDIA founder and CEO Jen-Hsun Huang said computing that helps companies build products is "a many billion dollar opportunity."

NVIDIA's graphics processing units (GPUs) and architecture have proven to be adept at tasks needed to develop artificial intelligence (A.I.) and, specifically, deep learning, like quickly finding patterns in very large, unstructured data sets. Just as computing power can be used to mine health care data to improve diagnosis and suggest different treatment options for different people, A.I. can be used to improve product designs and suggest product options for different users.

"Enterprise is sometimes said to be slow to adopt A.I., but the parts of companies that are developing products are moving fast," Huang said.

Making Supercomputing Accessible

There are a number of obstacles to increasing advanced computing use in the enterprise, including amassing enough data, labeling that data so A.I. can categorize it and, perhaps most challenging: training company stakeholders on how to implement A.I. According to Roy Kim, director of Accelerated Computing at NVIDIA, over the past two years the company has gone from 1,000 to 20,000 enterprise inquiries about training for deep learning and A.I.

Obviously, the easier it is to implement A.I. and high-performance computing solutions, the faster they will be adopted by industry. Democratization of advanced computing was the goal of SC16 announcements from both AMD and Intel as they embraced an open mantra.

AMD announced a new release of its Radeon Open Compute Platform (ROCm) at SC16 featuring software support of new Radeon GPU hardware, new math libraries and a foundation of modern programming languages the company says is designed to speed development of high-performance, energy-efficient heterogeneous computing systems.

Intel is expanding upon its Intel Scalable System Framework (Intel SSF), an architectural approach intended to simplify the procurement, deployment and management of HPC systems. At SC16, the company announced Intel HPC Orchestrator software to assist with setup and management of systems.

The fact that OEMs are rolling out advanced computing solutions to manufacturing is a good sign that industry democratization efforts are gaining momentum. This was Dell's first SC conference since its $60 billion merger with EMC. Ed Turkel, HPC Strategist for Dell EMC, said the merger allows Dell to pursue a broader marketplace. "EMC is an entry point to manufacturing customers," he said. "It's a huge opportunity to expand the business."

MORE → digitaleng.news/de/?p=33579

| ABBEY'S ANALYSIS |

FEA

by Tony Abbey

Analysis and Analogies

Editor's Note: *Tony Abbey teaches live NAFEMS FEA classes in the US, Europe and Asia. He also teaches NAFEMS e-learning classes globally. Contact tony.abbey@nafems.org for details.*

An analogy is a comparison between two related concepts, usually made to help understand or remember the basic idea. This article reveals some of my favorite analogies for structural analysis.

Sausages Anyone?

The membrane stresses in a thin wall pressure vessel are in hoop and axial directions. Stress equations are Pr/t and $Pr/(2t)$. P is pressure, r is radius and t is wall thickness. When doing a sanity check for an FEA (finite element analysis) result, would you rather remember which is which, or turn to a handbook or online search? My memory is bad, so I use this food analogy.

Overcooking sausages on the barbecue often results in split skins. The split is always longitudinal. The sausage is subject to the same stress state as the pressure vessel. Hoop stress is double axial stress, so the poor sausage splits longitudinally every time. A course attendee once claimed his sausages burst circumferentially, but then admitted to pricking around the sausage with a fork!

Carrots and Exploding Dough

If a shaft is twisted in torsion, it can fail in one of two ways. A ductile material will tend to fail in a flat plane normal to the longitudinal axis. A brittle material will tend to fail on a 45° plane. A good analogy of this is to take a frozen carrot and twist it. Behold—the failure plane will be roughly at 45°! Internally, the pure shear stress state can be resolved into equal and opposite principal stresses acting at 45°. The brittle material will tend to fail locally under action of the tensile principal component.

A second analogy reinforces this concept. Ready-made dough is sold in long cardboard tubes, similar to kitchen or toilet roll tubes. The tube is helically wound with the strip edges glued. The dough is stored under pressure inside the tube. One enjoyable way to get the dough out is to grab both ends and give a good twist. The tube bursts with a satisfying pop. The failure mode occurs as in the brittle material. The tensile principal stress orientated at 45° to the axis is pulling across the glue line and the weak glue fails. Warning: This experiment is addictive. My wife gets upset with all those exploded tubes in the refrigerator!

Soap Bubbles

Remember blowing soap bubbles? As you blow into the ring the film bulges and forms a dome-like shape. Maximum curvature is at the edge. Zero curvature is at the center. Torsional shear stress is directly proportional to the soap film curvature! The mathematics are horrible, but the potential field equations are identical. Torsional shear stress in a circular cross-sectional shaft is maximum at its free edge and zero at the center. The distribution through thickness is the same as the soap film curvature.

Fig. 1 shows a sketch from an early experiment. A flat plate has a hole cut out in the shape of the beam cross-sectional area. A soap film is formed across the cut out and blown from underneath. The sketch shows the contours of the soap bubble. We are interested in how closely the contour lines are spaced. Tight contours, the steeply sloping parts of the soap film, show the high shear stress regions. The high shear stresses are at the inner radii of the cross-section.

More Analogies Wanted

There are probably many other similar analogies that are useful for explaining or remembering structural analysis concepts. If you have any favorites, do drop me a line at tony.abbey@nafems.org and I will include them in a future article. DE

Tony Abbey *works as training manager for NAFEMS, responsible for developing and implementing training classes, including a wide range of e-learning classes. Check out the range of courses available: nafems.org/e-learning.*

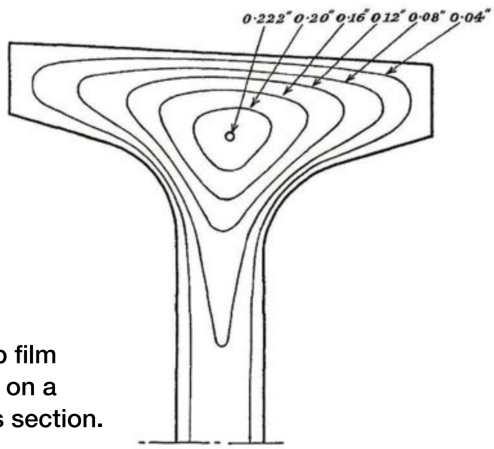


FIG. 1: Soap film experiment on a beam cross section.

Designers Living in a Materials World

The promise and challenges of a systems-level approach to lightweighting.

BY BRIAN ALBRIGHT

LIGHTWEIGHTING RELIES ON A COMBINATION of both design and manufacturing innovation, as well as the use of new, lighter materials. Current approaches, however, are often limited by focusing on parts of a design, rather than the whole.

Lightweighting can be achieved by switching a component to a lighter material that can meet structural requirements, changing the structural shape of a component, or altering the configuration of materials to improve efficiency. Still, these efforts are often pursued on a component-by-component basis. The design, materials and production methods used to produce each component are not often considered in an integrated fashion.

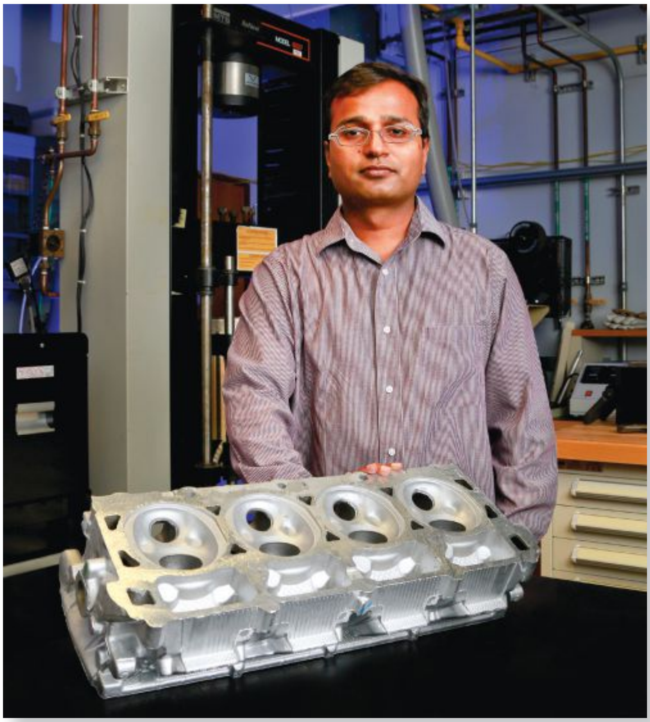
A systems-level approach to lightweighting that takes all of these factors into consideration, and relies on collaboration among materials engineers, designers and other stakeholders can result in new design innovations.

"In a systems-level approach, it is possible to predict the specific in-service conditions of each component in the overall system being modelled," says Dr. Will Marsden, director of industry relations at Granta Design. "If you understand those specific conditions, you can understand the interplay of the system as a whole, and then identify the key areas (e.g., materials selection), which dictate the performance of the overall system rather than designing components in isolation."

Approaching Integration

One such systems approach is Integrated Computational Materials Engineering (ICME), which takes into account design, material and processing methods to optimize the use of materials for a given component. ICME requires collaboration across various specialties to succeed.

"It's not just the tools that have to talk to each other, the people have to talk to each other, too," says George Spanos, technician director at The Minerals, Metals & Materials Society (TMS). "That's really key for practical implementation because it involves engineers that are used to working on the product development cycle, as opposed to the fundamental science framework."



A team of researchers led by ORNL's Amit Shyam is using high-performance computing to speed the development of new high-temperature aluminum alloys for automotive cylinder heads. ***Image courtesy of ORNL.***

TMS has produced a lengthy report (*ICME: Implementing ICME in the Aerospace, Automotive, and Maritime Industries*: tms.org/icmestudy) that includes detailed steps for implementing ICME in those verticals.

ICME involves the integration of personnel, models, computational tools, experiments, tests, analyses, design and manufacturing processes across the entire product development cycle. It allows designers to explore a much larger design space more quickly than using traditional experimental approaches.

"When you integrate this optimization scheme, you approach design without the restraint of the exact materials being fixed up front," Spanos says. "The designer can have more latitude. It doesn't tie your hands to a limited type of alloy. Topol-

ICME Examples

While there are a number of challenges to Integrated Computational Materials (ICME), there are projects underway and several manufacturers have already put the approach into deployment.

The Department of Energy (DOE) has funded a number of projects aimed at the development of third-generation of advanced high strength steels (3GAHSS) for automotive manufacturing applications that not only focus on component designs, but on the development of the new steels based on performance requirements.

Lockheed Martin is also using ICME to concurrently design materials, components and manufacturing processes. This approach was key in the development of the company's APEX multi-scale reinforced nanocomposites, new chemical sensors and new semiconductor materials.

Lockheed Martin has also used ICME to develop informatics and rapid characterization tools that are being integrated into a high-throughput carbon nanotube materials discovery platform to help create single-walled nanotubes with specific electron configurations.

The Ford Virtual Aluminum Castings (VAC) project is probably the best known case study, and resulted in a 15 to 25% reduction in development time, as well as lighter engine designs and $120 million in savings. At Ford, computational modeling was used to simulate the linkages between thermal processing and the microstructure of an aluminum alloy, and then predict the performance of cast engine components made from that alloy.

According to Ford, the VAC program makes it easier to determine the best manufacturing process for a component through modeling. General Motors, Pratt Whitney and other companies have also deployed ICME for specific projects.

While cost savings are important, time to market is an even bigger driver of the business case for ICME. "Someone in the aerospace industry said to me that saving development costs is good, but if they could get a new product out to market and beat their competitors, then it represented potentially billions in new contracts," says George Spanos, technician director at The Minerals, Metals & Materials Society (TMS).

ogy optimization, which is done in the mechanical world, can help free up the parameters of the materials a bit."

For example, engineers could vary the properties of the chosen material across a component to maximize the utilization of "local" properties to meet the performance requirements of the system, Marsden says.

"This can unlock the full potential of the selected material/process combination," he says. "This assumes precise control of the processing parameters needed to create the required structures within the materials (grain structure for metallics or fiber distributions for composites) that exhibit the desired properties from which the desired system performance is derived."

It is an iterative process. "You want to identify the basic geometric envelope of a part, and to optimize the geometry assuming homogenous materials properties," Marsden says. "You then identify the areas in which the stresses are greatest and see if the introduction of locally-focused material properties would be advantageous."

The processing of the materials in each location across a part can be modelled using the appropriate techniques (e.g., calculation of phase diagrams or finite element analysis) so that the relevant heat/deformation history (in the case of metals) can be derived. The local processing history can then be used to derive the local properties to be predicted. The models can be tested in order to find an approach that produces the desired results.

"Another angle is that there may be multiple steps involved in manufacturing a part," Marsden says. "If you can model each step, and then combine the results of those different modelling approaches sensibly, you will be closer to modelling reality."

By using computational models at different length scales in the ICME environment, companies can model ways to improve material development and design optimization, model new assembly processes and predict finished product performance. It can also reduce the need for prototype production and testing, while accelerating time to production and improving weight reduction.

"It cuts down on the matrix of experimental testing that you need to do," Spanos says. "You don't eliminate experiments, because you have to validate and certify the materials, but you don't have to go into the granularity of doing hundreds of tests."

The Materials Data Challenge

An integrated approach to lightweighting requires a significant increase in the availability of materials information, as well as a new family of material models that can predict the properties of the materials based on a whole range of relevant processing parameters.

It also requires information to be transferred efficiently between different methods, and for the links between related items of information to be captured and available for interrogation.

"For example, if you can understand the link between the processing parameter, the structures within the material they create, and the resulting property displayed by that structure, then the performance of the part can be predicted—and optimized," Marsden says. He adds that Granta provides a materials

> **"When you integrate this optimization scheme, you approach design without the restraint of the exact materials being fixed up front. The designer can have more latitude. "**

information "backbone" for the ICME process—a single system in which all of the material and process data from simulation and experimentation can be captured, together with its interrelationships and technologies to get the information into and out of simulation codes, analysis packages and test programs.

However, there is currently a lack of standards for constructing and maintaining database structures so that materials information and tools can be easily accessed and exchanged. In addition, intellectual property concerns may impede these sharing efforts, as well as cost concerns about the effort required to share the data in the first place. In most cases, there is also imperfect knowledge of the precise conditions at each location of a part within every step in each process.

There are efforts underway to improve knowledge sharing. The White House Materials Genome Initiative was launched to help accelerate the development and deployment of new materials, for example. TMS is currently conducting a study on storing and sharing materials data in a way that companies can pass the information back and forth reliably and securely. "In this systems framework, it's really important to determine how we share data, and that goes across the product development cycle," Spanos says.

A promising approach is using a federation of databases in different communities that can speak to each other. "The government is going to play a big role in how to share that data," Spanos says. "Once industry gets involved, there are proprietary considerations, of course. The idea is you define that precompetitive place, and then you do as much as you can within those definitions."

New Levels of Collaboration Required

The systems-level approach requires collaboration among designers, materials specialists, mechanical engineers and manufacturing to create an integrated product development team.

"It involves design engineers interacting more closely with other engineers. There have to be champions within management to break down certain stovepipes and change the culture internally," Spanos says.

This requires internal education and training, as well as the need for ICME-experienced staff.

Verification of models and simulations will also be critical, along with managing and mitigating uncertainty quantification and risk in the modeling results.

"There is a lot of great modeling and simulation, but not enough experimental validation," Spanos says. "It's important to validate models and simulations, and that's a key activity that needs to be promoted."

There are additional challenges. In some vertical markets, there is a lack of good quantitative modeling tools, as well as data on structure-property relationships for materials. It can also be difficult to effectively integrate different codes and models.

Marrying advanced materials modeling and simulation to ICME principles could help simulate the performance of a completed part (like an aircraft or automotive component) without an extended build and test period.

Tailoring New Materials

The use of ICME could also help speed the development and use of new materials. Engineers often don't understand the properties or failure tendencies of new materials. Because it's more difficult (and often more expensive) to test and understand them, designers often fall back on traditional materials.

In the aerospace industry, this has been a particular problem as qualification time and costs have made it difficult to qualify new materials for use in aircraft. In addition, the materials have to be understood in the context of different types of production methods to predict their performance. ICME can help accomplish that.

ICME can also generate information could speed development of new materials, a process that can take decades.

