NOVEMBER/DECEMBER 2021 | VOL 179 | NO 8

ADVANCED MATERIALS & PROCESSES

MATERIALS TESTING/CHARACTERIZATION

AUTOMOTIVE ALUMINUM PART XII

P. 16

ASM INTERNATIONAL

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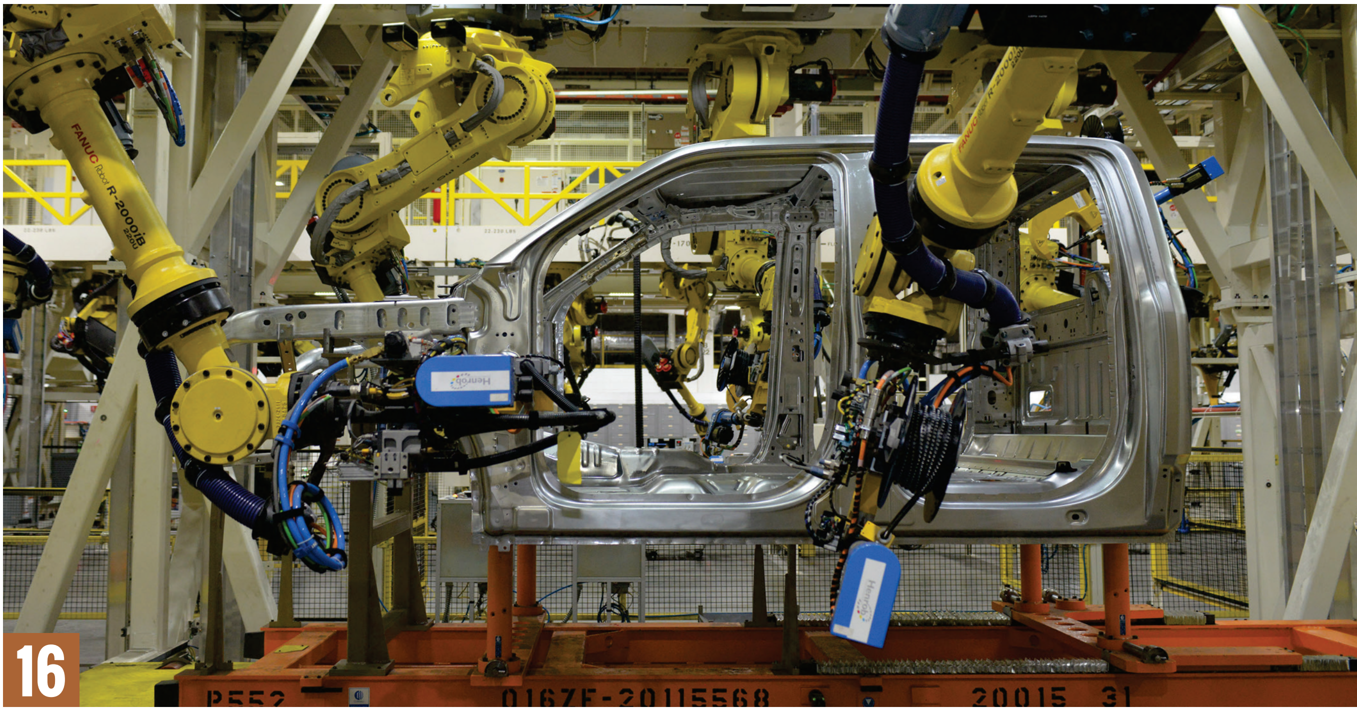
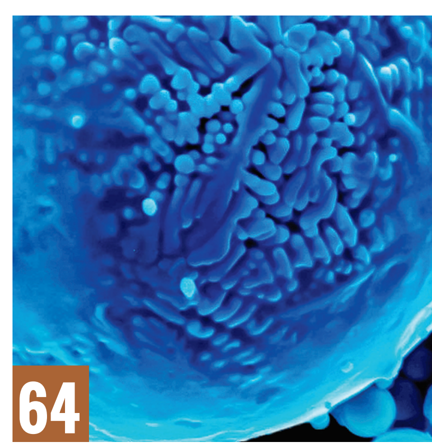


On the Cover:

Ford's 2015 F-150 features an all-aluminum body. Courtesy of Ford.



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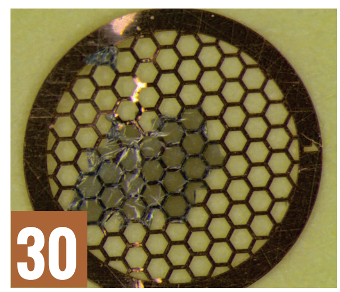
FEATURES



TRENDS

INDUSTRY NEWS

DEPARTMENTS

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ADVANCED MATERIALS & PROCESSES

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OPPORTUNITY TO THRIVE

The bipartisan infrastructure bill recently signed into law in the U.S. has financial analysts placing bets on which companies are sure to benefit. Some of the names touted include Caterpillar, whose heavy machinery will literally lay the foundation for improved roads, and giants like Cleveland-Cliffs, whose iron ore and steel will bolster the scaffolding of our nation's bridges. You likely have favorites as well.

In terms of the professional workforce, civil engineers will be in high demand as will construction, process, and project management engineers. But what's good for our adjacent engineering disciplines is also good for materials engineers.

Take the increased need for nondestructive testing on all those bridge improvements. The 42% of *AM&P* readers who are involved in some aspect of testing and inspection may see an uptick in phone calls. Portions of the new law also support clean energy. ASM members in organizations such as First Solar, Siemens, EPRI, and the Department of Energy's national labs are already working toward that goal. Their expertise may be leveraged. The bill also calls for enhancements to car safety. Our materials and design engineers in the automotive sector will be looking for ways car bumpers and hoods can provide more protection. Engineering as a whole should see benefits.

Steering back to *AM&P,* we conclude our 12-part Automotive Aluminum series in this issue. And what a thrilling ride it's been! The series started by taking us back to 1899, when aluminum sheet was first introduced to the auto industry to save weight in a sports car and give it a high-tech appearance. The series continued to describe the development of aluminum usage by the Big Three along with cameo appearances from Audi, Honda, Jaguar Land Rover, Porsche, and Toyota. Of course, Alcan and Alcoa are strong leads throughout the series. The concluding article provides a dramatic narrative of how Ford achieved its successful use of aluminum auto body sheet in the F-150. It ends with a discussion on electric vehicles and how they pose new challenges to the use of aluminum in future models.

1907 Rolls-Royce Silver Ghost clad in polished aluminum. From Automotive Aluminum: Part I.

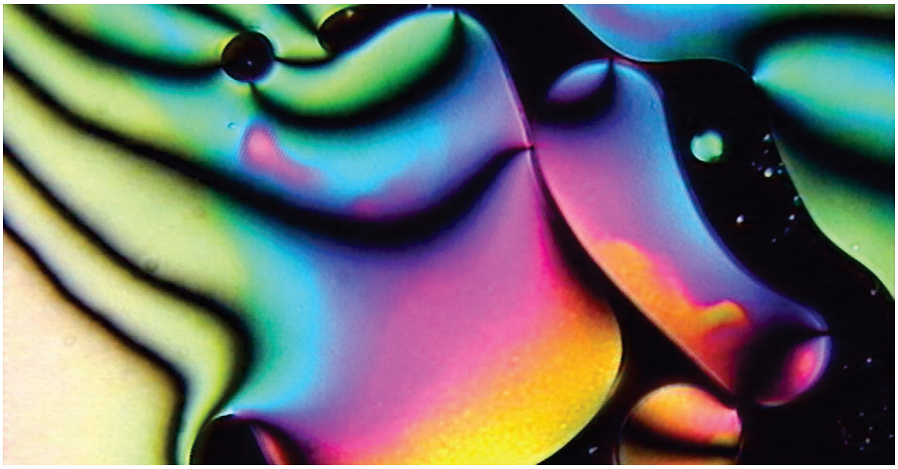
Thank you to authors Laurent Chappuis and Robert Sanders who took us on this compelling journey through automotive aluminum history and made each article more interesting than the last. Through their connections, the articles are getting some extra mileage by being housed as part of the permanent collections at both the Aluminum Museum in Paris and the Ford Museum in Detroit.

As a Society, we've reviewed our own history as well and are implementing a tune-up to our infrastructure. In her first "From the President's Desk" column, Judith Todd, FASM, introduces a Decade of Opportunity. This next phase for ASM starts off by instituting leadership transitions and leveraging our digital aptitude. Pair those changes with the launch of the Data Ecosystem in the new year—read the exciting details on page 54—and ASM is poised to thrive. As we head down the road of our Decade of Opportunity, all bets are on ASM.

Joanne Miller

joanne.miller@asminternational.org

RESEARCH TRACKS



Liquid crystals in the nematic phase, in which their rod-like molecules line up in a disorderly yet parallel manner. Courtesy of Wikimedia Commons.

SHAPESHIFTING LIQUID CRYSTAL

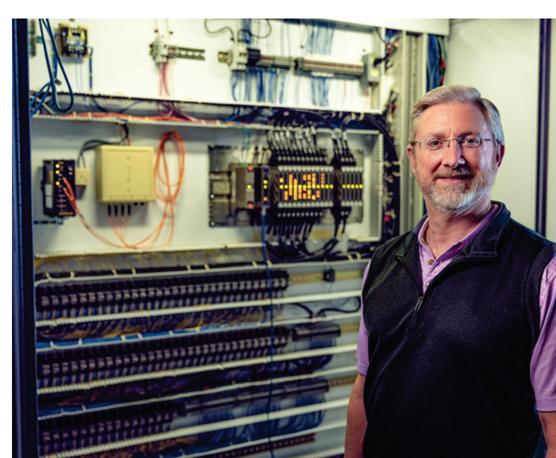
Physicists at Case Western Reserve University, Cleveland, and Tufts University, Medford, Mass., report changing the shape of a flat liquid crystal surface without applying any local stimulus. “This is a groundbreaking accomplishment and could prove to be the starting point for future applications—many which we cannot yet imagine,” says Case physics professor Charles Rosenblatt, one of the lead researchers. Previously, scientists who have similarly transformed the shape of liquid crystal surfaces have done so by using heat, light, or another force applied directly to the undisturbed surface. This team took a new path, changing the liquid crystal surface simply by placing a patterned substrate on the opposite side of a thin film in which the molecules are aligned in parallel. Future applications could lead to improvements in microchips and development of fluid microscopic tools that could perform repairs less invasively, flowing back into their original shape after use. In the new work, the team manipulated what Rosenblatt calls “an orientable Newtonian liquid,” a nematic liquid crystal that behaves predictably when an outside stimulus is applied. The nematic phase consists of cigar-shaped molecules arranged parallel to each other, but which can flow like water.

Consider that when a glass is filled with water, the surface where the air and water meet is essentially flat. In this case, the researchers forced the liquid crystal/air interface to change shape by exploiting the orientability of the molecules that comprise the liquid crystal. To do that, the team placed the patterned substrate on the opposite side of a thin nematic film. By doing so, they were able to control the alignment of molecules throughout the material. This resulted in a predetermined “bumpy” surface where the liquid and air meet—accomplished without any stimulus at the surface and without any control beyond the patterned bottom of the pool far from the surface. The relative change was as much as a 30-70% increase in height from a flat surface. Next, the team will next work on fine-tuning the surface shape by applying an external electric field and varying temperature. *case.edu.*

NEW SILICON CARBIDE FABRICATION FACILITY

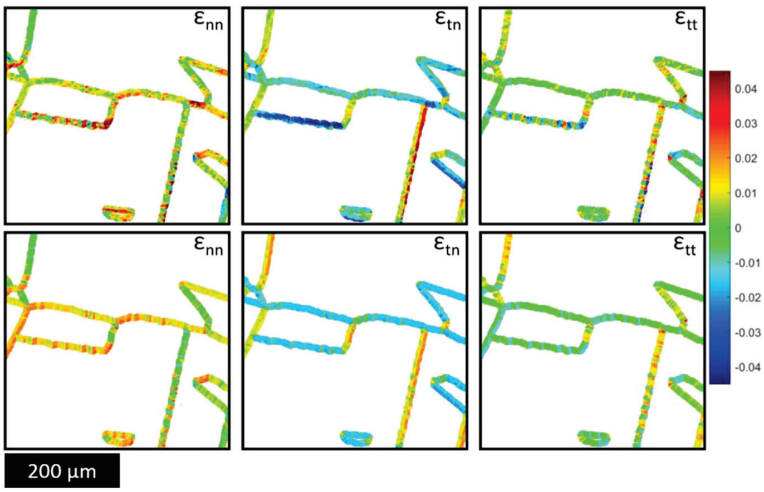
Engineering researchers at the University of Arkansas, Fayetteville, received $17.87 million from the National Science Foundation to build and operate a national silicon carbide research and fabrication facility. The team is led by Prof. Alan Mantooth. The open access center will fill a void in U.S. production of integrated circuits made with silicon carbide. Currently, all silicon carbide fabrication facilities in the U.S. are for internal use only, so U.S. research and development of silicon carbide integrated circuits relies on international fabrication.

The new center will provide domestic opportunities for prototyping, proof-of-principle demonstrations, and device design. It will be the only openly accessible fabrication facility of its kind in the U.S. with services available to external researchers. The aim is to provide integrated circuits, sensors, and devices for military and industrial applications such as solar inverters, electronics for cars, and systems used in heavy equipment and space exploration. *uark.edu.*



Alan Mantooth at the University of Arkansas, future home of an open access domestic silicon carbide fabrication facility.

MACHINE LEARNING | AI



Top row shows experimental measurements of three different strain components; bottom row shows corresponding network predictions of a neural network trained from a different set of experiments, illustrating that the model works.

USING NEURAL NETWORKS TO PREDICT STRAIN

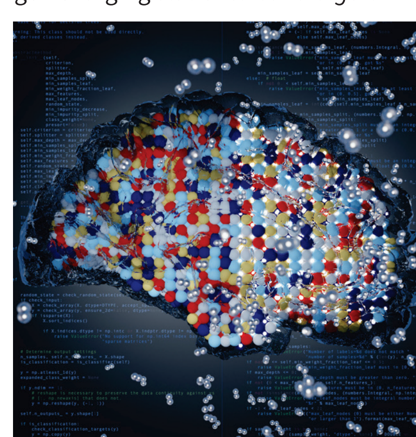
Scientists at the University of Illinois Urbana-Champaign recently used data from high-resolution images of stainless steel samples to train neural networks that make predictions about how the material will behave under strain at its grain boundaries. "Rather than using an extremely detailed and cumbersome physics model with a lot of fitting parameters, we used machine learning to train a neural network to make these predictions," explains researcher John Lambros. This is the first time the technique was applied to learn what happens in a metal microstructure under various loading conditions. In this experiment, the goal was to see how much strain accumulated at grain boundaries in a polycrystalline metal during creep.

"We believed the physical differences between the two grains adjacent to the boundary would be more important, or at least an equally important parameter. So, the most remarkable finding for me was that one single geometric parameter was able to predict the results 80% percent of the time," says Lambros. "It's the geometry—the angle at which you're loading it that made the most difference. It was surprising, because it means that all this sophisticated, multiscale modeling that we do to understand all the physics may be only about 20% percent important." Lambros notes that the current model only works near grain boundaries, and that a different set of inputs will be needed to work in the interior. *illinois.edu.*

MACHINE LEARNING SUPPORTS HYDROGEN STORAGE

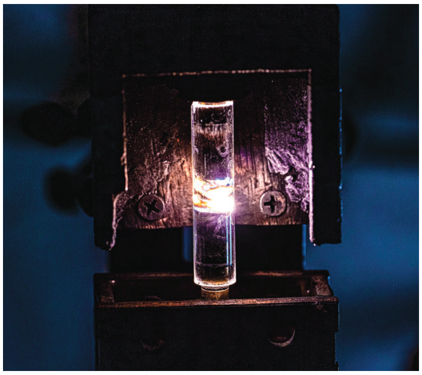
A team of materials scientists and computer scientists from Sandia National Laboratories, Angstrom Laboratory in Sweden, and Nottingham University in the U.K. spent more than a year creating 12 new alloys that demonstrate how machine learning can help accelerate the future of hydrogen energy by making it easier to create hydrogen infrastructure for consumers. Such machine learning models only take seconds to execute and can rapidly screen new chemical spaces: In this case, 600 materials show promise for hydrogen storage and transmission. The team demonstrated that machine learning techniques could indeed model the physics and chemistry of complex phenomena that occur when hydrogen interacts with metals. The researchers also found something else, results that have dramatic implications for small-scale hydrogen generation at hydrogen fuel-cell filling stations.

"These high-entropy alloy hydrides could enable a natural cascade compression of hydrogen as it moves through the different materials," says Vitalie Stavila of Sandia, adding that compressing hydrogen is traditionally done through a mechanical process. He describes building a storage tank with multiple layers of these different alloys. As hydrogen is pumped into the tank, the first layer compresses the gas as it moves through the material. The second layer compresses it even further and so on through all of the layers of differing alloys, naturally making the hydrogen usable in motors that generate electricity. "As hydrogen moves through those layers, it gets more and more pressurized with no mechanical effort," says Stavila. "You could theoretically pump in 1 bar of hydrogen and get 800 bar out—the pressure needed for hydrogen charging stations." *sandia.gov.*



Researchers are using machine learning models to discover new high-entropy alloys with attractive hydrogen storage properties. Courtesy of Matthew Witman.

PROCESS TECHNOLOGY



The flash Joule heating process has been adapted to recover valuable and toxic metals from electronic waste. Courtesy of Jeff Fitlow/Rice University.

FLASHING E-WASTE

Researchers at Rice University, Houston, developed a way to extract valuable metals from electronic waste that uses significantly less energy than current lab methods and produces a byproduct clean enough for agricultural land. They adapted the flash Joule heating method to produce graphene from carbon sources like plastic and food waste to recover rhodium, palladium, gold, and silver for reuse. The new research also demonstrates the removal of highly toxic heavy metals including chromium, arsenic, cadmium, mercury, and lead from the flashed materials.

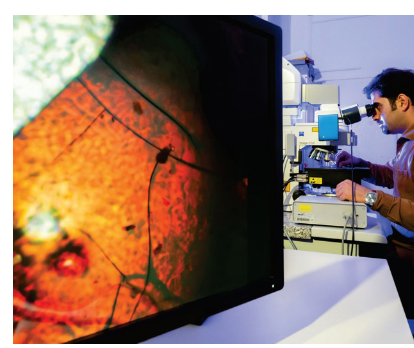
Instantly heating the waste to 3400°K—or 5660°F—with a jolt of electricity vaporizes the precious metals, and the gasses are vented away for separation, storage, or disposal. Once flashed, the process relies on evaporative separation of the metal vapors. The vapors are then transported from the flash chamber under vacuum to another vessel, a cold trap, where they condense into their constituent metals. The researchers reported that one flash Joule reaction reduced the concentration of lead in the remaining char to below 0.05 parts per million, the level deemed safe for agricultural soils. Levels of arsenic, mercury, and chromium were all further reduced by increasing the number of flashes, which take only one second each. The scalable Rice process eliminates the lengthy purification required by smelting and leaching methods. With more than 40 million tons of e-waste produced globally every year, the researchers say there is plenty of potential for this "urban mining." *rice.edu.*

MELTING THE UNMELTABLE

Due to the special properties of metal-organic framework compounds (MOFs), they are considered to have great potential for future applications in energy and environmental technology, in bio and life sciences, and as sensor components. The basis for the numerous applications is their high and largely controllable porosity. As MOFs are predominantly in powder form, a primary challenge is producing bulk components. Now, scientists from Friedrich Schiller University, Germany, and the University of Cambridge, U.K., are looking to glasses as a solution.

To produce components for industrial applications from MOFs, they must first be melted down before they can be processed into hybrid glasses. The researchers were able to show how normally nonmeltable substances from the MOF family of zeolitic imidazolate frameworks can be converted into a liquid state and, finally, a glass. "In this way," they explain, "the desired component can be obtained, for example, in the form of a membrane or a disk."

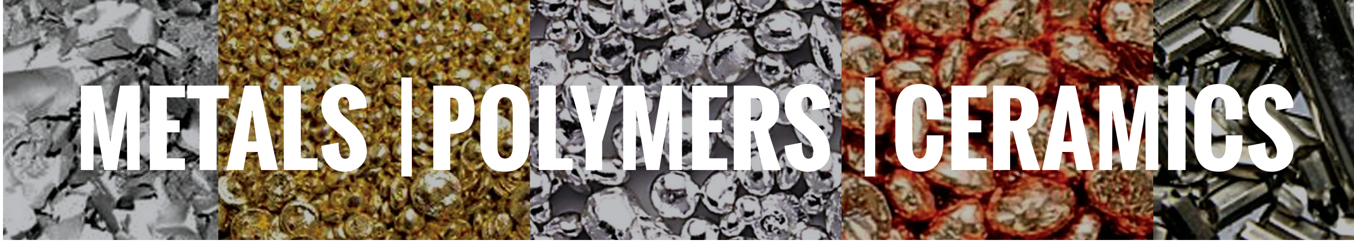
The key to future applications is the interactions taking place between the ionic liquid and the MOF material. These determine the reversibility of the process—the possibility of washing out the auxiliary liquid after the melting process. If the reactions are not adapted, either the pore surface is not adequately stabilized or there is an irreversible chemical bond between the MOF and parts of the ionic liquid. Therefore, ideal combinations of liquids, matrix materials, and melting conditions must be identified with a view to the desired application, so that large-volume objects would become possible. *www.uni-jena.de/en, www.cam.ac.uk.*



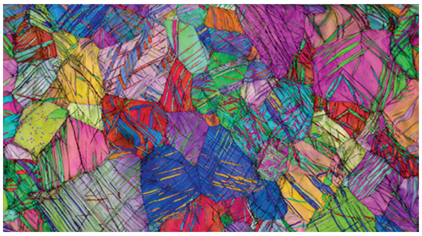
Vahid Nozari at the University of Jena examines the new synthetic glass. Courtesy of Jens Meyer/University of Jena.

BRIEF

Wall Colmonoy Ltd., U.K., completed an $825,000 upgrade to its casting foundry in Wales, adding new induction melting equipment and magnetically screened furnaces. The foundry supports multiple casting methods including investment, centrifugal, sand cast, and vacuum cast processes to serve multiple industries such as food, steel, glass, aerospace, and oil and gas. *wallcolmonoy.com.*



METALS | POLYMERS | CERAMICS



Electron backscatter diffraction was used to image pure titanium with a nanotwinned structure produced via cryo-forging. Courtesy of Andy Minor/ Berkeley Lab.

NANOTWINNING TITANIUM

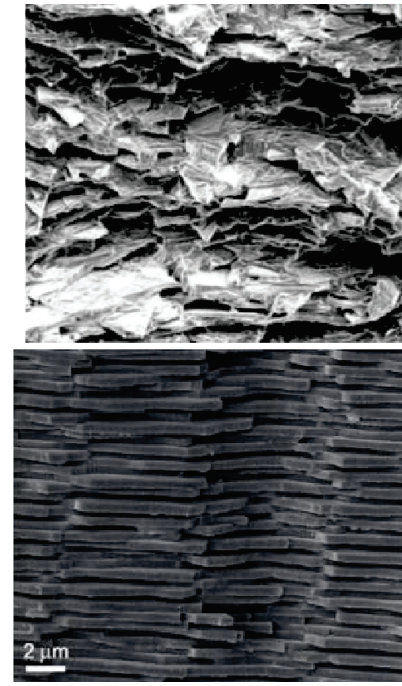
Researchers at the DOE's Lawrence Berkeley National Laboratory discovered they could use a method called cryo-forging to manipulate pure titanium at nanoscale and at ultra-low temperatures to produce extra-strong "nanotwinned" titanium without sacrificing any of its ductility. According to the researchers, this study is the first time a pure nanotwinned structure was produced in bulk material. The researchers put the newly formed material through a series of stress tests and used the Molecular Foundry's electron microscopes to uncover the source of its unique properties. During these tests, they found that nanotwinned titanium had better formability because it can form new nanotwin boundaries and undo previously formed boundaries, both of which help with deformation. They tested the material to extreme temperatures up to 1112°F and found it maintained its structure and properties, demonstrating the versatility of the material.

At super-cold temperatures, nanotwinned titanium can withstand more strain than normal titanium. The researchers found that nanotwinning doubled the metal's strength and increased its ductility by 30% at room temperature. At super-low temperatures, the improvement was even more dramatic—the nanotwinned titanium was able to double in length before fracturing. Fabricating nanotwinned titanium using cryo-forging is potentially cost-effective, scalable for commercial production, and produces an easily recycled product. From here, the researchers hope to take their new process and determine if it can be applied to other metals. *lbl.gov.*

SEASHELL-INSPIRED GLASS

Looking to the inner layer of mollusk shells, scientists from McGill University, Montreal, created stronger and tougher glass. Instead of shattering upon impact, the new material has the resiliency of plastic and could be used to improve cell phone screens in the future, among other applications.

Inspired by nature, the scientists created a new glass and acrylic composite material that mimics nacre or mother of pearl. "Amazingly, nacre has the rigidity of a stiff material and durability of a soft material, giving it the best of both worlds," says researcher Allen Ehrlicher. "It's made of stiff pieces of chalk-like matter that are layered with soft proteins that are highly elastic. This structure produces exceptional strength, making it 3000 times tougher than the materials that compose it."