DARPA's Materials Development for Platforms (MDP) program, for example, uses ICME to help compress the development cycle by as much as 75%. The program focuses on rapid materials development with specific capabilities and intended missions. Researchers will start with an application, and then work their way back to creating an appropriate material.

Oak Ridge National Laboratory, Nemak of Mexico and automaker Fiat/Chrysler are also using ICME to help accelerate the development of new materials to help achieve new fuel efficiency targets. The project is part of the DOE's Vehicle Technologies Office initiative that Ford, GM and Fiat/Chrysler are spearheading to develop a high-strength cast aluminum alloy that can be used to produce lighter powertrain components. The project is initially targeting the development of aluminum cylinder heads. The ICME approach (in combination with DOE's Titan supercomputer) is allowing the researchers to customize new alloys at the atomic level to help reach the desired material properties. They can model new alloys, then use the results to narrow their choices for additional experimentation.

As companies continue to struggle to drive weight out of their products, a systems-level approach can help speed those efforts while providing insight into new materials and production methods that can be leveraged in additional applications. **DE**

Brian Albright *is a freelance journalist based in Columbus, OH. He is the former managing editor of* Frontline Solutions *magazine, and has been writing about technology topics since the mid-1990s. Send e-mail about this article to de-editors@digitaleng.news.*

INFO → **Defense Advanced Research Projects Agency:** DARPA.mil

→ **Department of Energy's Vehicle Technologies Office:** Energy.gov/eere/vehicles/vehicle-technologies-office

→ **Granta Design:** GrantaDesign.com

→ **Oak Ridge Natioanl Laboratory:** ORNL.gov

→ **The Minerals, Metals & Materials Society:** TMS.org

→ **The White House Materials Genome Initiative:** WhiteHouse.gov/mgi

For more information on this topic, visit digitaleng.news

Optimize your Additive Manufacturing Know-How

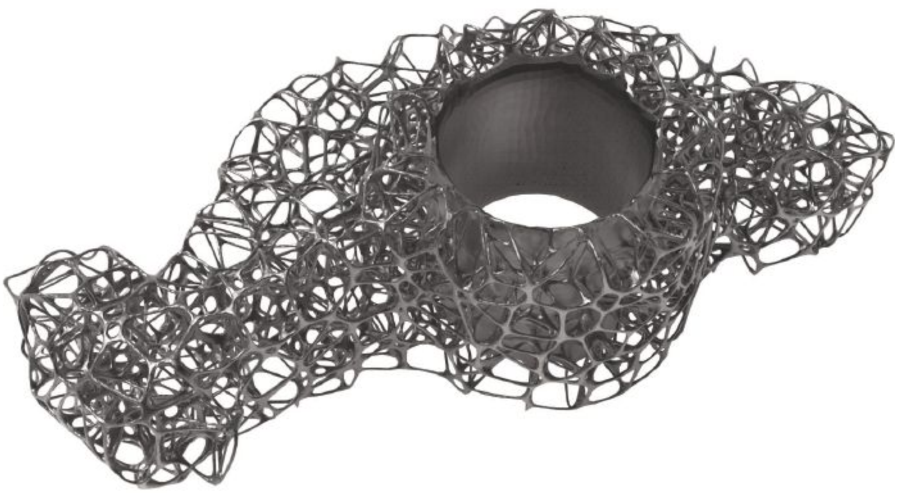
Learn from the best with these resources for part planning, design for AM, build optimization and other facets of the 3D printing world.

BY PAMELA J. WATERMAN

COVER STORY

WHETHER EMERGING FROM HOBBYIST-LEVEL INTEREST or supported by corporate mandates, AM (additive manufacturing) is becoming more mainstream for prototyping, tooling and production. But a surprisingly large percentage of design engineers (or their management) still don't make full use of its potential—and here's why. New users need to understand that just 3D printing the same old part misses out on the potential for lightweighting, simplifying or eliminating assemblies and taking advantage of customized materials. All aspects of the build process are relevant, too. Developing the mindset to create not only one-for-one replacements but optimized versions takes both motivation and the savvy to seek out learning opportunities.

During this past September's Additive Manufacturing Industry Summit in Dayton, OH, Stacey DelVecchio, AM product manager for Caterpillar, described the current situation. "Universities are [still] not graduating people that have much knowledge in AM," states DelVecchio. "Most that do are people who are personally interested in the topic and have explored it themselves."



Rendering of internal lattice structure of a metal AM part, stochastically generated with Element software from nTopology. *Image courtesy of nTopology.*

She added: "I would like to see mechanical engineers graduated with some basic knowledge of topology optimization. I want them to know these capabilities are here. It gives them a tool to really make something that they've never been able to make before."

At the same conference, John Murray, president and CEO at Concept Laser, echoed these thoughts, saying: "The game has changed. These are the tools of tomorrow. For kids who grow up with this, they won't have the [old] constraints in their minds."

PTC reinforces this idea on a webpage that simply states: "To incorporate AM, designers must change the way they think and act, and have the right tools to enable success."

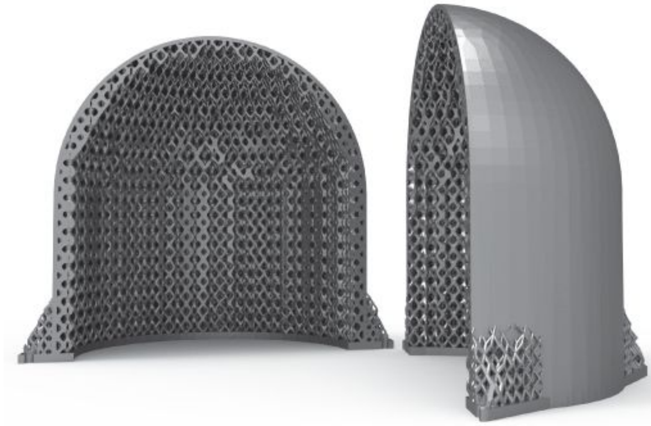
What all that means is AM is not just another approach to part construction; it changes the entire design process.

Fortunately learning to let go of traditional design constraints and think additively is quite do-able, given the increasing variety of resources developed for exactly that purpose. Software companies, design groups, universities and professional organizations all offer practical insight for newbies and experts alike.

TIP:

"Just because you can make any geometry does not make AM the best process. We all need to evaluate what process can generate the best end product at the most efficient cost. Awareness of more manufacturing processes and capabilities becomes an excellent tool in the hands and mind of a great engineer."

– Carl Dekker, president and owner, Met-L-Flo



Rendering of metal AM part, with internal lattice structure generated using Element software from nTopology. *Image courtesy of nTopology*.

Stepping up the Software

Software may be the area of greatest activity this past year, including several exciting, recently announced process simulation products. Look to both big-name companies and much newer entries for highly useful tools and expert insight. 3D CAD programs are a logical place to start, but you'll find the lines blurring as CAD programs also create lightweight structures, lattice-design companies offer FEA (finite element analysis) simulation, and thermal-process simulation packages drive changes in 3D models.

• **ANSYS SpaceClaim** is designed to simplify creating, editing and repairing CAD geometry, allow shelling, scaling and splitting models, and, of course, saving models in STL format. Now the ANSYS SpaceClaim STL Prep for 3D Printing module supports doing these tasks directly on STL files or other faceted formats such as OBJ and the new AMF. The latter—Additive Manufacturing File Format—includes some information for color and material.

• Besides its general 3D CAD modeling tools, **Autodesk** offers solutions for generative design/internal lattice structures (Autodesk Within) and the full AM workflow (Autodesk netfabb: model preparation, support design, custom lattices and design optimization). netfabb also now includes solid-modeling and near-net shape planning based on Autodesk PowerShape technology (formerly Delcam). The latest update incorporates Project Escher's open-source technology to power AM machines with multiple extrusion-based print heads working together on one part.

• **Dassault Systèmes SOLIDWORKS** 3D CAD software saves models as STL, AMF and 3MF files. With the 3MF format and Microsoft 8.1 and above, users can also directly preview/manipulate the model on the print bed and set print properties for supported 3D printers.

• **PTC** Creo 4.0 includes features that enable designers to design, optimize, validate and run print-checks on AM models in a single environment. It lets users prepare and check STL models before sending them to a printer and create parametrically controlled lattice structures. The software can also send files directly to a Stratasys Connex 3D printer, displaying and calculating support material, setting color and material, and positioning the print in the build volume.

• **Siemens PLM Software**'s flagship NX CAE product now offers three new technologies relevant to AM. Convergent modeling simplifies the ability to work with geometry consisting of a combination of facets, surfaces and solids, without the need for data conversion; topology optimization includes evaluating a model's design-for-manufacturability with AM; and the NX Hybrid Additive Manufacturing module simulates the setup of laser metal deposition and NC programming (for metal powders) and multi-axis robotics (for FDM printing and NC post-processing).

• INSPIRE from **solidThinking** lets designers easily investigate structurally efficient (generative) concepts that can be converted to CAD models suitable for AM. Newer capabilities include polynurbs tools like bridge and wrap, setup

TIP:

"AM for prototypes is not the same as AM for production. For prototyping, having multiple geometry translations—like tessellated files, which create data integrity issues—may not be important. But for production, this results in a disconnect between the CAD design and manufactured product."

– Jose Coronado, product manager, Creo Manufacturing & Creo Simulate products, PTC

TIP:
"The best way to learn design for AM is hands-on. It's just too difficult to integrate design guides without having an application to test them out on, and ultimately you'll learn more by designing and printing parts. I recommend working on an actual application and running it through the full qualification process, from design through destructive testing."

– Spencer Wright, product chief, nTopology

tools for enforcing displacements by known amounts (without knowing the force), and analyzing for buckling modes.

• **nTopology** is a new entry, with its Element software focused on helping users design, analyze and integrate all manner of 3D-printed internal lattice structures. The basic version is free; the Pro version adds more editing, analysis and data-exchange features, such as Offset Thickening, Stochastic Structures, Conformal Structures and Beam FEA, either a la carte or as a package of add-ons.

• **3D Systems** has introduced 3DXpert, a software package now available through the company's acquisition of Cimatron. This all-in-one solution targeted to metal AM helps users import part data, optimize geometry, create lattices, design customized supports, calculate scan-paths, arrange parts on the build platform and set up automated post-processing machining.

• The 10 different products within the **Materialise** Magics 3D print suite are industrial-grade tools applicable to all sorts of AM systems. Different packages help users optimize and modify (scale, texture, lattices) STL, scanned and CAD data, repair files, automatically create support structures (including for DLP-type bottom-up resin printers), set up the build platform, automate the workflow and more. The company has 25 years of experience providing 3D printing workflow solutions.

• Led by AM expert Phill Dickens, **Added Scientific** is developing Flatt Pack: the Functional Lattice Package, aimed at providing a simple method to embed triply periodic minimal-surface lattices into common 3D print files, for reduced material consumption and possibly the benefits of thermal management and impact absorption.

AM Process Simulation/Optimization

Although even the greenest mechanical engineer knows that the actual AM build process is not a push-one-button operation, the entire industry is still at the beginning of working out all the cause-and-effect details. Particularly for metal applications, sufficiently understanding the physics of each process to predict outcomes will drive specific design and/or process steps that can reduce such problems as warpage, uneven layer adhesion and residual stresses.

• **3DSIM**'s exaSIM Beta software is a cloud-based AM simulation tool that gives metal-laser-sintering users rapid insight into residual stress and distortion predictions, layer by layer. This information can guide support generation and identify trends; it is based on uniform assumed strain or scan-pattern dependent strain. 3DSIM's FLEX package, targeted to metal AM researchers, increases understanding of changes in machine, material, geometry and process parameters. Currently, it predicts porosity and melt-pool dimensions; more thermal capabilities are in the works.

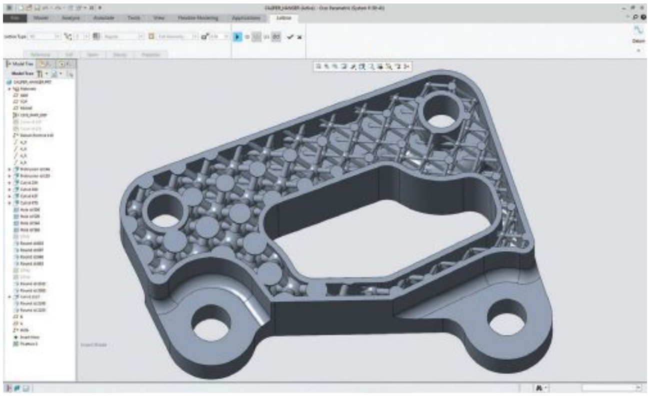
• **ANSYS** and the **University of Pittsburgh** Swanson School of Engineering have combined efforts to work on simulation tools that can address melt-pool physics and help designers avoid residual stresses. (See related coverage on page 21.) ANSYS says its next release, v18, will include use of FEA to create microscopic cellular structures within a part to improve its macroscale properties.

• The latest release of **Autoesk netfabb** helps users test, optimize, prepare and 3D print commercial-quality parts through several new features. Its Simulation for netfabb, built on technology acquired from Pan Computing, predicts part distortion based on process parameters, so designers can allow for them. This option is now available on the cloud.

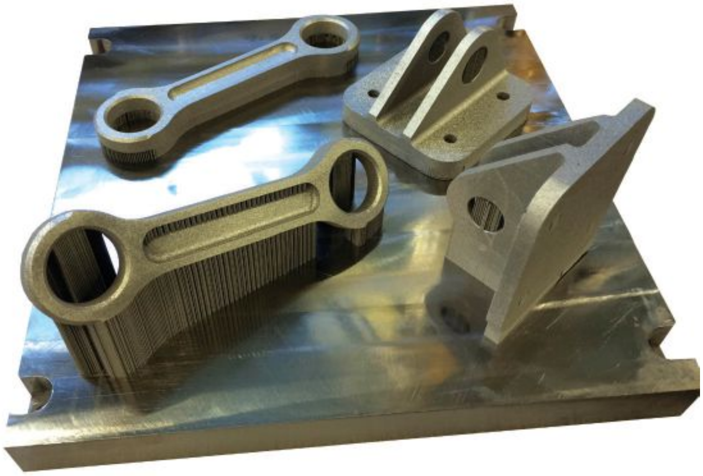
• **Simufact Engineering**, owned by **MSC Software** since 2015, has added a new offering to its line of manufacturing simulation products, Simufact Additive, for metal laser powder-bed-fusion processes. This software guides users through building calibration parts, correlating measured deformations with predicted values and identifying residual stresses. The influence of different support structures and the varied effects of cutting a part off the base plate can all be evaluated. A thermo-mechanical coupled

TIP:
"AM lets you prototype the part, test the part, select the best design and move into production—all in a fraction of the time compared to traditional methods. Having a quality STL file plays a very important role in getting a quality 3D print."

– Bryan Crutchfield, VP & GM, Materialise



Variable-size internal lattice structure design for an additively manufactured caliper-hanger, created with Creo 4.0 from PTC. *Image courtesy of PTC*.



Two additively manufactured Ti64 parts built in two orientations with supports auto-generated by exaSIM simulation software from 3DSIM. *Image courtesy of University of Louisville.*

transient analysis is coming soon.

• PrintRite3D, **Sigma Lab**'s In-Process Quality Assurance (IPQA) software, has been developed to improve repeatability and quality control of many types of manufacturing processes, including AM. The current focus is on direct metal laser sintering (DMLS); the package includes three cloud-based software modules for layer-by-layer temperature monitoring, visual inspection and data analytics. A hardware package integrates various sensors and an interface.

Other AM Resources

Do not overlook the value of lessons learned dealing with materials themselves and their role in design choices and process definition. The websites of AM equipment manufacturers provide a great starting point.

Additionally, as systems have become more open, third parties that develop, test and supply materials offer another avenue for targeted information. In the latter grouping are **Advanced Laser Materials** (plastic powders) and **DSM** (resins and now filaments), and, for metal powders, **Advanced Powders & Coatings**, **Sandvik Osprey**, **Lucideon** and **LPW Technology**. (Lucideon regularly presents webinars that cover metal-processing challenges.) And coming from yet another angle is **Senvol**, offering an online, finely searchable information database on AM machines and materials that is both comprehensive and practical.

Finally, consortiums, training centers and research groups may offer the level of expertise and advice needed for a working partnership; the following is just a sample of the activity.

• **Additive Manufacturing Consortium**, operated by EWI (Columbus, OH), performs core research in a number of AM-related areas and provides industry support through sponsored projects.

• **America Makes**, the National Additive Manufacturing Innovation Institute (Youngstown, OH), is a public/private partnership with members from industry, academia, government, non-government agencies and workforce/economic development resources. The goal is to innovate

TIP:

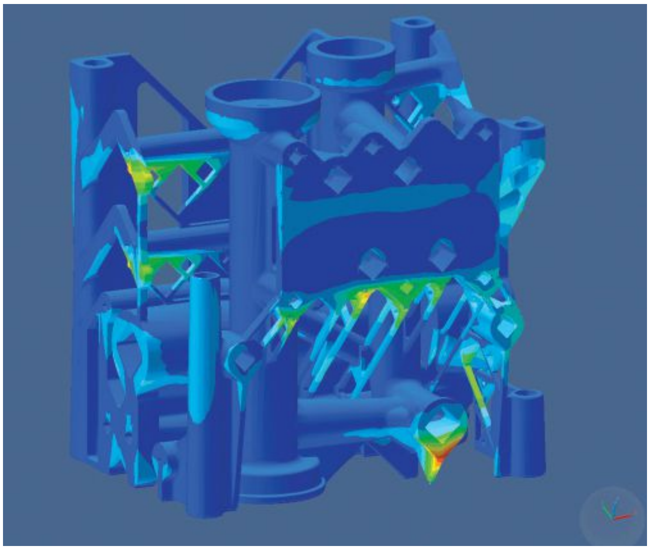
"Reducing the number of build tests as well as decreasing the build times and optimizing the required support structures (less material) will be a relevant leverage in terms of cost savings, and thus one of the criteria that will bring metal AM to a more mature and economical level."

– Michael Wohlmuth, CEO of Simufact, MSC Software

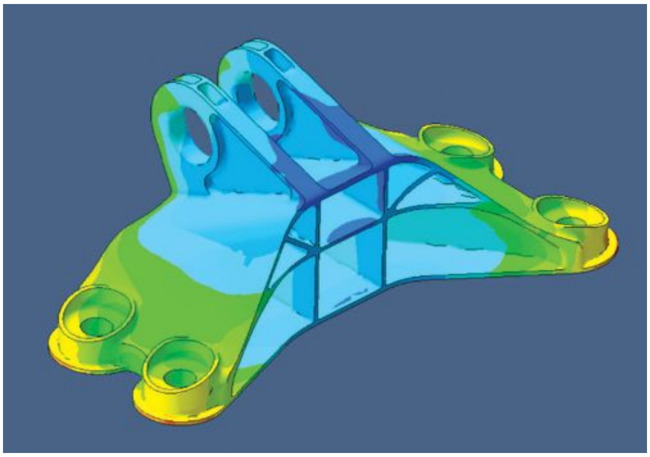
TIP:

"I encourage people to understand more about the 'physics' of how the processes work. Each process category, and within each category each type of material, may respond differently when trying to build a specific geometry in a specific orientation. Intuition based upon knowledge of one process or material may or may not be correct when applying it to another process or material."

– Brent Stucker, CEO, 3DSIM



Simulation of distortion in an additively manufactured metal manifold, performed with MSC Software Simufact Additive. *Image courtesy of MSC Software Simufact.*



Total distortion in an additively manufactured metal bracket is shown, simulated with MSC Software Simufact Additive. *Image courtesy of MSC Software Simufact.*

and accelerate AM and 3D printing at a national level.

- **Carnegie Mellon University NextManufacturing Center** (Pittsburgh) performs research in such areas as AM process modeling and planning, powder spreading and innovative component fabrication by AM; it also offers workforce training and educational outreach.
- **SME** (Dearborn, MI), in cooperation with the Milwaukee School of Engineering and America Makes, has defined a strategic AM body of knowledge that serves as the basis for its Additive Manufacturing Certificate Program. The certification course provides a solid foundation of AM knowledge.
- **University of Louisville AM Competency Center** is a joint effort between the university's long-established additive manufacturing research group and UL, a global safety science organization. The center offers hands-on training in all facets of AM for metals, specialized curriculum addressing AM manufacturing safety, and development of workforce expertise. **DE**

Contributing Editor **Pamela Waterman**, *DE's simulation expert, is an electrical engineer and freelance technical writer based in Arizona. You can send her e-mail to de-editors@digitaleng.news.*

INFO → **3D Systems:** 3DSystems.com

→ **3DSIM:** 3DSIM.com

→ **Added Scientific:** AddedScientific.com

→ **Advanced Laser Materials:** ALM-LLC.com

→ **Advanced Powders & Coatings:** AdvancedPowders.com

→ **America Makes:** AmericaMakes.us

→ **ANSYS:** ANSYS.com

→ **Autodesk:** Autodesk.com

→ **Carnegie Mellon NextManufacturing Center:** Engineering.CMU.edu/research/centers/nextmanufacturing.html

→ **Caterpillar:** CAT.com

→ **Concept Laser:** Concept-Laser.de/en/

→ **Dassault Systèmes SOLIDWORKS:** SOLIDWORKS.com

→ **DSM:** DSM.com

→ **EWI:** EWI.org

→ **LPW Technology:** LPWTechnology.com

→ **Lucideon:** Lucideon.com

→ **Materialise:** Materialise.com

→ **Met-L-Flo:** Met-L-Flo.com

→ **MSC Software Simufact:** Simufact.com

→ **nTopology:** nTopology.com

→ **PTC:** PTC.com

→ **Sandvik Osprey:** SMT.Sandvik.com

→ **Senvol:** Senvol.com

→ **Siemens PLM Software:** Siemens.com/PLM

→ **Sigma Labs:** SigmaLabsInc.com

→ **SME:** SME.org

→ **solidThinking:** solidThinking.com

→ **University of Louisville AM Competency Center:** industries.UL.com/additive-manufacturing

→ **University of Pittsburgh Additive Manufacturing Research Center:** engineering.pitt.edu/AMRL

For more information on this topic, visit digitaleng.news

The Changing Art of Making Parts

Part 2

Simulation-driven additive manufacturing advances to take on materials, organic shapes and new manufacturing techniques.

BY AMY ROWELL

WHAT IS ONE of the greatest challenges in additive manufacturing (AM)? The ability to model and predict the performance characteristics of the new materials being used in AM. Here, simulation software tools can be of significant value. There are a number of key areas where simulation can play an important role in 3D printing, such as generating a functional design, generating lattice structures, calibrating the material, optimizing the manufacturing process and in-service performance.

In particular, a critical aspect of any AM process is to be able to characterize the underlying material that is being used. Typically, with metal alloys for example, a high-intensity laser is applied to a powder bed along a CAD-software-guided path, fusing the metal layer-by-layer to build the part. The metal melts locally and, as the heat-source moves on, solidifies with the previous layer to create the fused part. The phase transformations, the cooling rates, and other machine-specific parameters, such as print speed, guide the metallurgy and the micro-structures that develop.

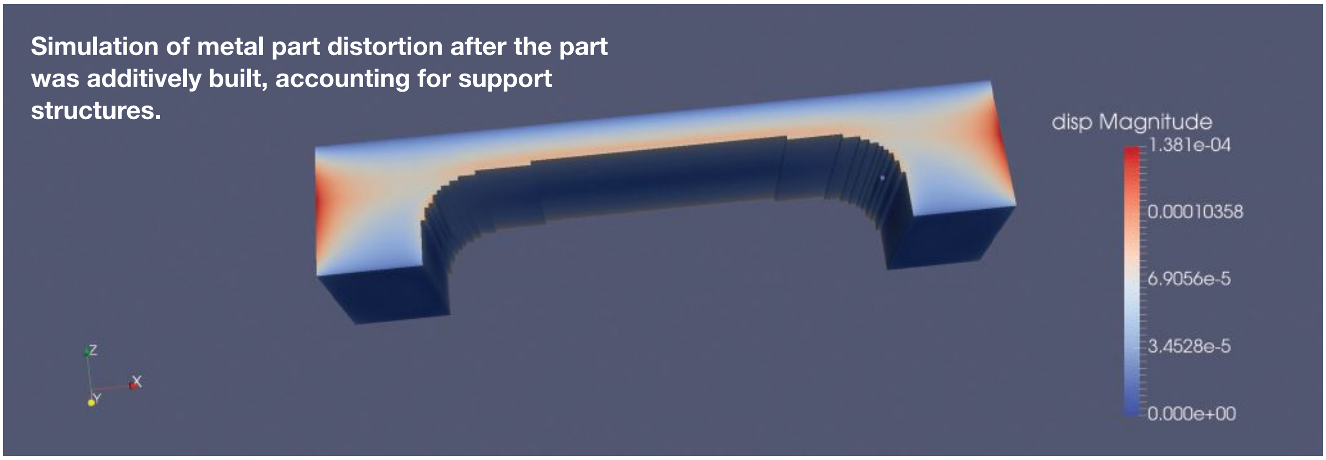
Such parts can be stronger than those made with traditional manufacturing methods such as casting, but the variabilities in mechanical properties can be significant. Therefore, there is a need to capture the multi-scale and multiphysics nature of the manufacturing process. Here, software such as Dassault Systèmes SIMULIA Abaqus user-subroutine framework can be used to aid researchers and industry to model the physics of the micro-mechanics behavior while leveraging Abaqus as the global solver for the macro-behavior of the parts.

Siemens PLM Software has tackled the AM-simulation challenge with convergent modeling and topology optimization. Convergent modeling is meant to help engineers optimize a part design for 3D printing, speed up the overall design process and provide scan-to-print functionality to make reverse engineering more efficient. Topology optimization helps analysts automate the iterative process for designing and optimizing parts for multiphysics performance including vibration, fluid dynamics and heat transfer. Together, these integrated simulation and predictive engineering analytics capabilities help evaluate the design for manufacturability and provide the confidence needed to qualify designs optimized for additive manufacturing.

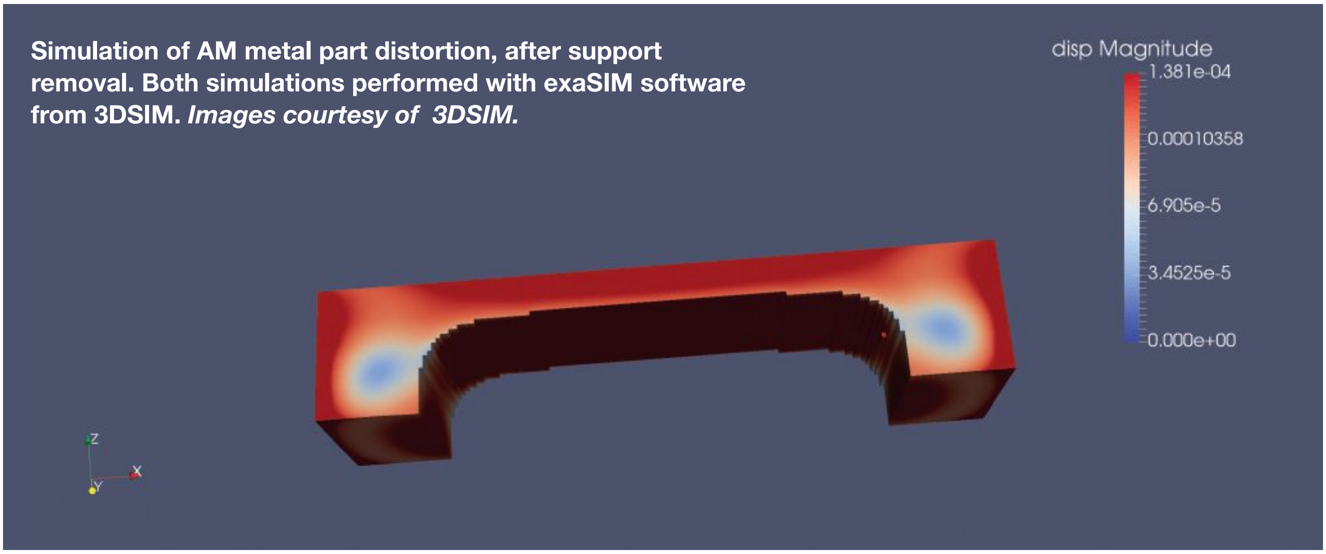
Altair, one of the market leaders in topology optimization, also offers several useful tools for tackling AM-simulation, including OptiStruct as well as Inspire from solidThinking, an Altair company. Altair has also partnered with Materialise to offer its 3-matic tool for design modification and remeshing, allowing users to redesign CAD, scanned or topology-optimized data for 3D printing.

ANSYS has also made moves to address the simulation challenges associated with additive manufacturing. Earlier this year,

If this heat exchanger was manufactured by conventional methods, it would comprise an assembly of over 100 individually manufactured components. By making some minor additive manufacturing design changes and utilizing the EOS M290 direct metal laser sintering machine, the heat exchanger assembly was 3D printed as a single component. ***Image courtesy of University of Pittsburgh.***



Simulation of metal part distortion after the part was additively built, accounting for support structures.



Simulation of AM metal part distortion, after support removal. Both simulations performed with exaSIM software from 3DSIM. *Images courtesy of 3DSIM.*

ANSYS forged a partnership with the University of Pittsburgh (Pitt) to solve some of the industry's toughest additive manufacturing problems, and has established an innovation center in Pittsburgh with the stated goal of pushing the boundaries of additive manufacturing.

3D printing metal is particularly challenging because it typically involves the use of a laser. While the laser optimizes the density of the metal for the particular application, it can also melt the metal in unexpected ways, causing the product to fail. And the rapid heating and cooling causes stresses that can deform the end product. To address this issue, ANSYS and Pitt are working together to simulate those deformations before printing to ensure that the product not only has the desired shape, but also performs as expected.

As part of the partnership, the university is also opening a 1,200-sq.-ft. additive manufacturing lab in the Swanson School of Engineering. The ANSYS Additive Manufacturing Research Laboratory is equipped with some of the most advanced additive manufacturing devices that use metals, alloys, polymers and other materials to laser print components for nearly every industry.

The partnership will also support faculty and students conducting collaborative research with ANSYS and other industry partners, including those in the biomedical, aerospace and defense industries. Lab workers will have access to the ANSYS portfolio, enabling them to explore, simulate and analyze solutions for stress and fatigue on critical components that go into products such as airplanes, cars and medical devices.

While additive manufacturing allows for precise control in creating a component at the micro- and nano-scale level (see digitaleng.news/de/?p=33673), new processes and software are required to help engineers develop parts that are designed to perform a desired function under a set of conditions. Simulation-driven product development changes the process by virtually exploring the properties of a number of design options early on, before committing to specific material and design choices. The benefit of such physics-based computational tools is that they can test millions of permutations of designs, materials, flows and shapes to find the optimal design before the engineer needs to build a single physical prototype. Not only does this new approach promise to unleash the next wave of innovative physical products, but it is a necessity to make designs more energy-efficient and sustainable.

The Need for Repeatability

What we don't know is how to effectively represent AM's multi-scale geometry in a CAD environment or how to efficiently optimize the multi-scale features of 3D printing materials, according to Dr. Brent Stucker, DFAM (Design for Additive Manufacturing) expert and co-founder of the company 3DSIM. Developers also struggle with how to efficiently simulate the link between AM process parameters and microstructures, and how to efficiently compute the effects of changes in microstructures on part performance.

Indeed, because additive manufacturing is still an evolving science, and because so many different approaches and materials are now being used to deliver specific design objectives, it is difficult to consistently achieve the kind of repeatability, reproducibility and quality (e.g. accuracy, surface finish, porosity, mechanical properties) necessary to qualify AM as a vehicle for delivering commercial-grade products, rather than just prototypes. In short, while the focus in a prototyping environment is on flexibility and short delivery times, the focus in a manufacturing process is on repeatability and traceability.

According to Stucker, the ability to successfully deliver innovative AM offerings has largely been a matter of trial and error, thanks to limited process control, evolving materials and a lack of established standards. Barriers like these introduce considerable uncertainty into AM processes, he says, and companies waste a considerable amount of time and money with failed builds on the journey to perfecting a part. To address these challenges, 3DSIM developed ExaSIM, a cloud-based AM simulation tool that is used to predict how metal-powder-bed AM machines will work by allowing its users to experiment virtually with different materials, processes, build setups and parameters—and predict their outcomes. "It's going to make it possible to qualify, certify and bring to market products from AM much more quickly," Stucker says.