Glass microstructure (top) and nacre microstructure (bottom). Courtesy of McGill University.

The scientists took the architecture of nacre and replicated it with layers of glass flakes and acrylic, yielding an exceptionally strong yet opaque material that can be produced easily and inexpensively. They then went a step further to make the composite optically transparent. "By tuning the refractive index of the acrylic," they explain, "we made it seamlessly blend with the glass to make a truly transparent composite." As next steps they plan to improve it by incorporating smart technology allowing the glass to change its properties, such as color, mechanics, and conductivity. *www.mcgill.ca.*

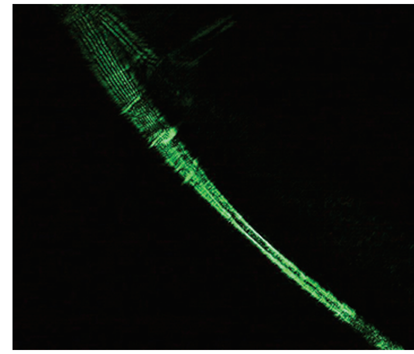
BRIEF

Swagelok Company, Solon, Ohio, held a ribbon cutting ceremony on August 24 to celebrate its new global headquarters. The 124,000-sq-ft facility includes an innovation laboratory and the Edward A. Lozick Customer Collaboration Center, which are connected to the company's newly renovated main plant. *swagelok.com.*

STRONGER CONDUCTING FIBERS

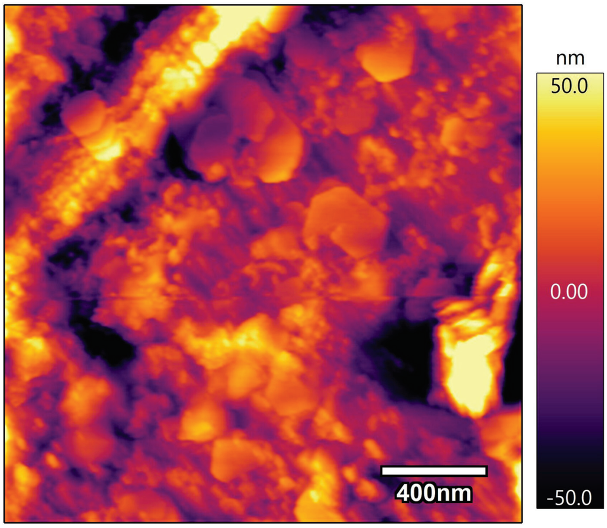
A research team at the University of Tsukuba, Japan, is harnessing the strength of bagworm silk to produce a strong, flexible, conductive fiber. They're building on recent findings that bagworm silk is superior to spider silk in both strength and flexibility. The research could lead to new flexible electronic devices, such as wearable electronic materials. It is also possible to create biocompatible materials that can be used in regenerative medicine and biomedical materials.

The research team combined polyaniline with bagworm silk obtained from a bagworm nest. The composite fibers collected from the silk and polyaniline were 2 microns in diameter and acted as optical waveguides. They demonstrated that green laser light propagates along these fibers while remaining confined within each fiber. To determine the magnetic properties of the material, the investigators performed superconducting interference device measurements. The results revealed that the composite fibers can act as paramagnets—the fibers become magnetized when placed in an external magnetic field. The team also confirmed the composite fiber is suitable for use in textile transistors by applying the bagworm silk and polyaniline composite in a field-effect transistor device. The successful production of a strong conductive fiber comprised of bagworm silk and polyaniline will pave the path toward the application of these fibers in a variety of fields such as tissue engineering and microelectronics. *www.tsukuba.ac.jp/en.*



Starting with natural silk from bagworms, researchers developed a strong conducting fiber that shows promise for flexible electronic materials. Courtesy of University of Tsukuba.

TESTING | CHARACTERIZATION



Iron carbonate and calcium carbonate films form on polished iron as it corrodes. Courtesy of Mikhail Trought, Perrine group. Reprinted with permission from *The Journal of Physical Chemistry A*. Copyright 2021 American Chemical Society.

ANALYZING CORROSION

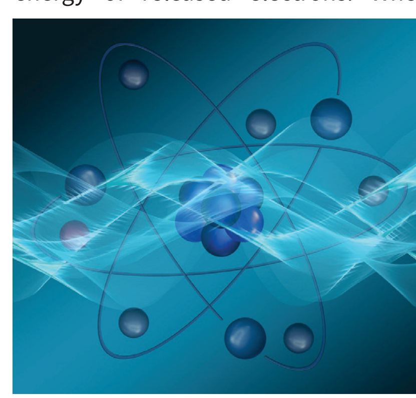
The initial stages of iron corrosion can now be studied in greater detail with a new surface analysis approach developed by researchers at Michigan Technological University, Houghton, Mich. A better understanding of the corrosion process and how fast minerals form creates possibilities for monitoring carbon dioxide capture, water quality byproducts, and improving infrastructure management for old bridges and pipes. The group's main finding is that the cation in solution—positively charged sodium or calcium ions—influences the type of carbonate films grown when exposed to air. The gradual exposure of oxygen and carbon dioxide produces carbonate films specific to the cation. The iron hydroxides of different shapes and morphologies are without gradual air exposure, not specific to the cation.

Using a variety of surface-sensitive spectroscopy and microscopy techniques, the team observed in depth the initial stages of corrosion as a function of time. The team's surface catalysis approach helps researchers better understand fundamental environmental science and other types of surface processes. The researchers think their method could help uncover mechanisms contributing to polluted water, find ways to mitigate carbon dioxide, prevent bridge collapses, and inspire smarter designs and cleaner fuels, as well as provide deeper insight into Earth's geochemical processes. *mtu.edu.*

MEASURING ULTRAFAST PROCESSES

Researchers at the University of Freiburg, Germany, developed a new measurement method to investigate ultrafast processes at the atomic and molecular levels in matter. The method, which combines different spectroscopy techniques, enables new insights into the energy structure in matter and the probability distribution of electrons. According to the researchers, fundamental molecular processes can now be understood more precisely with their technique.

A general problem in coherent, multidimensional spectroscopy is the complexity of the measurement data, which often makes a clear interpretation of the experimental results difficult or even impossible. The situation improves significantly when the experiment is combined with the use of, for example, a mass spectrometer. "This approach gives us the additional and very useful information about the chemical composition of the substance under investigation—a major advantage in the study of ultrafast chemical reactions," explain the researchers. For the new procedure, they combined coherent, multidimensional spectroscopy with photoelectron spectroscopy to ionize substances and measure the energy of released electrons. When



A combination of spectroscopy techniques provides new insights into the energy structure in matter. Courtesy of Pixabay/CC0 Public Domain.

BRIEF

Smithers announces that its testing laboratories in Akron, Ohio, are now Nadcap accredited for nonmetallic materials testing. The accreditation includes both tensile and flexural ambient temperature and strain measurement, tensile/elongation, and impact strength; physical testing, including density/specific gravity; chemical testing, including IR/FTIR; and composites testing. *smithers.com.*

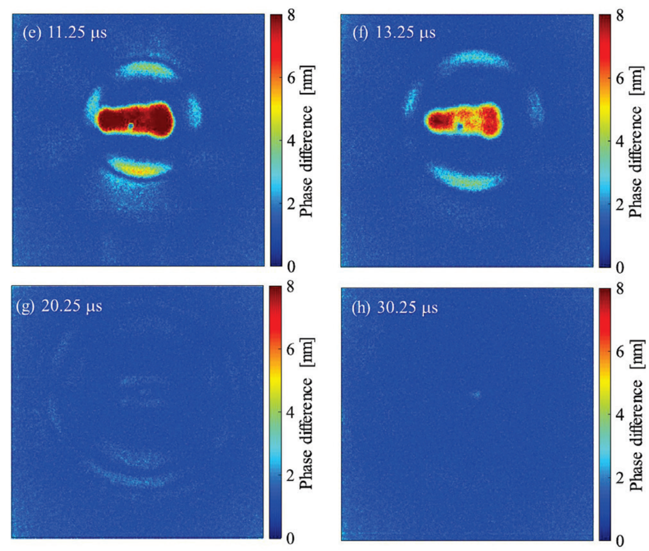
photoelectron spectroscopy is combined with x-ray light sources, precise measurements with specific atomic selection are possible.

"Our approach opens up a variety of exciting new developments," the researchers say. "This ranges from extending our method for simultaneous energy- and angle-resolved electron measurements to experiments with x-rays to obtain atom-specific information." As another benefit of their new approach, the sensitivity of the multidimensional spectroscopy experiments has been improved by orders of magnitude. The increased sensitivity allows for the study of very clean samples in an ultrahigh vacuum environment. *www.uni-freiburg.de/en.*

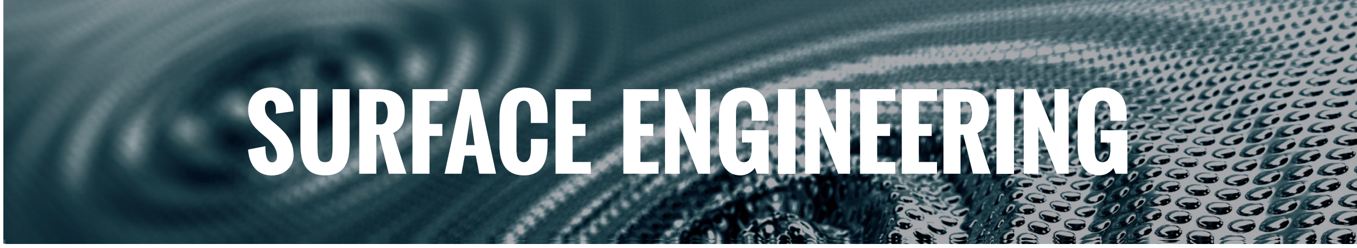
CONTACTLESS DAMAGE DETECTION

A collaborative research team from Shibaura Institute of Technology and Photron Ltd., Japan, developed a novel framework for the generation and detection of zero-order symmetrical mode Lamb waves in transparent materials. First, the team had to find a suitable technique to generate Lamb waves without damaging the sample. They leveraged a previously used approach to generate mechanical oscillations in a contactless way—laser-induced plasma shock waves. Next, the researchers measured the generated waves with a high-speed polarization camera. This polarization contains information directly related to the material's mechanical stress distribution, which in turn reflects the propagation of Lamb waves.

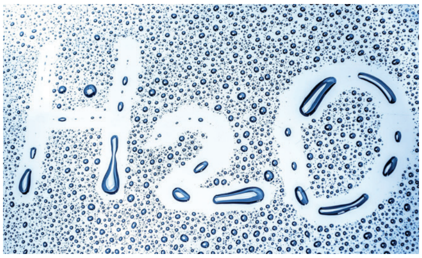
To put their strategy to the test, the team created microscopic scratches on a few flat, transparent polycarbonate plates and compared the propagation of Lamb waves on damaged and pristine samples. As predicted, the scratches caused noticeable differences in the stress distribution of the plates as the waves propagated over the damaged areas, demonstrating the potential of this novel approach by detecting scratches measuring only several dozen micrometers. According to the researchers, this nondestructive damage detection scheme could help reduce the production costs of high-quality transparent materials, though further studies are warranted. *www.shibaura-it.ac.jp/en.*



Nondestructive Lamb waves are captured on a transparent plate produced by shock waves from a laser-induced plasma. Courtesy of Prof. Naoki Hosoya/SIT.



SURFACE ENGINEERING



A new type of water-resistant coating is also sustainable. Courtesy of CC0 Public Domain.

VERSATILE SELF-HEALING COATINGS

Researchers from the University of Illinois Urbana-Champaign developed a tougher ultrathin material by merging thin-film and self-healing technologies. They found that the rapid evaporative qualities of a specialized polymer containing a network of dynamic bonds in its backbone help form a water-resistant, self-healing coating of nanoscale thicknesses. The new material has an expansive list of potential applications, including self-cleaning, anti-icing, anti-fogging, anti-bacterial, anti-fouling, and enhanced heat exchange coatings, according to the researchers.

The research team's primary focus was increasing the efficiency of steam power plants—the biggest producers of electricity globally—by using these types of coatings in their condensers. "The coatings, when applied to the surfaces of the condensers, make them more water-resistant and efficient at forming water droplets, which optimizes heat transfer," explain the researchers.

Previous studies have shown that most ultrathin coatings develop tiny pinhole defects once they cure onto a surface. Steam penetrates through these defects, leading to the gradual delamination of the coating, the researchers say, so their goal was to develop a pinhole-free, water-resistant thin-film and enhance the overall energy efficiency of steam power plants by several percent.

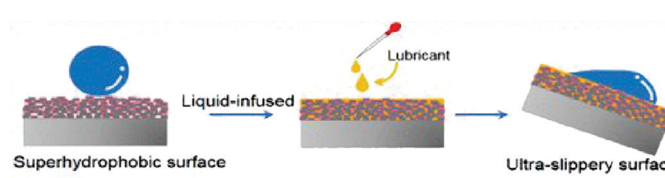
"Self-healing materials can recycle and reprocess themselves," says one of the study's lead researchers, Christopher Evans. "We found that we can successfully utilize the healing enabled by the dynamic bonds, allowing the coatings to self-repair in response to scratching or to prevent pinholes from growing." The material can be easily dip-coated onto materials in nanoscale layers on various surfaces like silicon, aluminum, copper, or steel. *illinois.edu.*

COMPARING ULTRASLIPPERY SURFACES

A research team from the Chinese Academy of Sciences systematically compared superhydrophobic and liquid-infused slippery surfaces with special wettability. The intrinsic hydrophilicity, liquid adhesion, surface contamination, corrosion attack, and ice-over phenomena of metallic materials greatly restrict their wide utilizations. Given the unique interfacial phase contacts and water repellency properties, lotus-leaf inspired superhydrophobic surfaces and pitcher-plant inspired liquid-infused slippery surfaces are promising candidates for multifunctional applications. The team set out to determine which surface is better performing.

The researchers prepared superhydrophobic and lubricant-infused ultraslippery surfaces through chemical etching, low surface energy molecule grafting, and lubricant oil infusion. Then they compared the surface wettability, self-cleaning, anti-icing, anticorrosion behaviors, and mechanical durability to study the functional differences and mechanisms. They found that both superhydrophobic and lubricant-infused surfaces exhibited self-cleaning ability, ice-over delay effect, marked decrease in the ice adhesion strength, and distinct increase in charge-transfer resistance.

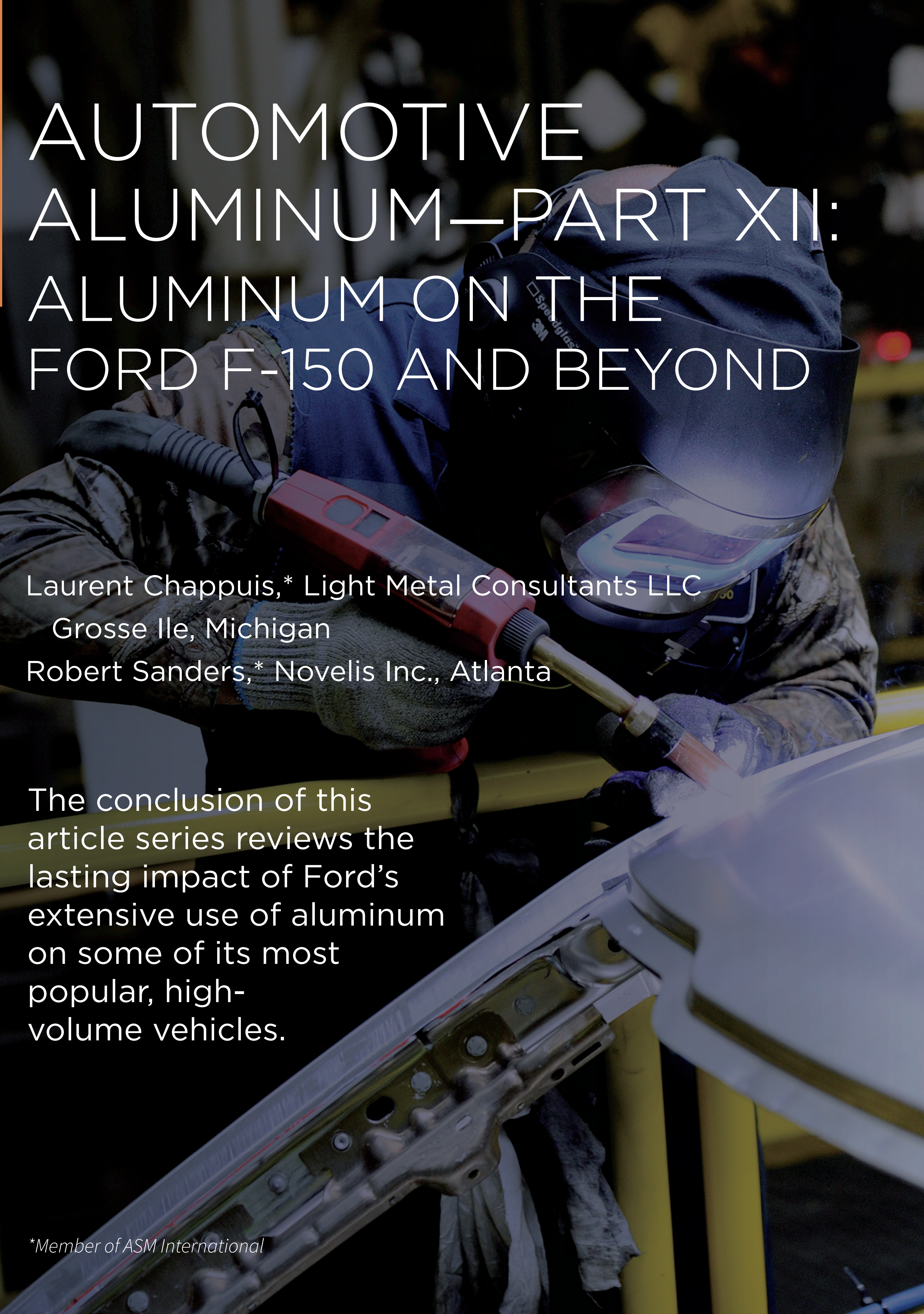
"Most notably," the researchers say, "given the existence of a stable, defect-free, and inert lubricant-infused layer, the lubricant-infused ultraslippery surfaces possess superior mechanical robustness against abrasion or knife scratching damage and better long-term corrosion resistance." *english.cas.cn.*



Liquid-infused slippery surfaces are less prone to corrode over time. Courtesy of *Langmuir.*

BRIEF

University of Cambridge, the **Icahn School of Medicine at Mount Sinai, ResInnova Labs,** and **Ascend Performance Materials** discovered that a nylon fabric embedded with zinc ions successfully inactivated 99% of the viruses that cause COVID-19 and the common flu. The findings could lead to more effective advanced personal protective equipment. *ascendmaterials.com.*



AUTOMOTIVE ALUMINUM—PART XII: ALUMINUM ON THE FORD F-150 AND BEYOND

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The conclusion of this article series reviews the lasting impact of Ford's extensive use of aluminum on some of its most popular, high-volume vehicles.

*Member of ASM International

Continuous cold mill tower at Alcoa's North Plant in Tennessee.

In our last article (Part XI, January 2021 *AM&P*), the launch of the 2015 F-150 was discussed from the automaker's perspective. In this final installment, some other aspects of the story are explored. We then conclude this series by reviewing the impact of Ford's actions on the automotive and aluminum industries.

The decision to switch to aluminum for the P552 platform coincided with a strategic realignment of other Ford truck platforms. The 2017 Super Duty, codename P558, would now share most of its sheet metal with the light duty version, albeit with a unique front end and pick-up box. In addition, the 2018 Expedition and Navigator, codenames U553 and U554, would switch to aluminum as well. These two decisions had added enough volume to justify a third continuous heat treatment and finishing line at Novelis Oswego in New York. But the added volume exceeded the capacity of Alcoa's Davenport expansion, and on August 29, 2013, Alcoa announced a $275 million expansion at its North Plant in Alcoa, Tennessee, adding a new tandem cold mill and continuous heat treat line.

To any outside observer, all of this aluminum conversion activity should have provided Novelis and Alcoa with immense satisfaction: The 2015 F-150 was a transformative moment for both aluminum suppliers, seeing them grow from the perennial side show to the main act. In reality, both companies found their resources stretched beyond any expectations by the dizzying complexities of the largest automotive launch in a century. A resurgent light truck market soon added an additional layer of complications.

NOVELIS AND ALCOA BOOST CAPACITY

In the 30 months between signing the historical supply agreements and building the verification prototypes, Ford had revised the planned volume capacity for the 2015 F-150 and the 2017 Super Duty by more than 25% and 50%, respectively. Because both projects were progressing under a cloak of secrecy, Ford had kept that information to itself. In summer 2013, just 15 months before the planned F-150 launch date, Ford Purchasing finally shared the good news with its suppliers. To Ford's surprise, neither partner was overly enthusiastic. The truth was that neither had the immediate capacity to support such increases. Each had capacity expansion in place for the 2017 Super Duty and the later SUVs; the issue was that the F-150 increase represented more than half the volume originally set aside for the Super Duty, and it was needed six months earlier. This translated into a considerable challenge that would tax the ingenuity and resilience of both aluminum suppliers as well as Ford.

2017 Ford F-Series Super Duty.

Novelis was in a better position than Alcoa at this point. It had some open capacity in Kingston, Ontario, for thin-gauge skin parts and it could convert some 5xxx parts to batch anneal, as long as they did not require the surface pretreatment that was part of the new integrated lines. Other than adding the new process routes to the qualification process, the increased volume could be contained within the plant's existing infrastructure.

Alcoa's situation was more difficult because its auto body sheet (ABS) capacity was sold out, and additional volume depended on the conversion of its North Plant. The facility had originally opened in 1942 to produce aircraft sheet for WWII, followed by a wide variety of sheet and foil products until the mid-1980s. In 1987, the plant had completed a massive modernization to produce can body stock. Its streamlined process and extremely efficient three-stand continuous cold rolling mill produced more than 500,000 metric tons of 3104-H19 aluminum sheet every year for almost 30 years.

The automotive expansion announced in 2013 was a complete transformation that dwarfed those that had taken place in Davenport or Oswego, plants that had either produced or rolled aluminum ABS for decades. Switching from can body stock to ABS would touch every aspect of the production path, from the melt shop to the continuous heat treat line to customer-facing business systems. The only missing component would be the surface finishing that would continue to be done in Davenport. Complicating matters, the planned heat treat line was not a simple copy of the new Davenport line, but a modified design with increased capacity. Success would require an active collaboration between Ford and Alcoa's entire automotive business, including the Alcoa Technical Center in Pittsburgh, the Automotive Customer Center in Farmington Hills, Michigan, and Davenport Works in Iowa. A number of Davenport employees familiar with ABS relocated to Tennessee, among them Leslie Shuman who joined the effort as director of operations readiness, having overseen the launch of the new Davenport lines.

ALCOA RAMPS UP VOLUME

The Tennessee can stock flow path depended on recycled cans, while ABS is rolled from alloys with much less tolerance for impurities. Alcoa and Ford had agreed that their allocation of scrap from Ford's stamping plants would be returned to Tennessee in a closed-loop arrangement. The Tennessee ingot/can recycling manager Johnny Kincaid quipped, "We used to call it can rec, now it's car rec." The North ingot plant was converted to low head composite casting tools to increase productivity and reduce scrap losses, with ingot widths from 1600 to 2030 mm to cover the product range ordered by Ford.

Tennessee has some of the largest continuous pusher furnaces in the world, capable of holding 48 ingots. These furnaces would prove critical to the quality and consistency requirement for high-volume ABS. Despite this being the first time Alcoa produced ABS in pusher furnaces, homogenization of the ingots caused no major problems and the North Plant was ingot qualified for Davenport in November 2014. Building on that success, Davenport would later convert to pushers.

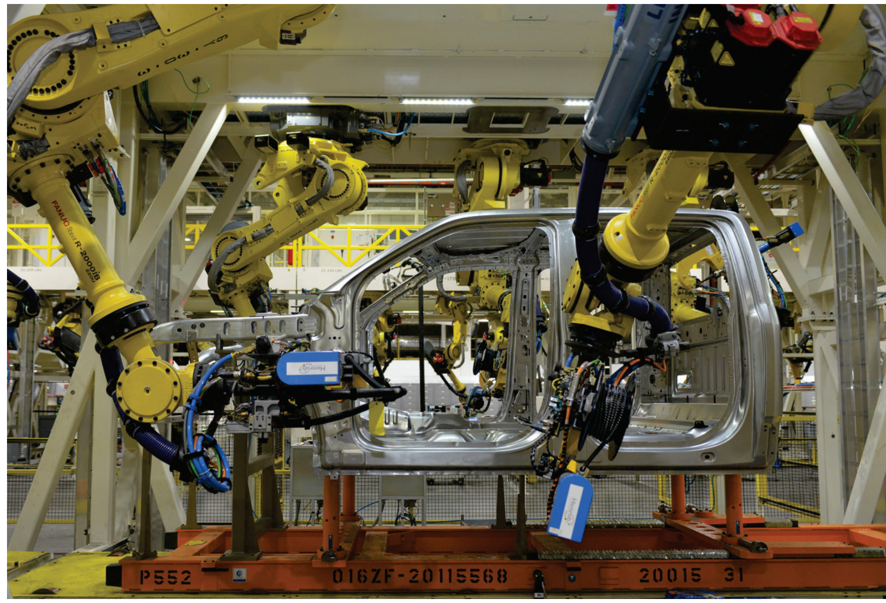
Perhaps the key piece of equipment in any aluminum rolling operation is the hot mill. Tennessee's 1940s vintage five-stand continuous mill had been rebuilt in 1990 as part of the can stock modernization. The chief requirement remaining was to specify the metallurgical parameters for 6xxx alloy ABS, such as target temperatures and reduction schedules. Tennessee Operations hired Ryan White, Davenport's hot mill metallurgist, to develop the practices necessary to make a product transparent to Ford's manufacturing process, matching the strength, formability, surface quality, and dimensional tolerances of the Davenport product. As the effort evolved, the process experience of Tennessee in producing can body stock proved valuable because controlling temperature, deformation schedules, and surface are key to both products. White brought the quality approach and procedures used at Davenport that had served to satisfy automotive customers such as Ford.

The original workplan for the launch of Alcoa Tennessee had been laid out to support the launch of the 2017 Super Duty, with delivery of the first coils to Ford's Kentucky Truck Plant in February 2016. But the additional volume requirements for the F-150 simply could not be met without the new Tennessee capacity. Ford made it clear it would not accept the loss of a single production unit in what would be the most scrutinized launch in a century. Filling the production gap became the focus of an intense team effort, followed at the highest levels of management of both companies. The hard reality was that there was no way to change the equipment ready date (ERD) of April 15, 2015. And the ERD was simply the starting point of the qualification work. Qualifying 6xxx ABS is complex and time consuming because it covers several long lead time processes, such as confirmation of the natural aging behavior, structural adhesive bonding performance, and the prove-out runs at the stamping plants.

Further, in Alcoa Tennessee's case, the metal destined for structurally bonded parts needed to be finished at Davenport, from which the test samples had to be prepared and then put through weekslong adhesive durability testing. In addition, the affected stamping plants needed to run production trials for each gauge and alloy combination—and do so during the launch acceleration period. All of this preparation work required months of intense cooperation between the two companies. To save time, the two parties agreed to follow the same accelerated qualification process used by Davenport, using the equipment verification coils as the qualification coils, precluding any second guessing of production processes. By focusing on a list of parts that would not require pretreatment, the fastest schedule would make the first production coils available for delivery by the end of August 2015, about four months past the crossover point between demand and capacity.

Pressure mounted as weeks dragged on without any acceptable solution to the potential loss of nearly 50,000 units and hundreds of millions in profits for Ford. The solution came at a joint working level review meeting: The Dearborn Truck Plant launch plan saw production ramping up slowly at first and then accelerating to full overtime production in early January 2016, in time to cover Kansas City's own production ramp-up. If both sides could agree, Alcoa Davenport would go on a full production schedule at the very start of the F-150 launch in September 2014. Davenport's excess production could be banked, with the stockpile growing until demand outstripped supply. From there, the bank would shrink and cover the production gap.

However, many open questions remained, chief among them the required size of the bank and the limited shelf life of the metal. A quick computer model confirmed both aspects and that a strict "first in, first out" management of the inventory would work. From there, it was only a question of selling the idea to upper management and resolving the myriad purchasing issues associated with placing and paying for orders unsupported by production requests and storing the massive tonnages in play. Details were ironed out by early summer 2014, just weeks before the start of F-150 stamping production. The whole scheme represented a level of mutual trust between the two parties that would have been simply unthinkable three years earlier. Any misstep on either side would result in millions of dollars in losses: Ford needed to nail the production ramp-up at all their plants to support consumption estimates, while Davenport could not suffer any production disruptions, all the while launching Alcoa Tennessee perfectly.



Ford begins building all-new 2015 F-150.

2015 Ford F-150.

STAMPING PRODUCTION BEGINS

Stamping production began on schedule at the various stamping plants in late September 2014, with Davenport running at full production rate. Dearborn Truck exceeded its ramp-up schedule, creating a bit of added tension. Kansas City started on schedule and it too slightly bested its ramp-up. By then it was abundantly clear that Ford Marketing had nailed its demand estimates and Ford was selling every unit. All eyes were now on Tennessee where the equipment was in place and the first coils were going through. ERD was achieved on schedule and the race to qualification was on, under the shadow of a now inexorably depleting bank. In the end, all the hard work of the Alcoa Tennessee launch team paid off and the first coils quietly began shipping to Ford in late August 2015. The bank had held, and the intense cooperation between Ford, Alcoa Tennessee, Davenport, the Technical Center and the Customer Center had paid the highest dividend: Not a single unit had been lost. Alcoa Tennessee had beaten the original launch plan by a full six months and the F-150 was on track to keep its sales crown for the 35th year in a row. In a public sign of their increased collaboration, Ford and Alcoa announced a partnership to commercialize Alcoa's new Micromill aluminum on the F-150 on September 14, 2015.

Ten days later, Ford unveiled the Super Duty at the State Fair of Texas, one year after the first units of its light duty sibling had passed through the new body shop in Dearborn. The same day, Alcoa officially announced the completion of the Alcoa Tennessee expansion. Three days later, on September 27, Alcoa announced it would split into two companies.

The first coils from Alcoa Tennessee arrived on schedule at Kentucky Truck Plant in February 2016. Meanwhile, Novelis celebrated the commissioning of its third line in Oswego on May 23, 2016, in time to support Kentucky Truck. By the end of the year, after 25 months of production, the aluminum-bodied F-Series production had surpassed the cumulative production of all other aluminum intensive vehicles (AIVs) of the past 25 years.

The fourth generation Expedition was unveiled on February 7, 2017, at the Dallas Cowboys training facility, Ford Center in Frisco, Texas, ahead of its Chicago Auto Show debut. Its stablemate, the 2018 Lincoln Navigator, followed on April 12 at the 2017 New York International Auto Show. Production began at Ford's Kentucky Truck Plant on September 25, 2017, with vehicles arriving at dealerships in November. Ford and its suppliers had completed the largest material substitution in automotive history, on track to produce more than one million aluminum-bodied vehicles per year.

FORD FACES COMPETITION

Ford's introduction of the F-150 at the 2014 North American International Auto Show (NAIAS) prompted a lot of speculation regarding the response from archrivals General Motors and Ram Trucks. Within a month, on February 20, The Wall Street Journal reported that GM was "accelerating efforts to field a largely aluminum-bodied pickup truck by late 2018." In a briefing on May 7, 2014, regarding future plans for the Ram 1500, Fiat Chrysler's Sergio Marchionne stated, "We can do aluminum in '17," but qualified that statement by adding, "I have better use of aluminum in this house than a pickup truck."

In the end, no competitor has followed Ford in converting any high-volume vehicle to aluminum ABS. When the next-generation Silverado officially debuted in 2018, it only added aluminum doors and an aluminum tailgate to its aluminum hood. GM elected to follow a series of safer and more incremental weight saving actions, coupled with additional powertrain choices. The company added a four-cylinder turbocharged gasoline engine as well as a small V6 diesel engine to the options list.

The 2019 Ram 1500, announced at the 2018 NAIAS, similarly added an aluminum tailgate to its existing aluminum hood. It also added aluminum parts to the chassis and suspension, but mostly used high-strength steels to achieve incremental weight savings in the body and chassis.

Nissan made no material substitutions for its 2016 Titan, and Toyota soldiered on with a refresh of its Tundra. So, during its last year before its first major refresh, the 2020 model year F-150 sat unrivaled as the lightest pickup truck on the market, more than 150 kg (331 lb) lighter than the equivalent Silverado, and 170 kg (375 lb) lighter than the lightest equivalent Ram 1500. The Japanese pickups, in the absence of any meaningful diet, remained the heaviest by far with the Toyota Tundra tipping the scales at more than 330 kg (728 lb) above an equivalent F-150, and the Nissan Titan carrying at least 480 kg (1058 lb) more than a similar Ford model.

While aluminum ABS has been growing in the years since the F-150 launch, only Jaguar Land Rover (JLR) in the U.K. and Nio in China have launched aluminum ABS-based bodies. Others have retreated. After pioneering aluminum-intensive body design with the 1994 A8, Audi rejoined the other German luxury carmakers for its fourth generation in 2018, opting for a mixed material solution and taking the resultant weight hit. Tesla also went with mixed materials for its higher volume Model 3 and Model Y vehicles.

WHILE ALUMINUM ABS HAS BEEN GROWING IN THE YEARS SINCE THE F-150 LAUNCH, ONLY JAGUAR LAND ROVER (JLR) IN THE U.K. AND NIO IN CHINA HAVE LAUNCHED ALUMINUM ABS-BASED BODIES. OTHERS HAVE RETREATED.

FUTURE PROSPECTS FOR ALUMINUM ABS

For the aluminum suppliers, the past five years have seen many transformations. Alcoa's rolling mills now operate as Arconic and a group of investors led by a private equity firm pushed out its CEO over the sale of the surface treatment technology used in the Ford projects. The joint venture between UACJ Corp. and Constellium officially inaugurated its heat treat and finishing line in Bowling Green, Kentucky, in September 2016, and after a rocky start it now successfully supports a growing list of automotive customers. But joint operation proved difficult, and within two years Constellium had bought out its partner and was completing an ambitious capacity expansion at its newly acquired facility in Muscle Shoals, Alabama. During the same period, it also opened a new modern ABS line at its Neuf-Brisach plant in France.

In the U.S., with an eye on aluminum ABS, Tri-Arrows Aluminum Inc. announced a new cold rolling mill at its Logan, Kentucky, facility in May 2017.

The tormented history of Aleris continued. Pursued unsuccessfully for 15 long months by the American arm of a Chinese aluminum concern, Zhongwang USA, Aleris managed to successfully launch its new ABS line in Lewisport, Kentucky, in time to support GM's new 2018 T1 truck platform. This was just as Novelis announced a push to acquire Aleris. By the time the antitrust dust settled in late 2020, Aleris Duffel, in Belgium, was operating as part of the Alvance Aluminium Group. Aleris Lewisport was back on its own as Commonwealth Rolled Products after being sold to American Industrial Partners, a private equity firm.

AMAG Austria Metall AG continues on its own independent path away from the merger turmoil, slowly growing its share of the European ABS market.

In China, European carmakers needed aluminum ABS to support their growing local production, so both Kobe and Novelis opened new ABS heat treat and finish lines in 2017, supplied with cold rolled coils from Japan and Korea, respectively. Kobe started an expansion aimed at doubling its Moka Plant capacity, all to support the growing ABS market in China. Kobe and Novelis later formed a joint venture in Ulsan, Korea, to feed their respective Chinese finishing lines, with Novelis breaking ground for a second line at its Changzhou plant in October 2018. All of this activity attests to the growth of the Chinese aluminum ABS market. Domestic Chinese suppliers have not ignored the opportunity and have begun offering their first samples to prospective customers.

Growth has taken place entirely using conventional direct chill casting technology, as the long-anticipated switch to continuous casting has not materialized. The most serious experiment, Alcoa's San Antonio Micromill, was a narrow production line built to demonstrate its new continuous casting and heat treating technology. Despite its width limitations, Alcoa and Ford successfully converted several production parts to the new materials, until the plant closure in late 2019. To date, there are no known plans to produce modern aluminum ABS using continuous casting, although a few specialty producers such as Golden Aluminum in Colorado supply limited quantities of 5xxx sheet to some automotive customers.

The separation between primary aluminum producers and rolling mills is now virtually complete, partly a result of the relentless cost pressures on primary aluminum from China. The response of the Western primary suppliers has been to emphasize their green credentials and focus on their lower carbon footprint. Several new technology projects have resulted in significant advances, some driven by nontraditional customers. For example, Apple announced in December 2019 that it had bought the first-ever carbon-free aluminum from Elysis, an Alcoa-Rio Tinto joint venture.

The emergence of credible 6xxx ABS sheet capability from China is bound to inflict similar cost pressures on the current Western suppliers, who find themselves operating in a world very much removed from the technology-driven aerospace sphere or recycling-dominated beverage can market. And unlike them, ABS is the subject of both cost and CO_2 footprint pressures. The rationale for using aluminum ABS began in pursuit of improved fuel consumption and performance. A maturing regulatory environment has replaced lower fuel consumption targets with reductions in CO_2 emissions. Classic life cycle analysis models based on internal combustion engines show that aluminum-intensive solutions supported by direct stamping scrap recycling, such as Ford's F-Series enterprise, have a net positive carbon footprint. The growth of aluminum ABS in closures and selected parts in mixed body solutions is a testament to its effectiveness for lightweighting. But the increased acceptance of lower-cost Chinese products and their higher CO_2 footprint leave aluminum ABS vulnerable to doubts of its CO_2 reducing credentials, especially without prompt scrap recycling from the stamping plants (Fig. 1).

As this article series shows, all of today's aluminum sheet-intensive products use technology that flows directly from the developments by Alcan and Ford in the early 1990s. But the progress of high volume, aluminum-intensive body-in-white (BIW) vehicles has stalled in a business that is by definition risk averse, owing to the large investments required and small profit margins. New weight saving alternatives have become available as other technologies have matured, such as forged aluminum suspension components. Improved alloys and high-pressure die casting (HPDC) technologies have yielded high performance thin-walled automotive body and chassis components. Tesla and other manufacturers have started to invest in HPDC capabilities as an alternative to formed and joined sheet body structure. As of this writing, Tesla has purchased several of the largest pressure die casters in the world that it calls Giga Press to make very large structural components for its cars. The first one on the Model Y consolidated 70 parts into a single casting (Fig. 2). The press uses a non-heat treatable alloy specially developed by Tesla to accept the prompt scrap from its collocated stamping operation, an elegant financial and operational solution that also improves the CO_2 footprint.

The future of sheet structures, alternative wrought products, and die castings will undoubtedly be written together as the industry moves toward a

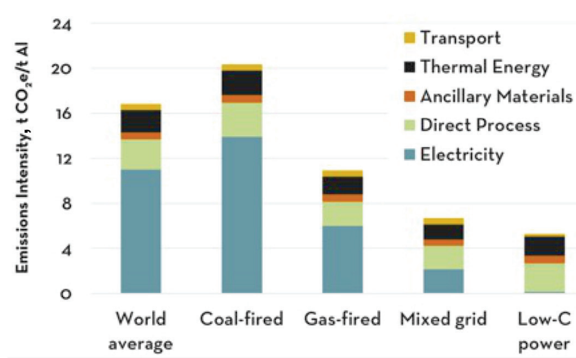


Fig. 1 — 2018 world average and example power mix cradle-to-gate emissions intensity of primary aluminum (tons CO_2 emissions per ton of aluminum). Courtesy of world-aluminium.org.

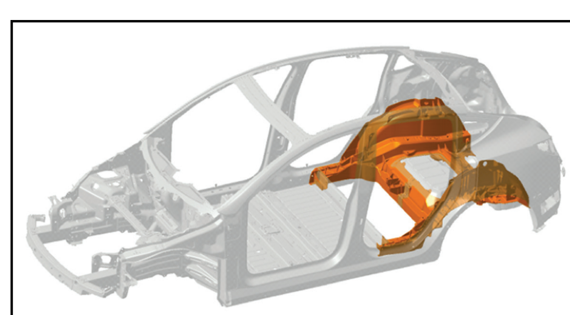


Fig. 2 — Diagram of Tesla Model Y with cast rear floor highlighted.

new generation of e-vehicles. In the current hyper competitive automotive environment, upper management must be convinced that the program team leading any aluminum-intensive solution has the capacity to deliver the successful execution of a winning cost/profit equation.

For aluminum ABS, it means having body engineers who understand it, working in close collaboration with tooling engineers capable of delivering an entire program worth of stamping tools on time and on budget. Absent such a conviction, aluminum-intensive programs always fail to materialize. JLR and Ford benefited from decades of development, supported by a visionary management team that valued both product and manufacturing expertise. Retirees from both companies were then able to provide Nio that expertise. But the competition between powertrain and body structure solutions is relentless, and it is taking place as aluminum ABS faces an increasingly fractured R&D environment. Recent developments might now favor powertrain solutions.

ELECTRIC VEHICLE CHALLENGES

The electrification of the light vehicle market has brought challenges and opportunities for aluminum ABS. For EVs, weight savings allow reductions in battery size, and given the high cost of batteries, meaningful cost opportunities exist for lightweighting. At the same time, the cost of batteries has fallen steadily and is now only 10% of what it was 10 years ago. Meanwhile, power density has tripled, leading to further weight reduction. Program management teams, aware of growing affordability concerns, are increasingly betting on batteries—prompted by engineering and tooling teams unwilling to take a chance on an unfamiliar aluminum ABS body solution.

Further, the electrification effort has meant refocusing resources away from body engineering and especially from its related activities, such as stamping processing and tooling engineering. Years of downward cost pressures have prompted an erosion of capabilities from both the carmakers and their tooling suppliers. For startups, the situation is even worse, because they mostly outsource body engineering to a supply base unaccustomed to leading the development of a whole project. These body engineering enterprises have only minimal in-house support for stamping feasibility and processing. Therefore, toolmakers increasingly find themselves responsible for the totality of the stamping and tooling engineering effort, from feasibility to tool delivery. They do this under contract to organizations with only little limited oversight capability, and under increasingly stringent cost and timing pressures.

The most damaging aspect of this situation is that there is no meaningful feedback loop linking product engineering, stamping engineering, toolmaking, and stamping production. The current environment actually operates under a negative feedback loop: Inexperienced engineers working with poor feasibility support create part designs that cause tool timing and cost overruns. Late tooling delays the launch of production, and suboptimal tools never achieve acceptable quality and productivity targets, leading to sustained reservations about aluminum ABS body solutions.

FINAL THOUGHTS

Finally, it is worth remembering that the drive toward aluminum ABS body structures was designed to replace steel ABS and take advantage of an existing and very expensive industrial infrastructure. Most start-ups do not have any such legacy infrastructure, affording them the opportunity to explore alternatives such as large structural castings.

In conclusion, the story of aluminum ABS is not over and its future is far from clear. The next chapter may be in the hands of the sheet stamping and tooling industry, as it has been for the past 20 years. However, technologies such as high-strength extrusions and large die castings may offer alternative paths forward to reduce part count and assembly cost. Undoubtedly the experiences and lessons learned from the latest generation of aluminum-intensive vehicles will be useful as the industry moves forward. **~AM&P**

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Contributors

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Carolyn Kidwell – metallurgist, Arconic-Tennessee hot line until 2017

Ryan White – plant metallurgist, Arconic-Tennessee

Johnny Kincaid – ingot/can recycling manager, Arconic, Alcoa-Tennessee, retired 2017

Tim Knight – Ford supplier technical assistance

Donna Sagonowsky – Ford supplier technical assistance manager for aluminum ABS (retired 2015)

Mark White – executive director, Alumobility, JLR, retired 2016

ARCHAEOMETALLURGICAL STUDY OF AN ANCIENT NORTH AFRICAN IRON-BASE ARTIFACT

A metallurgical study of a 10th century iron-base nail from the central-East coast of Tunisia reveals how early metallurgists without modern scientific knowledge created parts with engineered properties.

*Nihad Ben Salah**

NBS-M&P Consulting, Quebec, Canada

Tunisia is a country with a very rich history and loaded with archaeological sites and metallic artifacts. These can be dated back to early civilizations that shaped the history of the region, namely the Punic, the Romans, the Byzantines, and the Islamic conquest including the Aghlabids and the Ottomans. Artifacts were found in different archaeological sites and could be retraced back to 300 B.C.

An archaeological excavation in Monastir, a city in central-eastern Tunisia (Fig. 1) dug out iron-base artifacts that were dated back to the Aghlabid dynasty, who were known for their construction work.

The artifact targeted in this article is a 18.8 cm nail dated by archaeologists to the 10th century A.D. and found with others near a housing site where wood was substantially used. The dimension suggests that it could have been used for construction.

The scope of the metallurgical analysis was to investigate the morphology of the nail, its chemistry, microstructure, and anything that would lead to the understanding of its processing.

EXTERNAL AND INTERNAL MORPHOLOGY

The artifact had an apparent conical shape with a homogenous corrosion layer. It was very important to avoid altering the state of the artifact, so destructive testing was not allowed except on a tip that was detached from another nail at the same site (Fig. 2).

Visual observations backed by cross-section analysis of a broken tip of a parent nail, revealed that the basic structure of the nail may be pyramidal (Fig. 3a).

X-ray radiography (Fig. 4) helped to define the internal structure of the nail (Fig. 5). At the surface, a layer, less dense than the core, was identified. Cross-section observation shows that this layer might be oxidization of about 20% of the surface (Fig. 3b).

Fig. 1— The Aghlabid dynasty expansion in the Mediterranean Sea (in orange) encompassing Tunisia. Adapted from en.m.wikipedia.org/wiki/Aghlabids. Courtesy of Nanoxyde.

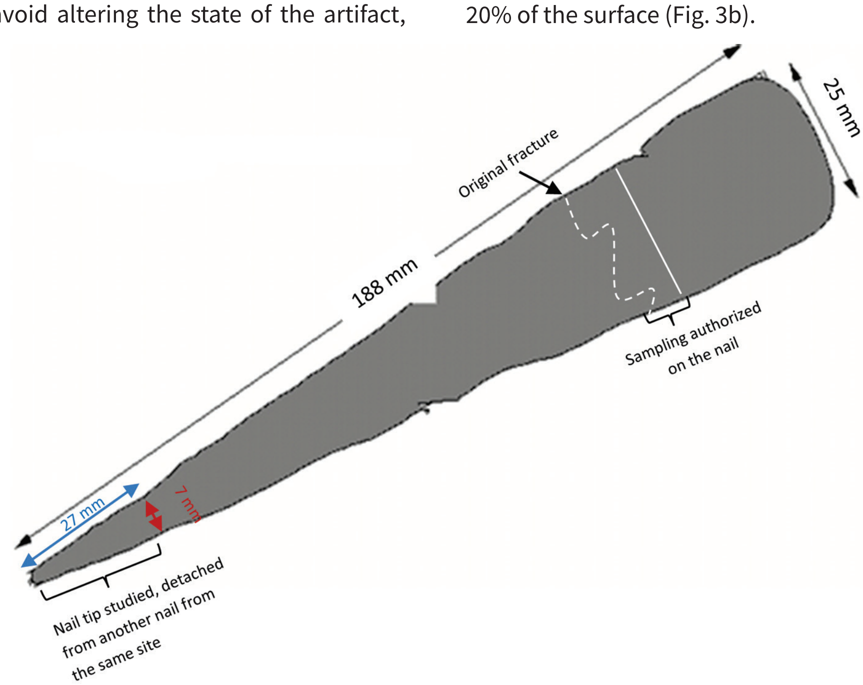
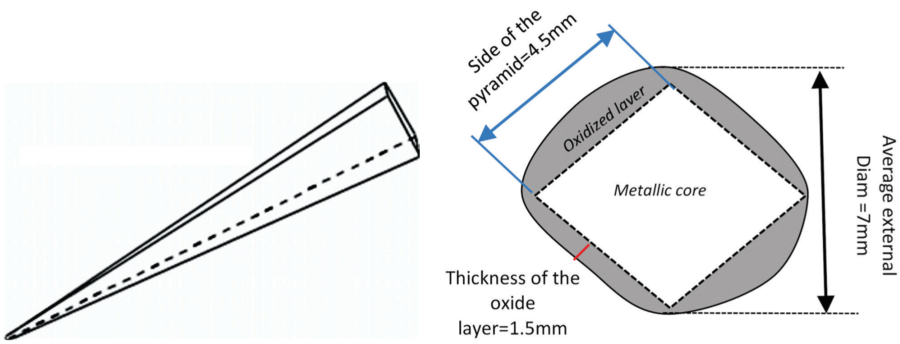


Fig. 2 — Apparent shape of the nail and sampling authorized for the study.

*Member of ASM International



(a) **(b)**

Fig. 3 — Basic shape of the nail deduced from visual and cross-section examinations.

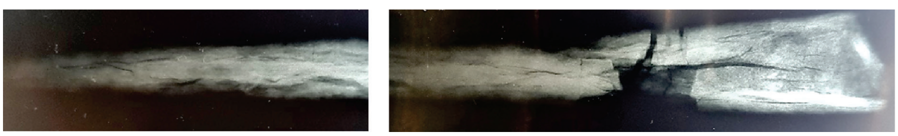


Fig. 4 — X-ray radiography images showing longitudinal veins (darker areas are those that let x-rays pass through and are then less dense).