Actual 3D printing speed is also an issue—in spite of claims that many of these manufacturers make regarding their 3D printing processes being "X-times faster" than their competitors. (It can, for example, take days for certain types of 3D metal-printing to deliver a finished part.) That said, industrial-strength 3D printers are increasingly finding their way into production in automotive, aerospace and the medical industry where they are showing promising results. In June 2016, for example, Airbus announced that it would be deploying Dassault Systèmes' collaborative design and simulation applications for the additive manufacturing of tooling, prototyping and parts for test flights and for production use on commercial aircraft.

Streamlining the CAD-to-Print Process

And then there are the design tools. Both the CAD/PLM providers and the AM manufacturers are eager to help make the transition to additive manufacturing as seamless as possible. We are beginning to see capabilities—both within 3D design software and AM tools—that promise to help streamline the hand-off from design to manufacturing. Many of these developers are on a quest to deliver a robust "print preview" for 3D parts that would enable engineers and designers to better evaluate not only the appearance, but also the quality and performance of a 3D printed part prior to manufacture.

For example, Autodesk's Inventor 2016 + Fusion 360 is equipped with a tool called 3D Print Studio; SOLIDWORKS 2016 offers its Print 3D Property Manager; Stratasys (through its acquisition of GrabCAD) enables users to print parts directly from the CAD file with GrabCAD Print; and 3D Systems' recently announced partnership with PTC leverages 3D Systems' 3DXpert metal printing software to provide PTC Creo users with direct CAD-to-print functionality for metals-based AM.

The reality is that we are on the brink of a major market disruptor—the mass adoption of additive manufacturing as a complement to traditional manufacturing methods. That's because being able to fabricate complex medical-grade and industrial-grade metal or plastic parts using an additive manufacturing process is more convenient, more versatile and more cost-effective than traditional manufacturing approaches in some situations.

Indeed, today's advanced additive manufacturing (AM) processes, coupled with innovative new AM tools and equipment, and a growing assortment of new materials—from strong metal alloys and specially-engineered polymers to bio-materials—promise to create a whole new class of manufactured goods and services, alongside a whole new ecosystem of customers and suppliers. However, there is still a great deal of work to be done to achieve the Holy Grail of AM: mass customization using on-demand custom materials. **DE**

Amy Rowell *is an industry analyst with a passion for researching topics related to innovation in next-gen product design and manufacturing—and all the tools that are making it possible. Send email about this article to de-editors@digitaleng.news.*

Editor's Note: *Read part 1 of this article, which appeared in the December 2016 issue, on DE's website at digitaleng.news/de/?p=33666.*

INFO → **3D Systems:** 3DSystems.com

→ **3DSIM:** 3DSIM.com

→ **Altair:** Altair.com

→ **ANSYS:** ANSYS.com

→ **Autodesk:** Autodesk.com

→ **Dassault Systèmes:** 3DS.com

→ **EOS:** EOS.info

→ **GrabCAD:** GrabCAD.com

→ **Materialise:** Materialise.com

→ **Siemens PLM Software:** Siemens.com/PLM

→ **SIMULIA:** SIMULIA.com

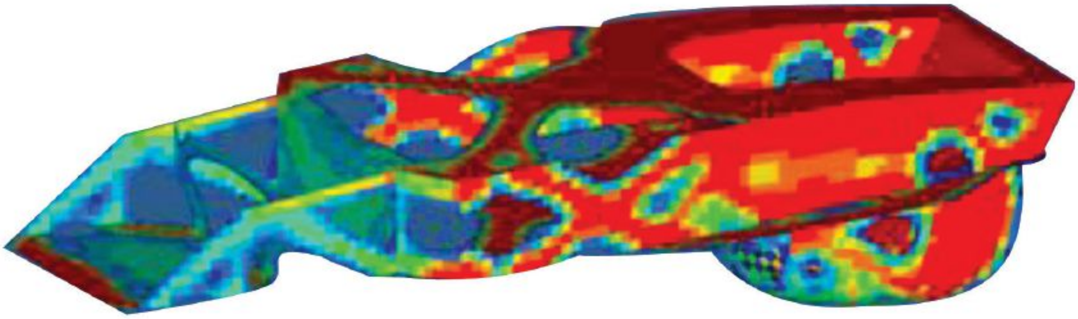
→ **solidThinking:** solidThinking.com

→ **SOLIDWORKS:** SOLIDWORKS.com

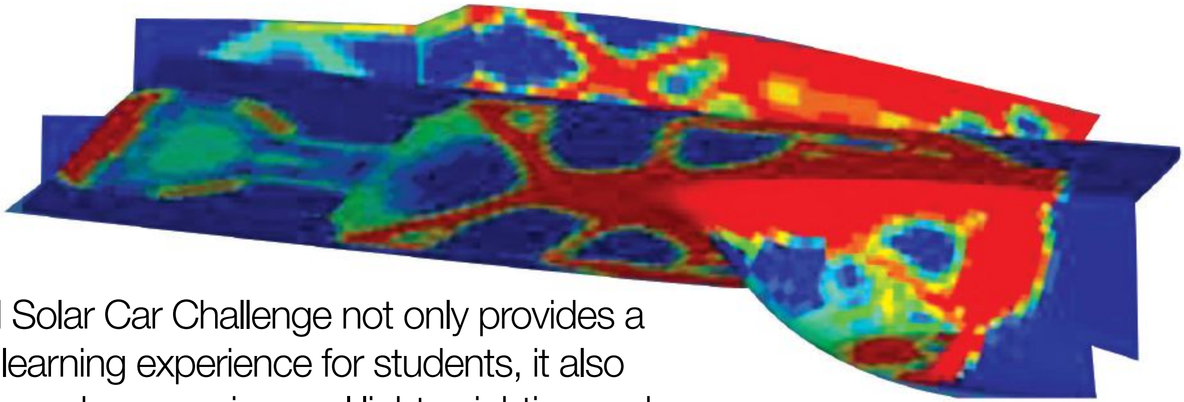
→ **Stratasys:** Stratasys.com

→ **PTC:** PTC.com

For more information on this topic, visit digitaleng.news



Lessons in Lightweighting



The World Solar Car Challenge not only provides a hands-on learning experience for students, it also provides a crash course in novel lightweighting and aerodynamics techniques.

BY BETH STACKPOLE

AS A PHYSICS MAJOR and a sophomore at MIT, Veronica LaBelle vowed from the start to take advantage of every opportunity and resource the prestigious university could offer. The roll-up-your-sleeves, can-do spirit of the Solar Car Challenge piqued her interest and LaBelle hopped on board.

Fast forward a year and LaBelle now serves as captain for the MIT SEVT (Solar Electric Vehicle Team) and is gearing up for the world competition in Australia next fall. More importantly, she's relishing the hands-on learning experience and says the crash course in aerodynamics and lightweighting far exceeds anything she could soak up in the classroom.

"It's been an invaluable experience compared to the classroom where you learn about a concept, work out an equation or do a lab," she explains. "Getting actual hands-on experience can't compare to classroom knowledge, and there's something about being set free with other students to produce a car that actually runs."

The 2017 Bridgestone World Solar Challenge—the grand prix, if you will, of the student solar car competitions—tasks teams to build an energy efficient solar vehicle that will be raced in October in Australia, on a 3,000 km journey from Darwin to Adelaide. The challenge, an exercise in design and energy management, limits solar car contenders to 5kW hours of stored energy (about 10% of what would be required) and tasks teams to come up with a design that draws the remaining energy from the sun or recovered through the kinetic energy of the vehicle.

The World Solar Challenge, like so many student engineering competitions, not only gives student competitors an opportunity to showcase their design chops and benefit from hands-on learning, it has also become a breeding ground for advances in lightweighting and aerodynamics techniques that have commercial applicability.

"This is not just a little science project for students to get their head around," says Paul Lethbridge, student and startup program manager at ANSYS, which sponsors the MIT solar car team and about a dozen or so others globally. "These teams get fully immersed in very complex problems and they are solving them with the highest degree of engineering possible."

Designs in Flux

Next year's challenge for the class of single-seat solar cars designed for speed has a litany of requirements, some old, some new. For example, the solar car must fit

LEFT: Using Altair's OptiStruct, the University of Michigan's Solar Car team was able to minimize weight on the carbon fiber chassis for its past generation Quantum vehicle while still passing all the load cases. *Image courtesy of Altair.*

inside a right rectangular prism 5,000 mm long, 2,200 mm wide and 1,600 mm high; the primary source of energy is solar irradiation collected by the car itself; there are numerous safety standards (including rear vision systems) and the solar cars must be able to negotiate a figure eight course in less than 9 seconds per side and less than 18 seconds overall, according to the official guidelines. New to the mix this year are requirements that the cars have four wheels to make them closer to commercial passenger cars, the solar array area has been reduced, and there is a new requirement for a driver-controlled parking brake on all road wheels.

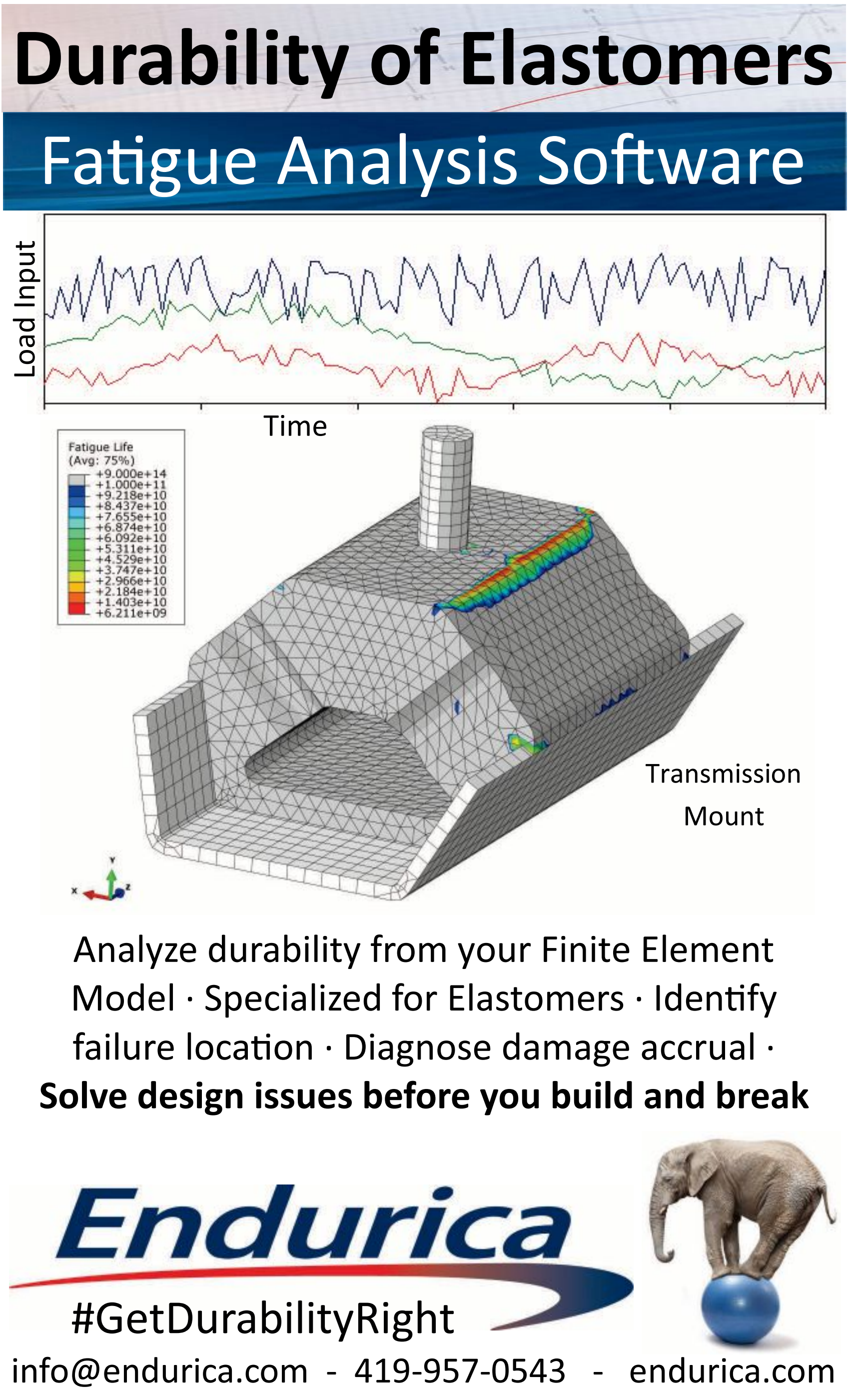
For the MIT team, the new regulations meant a reevaluation of its past generation Arcturus vehicle, which LaBelle says was a three-wheel design and leaned toward being overweight to ensure stability. With Flux, the new vehicle being readied for the 2017 race, lightweighting is a key design objective. It's being accomplished in three main ways: The team is using SOLIDWORKS finite element analysis (FEA) to determine where it can change materials, from steel to aluminum whenever possible; it's identifying areas where it can cut back on materials; and the biggest enabler—it's making increased use of composite materials throughout the vehicle. Specifically, Flux's new composite monocoque chassis is integrated into the composite lower body and serves as the backbone of the car to reduce weight, LaBelle says.

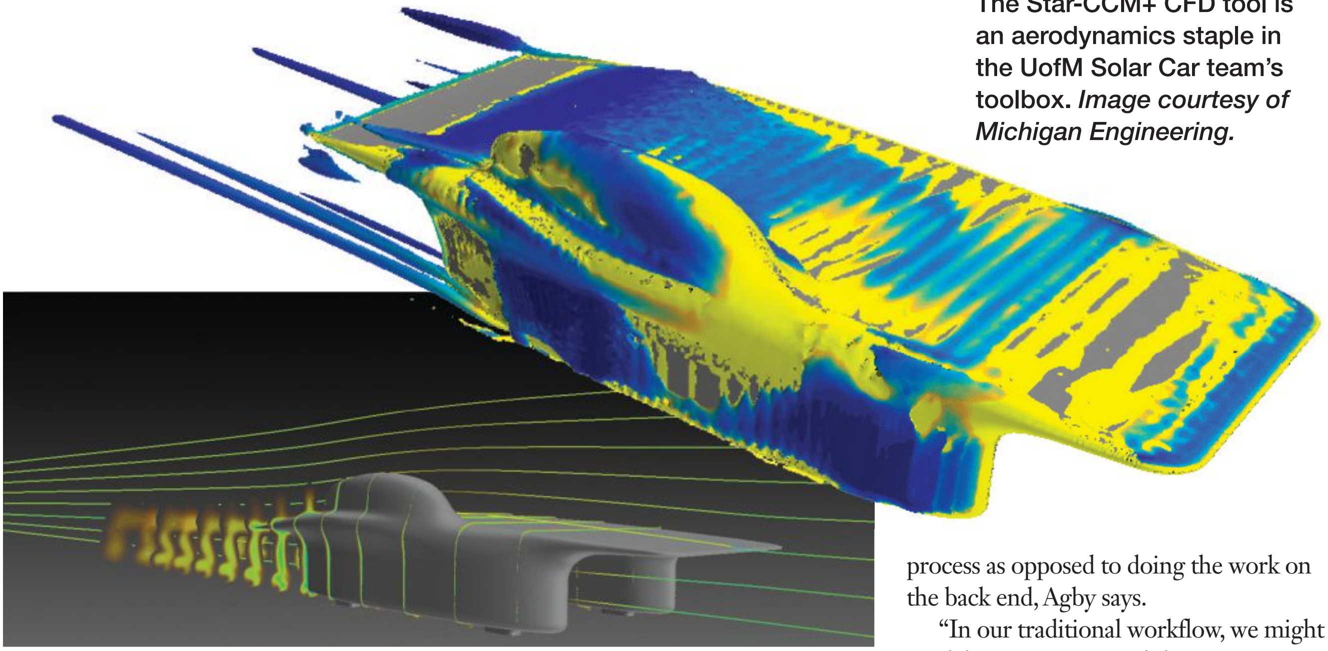
In addition to liberal use of composites, Flux uses an asymmetric design to position the driver on one side of the car in an effort to create a reduced frontal area that will minimize aerodynamic drag and power consumption, she explains. In addition, the aerodynamics team is iterating designs for the fairings and airfoil-inspired body to maximize laminar flow. Most of the modeling work was done in Rhino 3D, and ANSYS' Fluent computational fluid dynamics (CFD) was tapped to simulate the shape of the car for optimal aerodynamics.