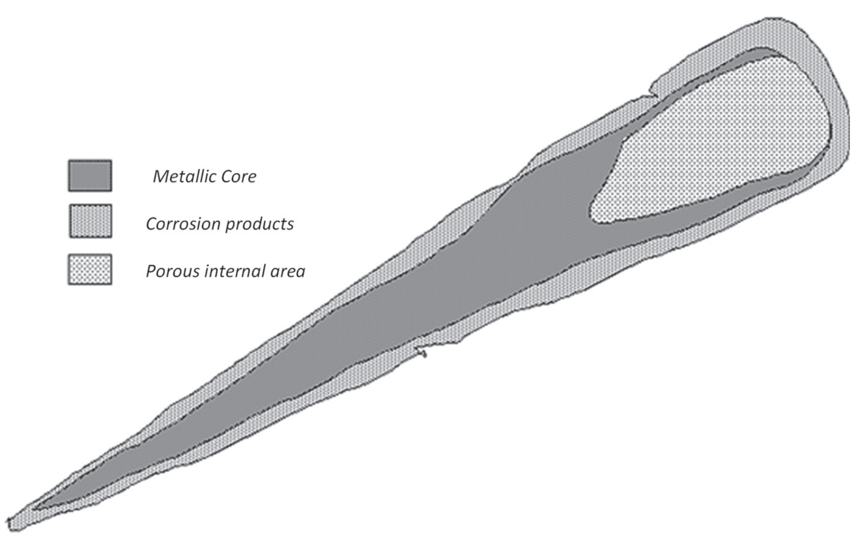
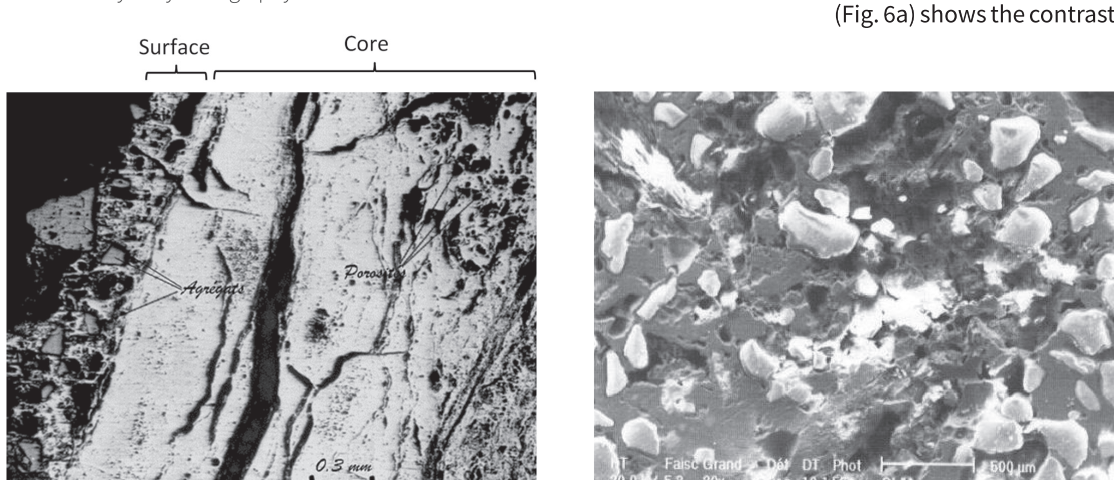


Fig. 5 — Areas revealed by x-ray radiography.



(a) **(b)**

Fig. 6 — Optical micrographs showing (a) the general microstructure and (b) surface as observed by SEM.

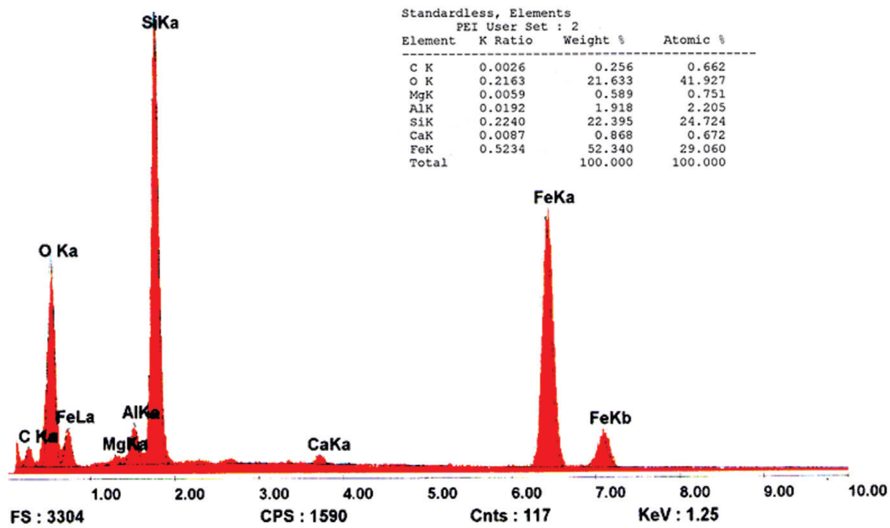
Longitudinal veins parallel to the main axis of the piece were revealed, too (Fig. 4), and could be either cracks or low-density products. However, the internal porous area located at the head of the nail remains to be understood.

CHEMISTRY AND MICROSTRUCTURE

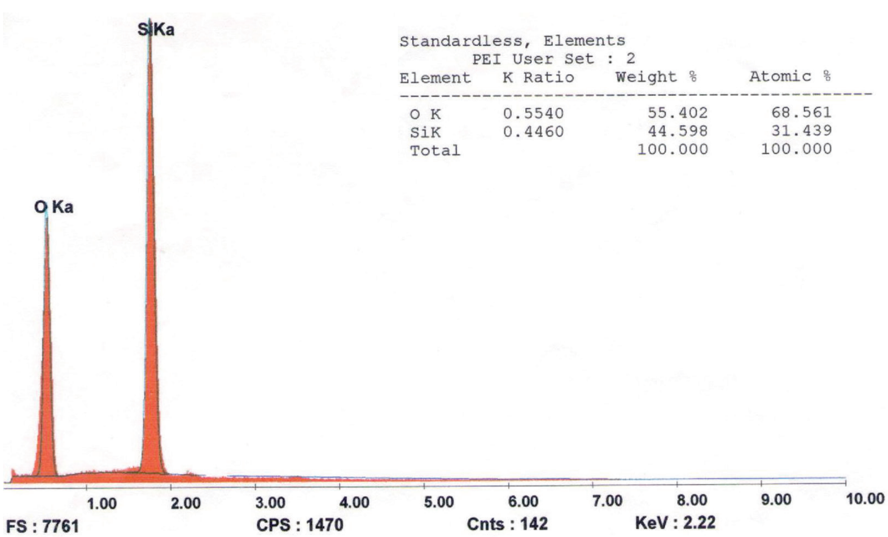
The general structure at the surface and in the core was observed and analyzed (Figs. 6 and 7). Chemical analysis by energy dispersive x-ray spectroscopy (EDS) of the cross section revealed the presence, in descending order, of the following elements: oxygen, iron, silicon, aluminum, calcium, carbon, and magnesium (Fig. 7a). Attempts to reveal the nail microstructure through the small, allowed amount of sampling showed that the nail is made with an iron-base low-carbon material. Etching with a solution of 5% nitric acid in ethanol (5% Nital), which is normally used in metallography to reveal the microstructure of steels, has not yielded any significant result. The steel was not sensitive to the etching reagent (Fig. 6) as low carbon iron alloys of ferritic microstructure (or wrought iron) would be.

The presence of Ca, Mg, Al, and Si is consistent with the chemistry of slags resulting from the smelting of iron ore[1] and would give information about the site from which the ore comes but the study did not go this far.

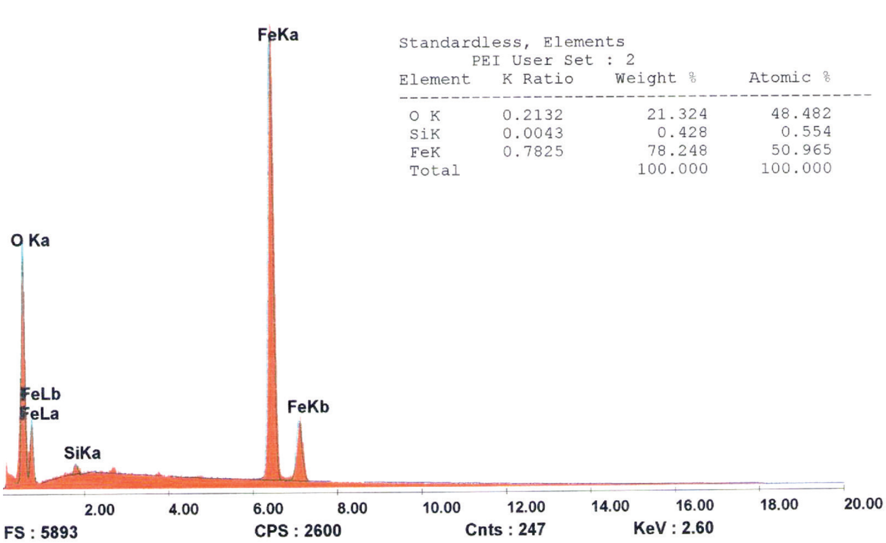
A low-magnification optical micrograph of the general microstructure (Fig. 6a) shows the contrast between the



(a)



(b)



(c)

Fig. 7 — Corresponding EDS analysis of the microstructure in Fig. 6. (a) General view; (b) aggregates A; and (c) adjacent matrix B.

surface and the core. The surface layer is about 0.6 mm thick. The core shows a fair amount of porosities and cracks corresponding to the veins revealed by x-ray radiography in Fig. 4. They seem to be internal cracks surrounded by Al-Ca-Mg-Si rich oxides (Fig. 7a).

SEM observations backed with EDS analysis (Figs. 6b, 7a, and 7b) revealed silicon and oxygen rich aggregates (100-300 µm), thus more likely SiO_2, embedded in an iron-base heavily oxidized matrix.

CORE OF THE ARTIFACT

Based on these results, it can be assumed that the material is a low-carbon wrought iron charged with inclusions elongated in the forming directions. Although the study did not go as far as needed to have a thorough identification of the inclusions, it is fair to say that they contain the main elements usually found in slags. These type of inclusions—rich in elements such as Al, Ca, Mg, and Si (though finer and more controlled)—are still found in modern steels[2] and are due to compounds added during the steelmaking process.

Archaeometallurgy studies of iron artifacts[3-5] have shown microstructures that resemble those observed in this investigation with vein-like features (as shown in Fig. 6) that seem to be characteristic of slag inclusions elongated in the direction of forming. The authors were able to demonstrate that the forming method would involve both wrought iron (sometimes carburized) and slag which are assembled by a forging operation, known as stratification, which includes heating-hammering-bending. Whatever the addition made by blacksmiths, it is the stratification process that seems to have given the observed metal/slag composite structure to the nail. It provided the needed properties for a construction nail that wrought iron alone would not have. However, given the very different physical properties of metal and slag, mainly their melting temperature and coefficient of thermal expansion, cracking can occur, which explains the cracks observed in the core of the part.

Stratification was developed as early as 1200 B.C. and was widely used for millennia, first in the Near and Middle East, India, Persia, the southern Mediterranean region, and later reached Europe[3,5,6]. These early metallurgists have found that slags facilitate the forging process. Indeed, given their lower melting point, they would melt during heating of the wrought iron and solidify during the shaping operation, allowing the blacksmith to make more hammer blows before having to reheat the part. Therefore, slags will take the shape imposed by the hammering. This cycle is made repeatedly until the part is completely shaped.

This study did not go as far as to pinpoint the source of the slags based on their composition. They could correspond to residue that the blacksmiths collect from the bottom of the forging furnace during the forging process, or additives they use to improve the formability of wrought iron.

SURFACE OF THE ARTIFACT

Iron-base artifacts are generally difficult to study due to the advanced state of corrosion. Parts are generally found in a state of 70 to 90% "mineralization" (or corrosion). Even though the nail was found in a coastal site of the Mediterranean Sea, no elements such as chlorine and sodium, were found at the surface, suggesting no corrosion reaction with a marine environment.

When iron pieces are found in a condition that allows for a metallurgical study, the focus is to understand what could have kept them in that condition. In this study, the state of mineralization of the nail is only 20% if we assume that the layer measured in Fig. 3 is a corrosion layer. However, chemical and microscopic analysis did not support this theory. The product on the surface is a composite layer of silica (SiO_2) aggregates embedded in a heavily oxidized low-carbon iron-base matrix.

Several studies pointed out that blacksmiths were familiar with the oxidation of metal parts during the forging process and knew that success of the operation lies in the protection of the surface. Therefore, in some cases, they used sand (consisting mainly of silica) as a cooling agent that would also protect against oxidation and maintain the hammering temperature higher for a longer time to reduce the overall cycles necessary to form the part[7]. This could be an explanation of the composite layer building up at the surface. Thus, at some point, blacksmiths realized that this operation also made their part more resistant to the environment, and they reserved this practice for the last hammering passes.

Moreover, studies[8] have shown that they could have discovered a protocol to prevent the formation of the least protective iron oxide (hematite, Fe_2O_3) at the surface of iron-base materials by a combination of heating, mechanical cleaning, and water rinsing to produce a more stable and protective magnetite (Fe_3O_4). The heavily oxidized matrix in which the silica aggregates are embedded could then be magnetite, which would explain how the composite microstructure of the surface layer prevented the progression of corrosion.

CONCLUSION

It is certain that these blacksmiths did not have the level of scientific knowledge and technological capabilities that are available today, but they surely had a sense of observation and a dexterity which made them find winning manufacturing processes. Bridging their work to current studies could certainly be very inspiring. **~AM&P**

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TECHNICAL SPOTLIGHT

AUTOMATING THE TESTING PROCESS

Labs without fully automated testing systems can benefit from adapting one or more parts of the process to increase throughput, decrease costs, and improve safety.

Testing labs face constant pressures to increase production, lower costs, and create safer working environments for their employees. While these goals might appear to conflict with each other, providers of materials testing equipment are using developments in automation to help labs achieve them simultaneously.

All leading materials testing suppliers offer fully automated solutions, which can provide enormous value through improved throughput, decreased operating cost, and increased safety. However, fully automated systems are significant capital expenditures; for many labs, the possible benefits of such a system fall short of justifying the cost.

To accommodate labs that do not warrant fully automated systems, materials testing suppliers are developing hardware and software solutions to automate many of the discrete actions required by a manual testing process. Some parts of the process have already been addressed, notably improving the throughput and reliability of a manually operated system, which also inherently reduces costs. Other areas have been targeted to make systems safer, protecting both equipment and operators.

This article discusses the following six emerging solutions and how their automated nature adds value to a lab:

1. Automated crosshead positioning
2. Automated fixture collision detection
3. Automated grip pressure control
4. Automated file change tracking
5. Barcode integration
6. LIMS integration

Fully automated testing systems like the Instron AT3 pictured can automate a variety of tests, including tensile, flexure, and compression.

AUTOMATED CROSSHEAD POSITIONING

Many testing labs use a materials testing system to examine different types of material, requiring different fixturing and test methods to control the crosshead. When switching from one test type to another, technicians have traditionally been responsible for swapping out fixtures and manually repositioning the crosshead to the location required for the next test. Manual positioning (also referred to as jogging) of the system's crosshead is typically performed with a handheld or frame-mounted control. Precisely setting crosshead position is fundamental to configuring the test's fixture separation, an important parameter specified in many of the most common ASTM and ISO test standards. When fixture separation is inconsistently configured, labs should expect nontrivial variations in displacement or strain data collected. This problem is worsened when labs have multiple technicians using slightly different techniques to position the crosshead manually.

Some providers have developed solutions to automate crosshead positioning to ensure the fixture separation is precisely repeated by any technician operating the system. One simple implementation links the crosshead position to the relevant test method, so when the technician selects a test method, the system knows exactly where to move.

AUTOMATED FIXTURE COLLISION DETECTION

Any time a test operator positions the crosshead during setup, there is a risk that the fixtures will accidentally collide. An unintended collision can cause serious damage to fixtures, force transducers (or load cells), or the test frame itself. Although most labs attempt to mitigate this risk by training technicians to remain vigilant when manually operating the system, errors happen, and nearly every lab has experienced the pain of breaking fixtures and the cost associated with replacement and system downtime.

Automated crosshead positioning features ensure the fixture separation is precisely repeated by any technician operating the system.

Built-in collision detection features automatically stop the crosshead when an irregular force is detected during test setup.

To prevent undesired collisions, some equipment suppliers have engineered features into their systems to automatically stop the crosshead when irregular force is detected during test setup. Further, the system automatically returns to a safer state by returning to a crosshead position when force is within an acceptable range. While thorough training is always recommended, collision detection features, such as this one, help labs protect their investments.

AUTOMATED GRIP PRESSURE CONTROL

Pneumatically actuated grips have been widely adopted as the preferred gripping solution for many tensile testing applications due to their superior throughput and clamping force repeatability. However, pneumatic grips are also one of the leading causes of safety incidents while operating a materials testing system due to pinched fingers. Traditionally, shields that mount to the grip itself are offered to mitigate this risk. Unfortunately, shields are not usable for all specimen types and can easily be removed and lost over the life of the system.

Pneumatic grips also require technicians to manually adjust the inlet pressure with an air regulator. Different materials require different clamping pressures, so technicians must remember to adjust the regulator accordingly. This adjustment adds time to the test process while also introducing undesired variability if one technician sets the pressure more precisely than another.

To address these established concerns, suppliers have developed automated air kits that are integrated into the system and communicate with the software. Now the system itself can adjust pneumatic pressure, eliminating any manual interaction. When technicians are inserting specimens, grips automatically close at a reduced pressure and speed to create a safer test process. Also, test methods configured in the system's software can be linked to grip pressures, eliminating any wasted time and variability.

AUTOMATED FILE CHANGE TRACKING

Keeping track of which test method parameters have changed from one revision of the file to the next can be a relentless challenge. Lab managers responsible for controlling the test methods struggle to identify who has made a change, when it was made, and why it was deemed necessary. When this information is not readily available, not only do labs spend hours tracking down the answer, but they face the risk of an unintended method change invalidating test results.

Some labs enforce manual record-keeping policies to mitigate this risk, but these techniques are time consuming and error prone. To address this need, many materials testing suppliers now offer automated tracking and approval features in their software. When enabled, the software automatically records the who, what, when, and why associated with changes to test templates, as well as sample data.

BARCODE INTEGRATION

Barcoding specimens or batches of specimens aims to reduce operator error caused by typing incorrect information into the test system. Many software packages offer barcode scanning that directly inputs fields, such as lot and batch numbers, into the software program. This is the most basic functionality where the barcode acts as a keyboard emulator. Not only is data entry more reliable, but the time required to enter lengthy IDs is reduced. When each specimen has its own ID that must be entered, however, wasted time can still quickly add up. Many users want to take barcoding a step further by linking the barcoded information to test methods. This allows a technician to scan a barcode or QR code on a batch of specimens that would then automatically open the correct software test method and populate all necessary fields. This allows the operator to scan a single field and immediately conduct a test, without the concern of making a simple human error that could invalidate the test results.

LIMS INTEGRATION

While barcoding automates the entering of data into the software, many users also want to automate the process of extracting test results and raw data from the system. Most labs use a network drive or company database to store or back up the results and/or raw data from their materials testing system.

Laboratory information management systems (LIMS) are designed to store large datasets from multiple pieces of testing equipment in one place. However, many LIMS are protected and come in a variety of shapes and sizes, making it difficult for a third-party equipment supplier to directly interface with them. For this reason, the current trend is to automate the process of extracting data from testing equipment in customizable file formats. By offering flexible export formats, IT departments that manage the LIMS can easily pull the exported data into their LIMS as part of a weekly, daily, or hourly process. Many software programs can also run an executable file to trigger a data pull after every export, further automating and simplifying the process of exporting test data.

By centralizing the storage of test data, labs can integrate analysis tools that query the LIMS database to gain insights on how their material has performed over time. For labs that do not possess this IT infrastructure but see value in performing centralized analysis, some equipment suppliers offer a standalone tool that enables users to track trends in data produced by multiple systems.

Many labs have successfully used one or many of the above solutions to introduce a degree of automation to their testing. Because so many different options are available, labs can be cost-conscious about choosing the software and hardware options that will demonstrate the greatest return for their investment. As demands for increased throughput, reduced costs, and safer operator environments continue to evolve, new automation solutions will continue to be developed to further enhance materials testing systems and processes. **~AM&P**

For more information: Dan Caesar, software product manager, Instron, 825 University Ave., Norwood, MA 02062, 781.575.5000, daniel_caesar@instron.com, www.instron.com.

Barcode scanners can be used to automatically input specimen or batch data into the testing software.

Automated air kits can be set to automatically close at a reduced pressure and speed to create a safer testing process.

STEEL PRODUCT DEVELOPMENT AIDED BY AUTOMATED PARTICLE WORKFLOW

In steel production, an automated particle workflow can increase the efficiency and statistical relevance of nanosized precipitate analyses, resulting in increased productivity and accuracy.

Steel is vital for the durable infrastructure development needed for growing populations. It provides affordable housing and mobility solutions and is indispensable for energy generation and distribution. Due to its central role in making modern society sustainable, manufacturers are preparing the next generation of stronger, lighter, and more sustainable steel. This product development requires testing at micro- and nanoscale.

In modern steel grades, the presence of precipitates, such as titanium nitride and niobium carbide, is key. Their size, distribution, and density are of utmost importance.

OCAS (OnderzoeksCentrum voor de Aanwending van Staal), a joint venture between ArcelorMittal and the Flemish Region, is a research center active in metallurgy, coating, and steel application development. About 95% of OCAS' work with transmission electron microscope (TEM) instruments involves testing a high volume of steel precipitates. By analyzing the size, morphology, distribution, and elemental characteristics of precipitates at the nanometer scale, OCAS helps its customers develop steel with the specific properties needed for high-strength structural applications.

In the past, OCAS manually determined the size distribution and chemical composition of precipitates, a slow and cumbersome process. The workflow involved capturing a TEM image of a sample, manually examining each precipitate with energy-dispersive x-ray spectroscopy (EDS) analysis, and then writing down the measurements. Data could only be gathered on 100-200 precipitates per sample. Operators also lacked an overview image that enabled them to see how both the small and large precipitates were distributed across the sample and whether the distribution was homogeneous. Determining the ratio between the small and large precipitates was not possible. Altogether, it typically took between one and three days to obtain the information required for a single sample, with 5-10 samples required for each project.

To improve precipitate analyses, OCAS moved to Thermo Scientific's automated particle workflow (APW) in 2020, which made it possible to quantify nanosized precipitates more accurately in a shorter timeframe. This workflow increased efficiency and statistical relevance of these analyses, enabling the research center to boost productivity and accuracy of results.

PREPARING STEEL PRECIPITATE SAMPLES

OCAS uses two methods of sample preparation to evaluate steel precipitates, depending on the request of the customer: replica and focused ion beam (FIB) lamella. In replica sample preparation, the sample surface is polished and etched by acid; a thin, amorphous carbon film of 20 nm is then deposited on the prepared sample surface. The carbon film-coated sample surface is then etched again.

With the dissolution of the matrix around the precipitates, the carbon film collects the precipitates that have been released from the sample surface and are floating in the acid. Those floating replica pieces are put on the copper mesh grid holder so the precipitates can be imaged and analyzed. Ultimately, the replica method can provide a large sample area. However, some precipitates might get lost during etching, and the precipitates may no longer retain their original spatial distribution.

In FIB lamella sample preparation, on the other hand, technicians use the Thermo Scientific SCIOS 2 DualBeam, an ultrahigh-resolution focused ion beam scanning electron microscope (FIB-SEM) system to prepare samples without changing the precipitates' spatial distribution. Using this method, they can quickly develop thin foil cross-sections that can be lifted out and attached to a TEM grid for analysis. This method retains particle orientation and size and lets technicians precisely hone in on specific areas they want to investigate.

TEM SCREENING AND OVERVIEW MAP

After replica sample preparation is complete, OCAS uses a Thermo Scientific Talos F200X G2 (scanning) transmission electron microscope ([S]TEM)

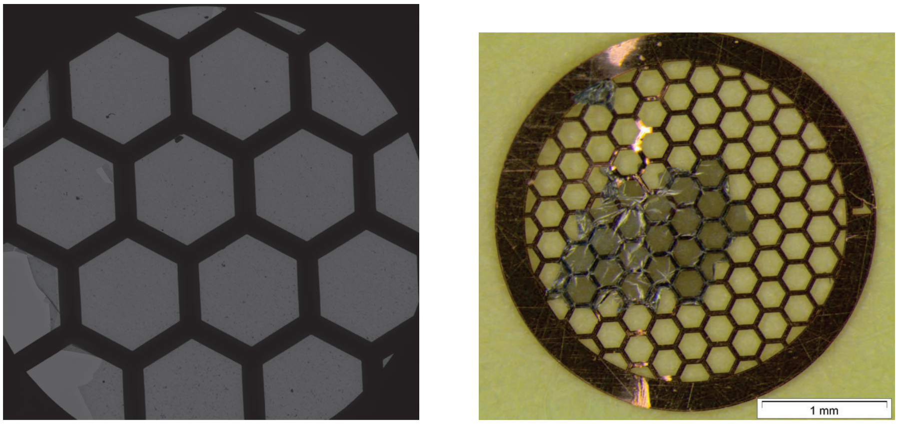

Fig. 1 — Left: The low-magnification TEM image is taken to assess the homogeneity of precipitate distribution on a large scale. Right: Example of 3 mm TEM grid with carbon replica film applied.

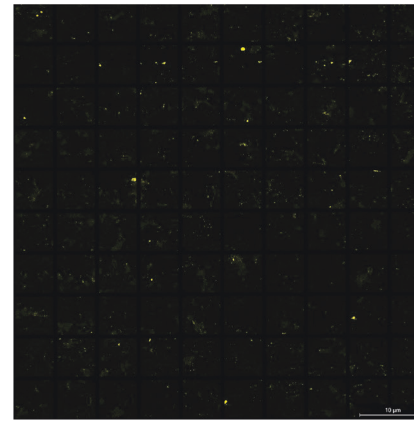

Fig. 3 — One hundred titanium EDS maps are collected in this 10 x 10 grid with 2.837 nm pixel size in an overnight run.

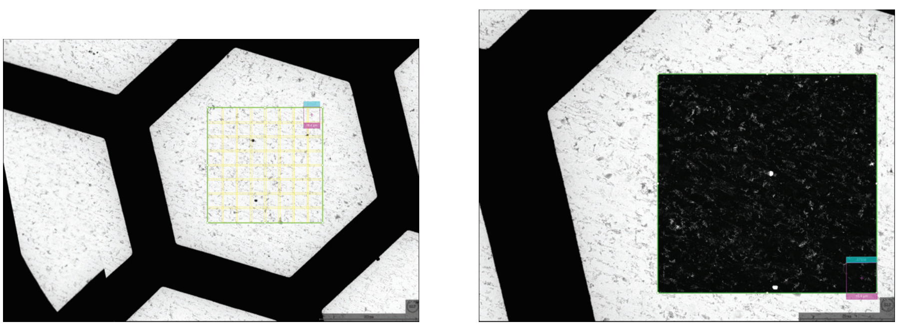

Fig. 2 — Left: An 8 x 8 grid is ready to collect 64 dark-field STEM images in the center of this randomly chosen grid hole. Right: The overview image has been completed with 8 nm pixel resolution.

that combines (S)TEM imaging with a Super-X EDS system that offers four EDS detectors to obtain the composition of precipitates. To accommodate this new instrument, OCAS built a new microscopy lab in the basement of its headquarters in Zelzate, Belgium, to ensure temperature fluctuations and vibrations are minimized. Using the Talos, technicians take a low-magnification TEM image to assess the distribution of the precipitates and determine the homogeneity of the distribution (Fig. 1).

After the homogeneity is evaluated for several of the hexagonal grid holes on a carbon replica, one grid hole is selected to represent the distribution across the sample for precipitate analysis, and 64 dark field STEM images are automatically launched at a user-specified location by Maps software (Fig. 2). These images are then stitched together to form the overview map of the selected hexagonal hole. The total area for the stitching is 117 x 117 µm, and the process takes approximately 2 minutes for manual setup and 10 minutes for automatic imaging and stitching.

With an overview map, technicians can see all precipitates across a defined area, including their morphology, size, and distribution. They can also zoom in to 8 nm per pixel and view precipitates in more detail while tracking how each examined area corresponds to its position within the larger overview map. When more information is needed for a region of interest on the overview map, a double-click on the region in Maps software leads directly to the spot, where a higher magnification STEM imaging or EDS analysis can then be launched.

The overview image serves as a roadmap, guiding operators to the precipitates they need to analyze in greater detail and more closely observe the parameters that are either enhancing or negatively impacting steel quality. In some cases, all the information that's needed can be obtained in the few minutes it takes to produce an overview map; no further analysis is required.

AUTOMATED EDS IMAGES

For full EDS information across a defined area, operators can also run automated EDS maps to determine the chemical makeup of pre-

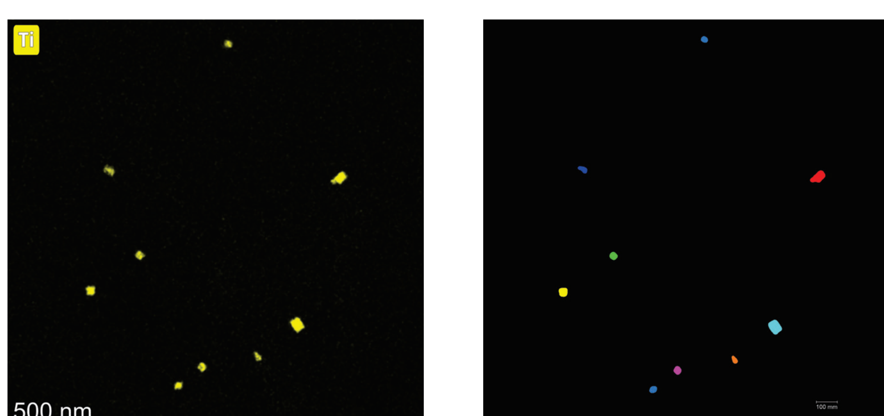

Fig. 4 — Left: One titanium EDS map. Right: The precipitates have been segmented and labeled by Avizo2D.

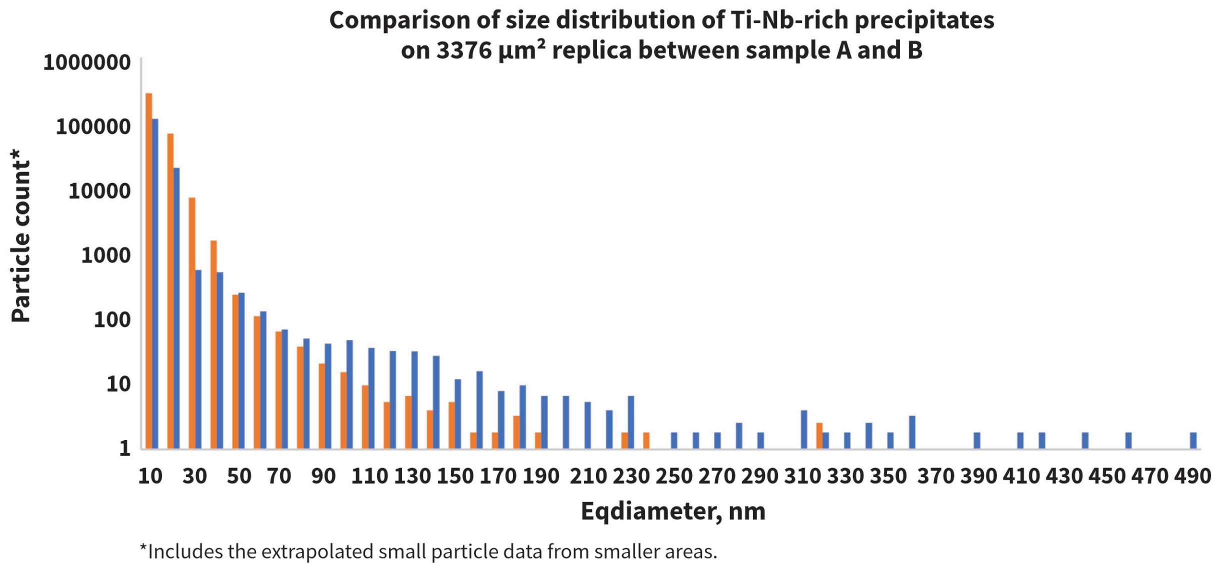

Fig. 5 — Comparison of size distribution of Ti-rich precipitates between two samples. This includes about 4000 precipitates over 30 nm in size from the original 2.837 nm resolution scan, in addition to an extrapolation of a second scan at higher resolution over a smaller area to characterize the smaller precipitates. Thus, the APW can evaluate the full-size range of precipitates to compare the difference between samples.

cipitates, whether they be titanium, niobium carbonitrides, or other elements (Fig. 3). A 10 x 10 grid is established, and 100 EDS maps are automatically collected over an area of 58.1 x 58.1 µm. The process takes 5 minutes of manual setup and 17 hours of automated work that can be completed overnight.

VISUALIZING THE DATA

Using Thermo Scientific Avizo2D with Thermo Scientific Velox software and Thermo Scientific Maps Software, (S)TEM and EDS images are automatically recorded as part of the workflow and transformed into particle data, where the precipitates are segmented and labeled (Fig. 4). Precipitates analyzed at the nanometer scale are combined with results from other techniques investigating large precipitates (>500 nm). Together, these methods provide a comprehensive picture of both small and large precipitates across the sample. This information is then used to generate histograms showing the size distribution of each precipitate, providing the final information OCAS' customers need for their samples of interest (Fig. 5).

FASTER, MORE ACCURATE DATA

Using APW, the morphology, size distribution, and chemical composition of steel sample precipitates can be captured in less than 18 hours, almost all of which involves automated, unattended work. APW enables up to 4000 precipitates (at this pixel resolution) to be studied at a time, representing 20 times what was possible with OCAS' previous workflow and leading to more statistically relevant data. It helps OCAS provide the precise information their customers need to produce steel for different applications. In addition to enabling the acquisition of more accurate data over a larger sample area, APW improves productivity, enabling technicians to analyze more samples in less time and freeing them up to perform other types of analyses while the automated work is in process.

CONCLUSION

Using Thermo Scientific's APW, which combines (S)TEM images with EDS mapping, OCAS has improved the efficiency and accuracy of its precipitate analyses. With this workflow, the research center can now quickly obtain the morphology, size distribution, and chemical composition of up to 4000 precipitates per sample. It can also accurately analyze the distribution of both small and large precipitates over a defined area to obtain the comprehensive data needed during the steel R&D process. **~AM&P**

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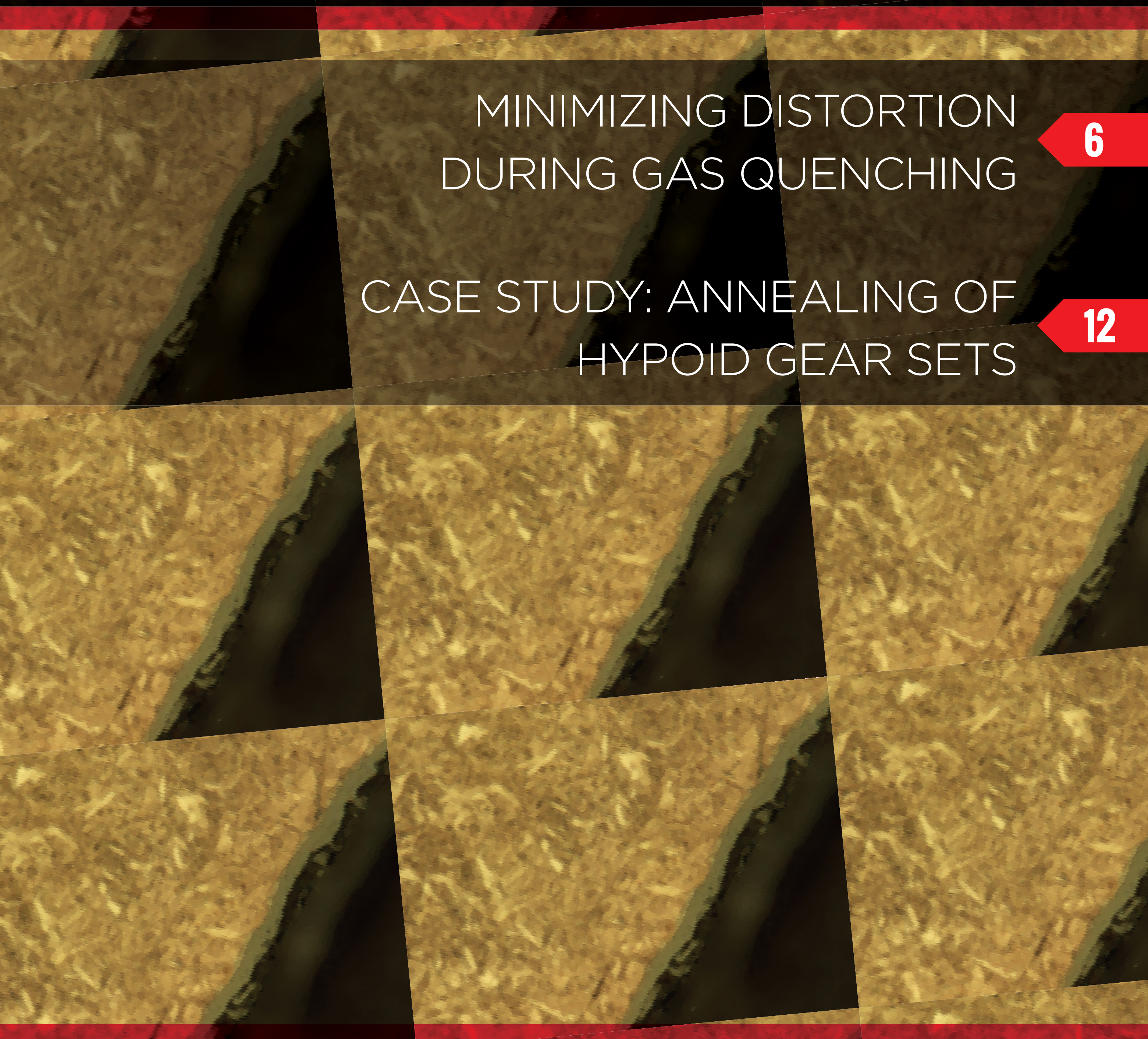

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EDITORIAL OPPORTUNITIES FOR *HTPro* IN 2022

The editorial focus for *HTPro* in 2022 reflects some key technology areas wherein opportunities exist to lower manufacturing and processing costs, reduce energy consumption, and improve performance of heat treated components through continual research and development.

March
Testing & Control

July/August
Thermal Processing in On/Off Highway Applications

November/December
Atmosphere & Vacuum Heat Treating

To contribute an article to an upcoming issue, contact Vicki Burt at vicki.burt@asminternational.org.

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ABOUT THE COVER

Microstructure of a carburized coupon processed using DANTE controlled gas quenching. Courtesy of DANTE Solutions Inc.

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AN INDUSTRY AT WAR 80 YEARS AGO


Burt

Recently a vintage 1942 issue of *Metal Progress,* the forerunner to *Advanced Materials & Processes,* found its way to my desk. Reading through each slightly moldy page, it became obvious this was an industry focused on the war effort. It had only been a few months since the December 1941 attack on Pearl Harbor which officially thrust the United States into World War II. By the time this issue was published in August 1942, nearly every part of American life: companies, associations, media, manufacturers, even religious institutions, was focused on activities related to war efforts.

Serving as a publication of the American Society for Metals, as ASM International was known then, *Metal Progress* jumped in to do its part not only in disseminating technical information used to ramp up manufacturing, but also in reporting and contributing to studies from the War Production Board (WPB). Page 221 of that issue features an article drafted by founding editor of *Metal Progress* Ernest E. Thum, titled “Secondary Copper for Bearings, War Work & Alloy Steel,” which suggests “ways and means whereby the maximum amount of metal can be guided into its best, quickest, and most economical use, without debasement of grade.” The article lies between two others: “Status of Steel Expansion Program” and “Standard Drawing Dies (Carbide) for Small Ammunition.” It’s clear that metals were going to play a part in this war.

On page 213 in the newly formed War Products Consultation column, a blower manufacturer asked for technical help. The article, “Fixing Bearing Metal in Steel Shells” notes that because of a tin shortage, the “emergency alternate” lead-base alloy substitute the company wanted to use did not easily attach to the steel shells. The proposed solution contributed by another company and advertiser used ASTM Emergency Alternate Alloy No. 15 and listed a detailed recipe for bonding the materials.

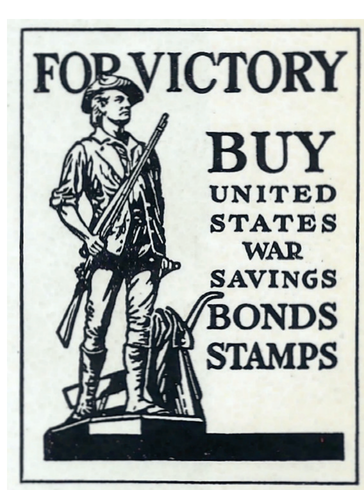
Speaking of advertising, there were ads from at least 150 companies, many in the heat treating industry, and almost all of them mentioning or inferring how their products and services are helping the war effort. Repeated themes include calls to buy war bonds, to collect and reuse scrap metal, suggestions for dealing with new restrictions on using metals, and of course making sure quality products are leaving the factories at every step for the “boys” on the front line. More than one ad would be considered politically incorrect today, directed at enemies of the Allied forces. We’ve scanned a few favorite advertisements that reflect the tone of the entire issue.

As a former book editor, I would be remiss if I didn’t also mention this gem: a listing of ASM books, including “Practical Metallurgy” by George Sachs and Kent Van Horn, and “Principles of Heat Treatment” by M.A. Grossman. For $8.50 and a note to the “Gentlemen” at ASM, both of these soon-to-be industry classics could be yours.

Assuming you don’t have a time machine, a copy of Grossman’s book is currently available on eBay for about $34, and old issues of *Metal Progress* also show up from time to time. Alternatively, most of us are more interested in recent developments in heat treating, and for that, be sure to read the proceedings from Heat Treat 21, now available in the ASM Digital Library at dl.asminternational.org/heat-treating. While it’s fun to look back, it’s amazing to think about how far this industry has come.

Victoria Burt
Editor, *HTPro*

Advertisement for furnaces from Holcroft & Company.



“Thousands of shells that will wing their way to Victory are being heat treated in Flinn & Dreffein furnaces.”

HTS NAMES NEW OFFICERS AND BOARD MEMBERS

Lesley Frame, assistant professor, University of Connecticut, succeeds as president of the Heat Treating Society (HTS), while **Eric Hutton**, vice president operations, ADE North America East, Bodycote remains on the board as immediate past president and treasurer. **Benjamin Bernard** serves as vice president and **Deidra Minerd** serves as secretary. Officers serve a two-year term.

In addition, the following members were appointed to the HTS Board for a three-year term: **Allen (Jeff) Fuller,** manager of process quality, Amsted Rail Brenco, and **Lee Rothleutner,** manager of materials R&D, The Timken Company. **Fred Hamizadeh,** director of manufacturing services, American Axle & Manufacturing, will serve a second three-year term. **Carlos Torres,** president and CEO, MATT-SA CRIO Group, was appointed as emerging professional board member for a one-year term, and **Rodolfo Canales Garcia,** Instituto Technologica de Morelia, was appointed to serve a second term as student board member.


Frame


Hutton


Bernard

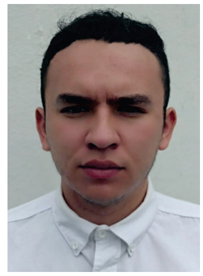

Minerd


Fuller


Rothleutner


Hamizadeh


Torres


Garcia

SCHMIDT RECEIVES 2021 GEORGE H. BODEEN HEAT TREATING ACHIEVEMENT AWARD

Frederick E. Schmidt, Jr., FASM, director materials technology, Advanced Applied Service, Engineering Systems Inc., St. Charles, Ill., is the recipient of the 2021 George H. Bodeen Heat Treating Achievement Award. Established by the ASM Heat Treating Society in 1996, the award recognizes distinguished and significant contributions to the field of heat treating through leadership, management, or engineering development of substantial commercial impact. Schmidt is recognized "for seminal thermal processing innovations for 40 years, developing and successfully implementing cost-effective technology. The establishment of novel heat treatment uses of commercial equipment, for military/ordnance, and strategic industrial processes."

Schmidt's 2021 Award.

SUNDARESH RECEIVES 2021 ASM/HTS SURFACE COMBUSTION EMERGING LEADER AWARD

The ASM HTS/Surface Combustion Emerging Leader Award was established in 2013 to recognize an outstanding early to mid-career heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award, endowed by Surface Combustion, includes a check for $4000. The winning young professional will best exemplify the ethics, education, ingenuity and future leadership of our industry. **Shlok Sundaresh,** engineering manager – North America, Techniques Surface USA, Dublin, Ohio, is recognized "for outstanding leadership and technical expertise in heat treatment, especially in development and application of nitriding/nitrocarburizing technologies across diverse market segments such as automotive, industrial machinery, and oil and gas."


Sundaresh

SOUSA WINS 2021 HTS/BODYCOTE BEST PAPER IN HEAT TREATING AWARD

Sousa

The winner of the 2021 ASM HTS/Bodycote Best Paper in Heat Treating Award is entitled, "Phase Fraction Quantification in Austempered Steels by Nanomechanical Mapping: AISI 5160 as a Case Study" by **Bryer Sousa,** Ph.D. student at the Worcester Polytechnic Institute.

The ASM Heat Treating Society established the Best Paper in Heat Treating Award in 1997 to recognize a paper that represents advancement in heat treating technology, promotes heat treating in a substantial way, or represents a clear advancement in managing the business of heat treating. The award includes a plaque and $2500 cash prize endowed by Bodycote Thermal Process-North America.

FRAME WINS PROF. VALENTIN S. NEMKOV ACADEMIC RESEARCH AWARD

Lesley Frame, through her roles as assistant professor at University of Connecticut and director of the Center for Materials Data Processing, has won the Prof. Valentin S. Nemkov Academic Research Award, presented at Heat Treat 21 in St. Louis. Frame was awarded for her contribution to excellent research that was part of the traditional oral program, Fluxtrol Student Poster Competition, and the inaugural Strong Bar Competition, in addition to participating on the organizing committee for the event and acting as a session chair.

The award is Fluxtrol Inc.'s annual recognition program for post-doctoral researchers, lecturers, and professors (academic researchers) that is presented to the researcher who had the greatest impact on that year's event in the area of thermal processing of materials.

The winner of the 2021 HTS Strong Bar Competition, sponsored by MTS, is **teaMAT** from the University Instituto Technologico De Morelia, Mexico.

Fluxtrol Student Research Competition, 1st place winner, Ethan Hoyt, Colorado School of Mines.

Fluxtrol Student Research Competition, 2nd place winner, Michelle Kent, Colorado School of Mines.

Fluxtrol Student Research Competition, 3rd place winner, Joseph Boettcher, MolyCop USA.

MINIMIZING DISTORTION DURING HIGH-PRESSURE GAS QUENCHING, PART I

A new method to control distortion in difficult-to-quench geometries addresses the nonuniform cooling inherent in most gas quenching processes.

Justin Sims,* Zhichao (Charlie) Li,* and B. Lynn Ferguson, FASM*
DANTE Solutions Inc., Cleveland

Distortion can generally be divided into two categories: size change and shape change. Solid-state phase changes occurring in steel alloys during thermal processing can result in permanent size change, due to the difference between the starting microstructure and the microstructure after heat treatment. Size change is unavoidable but can easily be predicted and accounted for in part design. Permanent shape change is a result of nonuniform plastic strain, caused by nonuniform phase transformations, thermal strains, or creep while at high temperature, and is more difficult to predict and control. The nonuniformities can be a result of alloy segregation, uneven heating or quenching, poor support while at high temperature, thermal expansion or contraction restrictions, or residual stresses from prior manufacturing operations.

Traditionally, liquid quenchants were used to quench most steel parts to obtain a martensitic microstructure. Liquid quenchants undergo a unique phenomenon, comprised of three stages, when a red-hot part is immersed into the liquid[1]. First, a thin vapor film is formed around the red-hot part, with extremely slow heat transfer rates. Nucleate boiling commences as the vapor blanket breaks down. Nucleate boiling results in the fastest heat transfer due to a combination of the latent heat of vaporization and aggressive convection. Convective cooling, the final stage, begins as the nucleate boiling subsides[2].

The continually changing heat transfer rates associated with liquid quenching can severely affect the cooling uniformity of a given part. First, the breakdown of the vapor blanket rarely occurs evenly on all part surfaces, being dependent on the part surface temperature, local flow behavior, and the liquid properties, creating brief periods of nonuniform heat transfer. The chaotic nature of this phenomenon is difficult to predict and can lead to inconsistent distortion within a single load of parts. Part geometry and immersion orientation also play a significant role in nonuniform cooling when quenching in liquids[3-5].

High-pressure gas quenching (HPGQ) does not involve a phase change of the quenching media, and therefore, has a more stable heat transfer rate. However, due to its low density and specific heat, gas is unable to absorb energy as well as liquids, and will suffer a temperature change as heat is removed from the part. The gas's low density also makes it more susceptible to local flow variations. HPGQ equipment can also significantly contribute to local flow variations[6].

In response to large distortion during HPGQ of complex geometries, DANTE Solutions devised a novel process, termed DANTE Controlled Gas Quenching (DCGQ), by which the martensitic phase transformation is controlled during gas quenching[7]. Because the transformation from austenite to martensite is driven by a reduction in temperature, and is not time dependent like the diffusive phase transformations, the simplest way to control the martensite transformation is to control the rate of temperature change within the component. By controlling the uniformity of martensitic transformation throughout the part, distortion can be significantly reduced, easily predicted, and consistently reproduced. This article describes the DCGQ prototype unit design and operation.

EQUIPMENT DESIGN AND CONSTRUCTION

The DCGQ process was developed after hundreds of hours were spent evaluating DANTE quenching models and determining temperature gradients which allowed for minimal distortion of difficult-to-quench geometries, generally encountered in power transmission applications. It was determined that by maintaining a set temperature difference between the fastest cooling point and the slowest cooling point on a part, distortion could be significantly reduced. If the temperature difference is kept sufficiently small, shape change can be completely eliminated, and only the resulting size change from the phase transformations is realized.

Atmosphere Engineering (now part of United Process Controls), in Milwaukee was contracted to design and construct the DCGQ prototype unit. The system includes a 1 m^3 working zone within the quench chamber, separate hot and cold chambers for temperature manipulation of the quench gas, a human machine interface (HMI) for system manipulation and process monitoring, and custom program logic developed by Atmosphere Engineering to

*Member of ASM International

follow time-temperature recipes by mixing gases from the hot and cold chambers.