Industry could learn a thing or two from the MIT team's work in aerodynamics and composites, notes ANSYS' Lethbridge. "The MIT car has one of the lowest drag coefficients and they have done a lot with lightweighting as well," he explains. "The use of composite materials is much more prevalent on this vehicle for lightweighting the suspension. Making use of modern materials for suspension components is very challenging because they take a hammering."

Building a Balanced Car

The University of Michigan is another long-standing contender in the Solar Car races, having come in third place a number of times, but never scoring a victory.





The Star-CCM+ CFD tool is an aerodynamics staple in the UofM Solar Car team's toolbox. *Image courtesy of Michigan Engineering.*

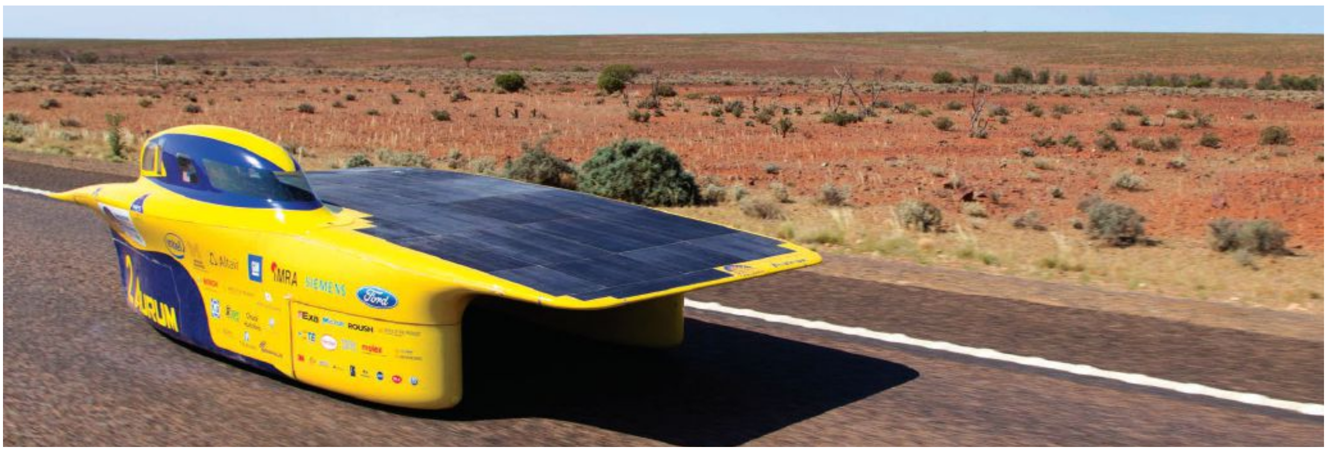
Building on what it learned with its Aurum vehicle, which competed in the 2015 race, the UofM team went back to the drawing board and decided to emphasize systems engineering tradeoffs as opposed to a straight focus on lightweighting for its next-generation vehicle.

"From the design of Aurum, we discovered that aerodynamics and lightweighting as well as other aspects (solar panel efficiency and battery design) can significantly impact each other," explains Jiahong Min, a first year graduate student studying mechanical engineering and the lead on aerodynamics. "We are doing more analysis and studying tradeoffs. As a result, the fastest car might not be the lightest, the most aerodynamically efficient or produce the most power from the sun. It would be the car that has the perfect balance between all these aspects and that's the design we are going for."

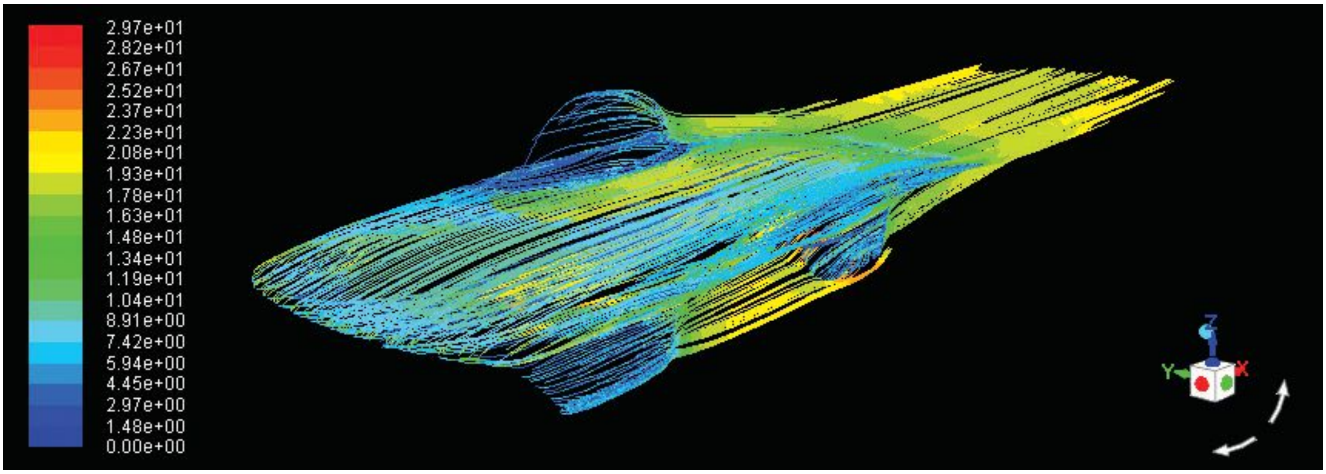
The team uses NX CAD software from Siemens PLM Software to model designs and perform structural analysis. In addition, Altair's OptiStruct optimization software is employed to help minimize weight while ensuring all the load cases are properly met according to Joshua Agby, lead mechanical engineer and manufacturing director for the UofM Solar Car team. Another big change with the next-generation car is moving simulation and optimization up further in the process as opposed to doing the work on the back end, Agby says.

"In our traditional workflow, we might model a component and then put it into a structural analysis solver to see if it passes the load cases and if it didn't, we modify it," he explains. "Now, we use the optimization software to design the part and then check with the structural solver, and nine times out of 10, it's right. Ultimately, it saves time and you get a better part."

Introducing students to simulation-driven design workflows is one of the main reasons Altair actively sponsors a lot of these student competitions, including the UofM Solar Car team, among others, according to Darius Fadanelli, Altair's director of Support Operations for the United States. "We want engineers to get comprehensive and accurate simulations so they can dramatically improve prod-



Building off lessons learned from the Aurum vehicle, UofM's Solar Car team is taking a more aggressive systems engineering approach with its latest design. *Image courtesy of Michigan Engineering*.



ANSYS Fluent enables the MIT team to perform detailed analysis to iterate designs for its work-in-progress Flux solar car. *Image courtesy of MIT, Micah Gale '18*.

Key to the MIT Flux's lightweight design is a new carbon fiber shell and chassis. *Image courtesy of MIT, Micah Gale '18*.

ucts and make better decisions," he says. "The best place to promote simulation-driven design is with students." In addition to OptiStruct, the UofM Solar Car team uses a variety of other Altair tools, including HyperMesh and HyperView.

PLM is another enabling tool used first in the Aurum effort and now being carried over the to the next-generation car, Agby says. The team is using Siemens PLM Software's Teamcenter to help manage and integrate files from the different disciplines, a task it had struggled with previously. PLM is also critical for enabling the systems engineering approach and focus on design tradeoffs, he adds.

Giving student teams exposure to tools like PLM along with getting them to pay serious attention to a design process built around tradeoffs is critical to building skills that will have lasting value over the course of their careers, explains Dave Taylor, global vice president of Marketing at Siemens PLM Software, which is a sponsor of the UofM Solar Car team, along with a team at the University of Leuven in Belgium and Principia College in Illinois.

"Tradeoffs are critical—they might start with ligh weighting as an objective, but find that by reducing the amount of material or using different material, they are suddenly faced with new challenges like a vibration or something breaking," adds Ravi Shankar, director, global simulation product marketing, at Siemens PLM Software. "None of this can be looked at in isolation, and they need to learn to take a holistic view."

There's no doubt the Solar Car team experience has taught Agby that and much more. Getting hands-on experience in FEA simulation is something not covered much in the engineering curriculum, and the lessons on how to collaborate effectively as a multidisciplinary team are invaluable and can't be replicated in a classroom environment, Agby says.

"Had I not joined the Solar Car team, I'd be a much more ignorant engineer," says Agby. "I've been forced to open up my mind and learn about other disciplines and work with people who may not understand what I'm doing. That's something you do daily in the workplace and is hard to learn in class." **DE**

Beth Stackpole *is a contributing editor to* DE. *You can reach her at beth@digitaleng.news.*

INFO → Altair: Altair.com

→ ANSYS: ANSYS.com

→ Siemens PLM Software: Siemens.com/PLM

→ World Solar Car Challenge: WorldSolarChallenge.org

For more information on this topic, visit digitaleng.news

Beyond Organic Shapes

The pursuit of biomimicry shouldn't be confined to mimicking natural shapes.

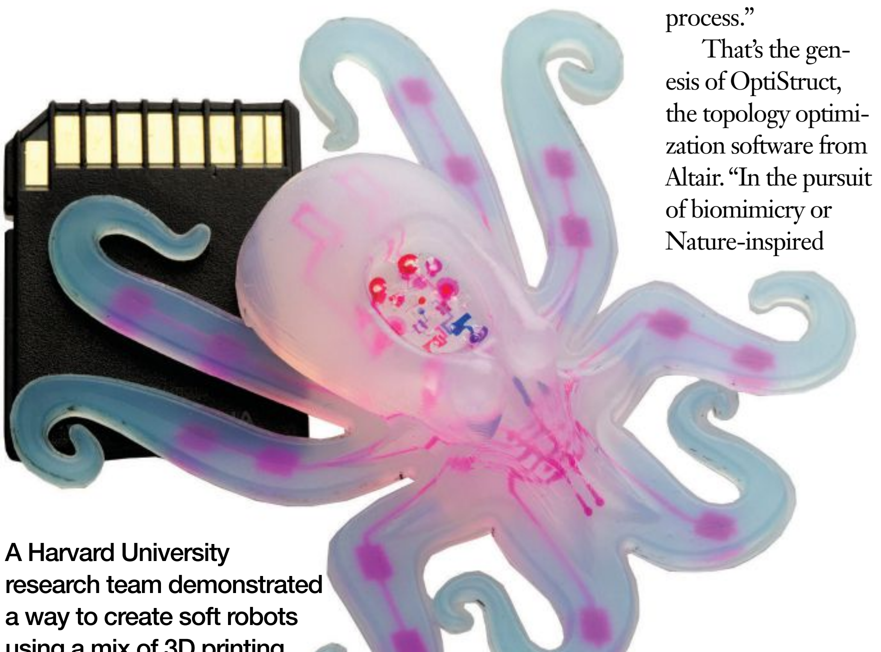
BY KENNETH WONG

SOME EXAMPLES OF BIOMIMICRY are easy to spot, because the form is a dead giveaway. The Dew Bank Bottle, a moisture-collecting device designed by the Seoul National University of Technology's Pak Kitae, not only works like, but also looks like, its biological inspiration: The dome-shaped back of the Namibian beetle. The structural beams of China's iconic stadium for the 2008 Olympic Games mimic the intricate woven twigs found in bird nests, the project's inspiration. The wedge-shape nose of Japan's Shinkansen bullet train bears a striking resemblance to the Kingfisher's beak, which the engineers studied to reduce noise and air pressure in the train's tunnel runs.

But others are harder to recognize. Sitting on an Airbus A320, most people would have no clue that the partition dividing their seating area from the rest is designed with the principles found in slime mold structures. Most drivers won't associate human bone growth with the chassis of their car—not unless they bother to dig into the history of a software program widely used in automotive for topology optimization.

In the 1990s, Jeff Brennan was a student working on his master's thesis. "I was researching orthopedic biomechanics," he recalls. "We were collaborating with Dr. Noboru Kikuchi in our study of bone growth. We figured if we could create a mathematical model of bone growth, we could simulate the process."

That's the genesis of OptiStruct, the topology optimization software from Altair. "In the pursuit of biomimicry or Nature-inspired design, you should study Nature's process, learn from it, and adopt the relevant, salient elements to your design. You shouldn't just copy the shape," Brennan, now Altair's chief marketing officer, says.



A Harvard University research team demonstrated a way to create soft robots using a mix of 3D printing, mechanical engineering and microfluidics. *Image courtesy of Michael Wehner, Harvard.*

Connecting the Dots

In 2014, Autodesk acquired The Living, a New York-based architecture and design studio. David Benjamin, The Living's founding principal, is adjunct assistant professor at Columbia Graduate School of Architecture and Pratt Institute. Now part of Autodesk Research, The Living explores new concepts and ideas using generative design, a way to leverage algorithms to seek and identify the best design options.

The Living's most prominent project was the bionic partition, a 3D-printed dividing wall between the seating area and the galley of a plane. Developed in partnership with Airbus and APWorks, Autodesk calls the component "a pioneering combination of generative design, 3D printing and advanced materials." It is "almost 50% lighter," according to Autodesk (autodeskresearch.com/projects/bionic-partition-project).

"We created a biological algorithm based on the growth of an organism called slime mold," explains Benjamin. "Slime mold grows to connect dots (sources of food) in networks that are both efficient and redundant. They are efficient because they use the least amount of material to connect the dots. And they are redundant because when one of the paths is broken, the network can route around the problem and stay connected ... Although the size and material of the partition is different than that of slime mold, the logic is similar. And in our application, this approach worked very well."

Altair's OptiStruct topology optimization software was used to explore architectural design variants for the Bionic Tower high-rise proposal. *Image courtesy of Altair and LAVA Laboratory for Visionary Architecture.*

Going Against Convention

Human bone growth follows a set formula, established by evolutionary demands. It's nature's countermeasure against stress and loads. "Based on Wolff's Law, when you place an implant, you can rely on the surrounding bones to adapt to the stress by placing more bone mass in optimal positions," explains Brennan.

Capturing the bone growth formula in mathematical terms ultimately led to the algorithm that now lies at the heart of OptiStruct. "We call it biomimicry," says Brennan, "not just because it originated from orthopedic research, but because we're mimicking nature's strategy to produce the lowest energy solution to loads."

While biomimicry principles are equally applicable to architecture and manufacturing, the adoption momentum appears to be greater in AEC (architecture, engineering and construction). That may have to do with AEC's openness to organic forms for their aesthetic appeal, and manufacturing's skepticism of such forms.

Many first-time optimization software users are surprised by the so-called mathematically optimized shape, which doesn't always conform to standard mechanical conventions. That presents a hurdle in promoting the use of algorithm-driven shape optimization, often part of biomimicry projects.

"Some conservative engineers might look at the odd-looking trusses and structures and say, 'Hmm, I don't know if I can trust this.' That's just not how things are done conventionally. So there's fear that it might break. There's a mental resistance to these odd shapes," says Brennan.

While the bone-like structures and natural shapes proposed by optimization software may look risky, the benefits could be persuasive. "We consistently create 20-30% lighter solutions even with simple brackets," Brennan says.

Brennan's experience shows people's attitude is shifting. "In the early days of OptiStruct, I had engineers remove me from meetings because they didn't think [the software-proposed shape] would work," he recalls. "But 10 years later, it's entirely different."

Failsafe Redundancy

What is mathematically optimal is not necessarily suitable for manufacturing, as many pioneers in optimization discovered. Using known principles of stress and strain, the software can propose the best geometry or topology to withstand them. But the software-proposed best structural shape is often filled with hollows or thin members that are impossible to machine or mold using conventional manufacturing methods.

To address this, Altair added Manufacturing Constraints to OptiStruct, allowing users to specify the type of manufacturing method involved. Taking these parameters into account, OptiStruct generates topology that's optimal but also manufacturing-suitable. "In 1993, when we first launched OptiStruct, it was just a 2D truss-based stress optimization solution. Now, we're able to control and leverage manufacturability, and can take advantage of advanced manufacturing methods like 3D printing that actually allow some of the previously unfeasible structural form factors to be made," says Brennan.