Figure 1 shows the front of the quenching chamber, where the parts are loaded. Figure 2 shows the back of the unit. The electrical panel, with the HMI unit, is in the foreground of Fig. 2, with the cold chamber directly behind it, and the hot chamber to its right. Figure 3 shows the HMI. The HMI allows access to, and manipulation of, the system logic and parameters, as well as being where recipes are entered, and processes monitored. Shown in Fig. 3 is the process monitoring function, which allows the user to view the recipe setpoint and the actual temperature of the gas entering the quench chamber, while also monitoring the position of all the various valves required to operate the equipment. The tables on the right of the screen show the temperature values of several thermal couples located within the chamber or thermocouples attached to a quench probe or part.

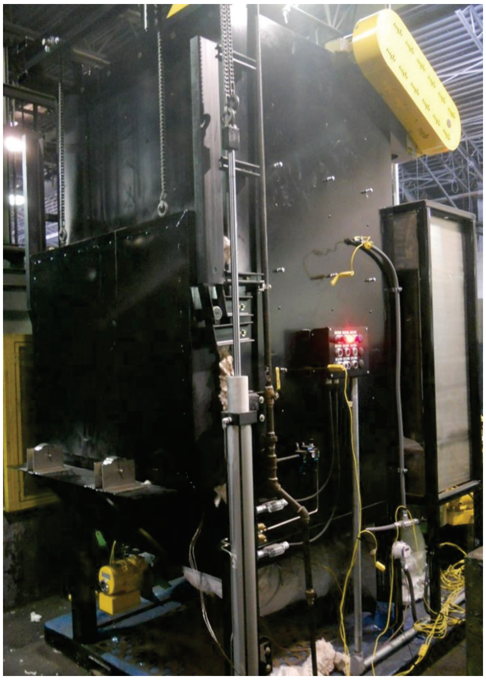


Fig. 1 — Front of the DCGQ prototype unit.

Fig. 2 — Back of the DCGQ unit.

EQUIPMENT OPERATION

The unit was constructed at Atmosphere Engineering and shipped to Akron Steel Treating in Ohio, where it was installed and tested. This first prototype unit requires heating to be performed in a separate furnace, with the part transferred by rail cart to the DCGQ unit after austenization is complete; future production equipment should integrate controlled heating, as well as cooling. The DCGQ unit is preheated to a predefined temperature during the austenitization process in preparation for quench; the preheat temperature is alloy and part geometry dependent. The DCGQ recipe programmed into the HMI begins once the front-loading door is closed. Figure 4 shows a comparison of the temperature of the quench gas entering the chamber ("Chamber Inlet PV") and the recipe setpoint temperature ("Chamber Inlet SP") with no hot part in the chamber. The recipe consists of 50°C temperature reductions over two minutes, starting at 425°C, with 20-min holds at each temperature step.

Figure 4 shows that the unit logic works well, and the system has no issues following the time-temperature recipe. The system did struggle a bit at lower temperatures, but still maintained the process temperature within 5°C of the recipe setpoint temperature, which was the tolerance programmed into the unit.

The time-temperature recipe shown in Fig. 4 represents schedules required for various geometries. For geometries with a thin, uniform cross-sectional thickness, such as rings, the designed temperature reductions can be relatively large, and the ramp and hold times can be short,

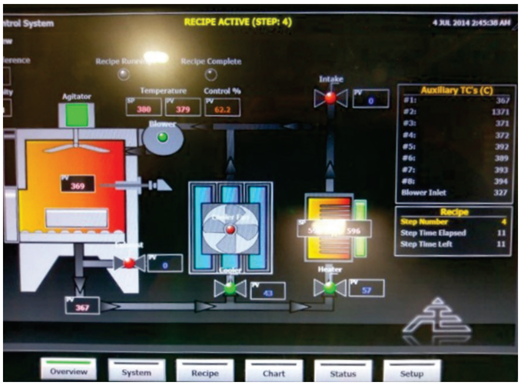


Fig. 3 — Human machine interface on DCGQ prototype unit showing process monitoring functionality.

as the part cools relatively quickly and uniformly. For thin geometries with a slightly nonuniform cross-sectional thickness, such as ring gears, temperature reductions should be kept small, due to the mass differences in the part, but the ramp and hold times can be relatively short, as the part will cool quickly. For parts with significant unbalanced mass distributions, such as crankshafts or eccentric bores, temperature reductions should be kept small, and ramp and hold times should be long.

To reduce recipe design time, and ensure an optimal recipe is achieved, with respect to distortion minimization and processing time, the equipment must be thermally characterized so heat treatment simulation and design software can be used for DCGQ recipe design. The following section describes the characterization of the DCGQ prototype unit.

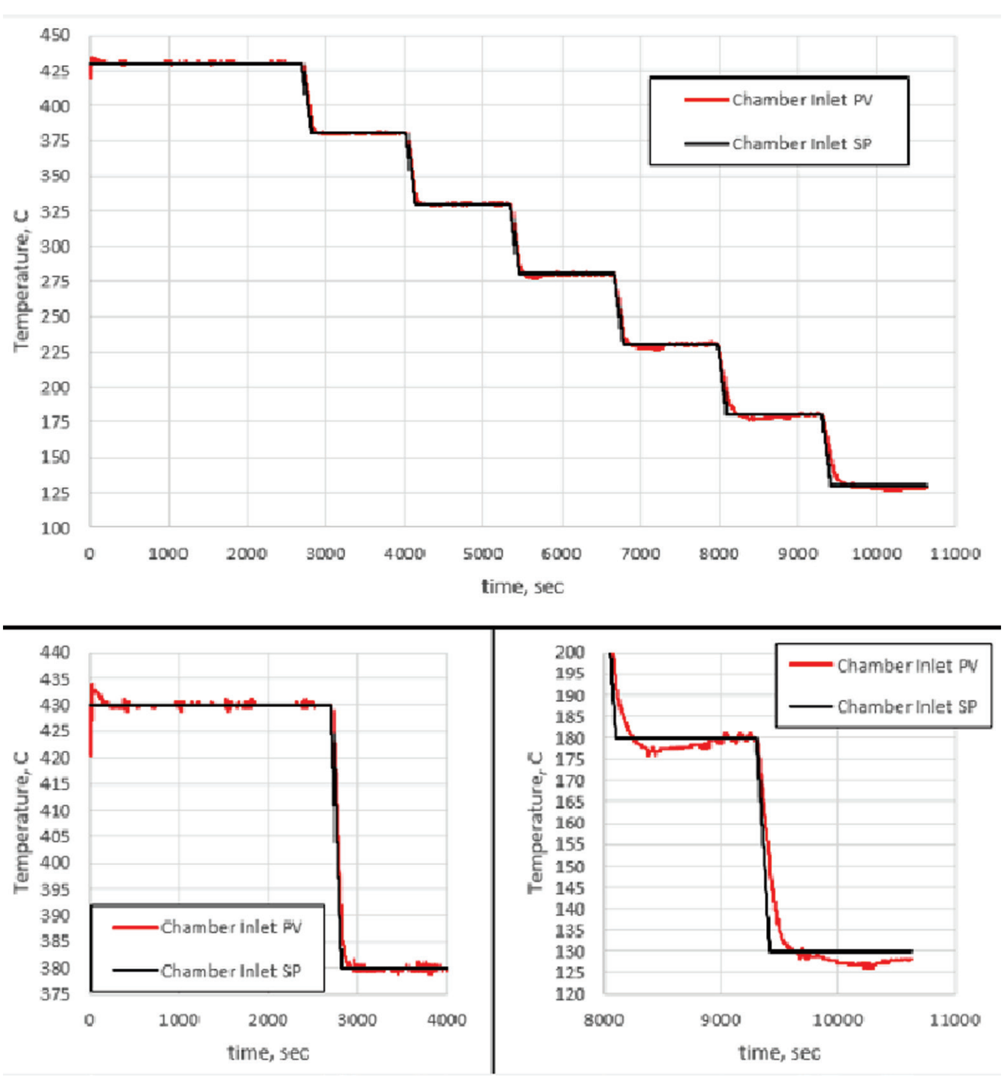


Fig. 4 — DCGQ prototype unit temperature comparison between quench gas entering the quench chamber and the recipe setpoint temperature, with an empty chamber.

EQUIPMENT CHARACTERIZATION

To properly characterize the DCGQ prototype unit for modeling and process design, or any other type of thermal equipment, it is necessary to determine the heat transfer coefficients (HTCs) and ambient temperatures acting on the component being treated. For liquid quenching operations, the convective HTC should be described in terms of part surface temperature, due to the significant difference in heat transfer between the vaporization, nucleate boiling, and convective stages of liquid quenching. The ambient temperature is assumed to remain constant, due to the liquid's large specific heat and overall volume in the quench vessel.

However, for gas quenching operations, it is assumed that the convective HTC remains constant because there is no phase change associated with cooling in gas, and the ambient temperature is a function of process time, due to the gas's low specific heat (generally a magnitude less than liquids) and volume in the quench vessel. The ambient temperature as a function of time will vary for any single piece of gas quenching equipment, operating at the same conditions, and is dependent on the total mass being quenched, surface area of the load, and the initial temperature of the load.

Figure 5a shows a cylindrical quench probe, made of AISI 304 stainless steel, used to characterize the DCGQ equipment. The cylinder has a 100 mm diameter and 100 mm height. There are five holes drilled to mid-height, four approximately 3 mm from the outer diameter and one in the center, which are fitted with K-type thermocouples. Thermocouples are also located in the DCGQ chamber at various dis-

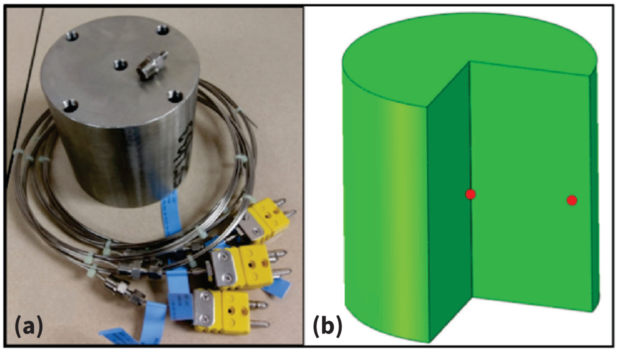


Fig. 5 — (a) Quench probe used for DCGQ equipment characterization, and (b) DANTE model of the quench probe.

tances from the probe to measure the ambient temperature. Using the time-temperature history of the quench probe and recorded ambient temperature for a given DCGQ recipe, along with a DANTE model of the quench probe, shown in Fig. 5b, the HTC and ambient temperatures can be determined.

For DCGQ processes, the ambient temperature as a function of time is dependent on total mass, surface area, and initial temperature, just as it is with HPGQ, but the ambient temperature for DCGQ is also dependent on the temperature ramp and hold times. Figure 6 shows the re-

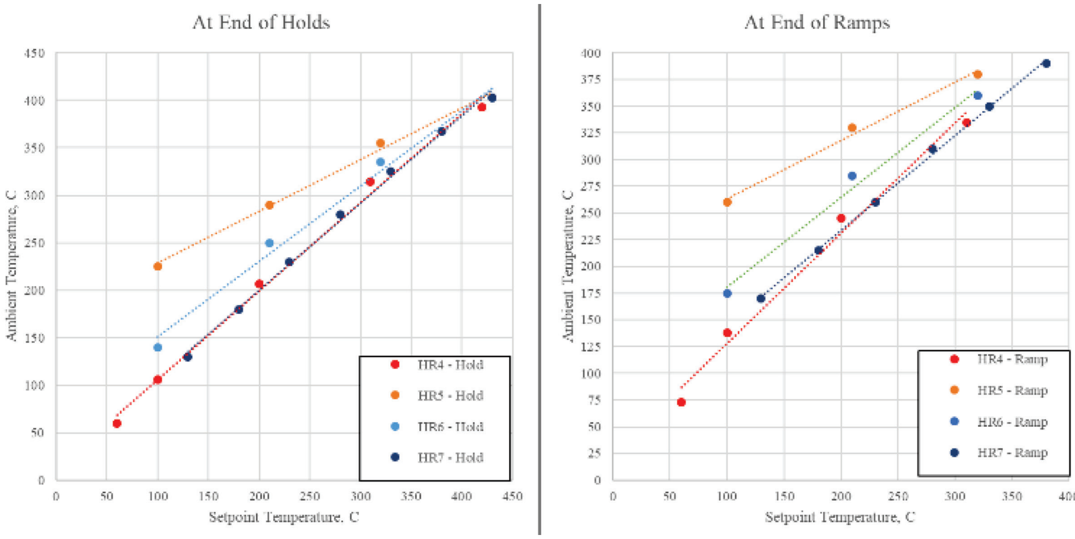


Fig. 6 — Relationship between recipe setpoint and ambient temperatures at the end of the holds (left) and ramps (right) used for DCGQ recipe design and analysis.

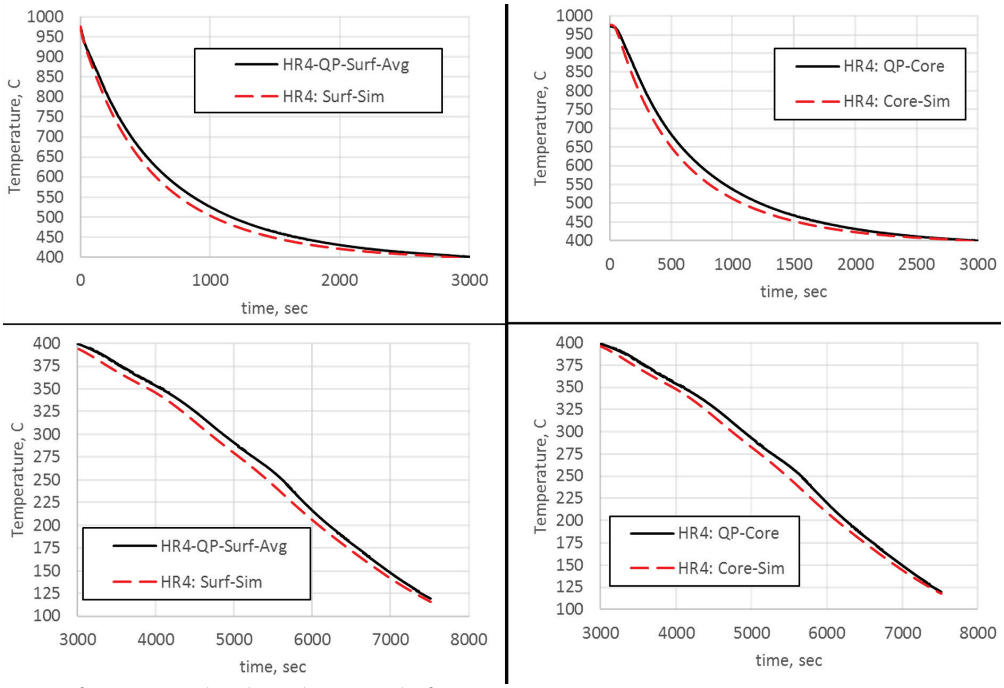


Fig. 7 — Comparison of experimental and simulation results for one DCGQ recipe.

sults of a comparative analysis between the setpoint and actual temperatures at the ends of the holds (left) and ramps (right) for various DCGQ schedules. Ideally, to make design and analysis of the DCGQ process simpler and more intuitive, the setpoint and actual temperatures should be equal at the end of each temperature ramp and hold. For the processes shown in Fig. 6, HR4 and HR7 abide to this equality, but as the ramp and hold times get shorter, these two temperatures begin to deviate; HR5 had the shortest ramp and hold times. This fact does not negate the use of modeling in recipe design, but rather solidifies the fact that processing equipment behavior should be thoroughly understood, within normal operating conditions, if the process is to be modeled. After the behavior is understood, it can be incorporated into the models for more accurate results.

Figures 7 and 8 show time-temperature results comparing the DANTE simulation, which used the single HTC and relevant ambient temperatures determined from experiments, and the actual time-temperature data. In addition to the two tests shown in this article, five more recipes were executed, with their data also used in characterizing the DCGQ equipment. There is good agreement between simulation and experimental results, with the tests not shown having similar agreement. Each DANTE model of the DCGQ process used the same HTC, but the ambient temperature varied depending on the temperature ramp and hold times of the given recipe.

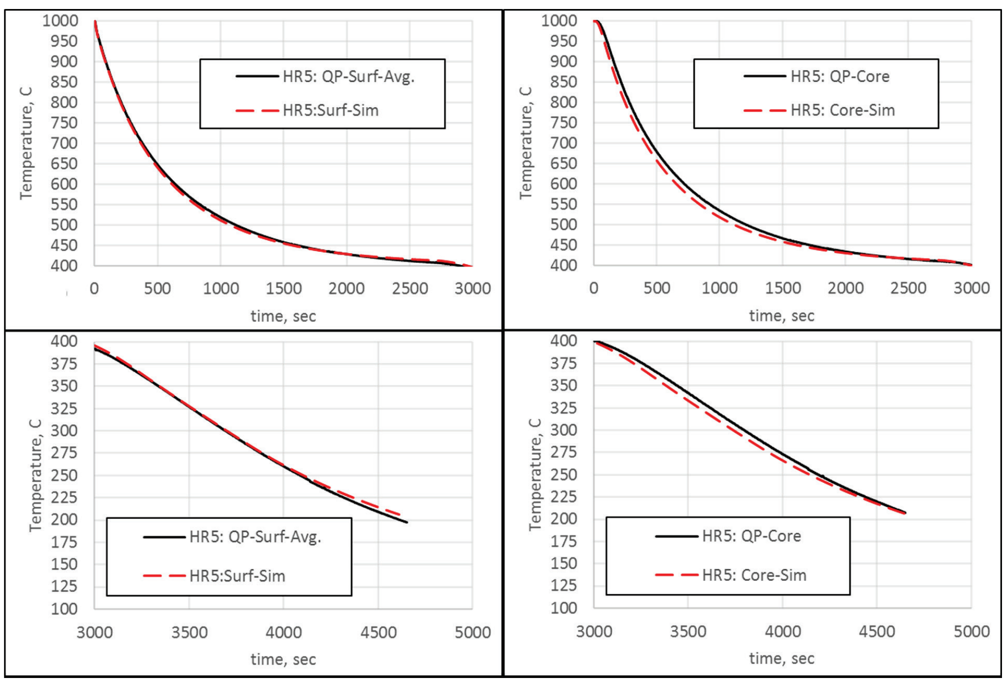
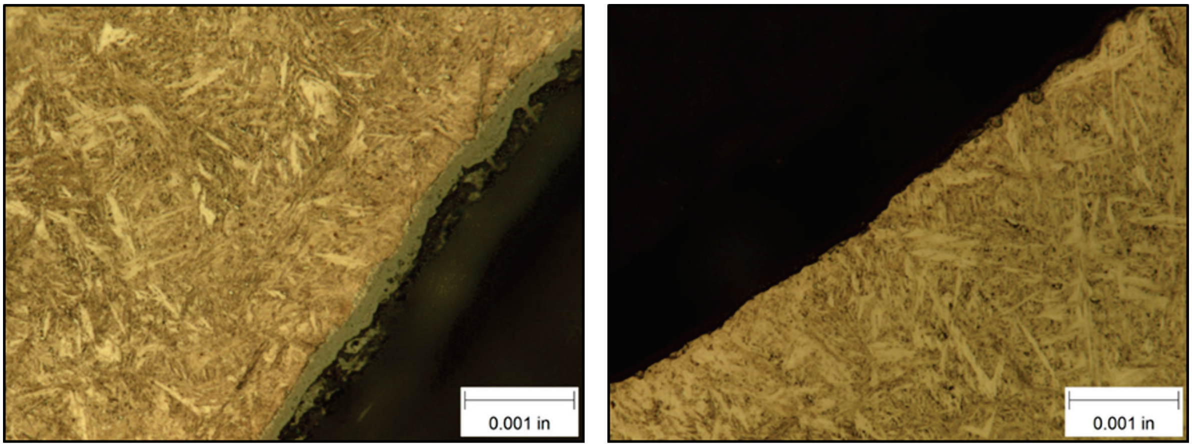


Fig. 8 — Comparison of experimental and simulation results for one DCGQ recipe.



(a) **(b)**

Fig. 9 — Microstructure of a carburized coupon processed using (a) DCGQ and (b) HPGQ, magnified 1000X.

CONCLUSIONS

The DANTE controlled gas quenching (DCGQ) process has the potential to handle difficult-to-quench part geometries without the use of expensive press quench tooling and reduce the amount of post-heat treatment processing required. The work presented here concluded that it is possible to control the temperature of quench gas entering a quench vessel, at atmospheric pressure, in order to follow a time-temperature recipe required to control the martensitic transformation rate in high hardenability steel alloys. The prototype unit constructed was able to achieve great control within the temperature range of 400 to 100°C, using varying rates of temperature change.

Figure 9 shows the microstructure, magnified 1000X, of a carburized (a) DCGQ processed coupon and (b) HPGQ processed coupon. As with previous experiments, there is no discernable difference between the two microstructures. **~HTPro**

Note: Part II of this series will describe materials testing, microstructural evaluation, mechanical testing, and residual stress and distortion.

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CASE STUDY: CONTROLLING THE DISTORTION OF A CROWN WHEEL (HYPOID GEAR)

This study looks at whether adding an annealing step to the heat treating process has an effect on residual stress and distortion on hypoid gear sets.

Yathish Rao*
Industry Professional, Pune, India

The primary function of a crown wheel pinion is to transfer power from the transmission to the wheel ends. Dimensional accuracy is extremely important to meet the part life requirement. A study was carried out to test the effects of an additional annealing step during heat treatment on a hypoid gear set, particularly on distortion. Heavy truck, full float axle gear sets made of DIN 20MnCr5 were used in this case study.

Distortion in hypoid gear sets is unavoidable and happens during case hardening[1]. Complete elimination of distortion is not practical because it involves a microstructural phase change from FCC austenite to BCT martensite. These crystallographic changes impart dimensional imperfection in the part, or distortion. But distortion can be minimized using heat treatment.

The gear sets are manufactured in a dry gear cutting machine. Batch A (three gear sets) serves as the control group and is heat treated via the typical process. Batch B (three gear sets) is annealed after the soft gear cutting step. Residual stress analysis test results show a reduction in stress levels in batch B gear sets. This residual stress reduction is also evidenced by lower distortions in batch B gear sets.

MECHANISM OF GEAR DISTORTION

Distortion as defined metallurgically, occurs when crystallographic changes take place. Whenever gears are heat treated microstructural changes occur. At the soft gear stage, the microstructure is ferrite and pearlite, and heat treating to a case carburizing temperature of 925°C changes its phase to austenite. Upon quenching the microstructure changes to martensite[2].

During this phenomenon, the crystal lattices of the soft gears is body centered cubic (BCC), changes to face centered cubic (FCC) at carburizing temperature, and upon quenching the crystal lattice changes over to body centered tetragonal (BCT).

The carburizing process diffuses the carbon atom to the gear surface. These carbon atoms occupy the void space available inside the crystal lattice. While quenching, the phase changes from austenite FCC to martensite BCT and the rearrangement of crystal lattice takes place. Fe atoms present in the FCC lattice move to the position and new orientation to form a BCT lattice. This complexity in the crystal lattice system generates the dimensional imperfection called distortion.

HEAT TREATMENT OF HYPOID GEARS

Case carburizing, hardening, and tempering are performed on both batches of test gears. Three samples SN1, SN2, and SN3 are taken from each batch. The annealing heat treatment for batch B is carried out in an inert nitrogen N_2 atmosphere to avoid scaling and decarburization. Furnace loading fixture and loading quantity are kept

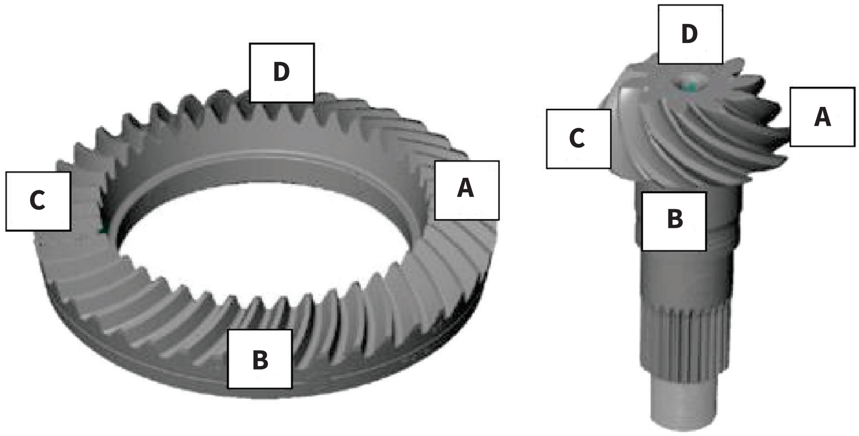

Fig. 1 — Residual stress measurement locations ABCD.

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TABLE 1 – RESIDUAL STRESS ANALYSIS TEST RESULTS

Characteristics	Location	Batch A and B after soft gear cutting			Batch B after annealing heat treatment		
		SN1	SN2	SN3	SN1	SN2	SN3
Residual stress, MPa	A	+97	+109	+155	+110	+88	+95
	B	+112	+135	+119	+90	+103	+85
	C	+150	+89	+95	+105	+97	+102
	D	+165	+145	+85	+95	+106	+95
Residual stress, MPa		+131	+119.5	+113.5	+100	+98.5	+94.25
Average residual stress, MPa		+121.3			+97.5		
% drop in tensile residual stress		19.50%					
Min residual stress, MPa		+97	+89	+85	+90	+88	+85
Max residual stress, MPa		+165	+145	+155	+110	+106	+102
Within-part variation, MPa		+68	+56	+70	+20	+18	+17
Average residual stress within part, MPa		+64.6			+18.3		
% reduction in variation within the part		71.60%					
Part-to-part variation, MPa		+18			+6		
% reduction in variation part-to-part		66.66%					

same for both batch A and batch B. Apart from this, quench press parameters and quench oil parameters are also kept the same.

RESIDUAL STRESS MEASUREMENT AND DISCUSSION

Residual stress is measured on the gear set tooth flank at four locations using an x-ray diffraction machine[3]. Locations are shown in Fig. 1. The gears are not sectioned but entire gear and pinions are exposed to machine. The analysis results show the residual stresses are tensile in nature. The stress analysis results are tabulated in Table 1. A graphical analysis shows the benefit of annealing on residual tensile stress, within-part stress variation, and part-to-part variation in stress. Results are shown in Fig. 2. The comparison between batches A and B shows the tensile stress variation within part is +64 MPa for batch A, and +18 MPa for batch B. This indicates the annealing heat treatment reduces the within-part stress variation to 71%. Similarly, the part-to-part variation for batch A is +18 MPa whereas batch B after annealing is +6 MPa. This data also shows the annealing process helped to reduce the part-to-part variation to 66.6%. Also, there is a drop in tensile residual stress. Batch A shows tensile residual stress of +121 MPa whereas batch B, post-annealing heat treatment shows +97 MPa. The 19.5% drop in tensile residual stress indicates stress relieving occurred during the annealing heat treatment.

HYPOID GEAR PROFILE MEASUREMENT TEST RESULT

Both batches of hard gear sets were tested in Klingelnberg P 65 test equipment and the topography of the tooth profiles were compared by gear group. The observation shows batch B has lower tooth distortion than batch A gear sets. Also, the distortion pattern in batch B is symmetric within the part and part to part, whereas distortion in batch A gear sets is on particular segments of the gear tooth; also the distortion pattern is asymmetric. A majority of batch B gear sets meet the AGMA class 8 requirements,

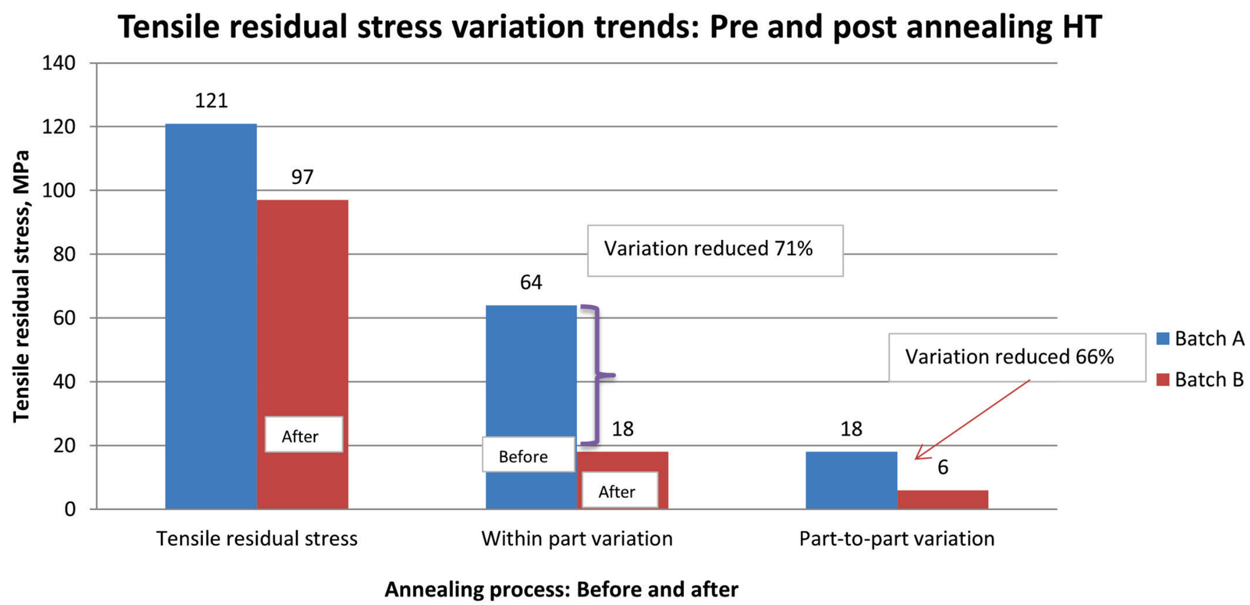

Fig. 2 — Annealing process improvement. Batch B is superior to batch A gear sets.

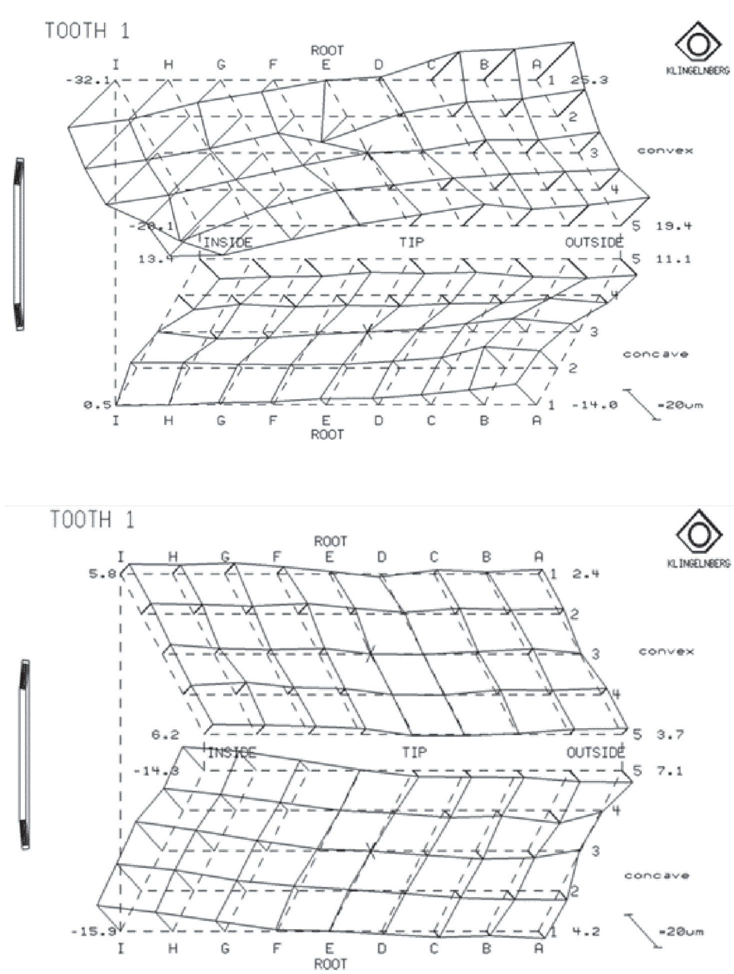

Fig. 3 — Batch A topography of a tooth (top). Batch B topography of a tooth (bottom). Batch B is superior to batch A.

however batch A gears did not. The topography of tooth profile is shown in Fig. 3.

CONCLUSIONS

Testing of two batches of hypoid gear sets shows that the annealing heat treatment introduced between gear set soft cutting and case carburizing helped to minimize the distortion. The residual stress analysis shows the variation in stress level within the part and part-to-part variation. The analysis after annealing shows the machining tensile residual stresses induced are relieved by annealing. This is evidenced by the gear set profile inspection carried out using Klingelnberg equipment. The tooth topography of batch B shows less dimensional imperfection by qualifying AGMA class 8 than batch A, which is evidence of the contribution of annealing in controlling the distortion of gear sets.~**HTPro**

For more information: Yathish Rao, industry professional, Pune, India, rao.yathish@gmail.com.

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ASMNEWS

ASM Affiliate Societies Announce New Officers and Board Members

In accordance with their Rules of Governance, the ASM Affiliate Societies have completed their elections for officers and board members for 2021. Please join us in welcoming the following appointments.

ASM Electronic Device Failure Analysis Society

EDFAS president, **James Demarest, FASM,** senior engineer, International Business Machine, and vice president/finance officer **Felix Beaudoin, FASM,** PMTS product development engineer, GlobalFoundries, welcome **David Grosjean,** senior staff engineer, Butterfly Network, as a new member for a three-year term. **Tom Schamp,** principal consulting scientist, Materials Analytical Services, is reappointed for a three-year term. **Lee Knauss, FASM,** director, engineering and science, Booz Allen Hamilton, immediate past president, and **Renee Parente,** senior program manager, AMD, secretary, remain on the board. Officers serve a two-year term. **Tommaso Melis,** University of Grenoble Alpes, France, is appointed as student board member for one year.

ASM Failure Analysis Society

Daniel Dennies, FASM, principal and CEO, DMS Inc., succeeds as president of FAS, while **James Lane,** director, materials science practice, Rimkus Consulting Group Inc., remains on the board as immediate past president. **Andrew Havics,** pH2 LLC, is appointed vice president and **Margaret Flury,** principal materials engineer, Medtronic, is appointed secretary. Officers serve a two-year term. **Joseph Quinn,** principal materials consultant, Materials FACT, and **Milo Kral,** professor, University of Canterbury, New Zealand, are appointed as new members to the FAS board for a three-year term. **Alexandria Springer,** materials engineer/quality specialist, Advanced Heat Treatment Corp., is appointed emerging professional board member and **Gladys Duran,** Instituto Tecnologico de Morelia, is reappointed as student board member. Both appointments are for one year.

ASM Heat Treating Society

The HTS board appointed a vice president, secretary, and two new members, and reappointed one member to the board. They also appointed an emerging professional board member and reappointed a student board member. See page 4 of *HTPro* in this issue for the full story.


Demarest

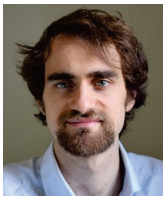

Beaudoin


Grosjean


Schamp


Knauss


Parente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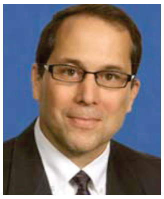
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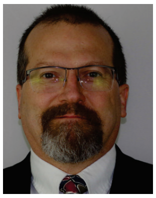
Lane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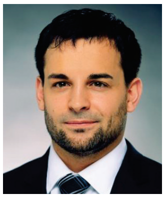
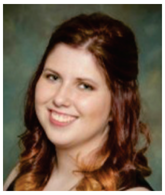

Quinn


Kral


Springer


Duran

In This Issue

ASM INTERNATIONAL
Submit news of ASM and its members, chapters, and affiliate societies to Joanne Miller, editor, ASM News | ASM International
9639 Kinsman Road | Materials Park, OH 44073 | P 440.338.5455 | F 440.338.4634 | E joanne.miller@asminternational.org
Contact ASM International at 9639 Kinsman Road, Materials Park, OH 44073 | P 440.338.5151 or 800.336.5152 (toll free in U.S. and Canada) | F 440.338.4634 | E MemberServiceCenter@asminternational.org | W asminternational.org

ASM AFFILIATE BOARD MEMBERS

ASM International Metallographic Society

Michael Keeble, U.S. labs and technology manager, Buehler, a division of ITW, succeeds as president of IMS, while **Daniel Dennies, FASM,** principal and CEO, DMS Inc., remains on the board as immediate past president. **Laura Moyer,** professor, Lehigh University, is appointed vice president, and **Gee Abraham,** STEM writer/editor, Gee Abraham Edits, is reappointed as secretary. Officers serve a two-year term. **Pablo Mendoza,** laboratory supervisor, Allied High Tech Products, is appointed as member of the IMS board for a two-year term. **Jack Grubbs,** Worcester Polytechnic Institute, is appointed as student board member for one year.

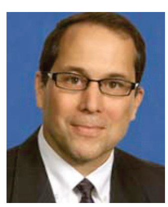
ASM International Organization on Shape Memory and Superelastic Technologies

SMST president **Othmane Benafan,** materials research engineer, NASA Glenn Research Center, and vice president/finance officer **Adrian McMahon,** principal R&D engineer, Boston Scientific SH, welcome these board members: **Timofei Chekalkin,** team leader at the R&D center, TiNiKo Co., South Korea, is a new member with a three-year term; and **Andreas Undisz,** full professor, Technische Universität Chemnitz, Germany, is reappointed for a three-year term. **Jeremy Schaffer,** senior engineer, Fort Wayne Metals, remains on the board as immediate past president. **Faith Gantz,** University of North Texas, is reappointed as student board member for one year.

ASM Thermal Spray Society

TSS president **William Lenling, FASM, TSS HoF,** founder/CTO, Thermal Spray Technologies Inc., announces new appointments to the TSS Board. **Molly O'Connor,** R&D prof. advanced ceramic materials, Praxair Surface Technologies, and **Daniel Sordelet, FASM,** engineering specialist, Caterpillar Inc., are appointed to the board for a three-year term. **Timothy McKechnie, FASM,** president, Plasma Processes LLC, is reappointed to the board for a three-year term. **Daniel Tejero Martin,** University of Nottingham, U.K., is reappointed as student board member, and **Shahed Taghian Dehaghani,** University of Alberta, Canada, is also appointed student board member. Both appointments are for one year.

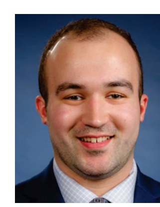

Keeble


Dennies


Moyer


Abraham


Mendoza


Grubbs


Benafan


McMahon


Chekalkin


Undisz


Schaffer


Gantz


Lenling


O'Connor


Sordelet


McKechnie


Martin


Dehaghani

FROM THE PRESIDENT'S DESK

ASM International: A Decade of Opportunity


Todd

As I begin my presidential year, I am proud to recognize the solid, multi-year foundation of strategic planning established by prior boards and presidents, particularly the initiatives led by President Essock, and to build on these as we enter our next **Decade of Opportunity**. Together with the ASM staff, we have emerged from the challenges of COVID-19 in stable financial condition with exciting new ways of doing business. Our digital forward preparation enabled ASM to pivot almost seamlessly to the virtual world and to enhance our communications with our members, through ASM Connect, and our chapters and global partners, through RingCentral. Our explorations with virtual, hybrid, and in-person meetings were successful, financially viable, and strongly supported by our industrial members—we are all looking forward to a return to in-person meetings and networking in the coming year.

For our digital successes, I would like to pay tribute to Ron Aderhold, who served as ASM's Chief Operating Officer and Chief Information Officer from 2016, and who led the staff as Interim Managing Director from May 2020. Ron recently accepted a position as Executive Partner with Gartner Inc., the world's largest technology-focused research and advisory group, where he will be a personal coach for executive teams of $1B+ companies, helping them to optimize the use of technology in growing their businesses. "This has been my dream job for the last 15-20 years," said Ron. Please join me in wishing him every success in his future career.

I am pleased to report that at the time of this article going to press, ASM has signed a contract with our next Executive Director—a candidate unanimously supported by the Search Committee and the Board of Trustees and brought to us by our search firm, Korn Ferry—who will join ASM on January 1, 2022. I would like to express my gratitude to Ryan Milosh, ASM Chief Sales and Marketing Officer, who has agreed to serve as Interim Managing Director through December 2021.

In this year of exciting transitions, the Board has identified key strategic initiatives that will define our future, going forward. We plan to:

- Advance our vision of being the ***leading global resource for materials information*** and, in particular, make ASM the "go-to" hub for materials curation, data repository, data access for members, and data analyses tools;
- Redefine ASM's value propositions across all segments of our Society;
- Embed sustainability into our strategic plan; and
- Become a world leader in articulating and advancing the important and essential role that **diversity, equity, and inclusion** must play in our Society going forward. Only together can we achieve our purpose.

As Past President Furrer has stated at almost all our Board meetings, "Achieving ASM's vision, mission, and goals is not a sprint but a marathon." As I initiate ASM's next phase of our marathon, I see endless possibilities in our future **Decade of Opportunity** and invite all of you to participate.

ASM President Judith Todd, FASM
judith.todd@asminternational.org

ASM Nominating Committee Nominations Due Dec. 15

ASM International is seeking members to serve on the 2022 ASM Nominating Committee. As noted in the ASM Constitution, approved at the ASM Annual Meeting on September 13, 2021, the committee will select a nominee for 2022-2023 senior vice president, (who will serve as president in 2023-2024), a vice president (who will serve as president in 2024-2025), and three nominees for trustee. Candidates for this committee can only be proposed by a Chapter through its executive committee, an ASM committee or council, or an affiliate society board. **Nominations are due December 15.** For more information, contact Leslie Taylor at 440.338.5472, leslie.taylor@asminternational.org or visit asminternational.org/about/governance/nominating-committee.

2022 Bradley Stoughton Award for Young Teachers

Winner receives $3000. Deadline March 1, 2022. This award recognizes excellence in young teachers in the field of materials science, materials engineering, design, and processing. Do you know a colleague who:

- Is a teacher of materials science, materials engineering, design, or processing
- Has the ability to impart knowledge and enthusiasm to students
- Is 35 years of age or younger by **May 15** of the year in which the award is made
- Is an ASM member

View the forms and rules at asminternational.org/membership/awards/nominate. To nominate someone, contact christine.hoover@asminternational.org for a unique nomination link.

Annual ASM Award Nominations due Feb. 1, 2022

The deadline for the majority of ASM's awards is **February 1, 2022,** and we are actively seeking nominations for all of these awards, a few of which are listed below:

Edward DeMille Campbell Memorial Lectureship
Distinguished Life Membership
William Hunt Eisenman Award
Gold Medal
Silver Medal
Bronze Medal
Historical Landmarks—*2022 marks the 50th anniversary of ASM Historical Landmarks!*
Honorary Membership
Medal for Advancement of Research
Allan Ray Putnam Service Award
Albert Sauveur Achievement Award
Albert Easton White Distinguished Teacher Award
J. Willard Gibbs Phase Equilibria Award

View rules and past recipients at asminternational.org/membership/awards. To receive a unique nomination form link, contact Christine Hoover at christine.hoover@asminternational.org.

Danielle Cote and Dharma Maddala both received the Bronze Medal Award in 2019.

DATA ECOSYSTEM

ASM to Launch Data Ecosystem in January 2022

ASM International is proud to announce the upcoming launch of the new Data Ecosystem, which seeks to package digital materials technologies in an all-in-one powerful and convenient platform. The Data Ecosystem Workbench will provide a custom and secure workspace for users to extract value from their analytical work for further discovery, transformation, or curation. The Data Ecosystem represents a significant change in how ASM will bring greater value to our membership and the entire scientific community.

The value of the Data Ecosystem starts with collecting and providing relevant materials data. ASM will transform data within their Digital Database products into machine readable formats, as well as form valuable relationships with data contributors to support the industry needs around design simulation and advanced analytics such as machine learning.

The next critical piece in this initiative is educating users on what can be done and how to do it. Like ASM's best-selling Metallurgy for the Non-Metallurgist course, Data Management education will be pragmatic. Students will be taught both the "Why" and "How" of going faster in a Materials 4.0 business environment. The first two courses will cover heat treat process simulation and materials data management fundamentals.

The last, and enabling piece of the Data Ecosystem brings innovative organizations with advanced materials and analytical tools together in one convenient Software as a Service (SaaS) platform—the Data Ecosystem Workbench. This secure platform will provide data structure, storage, and computational power for creating advanced analytical work products. ASM is pleased to be working with an initial group of industry respected Tool Providers for the launch of the Data Ecosystem:

- **ASCENDS:** "the Advanced data SCiENce toolkit for Non-Data Scientists" – a multidisciplinary team of researchers from Oak Ridge National Laboratory (ORNL) developed an advanced toolkit named ASCENDS to assist scientists and others who want to use their data for machine learning.
- **DANTE Solutions:** "A Practical Tool for Heat Treatment Simulation and Thermal Engineering Solutions" – DANTE Solutions maintains an active program of alloy characterization, process modeling consulting, continued innovation in application to new processes (i.e., vacuum carburizing, high pressure gas quenching), and technical support to software licensees.

- **PANDAT Software:** An integrated modeling platform for materials design, CompuTherm is a leading developer of software and databases for thermodynamic and phase diagram calculations as well as kinetic simulations based on the CALPHAD approach.
- **SMARTUQ:** A powerful machine learning and uncertainty quantification (UQ) software tool that incorporates real-world variability and probabilistic behavior into engineering and systems analyses.
- **Total Materia:** The world's most comprehensive materials database with more than 20,000,000 property records for over 450,000 metallic and nonmetallic materials presented in 26 languages and the largest single collection of advanced property data on the planet.

Ray Fryan, ASM's executive director of product development, explains how this platform will fulfill the needs of Industry 4.0 for ASM members:

> "Data has become the fuel of progress and advanced analytics is the engine that turns data into knowledge and solutions. Whether we're talking materials design, processing, or performance, Materials 4.0 will accelerate our members' performance. With our 100+ year history as 'the materials information society,' we believe ASM is the logical choice to enable Materials 4.0 for our members. In a nutshell, via Data Ecosystem, we'll help our members predict more, and experiment less, reuse data more, and recreate data less, and that is a big deal."

To learn more about the Data Ecosystem, contact Nate Bulcroft, ASM commercial director, at nate.bulcroft@asminternational.org.

Journal of Failure Analysis and Prevention Names New Editor-in-Chief


Beach

Elvin Beach, The Ohio State University, has been named editor-in-chief of the *Journal of Failure Analysis and Prevention* (*JFAP*). He succeeds Michael Stevenson, who served as editor-in-chief from 2011 until his sudden and unexpected passing in March of this year. Beach joined the JFAP editorial team as deputy editor for the journal in mid-2020. Prior to that he was an associate editor for the *Journal of Materials Engineering and Performance* since 2014. He has been as associate editor for *Metallography, Microstructure, and Analysis* since 2013, and continues in that position.

Beach is associate professor of practice in materials science and engineering at The Ohio State University. He received his B.S. in metallurgical engineering and M.S. in materials science and engineering from Michigan Technological University and a Ph.D. in materials science and engineering from The Ohio State University.

At Ohio State, Beach leads new initiatives in laboratory instruction, training teaching assistants who can support teaching of the labs, developing and implementing hands-on testing and characterization of materials, and coordinating undergraduate student employees to support the educational programs of the department. Maintaining scholarships in engineering education and outreach activities are also part of his role, in addition to overseeing the development and teaching of undergraduate course content. He enjoys creating laboratory-based class experiences that reinforce fundamental concepts learned in core classes and providing context for how these will translate to practice in industry.

ASM INTERNATIONAL CONNECT

New ASM Technical Communities and Committees

The ASM Connect platform enables ASM members to form *Technical Community* discussions on a particular topic. ASM members may propose a new *Technical Committee* to collaborate on an ongoing basis. Technical Committees often work on a variety of networking, programming, publication, and education activities that are needed in their area of interest.

Several ASM Technical Committees have recently formed:

- Archaeometallurgy
- Materials and Process Modeling
- Materials Data Management and Analytics
- Residual Stress

In addition, new committees are currently being organized:

- Additive Manufacturing
- Sustainable Materials Engineering

ASM members who are interested in getting involved with any of these new committees or who would like to investigate forming a new community or committee may contact Scott Henry at scott.henry@asminternational.org.

Student Speaker Symposium (S³) Winners

Created by the ASM Student Board Members in response to the COVID-19 pandemic, students created five-minute videos showcasing their research. Awards included first ($1000), second ($750), and third ($500) place prizes for both graduate and undergraduate categories. A Most Popular Presentation Award ($500) was given to the video presentation (title slide shown below) garnering the most "likes" on the ASM YouTube Channel. Congratulations to the 2021 winners of the S³!

Graduate Category

- First Place: Brady McBride, Colorado School of Mines, *Accumulative Roll Bonding of AA5083 Toward Low Temperature Superplasticity*
- Second Place: Diptak Bhattacharya, Colorado School of Mines, *Compositional Influence on Liquid Metal Embrittlement Susceptibility of Zn-Coated Advanced High Strength Steels*
- Third Place: Adie Alwen, University of Southern California, *Film Modification and Design via Plasma Variation in Hollow Cathode and Planar Sputtering*

Undergraduate Category

- First Place: Charles Mason Shoalmire, Texas A&M University, *Ragone Relationships in Thermal Batteries to Evaluate Phase Change Material Composite Design*
- Second Place: Parth Mahendru, University of Toronto, *Artificial Intelligence Models for Analyzing Thermally Sprayed Functional Coatings*
- Third Place: Hayley Wagreich, Case Western Reserve University, *Fatigue Performance of Nitinol and 35N LT in a Simulated Biomedical Environment*

Most Popular Presentation

- M. Khalid Hossain, Kyushu University, *Comparative Studies of Hydrogen Behavior in Proton Conducting Zirconates*

M. Khalid Hossain won the Most Popular Presentation award.

FROM THE FOUNDATION

Highlights from 2021

Wilson

ASM Materials Education Foundation is thankful for all the support we have received from ASM International members and others throughout the year. Those funds sustained our programs and activities so that we could provide professional development opportunities for teachers, host student virtual programs and opportunities, and serve as an asset in the materials science and engineering field. The Foundation looks forward to continuing to provide this programming for students and teachers with the help of supporters from all over. Some of this year's highlights include:

- Offering virtual ASM Materials Camps for teachers attending for the first time
- Advanced ASM Materials Camp for teachers who have incorporated experiments learned from Camp or currently teaching a materials science course
- ASM Materials Camp designed for K-5 teachers
- Teacher Institute for teachers who have previously attended an ASM Materials Camp and want to go in more depth on a specialty topic led by volunteers and master teachers
- Virtual ASM Materials Camp for students introduced materials science concepts in three one-week, 24-hour camps led by outstanding volunteers and Master Teachers
- Students and teachers conducted experiments from their own homes with supplies provided free of charge
- Opportunities for students and teachers to meet professionals in the field and learn about their careers

To continue to provide the resources and host a growing number of ASM Materials Camp for teachers and students, we need support from ASM members and others in our communities to encourage future generations to pursue materials science and engineering. Please consider a donation to ASM Materials Education Foundation to sustain our programs and increase opportunities for teachers and students as we plan for in-person activities in 2022. To donate online, visit asmfoundation.org/asm-donate/ or mail a check to: ASM Materials Education Foundation, 9639 Kinsman Road, Materials Park, Ohio 44073.