With more than two decades of experience and customer testimonies under its belt, Altair's OptiStruct development team now considers the next step—adding failsafe mechanisms into the software. "We can optimize for different load cases, like vibration, seismic loads, impact loads and large motion in addition to optimizing for damage tolerance. Fail safe is a way to produce topology with built-in redundancy. It might be suboptimal topology but it makes allowance for possible failures," says Brennan.

The Softer Side of Robotics

Most people think of robots as rigid mechanical beings, but some in the robotic community are seeking ways to build soft robots. Instead of conventional materials, they turn to silicon, plastic, fiber and other substances that can better mimic the behaviors of skin, muscle and blood vessels. In August, a team at Harvard University announced the birth of Octobot, spawned in a mixture of 3D printing, mechanical engineering and microfluidics.

"We do not claim that our device can mimic the octopus. We present it more as a tribute to the octopus, as we are inspired by its amazing capabilities," says Michael Wehner, a postdoctoral fellow and co-author of the paper on Octobot.

In this case, the shape of the Octobot is closely modeled on the source creature. The digital prototype was created not in a surface modeler (as its organic shape might suggest) but in SOLIDWORKS, a mechanical CAD package.

"The ultimate goal in developing the mold was to use CNC [computer-numeric controls] to cut the parts," says Wehner. "Thus, any files would ultimately be output in a suitable file format and imported to MasterCAM to generate G-code."

He says the likelihood of problems skyrockets with the addition of software packages, where importing from one to another could have caused inconsistencies, so he chose to start with SOLIDWORKS rather than beginning with a surface modeler and importing it into the mechanical CAD software.

The bionic partition, which separates the seating sections in an airplane, is designed using algorithms that mimic slime mold behaviors. *Image courtesy of Autodesk.*

Injected Circuitry

Perhaps the most innovative part of the Octobot is the semi-transparent belly and tentacles, revealing the circuitry inside like the veins through jelly skin. "The Octobot was fabricated using a novel fabrication approach called embedded 3D printing or EMB3D printing," Wehner says. "In this approach, uncured silicone elastomers are selectively poured into a mold. A needle (controlled by the 3D printer) is inserted into the still uncured silicones, and a sacrificial gel or ink is printed in the silicone. The paths printed with this ink become the internal features of the Octobot."

The Octobot is a technology demonstration of how soft robots could be manufactured. Having overcome the pesky manufacturing hurdles, the Octobot team is looking to upgrade it with autonomous navigation. "More robust actuation strategies and more sophisticated controllers are the next steps," Wehner says. "Considerable work has already been done to develop complex microfluidic devices, including analogs to the logic gaits found in electronic circuits. We believe this technology will quickly be folded into soft robot design to yield soft robots capable of sensing. This can be used for multiple gaits, steering and obstacle avoidance."

The Human-Machine Handshake

With algorithms and software playing an unprecedented role in design, the human engineers may have to redefine how they conceive, develop and test products.

"Generative design augments human creativity; it doesn't replace human creativity," says Autodesk's Benjamin. "There is a spectrum of ways to use generative design and some involve more human input than others. In all cases, the human works in collaboration with the computer to produce a design. And in some of the most amazing examples, the human creates inputs that are original and sophisticated (such as complex geometric systems) and then the computer produces outputs that are high performing and unexpected. The result is something that the human alone—or the computer alone—could never come up with."

For Wehner, biomimicry is a good reminder that human technology still has a lot to learn. "Nature provides us with extremely elegant solutions to problems," he says. "In biomimicry, we try to emulate (to a small extent) some of the surprisingly complex phenomena we see around us in nature. Looking to nature can provide us with limitless inspiration, but it also makes us realize just how rudimentary our existing technology really is." **DE**

Kenneth Wong *is* DE*'s resident blogger and senior editor. Email him at de-editors@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

INFO ➜ Octobot: wyss.harvard.edu/the-first-autonomous-entirely-soft-robot/

➜ **OptiStruct:** altair.com/optistruct

➜ **The Living, Autodesk:** autodeskresearch.com/groups/living

For more information on this topic, visit digitaleng.news

Generative Design

Generative design is an algorithm-driven approach. It relies on software programs with built-in formulas to explore and identify the best design option from a range of possibilities. Some have compared generative design to the Darwinian principle of natural selection. Examples of software programs in this market include Bentley Systems' GenerativeComponents or GC; McNeel & Associates' Grasshopper (a plug-in to Bentley Systems' GC); and Autodesk Within.

In manufacturing, the term "topology optimization" is far more prevalent than generative design. Like generative design, topology optimization software employs built-in algorithms and formulas to find the best—or optimal—shape based on user input. "Topology optimization is a subset of generative design," says David Benjamin, the founding principal of The Living, an Autodesk design studio. "Biomimicry can take advantage of generative design, but it can also use other techniques."

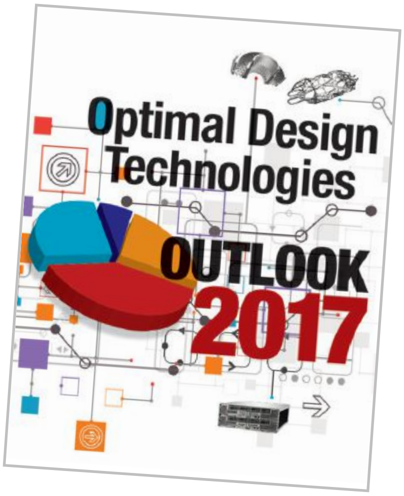
DE Digital Engineering

DE EDITORIAL WEBCAST DISCUSSION SERIES — INSIGHTS, INSPIRATION AND INFORMATION

LIVE Panel Discussion:

Optimal Design Technology Outlook

JANUARY 31, 2017 @ 2 PM ET



What is optimization? Why are some engineers skittish about it?

In the past, engineers relied on their industry knowledge, experience and aesthetic sensibilities to decide the shape of a product. Today, they have the option to turn to generative design, topology optimization and other technologies to solicit input from AI-like algorithms. But not enough of them may be taking advantage of the new tools, or even know about them.

In *DE*'s recent Optimal Design Technology Outlook survey, only 7% of the respondents say they're very familiar with topology optimization; 23% say they're somewhat familiar with it; 28% say they have never heard of it.

In this LIVE roundtable, *DE*'s Kenneth Wong moderates a panel of experts to discuss:

- How design optimization works;
- Whether the AI- or software-proposed answers can be trusted;
- Whether automated design will replace design engineers.

Moderated by
Kenneth Wong
DE's Senior Editor

Keith Meintjes
Practice Manager,
Simulation & Analysis, *CIMdata*

Andreas Vlahinos
Principal
Advance Engineering Solutions

Join us on Tuesday, January 31st for this LIVE roundtable talk!

Register Today at:
digitaleng.news/de/optimize

Don't Miss Out

Upcoming Editorial Webcast!

MARCH 2017:
Incorporating Sensor Data into System Engineering
We'll address how the growth of the Internet of Things ushers in new demands for design engineers to make use of the data being collected from connected sensors to improve system design.

Available on Demand

Next-Gen Technologies Now
DE's Kenneth Wong moderates a panel of experts as they discuss futuristic technologies that are already being implemented, and how to evaluate them for use in your engineering workflow.
digitaleng.news/de/nextgen

Predict Elastomer **Durability**

Accurate material testing is key to capturing elastomer behavior.

BY KENNETH WONG

USUALLY ROCK BANDS and music icons develop devoted fanbases, but can a rubber analysis class do that? Kurt Miller, president of Axel Products Inc., says his company's training courses do.

"A few of these classes have taken on a cult-like following over the years," he says. "We have cases where the attendee's boss attends [a class], and then the boss' boss attends it, and so on."

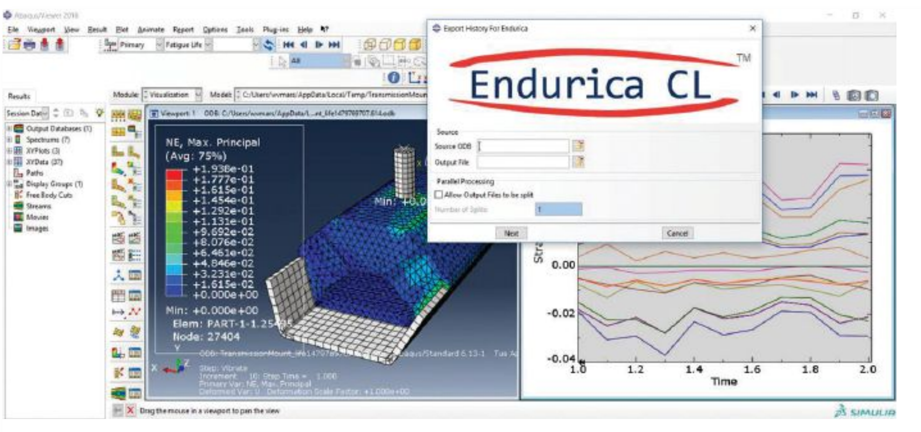
Axel offers material testing services for engineers and analysts. It focuses on nonlinear materials such as elastomers and plastics for users of simulation software. The classes listed at Axel's home page are usually labelled as "experimental:" ANSYS Mechanical Experimental Elastomers, [MSC Software's] Marc Experimental Elastomer Analysis, and so on. The term deserves an explanation.

"By 'experimental,' we mean we work with the simulation software companies to create a training course that involves both physical experiments like tensile tests and shear tests, and we use the analysis software to generate descriptive material representations in the simulation software," Miller says. "We turn real test data into realistic simulations. Attendees go into the lab and see the behaviors that the math describes."

There are some things about rubber that might not be intuitive to those used to working with metal. So, observing the eccentric behaviors of the elastomers is a good way to develop the judgments that some engineers may lack.

Rubber Eccentricities

Dr. Will Mars is a recognizable figure in the field of elastomer analysis. He won the 2007 Sparks Thomas award of ACS Rubber Division, and the 1999 Henry Fuchs award of Society of Automotive Engineers Fatigue Design & Evaluation committee. In 2008, Mars founded Endurica LLC. The company's first software product was Endurica CL, described as the "original, full-featured, standalone solver built specifically for elastomer fatigue analysis."



Endurica CL is a standalone package for elastomers, but it also integrates with other standard simulation programs like Dassault Systèmes' Abaqus. *Image courtesy of Endurica.*

"People in the metals field have been using a technology called Critical Plane Analysis for two decades," Mars explains, "This is an enabling technology that gives very accurate predictions of fatigue life when you have multiple load inputs and variable amplitude loading, as you do in real-world duty cycles. We were the first to implement it for elastomers. Our software allows you to model the impact of your part's actual multiaxial, variable amplitude duty cycle on durability."

Simulation software makers

who do not have their own solvers for elastomers usually seek partnerships with specialists like Endurica. The Endurica solver is available as a plug-in to Dassault Systèmes' fe-safe fatigue analysis software. The plug-in is called fe-safe/Rubber, and is distributed and supported by Dassault Systèmes. Endurica CL also integrates with ANSYS Workbench and can be added to many ANSYS Mechanical products, according to Richard Mitchell, lead product marketing manager for Structures at ANSYS.

The Endurica software comes with a preloaded library of elastomer materials, compiled from published scientific sources. Therefore, you can use it out-of-the-box by assigning an appropriate rubber type from the list to your digital model. But you can further refine your predictive model if you work with a testing lab to obtain accurate mathematical parameters relevant to your material.

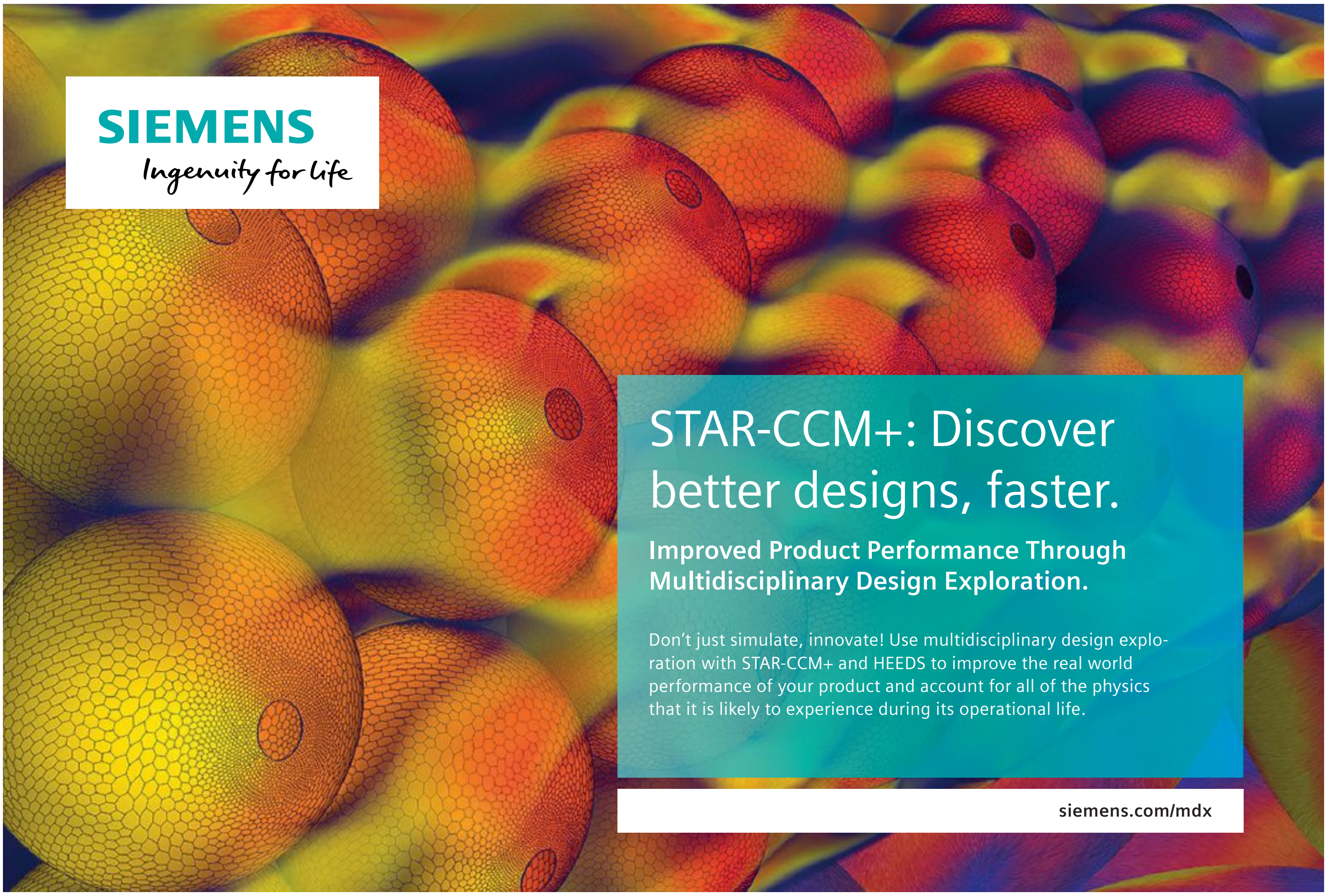
Physical Tests and Virtual Modeling

With metal, a single tensile test may serve as the foundation for virtual modeling, but not so with elastomers. "Nearly all elastomeric parts undergo complex, non-intuitive strain conditions," Miller says. "We need to perform a set of experiments subjecting elastomers to a few different states of strain to understand how they will perform in service."

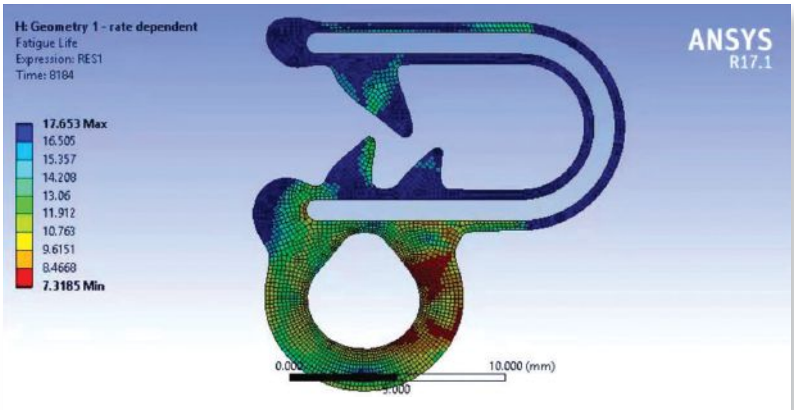
In elastomers, the mechanics of failure is nearly always related to a crack growing event. "To predict fatigue in elastomeric parts, we need to study how cracks start and how cracks grow in elastomeric materials under various loadings and temperatures," Miller says. "We also need to perform simulations where the orientation of stresses relative to crack surfaces is part of the fatigue calculation. This is sometimes referred to as critical plane analysis. Keep in mind that the stress field in elastomeric parts is very complex. It really isn't obvious where bad things may happen."

You can get a lot of information about your product's performance in the field by analyzing the damage mechanics, says Ed Terrill, applied research fellow, ARDL (Akron Rubber Development Lab). ARDL caters especially to the rubber and plastic industries. "We're very good at dissecting molded rubber goods," he says. "We do a lot of failure analysis and long-term cycling test for product life prediction."

Durability is the most time consuming to physically test, and it is therefore the most expensive, says Mars.



In elastomers, crack propagation is the typical damage mechanism. Endurica CL software, shown here, is described as the "original, full-featured, standalone solver built specifically for elastomer fatigue analysis." *Image courtesy of Endurica LLC*.



A rubber seal with contours of fatigue life resulting from a duty cycle, where the seal goes through open/close cycles. In this case, the predicted life is 21 million cycles, and failure is predicted to initiate at the red locations. Analysis done with ANSYS software. *Image courtesy of ANSYS*.

"That is why virtual methods for fatigue analysis are needed," he says.

It's also tough to model. "Fatigue behavior is extremely sensitive to many variables, and it varies on a logarithmic scale," ANSYS' Mitchell says. "You are doing good if you can predict life to within a factor of two or three. This is occasionally discouraging to new users who may be accustomed to predicting stiffness to within 10%. But it helps to keep in perspective that the output is only as good as the input, and that we rarely have enough knowledge of, or control over, the material properties, load histories and part geometry in a given scenario to really justify tighter error limits."

Advocates of digital prototyping believe that conducting destructive tests in pixels and polygons is much cheaper than doing it with full-size assemblies and physical mockups. When it comes to large structures and assemblies that are expensive to produce (for example, full-sized armored vehicles), or components that involve expensive tooling or molds to manufacture, the economics are certainly in favor of using software-based simulation and analysis. Yet, at the part and component level, the insights gained from physical testing is well-worth the nominal cost involved.

Stronger with Stretching

The properties that make rubber desirable in many applications also make the material difficult to simulate. "Rubber's stress-strain curve is nonlinear elastic, and it exhibits a cyclic softening phenomenon known as the Mullins effect," Mars points out. "The strength and fatigue properties of rubber depend strongly on temperature and rate. Sometimes in rubber, cracks can develop under long-term static loads due to creep or ozone attack."

One of the most peculiar features of natural rubber is strain crystallization. According to the article "Strain-Induced Crystallization and Mechanical Properties of Functionalized Graphene Sheet-Filled Natural Rubber" in Journal of Polymer Science, March 2012: "Natural rubber (NR) is a remarkable material that, when crosslinked, can be stretched to strains over 700% without rupture. At these high strains, rubber becomes 'self-reinforcing,' that is, it microcrystallizes, and the mechanical properties increase."

The phenomenon makes natural rubber a more preferable material than the non-crystallizing synthetic rubber for manufacturing crack- and rupture-resistant products, for parts that operate under conditions that induce crystallinity. "When that happens, the fatigue life can go up by factors of a hundred or a thousand," says Mars. "There's no equivalent to this behavior in ceramics or metal."

In most applications, rubber is compounded or mixed with various other ingredients. "Sometimes people use a gum rubber, but in most applications, you mix the rubber with fillers like carbon black, silica or clay," Mars notes. "The quality of filler dispersion can govern the size of crack precursors in rubber's microstructure, which strongly influences fatigue performance."

You can also adjust the stiffness or softness in a rubber part by using more or less curative. Take a typical tire, for instance. If you cut open a tire, you might find eight or nine different rubber compounds, says Mars: the tread, the inner liner, the sidewall ... "They all have quite distinct stress-strain and fatigue properties," he says.

With metal-based products, joints and fasteners present vulnerabilities. With rubber and elastomers, understanding the effects of adhesives may play an important role. "A lot of the molded rubber goods are laminates ... With hoses, belts and tires, we're often asked to test the adhesion strength," ARDL's Terrill says. "Products like cellphones are put together with layers and layers of adhesives and polymers. They don't use screws. So the adhesive has to hold everything in place and also act like a shock absorber."

Cluster-Powered Examination

To simulate the effects of stress on a product throughout its expected lifespan, testing service providers usually use heavy rigs, conveyer belts and environment chambers to expose the part to different loads. "One way to accelerate the aging process is to do the testing at elevated temperatures, then plot the rate of decay as a function of temperature and extrapolate to lower temperatures for the expected lifespan," Terrill says.

> **"Keep in mind that the stress field in elastomeric parts is very complex. It really isn't obvious where bad things may happen."**
>
> *— Kurt Miller, president of Axel Products Inc.*

Software-based fatigue life simulation can be run on typical engineering workstations, but larger jobs may demand additional help from the cloud or clusters. "When you model a part's fatigue cycle, your FEA job tends to get bigger—bigger files, longer run times," Mars says. "It's one thing to do an FEA to calculate stiffness. But modeling your duty cycle will involve a longer-running job with larger files."

How much larger depends on the application, ANSYS's Mitchell says. It can multiply job size "anywhere from 2x to 100x or more," he says. "The Endurica software has features that let users manage analysis size. For example, the discretization of the critical plane search can be adjusted for faster calculation, or thresholding can be applied to skip detailed calculations in elements where the loads are too small to cause damage. You can do useful calculations on an engineering workstation, but of course a cluster lets you solve much larger problems in less time."

With elastomers, physical tests and digital simulation are used to reinforce each other. The accurate material model obtained from coupon testing makes the subsequent digital simulation much more reliable. And the field sample tests may reveal unanticipated failure modes that could be used to improve the digital model for subsequent predictions.

"The most important thing is to get and test products from the field to determine how the properties of the materials change in real life," Terrill says. **DE**

Kenneth Wong *is* DE*'s resident blogger and senior editor. Email him at de-editors@digitaleng.news or share your thoughts on this article at digitaleng.news/facebook.*

INFO ➜ ANSYS: ANSYS.com

➜ **Akron Rubber Development Laboratory (ARDL):** ARDL.com

➜ **Axel Physical Testing Services:** AxelProducts.com

➜ **Dassault Systèmes:** 3DS.com

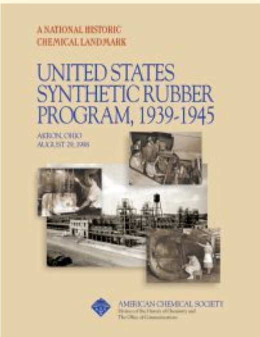
➜ **Endurica:** Endurica.com

For more information on this topic, visit digitaleng.news

The Birth of Synthetic Rubber

In a way, the Axis Powers' early territorial gains in World War II were responsible for the birth of synthetic or artificial rubber. According to the *United States Synthetic Rubber Program, 1939-1945*, a commemorative booklet by the National Historic Chemical Landmarks program of the American Chemical Society:

"President Franklin D. Roosevelt was well aware of U.S. vulnerability because of its dependence on threatened supplies of natural rubber, and in June 1940, he formed the Rubber Reserve Company (RRC) ... The onset of World War II cut off U.S. access to 90% of the natural rubber supply ... After the loss of the natural rubber supply, the RRC called for an annual production of 400,000 tons of general purpose synthetic rubber to be manufactured by the four large rubber companies. On December 19, 1941, Jersey Standard, Firestone, Goodrich, Goodyear and the United States Rubber Company signed a patent and information sharing agreement under the auspices of the RRC."



Learn more at acs.org.

Monitors Are **Looking Good**

Engineers can use large displays with increased resolution and touchscreen capabilities to improve how they interact with their designs.

BY JESS LULKA

AS THE PRODUCT DESIGN LIFECYCLE becomes more digitized, engineers spend their days looking at screens. Viewing files on a screen makes it easier to manipulate 3D CAD data and make changes to digital files; but that also means hardware manufacturers must ensure crisp color quality, ease of use and advanced interfaces.

"In the last couple of years, most of the technology advancements—and in-the-near future—will be about the resolution, size and aspect ratio," says Kenneth Mau, senior product marketing manager at ViewSonic.

Currently, standard resolution for HD displays is set at 1080p. With advancing display technologies and standards, more manufacturers are moving to 4K, which measures pixels horizontally and calculates a higher number of pixels and an average resolution of 3840x2160.

Despite the fact that there has been more of a push for these high-density resolutions for consumer-based applications, Mau says 4K screens offer professionals the ability to display finer details and more content, taking advantage of available display space.

Selecting a Screen

When looking at monitor selections, there are a number of factors to take into consideration before making a selection, according to Mitch Callihan, director, Commercial Displays Business Unit, HP. These include: quality, reliability, screen performance of the display (that is if the display is designed for the demands of engineering applications), warranty, bezel design, display size, resolution, color accuracy, connections, panel shape and 3D stereo capabilities.

"Any one of these, or a combination of these, display aspects can dramatically improve productivity, accuracy and quality of the work that is performed at the desk," Callihan explains.

Chris Wang, business line management, Monitors at BenQ America, agrees. "[The] right monitor that offers ergonomic adjustments and eye protection means work can be done more comfortably, especially as engineers have to spend hours working on their computers," he says.

With traditional desktop monitors, engineers can also find solutions that integrate touchscreens, new display types,

INFO ➜ BenQ: BenQ.us

BenQ PD 3200Q & 3200U (pictured)

- **Size:** 32 in.
- **Resolution:** 2560x1140
- **Type:** VA
- **Aspect Ratio:** 16:9
- **Connections:** 4 USB 3.0, HSMI 1.4, DVI, DisplayPort, Mini-DisplayPort

INFO ➜ Dell: Dell.com

Dell 27 UltraSharp InfinityEdge Monitor

- **Size:** 27 in.
- **Resolution:** 2560x1440
- **Type:** IPS
- **Aspect Ratio:** 16:9
- **Connections:** USB 3.0, HDMI HML, DisplayPort, Mini-DisplayPort

INFO ➜ ViewSonic: ViewSonic.com

ViewSonic VP2771 & VP2780-4K (pictured)

- **Size:** 27 in.
- **Resolution:** 2560x1440 and 3840x2160
- **Type:** IPS
- **Aspect Ratio:** 16:9 and 20M:1
- **Connections:** Up to 5 USB 3.1, HDMI, HDMI HML, DisplayPort, 3.5mm audio out

or are significantly larger in size. While some of these features are geared more toward the consumer market, they do have benefits for engineering use cases. "Touch, in general, will enhance the interaction between users and systems," says Mau.

Touchscreen and high-resolution displays are often segregated into different portfolios so engineers have to choose which feature would be more beneficial for their workflow. "[A touchscreen] is more often observed with high-end professional laptops or tablets, and not necessarily needed for desktop applications, as the uses of desktop can be different than a laptop/tablet," Mau explains.

However, some manufacturers are bucking this trend with all-in-one desktop computers and workstations that include touchscreens. For example, Microsoft's new Surface Studio has a 28-in. PixelSense display that can be used upright or tilted down to draw on it like a drafting table. The 10-point multi-touch screen has 10-bit color depth and is compatible with the Surface Pen, according to the company. When it arrives early this year, it will compete with HP's Z1 Workstation All-in-One models (digitaleng.news/de/?p=17550); first released in 2012 and already on their third generation.

Adding touchscreen capabilities and heightening resolution aren't the only advancements in display technology. Companies are also integrating OLEDs (organic light-emitting diodes). This type of display technology consumes much less power than a traditional LCD display because they do not require a backlight. OLEDs also enables displays to have a larger field of view and the ability to be produced in larger sizes. However, despite providing a brighter, crisper image, not all OLEDs have a longer lifespan than their LCD counterparts, and manufacturing costs are still somewhat high.

For enhanced user experience, engineers may also increasingly find displays that incorporate either anti-glare or low blue light mode. With this feature, users can reduce eye-strain by having reduced flicker rates or excess blue light.

Going Big

Larger displays that surpass the average desk size can offer benefits for collaborative engineering and design reviews. "A large-sized monitor with high resolution would ensure engineers get a holistic picture while eliminating the worry of missing out on crucial details as engineers can see clearly and have ample workspace for their UI (user interface) toolboxes as well as reviewing their work," Wang says.

One offering taking monitor size to the extreme is the Microsoft Surface Hub, which the company describes as "the future of group productivity." The Surface Hub comes in 55- and 85-in. sizes, and is equipped with Windows 10, Skype, OneNote and a handful of apps for viewing 3D models and CAD files. Google is also entering this "digital whiteboard" space with the Jamboard, a 55-in. 4K touchscreen that will be available later this year.

As designs increase in complexity and engineers spend more time designing and simulating digital models, ensuring the display is suited for CAD/CAM/CAE applications is critical. By taking advantage of more connectivity, higher resolution, larger monitors and even touchscreen capabilities, engineers can make sure even the smallest design details stand out. **DE**

Jess Lulka *is associate editor of* DE. *Send e-mail about this article to de-editors@digitaleng.news.*

INFO → HP: HP.com

HP Z1 G3 All-in-One Workstation
- **Size:** 23.6 in.
- **Resolution:** 3840x2160
- **Type:** IPS
- **Aspect Ratio:** 16:9
- **Connections:** 6 USB 3.0, 2 USB 3.1 Type-C, Thunderbolt 3, microphone, audio

HP Z27s
- **Size:** 27 in.
- **Resolution:** 3840x2160
- **Type:** IPS
- **Aspect Ratio:** 16:9
- **Connections:** 4 USB 3.0, 1 audio, HMDI 1.4, HDML MHL, DisplayPort, Mini-DisplayPort

HP Z34c Curved Display (pictured)
- **Size:** 34 in.
- **Resolution:** 3440x1440
- **Type:** VA
- **Aspect Ratio:** 21:9

INFO → Microsoft: Microsoft.com/surface

Microsoft Surface Hub (pictured)
- **Size:** 55 and 85 in.
- **Resolution:** 3840x2160 and 1920x1080, respectively
- **Type:** 100-point multi-touch, projective capacitance optically bonded sensor
- **Dynamic Contrast Ratio:** 1300:1 and 1400:1, respectively
- **Connections:** Multiple USBs depending on model, Ethernet, DisplayPort, 3.5mm stereo out, RJ11

Microsoft Surface Studio All-in-One
- **Size:** 28 in.
- **Resolution:** 4500x3000
- **Type:** 10-point multi-touch
- **Aspect Ratio:** 3:2
- **Connections:** 4 x USB 3.0 (one high power port), full-size SD card reader (SDXC) compatible, Mini DisplayPort, 3.5 mm stereo out, Ethernet

EDITOR'S PICKS

Each week, **Tony Lockwood** *combs through dozens of new products to bring you the ones he thinks will help you do your job better, smarter and faster. Here are Lockwood's most recent musings about the products that have really grabbed his attention.*

dSPACE Updates Hardware-in-the-Loop Simulator

Latest offering can hold up to 18 I/O boards.

The SCALEXIO LabBox is a hardware-in-the-loop (HIL) system for testing your new functions upfront, early and often in your development cycle from your desktop.

A SCALEXIO LabBox setup is two desktop-sized units that work as a team. The first is a SCALEXIO Processing Unit, a Xeon processor-based system with the computing power for real-time simulations of compute-intensive models. The second unit is the LabBox itself, which can hold up to 18 I/O boards.

MORE → digitaleng.news/de/?p=33141

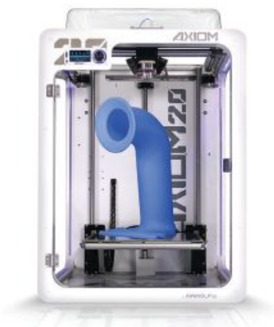
FARO Introduces Vantage^E Laser Tracker

New offering expands the company's laser tracker portfolio.