This holiday season I continue to be grateful for the amazing volunteers and donors with whom I have the pleasure to work with throughout the year. May you all be as blessed.

Carrie Wilson, Executive Director
ASM Materials Education Foundation

George A. Roberts and Pacesetter Awards – 2021 Winners

Schwartz

ASM Materials Education Foundation is proud to announce the winners of this year's George A. Roberts Award and the Pacesetter Award. In 2002, ASM Foundation trustees recognized the need to annually honor an individual who has made a significant impact on our ability to reach students and teachers, in efforts to increase awareness of materials and applied science careers, creating the George A. Roberts Award. The Pacesetter Award was established in 2009 as an annual corporate award to honor organizations for continued service to the ASM Materials Education Foundation and recognizes the impact in supporting educational outreach efforts that encourage young people to pursue careers in materials science and engineering.

Lyle H. Schwartz, FASM, is the 2021 George A. Roberts Award recipient. He is an honorary lifetime ASM member and was an ASM Foundation Board member from 2005-2019. Schwartz has demonstrated significant and sustained efforts in support of educational outreach and the Foundation's mission in particular. He has championed efforts in both formal and informal education environments, most notably encouraging materials science programming in science museums and centers.

ASM Materials Education Foundation announces **Honda** as the 2021 winner of the Pacesetter Award. Honda's consistent support of the Foundation began in 2002 and aligns the company's focus on youth education and STEM subjects with the Foundation's mission of serving teachers and students in materials science and engineering.

The ASM Materials Education Foundation staff and trustees are grateful to both recipients for their continuing commitment to the Foundation's mission.

ASM and its Affiliate Societies Seek Student Board Members

We're looking for Material Advantage student members to provide insights and ideas to ASM and its Affiliate Society Boards. We are pleased to announce the continuation of our successful Student Board Member programs. Each Society values the input and participation of students and is looking for their insights and ideas. An opportunity like no other!

- Expenses to attend meetings paid for by the respective Society
- Take an active role in shaping the future of your professional Society
- Actively participate in your professional Society's board meetings

Application deadline is February 15, 2022. Visit asminternational.org/students/student-board-member-programs for complete form and rules.

EMERGING PROFESSIONALS

Lessons Learned and Shared

Brittnee Mound-Watson, EPC Co-Chair

Mound-Watson

Per its bylaws, the Emerging Professionals Committee (EPC) "is to assist an early-career demographic, the future of ASM, to see, understand, and be involved with the inner workings of an internationally recognized professional society." When I first joined the EPC, I had just graduated from the University of Tennessee with a Ph.D. and started my career as a manufacturing engineer at Lockheed Martin in Orlando, Florida. At the time, I had the flexibility to focus on learning and growing in my new roles as an engineer and EPC member. Today, I no longer have that same kind of flexibility because I am now a working mom, a lead for a team of manufacturing engineers, and co-chair of the EPC. Rereading that statement in the bylaws reminded me that there are hundreds of other professionals who might be working parents and who also desire to be leaders in ASM and in their companies. It also reminds me that as an EPC member, I have an opportunity to share my experience as a working parent and full-time engineer so that it may provide encouragement or tools to others who are new to the journey. Here are three lessons I have learned so far that have helped me stay focused on my goals of being a leader while also adjusting to a new work-life balance:

1. Organization and scheduling are key to making sure you get everything you need to done in a day, but it's important to be flexible for last-minute changes. It is okay if you need to postpone an action to tomorrow.
2. Prioritize what brings you joy. Reprioritization has helped me focus my energy on actions that I enjoy doing.
3. Be open to those at work and in your ASM network. Remember that no one knows your challenges unless you bring them up. It is okay to reach out to the team and let them know you need some assistance.

As I continue on this new journey, I will remember that others may have similar challenges. The EPC is here to help other emerging professionals in their early careers and provide guidance.

WOMEN IN ENGINEERING

*This profile series introduces materials scientists from around the world who happen to be females. Here we speak with **Deidra Minerd,** operations manager, Euclid Heat Treating, Ohio.*

Minerd

What does your typical workday look like?

I spend part of my day quoting and pricing jobs. The quoting part involves reviewing the heat treat requirements and comparing them to our process capabilities. Sometimes that involves digging through specs and quality requirements, making sure we can meet them and figuring out what it would cost.

The other part of my day is spent communicating with all the departments and managing the processes. This may involve balancing customer demands with equipment availability or personnel needs with anticipated order volumes.

What part of your job do you like most?

The type of leadership I strive for is "servant leadership." I aim to provide our employees what they need to do a good job serving our customers in a timely, efficient way. Put another way, I try to remove obstacles that would otherwise prevent supervisors and shop floor employees from getting parts heat treated properly and out the door. The best part of my job is when we find a way to do something better or more efficiently, which makes the employees' lives easier and makes the customer happy.

What is your engineering background?

I received my B.S. in metallurgical engineering from The Ohio State University. I worked as a sales engineer at Therm-O-Disc before coming to Euclid Heat Treating.

What attracted you to engineering?

I decided to pursue metallurgical engineering with the intent of working at Euclid Heat Treating. I didn't know anything about engineering until I enrolled in the program. It was a great fit though, because I like science and math.

Did you ever consider doing something else with your life besides engineering?

Yes! I started out in the pharmacy program at the University of Toledo, then decided I would like to try working at Euclid Heat Treating, which was started by my grandfather. I switched schools and majors, and figured if I didn't like metallurgical engineering, I would switch back to pharmacy. However, I loved it and was hooked.

Best career advice, given or received:

Take every opportunity to learn something. It doesn't have to be formal credit-based, degreed learning. Have conversations with people who know things you don't, ask questions, watch webinars, and read books. Assume everyone has something to teach you.

Are you actively engaged with ASM or its affiliates?

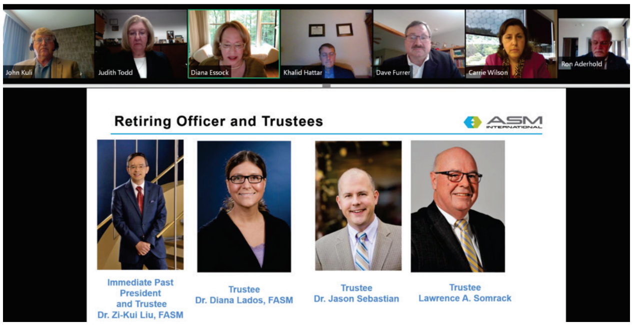
I am a member of the ASM Cleveland Chapter and also serve as secretary on the board of the Heat Treating Society, an affiliate of ASM International.

Favorite motto or quote?

"Perfection is the enemy of progress." – Winston Churchill

Do you know someone who should be featured in an upcoming Women in Engineering profile? Contact Vicki Burt at vicki.burt@asminternational.org.

PHOTO GALLERY: HIGHLIGHTS FROM ANNUAL MEETING



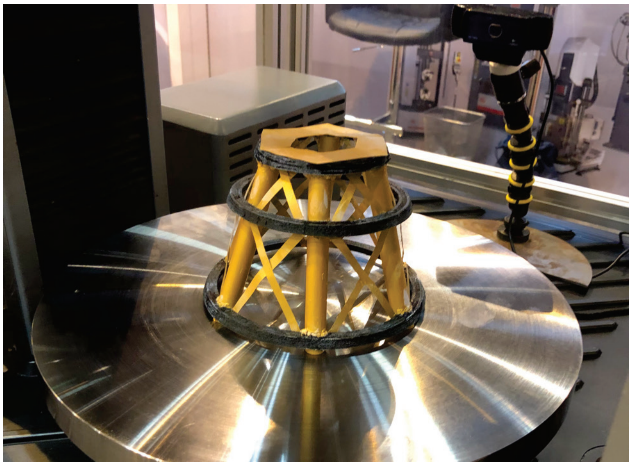
Outgoing ASM President Diana Essock thanks retiring officers and members during the ASM Annual Meeting, which was held virtually on Monday evening, September 13.

Also at the Annual Meeting, incoming ASM President Judith Todd speaks to the important role our Foundation plays in the society's future.

PHOTO GALLERY: HIGHLIGHTS FROM IMAT 2021

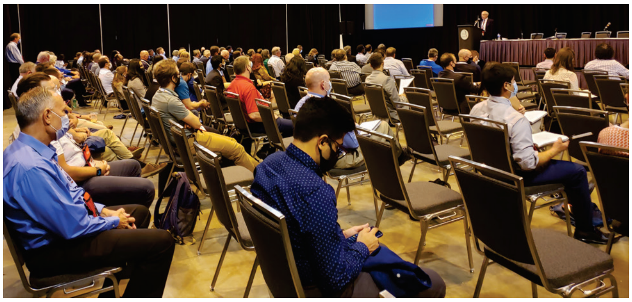
IMAT and Heat Treat goers enjoy a networking event at the Anheuser-Busch Biergarten/Brewery on Wednesday, September 15.

A well-groomed Clydesdale provides the perfect photo op for attendees during the Anheuser-Busch social.



A golden DomesDay submission gets put to the test at the contest held on the show floor in St. Louis.

As part of the IMS General Membership Meeting held in St. Louis, Michael Keeble (right), receives his IMS presidential pin from Daniel Dennies, FASM, who becomes the affiliate's immediate past president.



James Boileau, FASM, retired from Ford, speaks during the Heat Treat/IMAT Joint Keynote on Tuesday, September 14.

A spirited group poses during the Joint Young Professionals Reception on Tuesday evening in St. Louis.

For photos from the Heat Treat 2021 event, see page 5 of this issue's *HTPro* supplement.

CHAPTERS IN THE NEWS

Cleveland Holds Hybrid Meeting

The ASM Cleveland Chapter conducted its first hybrid meeting on October 14 to celebrate Manufacturing Day 2021 and Heat Treaters Night. Dave Deiwert of Pfeiffer Vacuum gave a presentation to members and Material Advantage students from Cleveland State.

Chapter chair John Pickens (left) presents an appreciation certificate to speaker Dave Deiwert.

Drexel Enjoys Welcome Week

The Drexel MA Student Chapter hosted a well-attended event on September 14 as part of the university's Welcome Week festivities. More than 200 students participated in hands-on bath bomb and slime activities.

MATERIAL™ ADVANTAGE
The Student Program for Materials Science and Engineering

Material Advantage Chapters of Excellence Awards

Each year ASM administers the Chapters of Excellence (COE) Awards Program on behalf of the Material Advantage Student Program. This competition judges the student social activities, chapter management, and overall report quality. Winners were formally announced at the Student Awards Ceremony at MS&T 2021. Congratulations to this year's winning schools!

Most Outstanding Chapter – plaque and $750 prize:

- University of North Texas

Chapters of Excellence – plaque and $450 prize:

- Colorado School of Mines
- Indian Institute of Technology, Kanpur
- Instituto Tecnológico de Morelia
- Suez University
- Wuhan University of Technology

Certificate of Achievement:

- Purdue University

MEMBERS IN THE NEWS

Shingledecker Honored by Stuttgart

Shingledecker

John Shingledecker, FASM, of EPRI, Charlotte, N.C., was awarded the Carl von Bach Commemorative Medal 2021 by the MPA (Materials Testing Institute) University of Stuttgart. The medal is awarded to individuals who render outstanding services to the strengthening of research, development, and teaching in the field of materials testing and strength calculation in the spirit of Carl von Bach, founder of MPA. Andreas Klenk, deputy director, presented the award in a virtual ceremony. He cited Shingledecker's long history of collaboration with MPA in the field of life assessment issues, materials for advanced ultra-supercritical plants, weld behavior, and properties of martensitic steel. Shingledecker is only the second winner from the U.S. in the past 31 years. He is also vice chair of the AM&P Editorial Committee and a member of ASM's Content and Data Products Council.

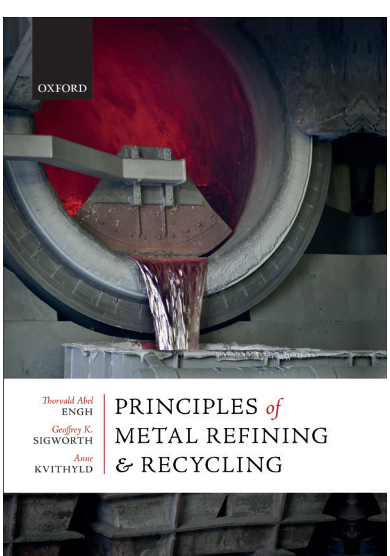
Todd Named Franklin Institute Committee Chair


Todd

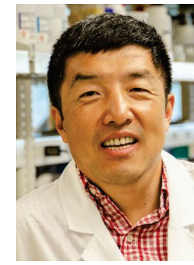
Judith Todd, FASM, ASM president, was recently named chair of the Franklin Institute's Committee on Science and the Arts. The Franklin Institute was founded in 1824 in Philadelphia as a center of science education and development in tribute to Benjamin Franklin. Since its founding, the institute has issued Benjamin Franklin Medals around the world for outstanding achievements in science, engineering, and industry. Todd previously served as a member and chair of the committee's civil and mechanical cluster, where she contributed to awarding a medal to Subra Suresh, FASM, in 2013 for mechanical engineering and materials science, and John Rogers in 2019 for materials engineering.

Sigworth Book Release

Geoffrey Sigworth, mining and metals professional from Harrisburg, Va., recently co-authored a book published by Oxford University Press, "Principles of Metal Refining and Recycling." The first chapter provides examples of how impurities affect metal properties. The remaining chapters are divided into three categories: fundamentals, problems and methods, and applications. Each chapter includes an extensive bibliography for further study. The book also covers important principles underlying the science, so it may be useful for advanced students. Sigworth, formerly with Alcoa Primary Metals, is now retired. He is a member of the ASM Washington DC Chapter.



Liu Awarded Title and Funding


Liu

Xingbo Liu, FASM, Morgantown, W.Va., was recently promoted to associate dean for research, Statler College of Engineering and Mineral Resources at West Virginia University. He is also a professor in the department of mechanical and aerospace engineering. Liu served as associate chair for research in the department for seven years prior. In addition, earlier this year the U.S. Department of Energy announced funding of Phase II of his team's project to develop additive manufacturing approaches to improve dissimilar metal weldments. Support will come from the DOE's National Energy Technology Laboratory.

Sahay Elected Fellow of INAE


Sahay

Satyam Sahay, FASM, was recently elected as Fellow of the Indian National Academy of Engineering (INAE). He was selected in recognition of his distinguished contributions in science and technology. The Academy honors Indian and foreign nationals who are elected by peer committees in recognition of their personal achievements in engineering, which are of exceptional merit in new and developing fields of technology. Sahay is a John Deere Fellow–Materials Engineering in Pune. He is a 29-year member of ASM International and currently serves on the ASM Handbook Committee, AM&P Editorial Committee, and Technical Committee and Academic Engagement Board Task Force.

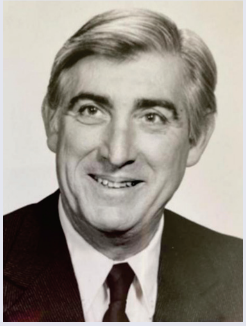
IN MEMORIAM

Kashar

Lawrence J. Kashar, FASM, of Los Angeles, died on August 27 at age 88. He was principal of Kashar Technical Services for the past 30 years, providing consulting services that specialized in failure analysis, materials problem solving, and product liability investigations for legal and industrial clientele. He previously provided similar services for nearly 20 years at SEAL Laboratories (now EAG Laboratories/Eurofins Materials Science). Kashar's earlier professional career included work as a researcher and metallurgist at the U.S. Steel Applied Research Laboratory and the American Metal Climax R&D Laboratory. He earned his M.S. in metallurgical engineering at the Carnegie Institute of Technology and his Ph.D. in metallurgy and materials science at Carnegie Mellon University. Kashar was a founding member of the Independent Metallurgical and Materials Engineering Consultants of California and cofounded the International Society for Testing and Failure Analysis. He was a past chair of ASM's Los Angeles Chapter and general chair of the 1982 ASM WESTEC Conference. He frequently taught the ASM course "Electron Microscopy in Failure Analysis."

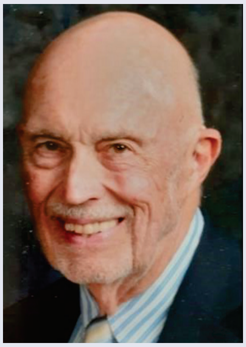
Sherman

Russell G. Sherman, FASM, 95, a metallurgical engineer from Santa Monica, Calif., died on July 20. After graduating from the University of Pennsylvania, he became active in ASM and the Los Angeles Chapter, serving as its chair in 1973-74. His research and development concerning alloys and heat treating protocols for the titanium industry expanded the use of titanium fasteners in aircraft and space vehicles. He worked on the Surveyor program, American vehicles that soft-landed on the moon well before Apollo and Neil Armstrong. Sherman developed thermo-mechanical treatments for the production of high-strength superalloys A286 and Inconel 718 that became the standards still used by the aircraft industry and the military. He also introduced warm rolling of titanium threads that enabled mass production of fasteners for 747 aircraft wings and steel bolts for landing gear. He patented the fit fastener, Sine-Lok, that was used in all U.S. jet engines. Sherman received the Lifetime Achievement Award from the International Titanium Association in 2018 and the Technical Achievement Award from Fastener Technology International in 2008. In his honor, his family established the Russell G. Sherman Student Scholarship Fund for the ASM Los Angeles Chapter.



St. Pierre

George R. St. Pierre, FASM, The Ohio State University Distinguished Professor and Chair Emeritus, department of materials science and engineering, passed away on March 4, 2020. He was 89. He received his doctorate degree in 1954 from the Massachusetts Institute of Technology. After serving active duty in the Air Force Materials Laboratory, St. Pierre joined the faculty at The Ohio State University in 1957. He held several roles at the university, serving as a full professor from 1964-1994, associate dean of the University Graduate School from 1964-1966, as chair from 1983-1992 (metallurgical engineering, 1983-88; mining engineering, 1985-92; materials science and engineering, 1988-92), and receiving the appointment as Presidential Professor in 1988. After retirement, he served as Chief Scientist, Materials Directorate at Wright-Patterson Air Force Base and continued to participate in university programming until 2019. He authored over 150 papers, manuscripts, and book chapters. St. Pierre received ASM's Bradley Stoughton Award for Young Teachers in 1961 and the Albert Easton White Distinguished Teacher Award in 1997.



Wistehuff

William Eugene "Gene" Wistehuff, of Saginaw, Mich., passed away on October 19, 2020, after a brief illness at the age of 81. He was born on July 23, 1939, in Taylorville, Ill. Wistehuff attended Taylorville High School, graduating in 1957. He attended Missouri School of Mines, receiving a B.S. (1961) and M.S. (1963) in metallurgical engineering. He joined General Motors at Central Foundry in 1963, later being appointed supervisor of the Current Products Laboratory, retiring in 1998. Wistehuff was an active member of ASM International and his local Saginaw Valley Chapter, as well as the Society of Automotive Engineers.

Word has been received at ASM Headquarters of the death of Life Member **James T. McGrath, FASM,** 89, of Ottawa, Canada. He passed away on August 14. McGrath was an ASM member for 47 years and a member of the ASM Ottawa Valley Chapter.

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Instron	5
Master Bond Inc.	11
Thermo-Calc Software AB	IBC
Verder Scientific Inc.	IFC
Westmoreland Mechanical Testing & Research Inc.	63

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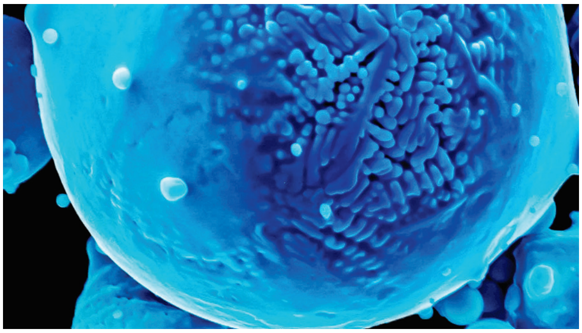


A colorized electron micrograph of a nickel powder alloy used in Texas A&M's study. Courtesy of Raiyan Seede.

FINE-TUNED MICROSTRUCTURES FOR LPBF PRINTING

Researchers from Texas A&M University have used a combination of machine learning and single-track 3D printing experiments to identify the favorable alloy chemistries and process parameters, like laser speed and power, needed to print parts with uniform properties at the microscale.

"In this study, we take deep dives into fine-tuning the microstructure of alloys so that there is more control over the properties of the final printed object at a much finer scale than before," says Raiyan Seede, doctoral student in the department of materials science and engineering.

The laser powder bed fusion (LPBF) process starts with rolling a thin layer of metal powder on a base plate and then melting the powder with a laser beam along tracks that trace the cross-sectional design of the intended part. Then, another layer of the powder is applied and the process is repeated, gradually building the final part.

Alloy metal powders used for additive manufacturing can be quite diverse, containing a mixture of metals, such as nickel, aluminum, and magnesium at different concentrations. During printing, these powders cool rapidly after being heated by a laser beam. Because the individual metals in the alloy powder have very different cooling properties and consequently solidify at different rates, this mismatch can create a type of microscopic flaw called microsegregation.

Seede says this defect appears as tiny pockets containing a slightly different concentration of the metal ingredients than other regions of the printed part. These inconsistencies compromise the mechanical properties of the printed object.

To rectify this microdefect, the research team investigated the solidification of four alloys containing nickel and one other metal ingredient. In particular, for each of these alloys, they studied the physical states or phases present at different temperatures for increasing concentrations of the other metal in the nickel-based alloy. From detailed phase diagrams, they could determine the chemical composition of the alloy that would lead to minimum microsegregation during additive manufacturing.

Next, they melted a single track of the alloy metal powder for different laser settings and determined the process parameters that would yield porosity-free parts. Then, they combined the information gathered from the phase diagrams with that from the single-track experiments to get a consolidated view of the laser settings and nickel alloy compositions that would yield a porosity-free printed part without microsegregation.

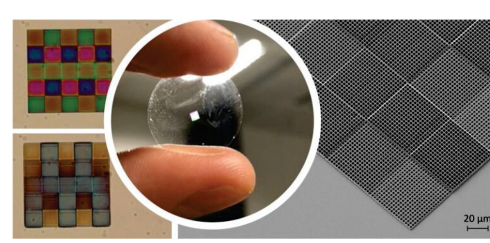
Last, the researchers trained machine-learning models to identify patterns in their single-track experiment data and phase diagrams to develop an equation for microsegregation applicable to any other alloy. Seede said the equation is designed to predict the extent of segregation given the solidification range, material properties, laser power, and speed.

The researchers add that the uniqueness of their methodology is in its simplicity, which can easily be adapted to build sturdy, defect-free parts with an alloy of choice. *tamu.edu.*

COLOR CHANGING, MICROSCOPIC GAS SENSORS

A team from Trinity College Dublin and GE Research in New York are printing color-changing gas sensors using new materials and a high-resolution form of 3D printing. The sensors, which are responsive, printed, microscopic optical structures, can be monitored in real-time, and used for the detection of solvent vapors in air. There is great potential for these sensors to be used in connected, low-cost devices for homes, or integrated in wearable devices used to monitor human health.

The team uses a technique known as direct laser-writing (DLW), which allows them to focus a laser into an extremely small spot, and then use it to make tiny structures in three dimensions from the soft polymers developed in the lab. The tiny arrays respond to light, heat, and humidity. *www.tcd.ie.*



Left, zoomed-in optical microscopy images showing the pixelated sensor in response to different vapors; center, photo of the glass substrate showing the 3D-printed sensor; right, scanning electron microscopy image of the pixelated sensor, showing the different heights of the periodic structure. Courtesy of Trinity College Dublin.

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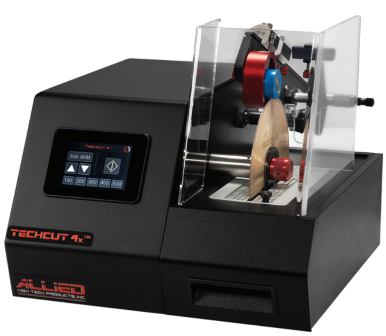

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