The Vantage^E is intended for short- to medium-range applications, which means its provides you a measurement range of up to 82 ft. (25 m) to work in. In comparison, the premium Vantage Laser Tracker can handle short- to long-range measurement applications of up to 262 ft. (80 m). Both offer accuracy of up to 0.0006 in. (0.015 mm).

The Vantage Laser Trackers come ready for wireless communications and fully support FARO's line of 3D metrology software.

MORE → digitaleng.news/de/?p=33334



Airwolf 3D Printers Ships AXIOM 20 System

Users can take advantage of auto-calibration and dual extruders.

The just-announced AXIOM 20 additive manufacturing system from Airwolf 3D Printers is a desktop 3D printer suitable for industrial use in an industrial-strength steel and aluminum frame with see-through, 4 mm thick borosilicate glass plate sides. It has a 25x23x35 in. (635x584x889 mm) footprint, and the company says that it can run 30-plus hours at a shot.

The AXIOM 20 calibrates its print bed automatically before beginning every print, and has dual extruders.

MORE → digitaleng.news/de/?p=33388

BOXX Technologies Equips Workstation for VR

GoBOXX MXL VR is suited for engineers, architects and digital content creators.

The GoBOXX MXL VR is built around an Intel Core i7-6700K processor running at 4GHz. That's a quad-core, desktop-class CPU. It has Turbo Boost technology to overclock processing performance to up to 4.2GHz, and it has 8MB cache memory. You can extend the GoBOXX MXL VR's base 16GB of RAM up to 64GB. Your operating system is 64-bit Windows 10.

For graphics, the GoBOXX MXL VR is equipped with an 8GB NVIDIA GeForce 1070 GPU.

MORE → digitaleng.news/de/?p=33492

FAST APPS

Engineering Case Studies

Built-In Performance

The Evora chassis from Lotus Cars was designed to be lightweight from the start.

The Evora chassis is composed of an extruded and bonded aluminum structure, developed for its lightweight yet incredibly stiff design. The front subframe carries the suspension, brakes, cooling and steering, while the central tub contains the driver's cockpit and safety cell—a format closely reflecting the layout and construction of modern-day racing cars—with the rear subframe carrying the engine, transmission, suspension, brakes and exhaust system.

The Evora is renowned for its precise handling and excellent ride. This is due in part to the award winning, lightweight and stiff chassis design. It's so stiff that it takes 27,000 newton meters to twist it just 1°. The chassis' strength allows Lotus engineers to make the suspension more compliant, increasing comfort without compromising the ride and handling dynamics. Completed cars undergo rigorous rolling road and water-ingress tests to ensure ultimate reliability and performance.

How Did it Start?

Lotus needed to create a chassis design with maximized performance and commercial efficiency for the planned volumes of 2,000 per year for six years. Additionally, the time to market was set at 24 months. This is typical of the challenges faced by Lotus Lightweight Structures.

The key to success is a strong DFM (design for manufacture) process in parallel with the product development, and engineers spent many weeks seeking the optimum architecture with the design team that would generate the required stiffness, crash performance and manufacturing project efficiency.

Key Developments

Achieving a highly controlled front-end crash performance is important. The team worked on a stacked series of extrusion sections to initiate primary and secondary collapse modes. The buckling of these was further controlled by the distribution of the self-pierce rivets within the front-end assembly. Results were validated both virtually and in the laboratory to ensure NCAP compliance.

The bonded chassis also includes use of a double-folded side member to carry the main loads in the frame, but without the need for complex stretch- or hydro-forming. This is enabled by notching the extrusion, followed by a controlled fold. The section is stabilized with local welds through the component process, and the joint is completed as part of the final assembly. High levels of stiffness are retained.

MORE ➜ digitaleng.news/de/?p=33984

Racing to a Lighter Design

ELBFLORACE and Technische Universität Dresden collaborate for a lighter, stronger steering column mount.

Michael Süß is a Research Fellow at the Technische Universität Dresden who is currently working on his doctorate focusing on design guidelines for additive manufacturing/electron beam melting. In addition to this, Süß also works closely with the Fraunhofer Institute for Manufacturing Technology and Advanced Materials IFAM.

When looking for a demonstrator to design as a portion of his research, Süß thought back to his time working on a Formula Student team. "I had a history of working on a Formula Student team and wanted to help the current team at the Technische Universität Dresden out," notes Süß. "I asked the ELBFLORACE Electric Formula Student Team to suggest a volunteer who is currently working on their project thesis to collaborate with on this project." This is where Süß met Lucas Hofman, a current student at the Technische Universität Dresden.

Together, Süß and Hofman set out to find a current part on the car that made the most sense to be redesigned for additive manufacturing/electron beam melting. Ultimately the part selected for the redesign was the steering column mount. "The current steering column mount had four different areas that were at different angles to each other, because of this, it was extremely difficult to produce with a 5-axis milling machine," says Hofman. "The solution to produce this part consisted of four different milled aluminum parts that were all bolted together."

solidThinking Inspire in the Design Process

Süß and Hofman both learned about solidThinking Inspire in different ways. Süß was first introduced to Inspire at a workshop that took place at the international trade show, Euromold. Hofman was first introduced to the tool at a Formula Student workshop that his university was involved in. Both were immediately impressed with the ease of use of the tool. Süß notes: "I love how easy it is to use the PolyNURBS features, it allows us to quickly take optimization results and reconstruct the part so it is ready for manufacturing."

MORE ➜ digitaleng.news/de/?p=33974

➜ For the full application stories, visit digitaleng.news/de/fastapps

AD INDEX

| COMMENTARY |

by Fernando de la Vega

How Do We Design Thin, Flexible Phones?

THE FIRST SMARTPHONE, SIMON, was released by IBM in 1992. The device was 200x64x38 mm and weighed a hefty 1.1 lbs. Size was not the only reason that Simon didn't last long on the market—but it was certainly chief among them.

Phones shrank dramatically in the 15 years after Simon hit the market, then the rate of shrinkage stalled. In recent years, the thickness of the smartphone has barely budged. Other innovations to the smartphone form factor, such as flexibility and weatherability, are also stalled.

Many consumers are interested in a thin, flexible phone design. Back in 2011, researchers at Queen's University in Canada devised a paper-thin phone prototype. The appeal was obvious enough that commentators predicted full commercialization within five years. Yet a thin, flexible design aesthetic for smartphones has so far failed to reach the market. Now more than ever, as display size begins to grow again due to rising demand for mobile video, there is an acute need for phones to become thinner to offset increases in width and height. As manufacturers struggle to distinguish themselves in a crowded market, the appearance of the phone and the price tag are two of the only differentiators available. A thin phone design stands out from the pack.

How can we achieve the dream of the super-thin, flexible phone that many consumers still hold dear? And more vitally, how can it be done at a price point that consumers find appealing?

Cellphones can use new technology to bring thin, flexible and durable phone design to consumers on a large scale. Incredibly, technology has progressed so quickly that thin, flexible designs could conceivably be offered at a lower price point than thicker phone designs. All that's needed is for manufacturers to adopt and scale these technologies.

Inspiration from the Now

One technology that could enable thinner phones is wireless headphones. Wireless headphones have just recently broken into the mass market with the iPhone 7. However, Apple has not yet seized the opportunity to redesign the phone, even though the advent of wireless headphones gives them the option to make the phone body thinner. The iPhone 7 is 7.1 mm thick, just like the iPhone 6. However, the absence of a headphone jack leaves the possibility open for the design team at Apple to make the phone thinner—or even flexible—in the future.

A second step toward a thin design aesthetic is printing antennas directly onto the phone body. All antennas have metal in them, but most of the antennas in smartphones today are made separately from the phone, and as a result they are bulky and relatively expensive.

In modern phone design, every millimeter counts. Today's smartphones hold up to 13 antennas inside the main body, which transmit and receive radio signals. By jetting conductive ink onto pre-manufactured plastic parts, phone manufacturers can equip devices with lightweight and highly receptive antennas that take up less space inside the phone's body.

Printed antennas can be affordably introduced with low-cost conductive ink that contains nano metal particles. This process, through which antennas can be printed onto existing phone parts such as the case or the boards, is called additive digital production. Printing antennas directly on to phone parts through additive digital production will allow manufacturers to make less expensive devices and also to reduce the volume of the phone. This unlocks new design opportunities, including a thin phone design or even flexible and weatherproof designs.

Printed antennas are more common today than in the past, but cell phone companies have far to go before the space used for antennas is minimized. Using conductive ink to fabricate printed antennas is a good first step. Conductive ink transmits and receives electromagnetic waves well, while using less space. Printed antennas also offer meaningful cost reductions for the manufacturer—electronic printing in 2D saves on materials and can reduce overall cost of production, especially because the ink can support 24/7 production and high throughput.

Consumers are increasingly excited by the potential of super-thin and bendable phones. Manufacturers now have the tools to make this holy grail of smartphone design a reality. Wireless technology for audio and conductive ink for printed antennas are two of the most promising technologies that are available today for thin phone innovation. Soon, super-thin and flexible phones may be available to consumers for the first time. **DE**

Fernando de la Vega *is the founder and CEO of PV Nano Cell Ltd (pvnanocell.com). Send email about this commentary to de-editors@digitaleng.news.*

INJECTION MOLDING THAT CRUSHES CONVENTIONAL MANUFACTURING WISDOM.

At Proto Labs, we have the automation and capacity to deliver low-volume production runs in just 15 days or less. We call this a game-changer.

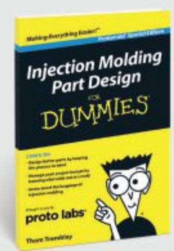
DIGITAL MANUFACTURING FOR THOSE WHO NEED PARTS TOMORROW.

proto labs®

Real Parts. Really Fast.®

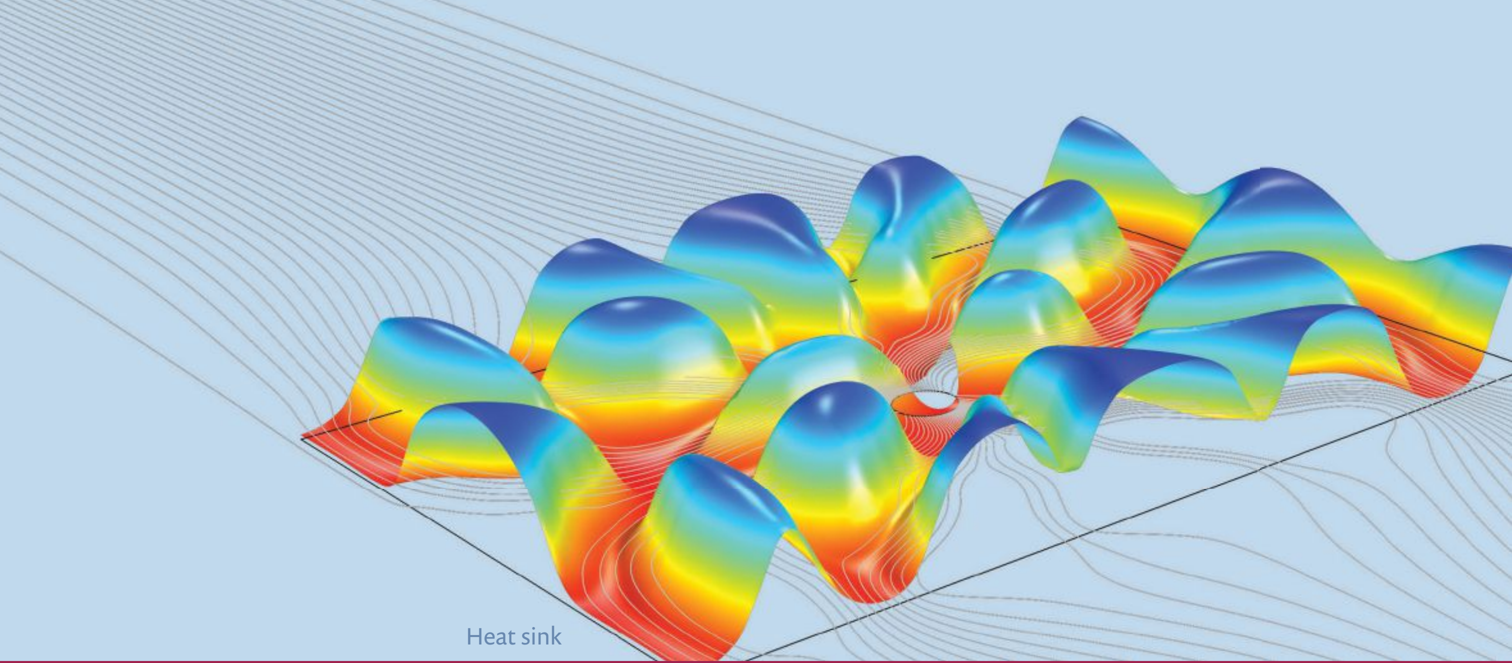
3D PRINTING | CNC MACHINING | INJECTION MOLDING

ISO 9001: 2008 Certified | ITAR Registered | © 2017 Proto Labs, Inc.



FREE BOOK

Request your Injection Molding for Dummies book at **go.protolabs.com/DT7ED.**



MULTIPHYSICS FOR EVERYONE

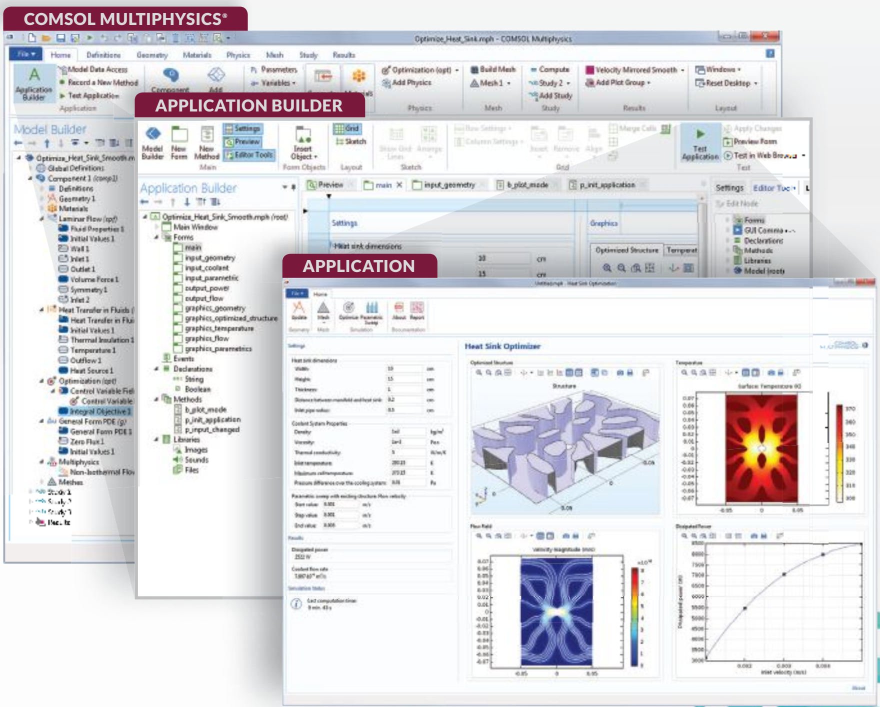
The evolution of computational tools for numerical simulation of physics-based systems has reached a major milestone.

Custom applications are now being developed by simulation specialists using the Application Builder in COMSOL Multiphysics®.

With a local installation of COMSOL Server™, applications can be deployed within an entire organization and accessed worldwide.

Make your organization truly benefit from the power of analysis.

comsol.com/application-builder



COMSOL

© Copyright 2016 COMSOL. COMSOL, the COMSOL logo, COMSOL Multiphysics, Capture the Concept, COMSOL Desktop, COMSOL Server, LiveLink, and Simulation for Everyone are either registered trademarks or trademarks of COMSOL AB. All other trademarks are the property of their respective owners, and COMSOL AB and its subsidiaries and products are not affiliated with, endorsed by, sponsored by, or supported by those trademark owners. For a list of such trademark owners, see www.comsol.com/trademarks.