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Automotive Materials & Applications

INCLUDED IN THIS ISSUE

- *Inclusions in Magnesium Alloys*
- *Identifying Particle Contamination*
- *NDI of Resistance Spot Welds*

AN ASM INTERNATIONAL PUBLICATION

ON THE COVER:
The CALIPRI measurement device uses three laser lines to scan profiles and swivels to measure from different perspectives. The device can be used to analyze the folded edges of sheet-metal body parts that form gaps. Courtesy of NextSense GmbH, Austria. www.nextsense.at.

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materials witness

Start me up

Working as we all do with scientists and engineers, it pays to have a few one-liners on hand for networking events. If you're reading this column, you know what I'm talking about: We live in a world predominantly made up of introverts. This is not necessarily a bad thing, but rather an opportunity to hone conversation skills and find out what makes these brilliant people tick. One of my go-to, no-fail, works-every-time questions is this: "So, what's your dream car?"

For most of us working stiffs (Greg Olson and his Lotus Elise SC excluded), there's the *car we drive* and the *car we want*. Perhaps you can relate. Whether it's an uber-practical Camry or Sonata or a family-friendly Escape SUV or Town & Country minivan, let's just go ahead and admit this is *not* the car you've always dreamed about. Once you get people talking about their true automotive desires, it ignites a certain spark and lively conversation with even the most serious scientists among us.

Case in point: Last month when I visited NIST to learn about their Center for Automotive Lightweighting (featured in this month's "Success Analysis" department, p. 60), I was picked up from the Metro station by one of the top researchers (who shall remain nameless) in his "summer car." His wife's car was having issues, as all cars do, so she had borrowed his car and he took his "baby" out of storage for the day. It was a gorgeously curvy Corvette a few years young in mint condition, which he happily explained goes from 0 to 60 in 3.8 seconds. I can attest that it does.

In this month's annual automotive issue, we take a look under the hood at some of the technology at the heart of vehicle performance. From lightweighting initiatives such as research into magnesium inclusions to nondestructive spot weld analysis to laser beam texturing of sheet metal, much progress is taking place in the automotive arena. Some of the most exciting research is being spurred by various competitions.

One of these is the Valeo Innovation Challenge, with 969 teams of engineering students from 55 countries (representing 455 universities) submitting projects with a goal of winning the €100,000 first prize. Of the entries, 20 top teams will be announced on April 15 and Valeo will grant each one €5,000 to create functioning prototypes. Six of these teams will then be chosen to travel to Paris in September and present their concepts in front of a jury who will select the winning project. The purpose of the Valeo contest (www.valeo.com) is to invite students to imagine equipment that, between now and 2030, will make cars more intelligent and intuitive. Many of these students will become our future vehicle designers and competitions like this will help spur next-generation concepts we can't even imagine today.

So, what's *your* dream car? Little red Corvette? Shiny black Mercedes? Perhaps a Porsche Panamera? We'd like to hear from you about your deepest automotive desires and technology coming down the pike that you feel is the most promising for future designs.

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SMST 2014

fig. 1 *fig. 2* *fig. 3*

The Shape of Things to Come

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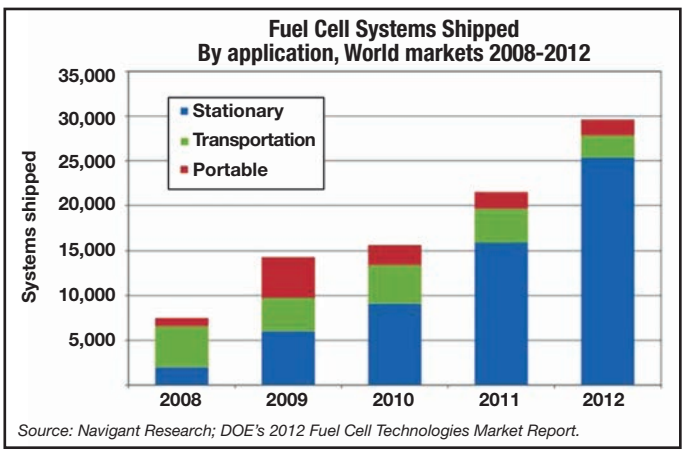
e-ELASTIC News for the Shape Memory Industry

market
spotlight

DOE report indicates promising future for fuel cells

A new report from the DOE takes a close look at the growing fuel cell industry. The *2012 Fuel Cell Technologies Market Report,* published in October 2013, explores the major markets for this technology and presents a promising outlook. Fuel cells are electrochemical devices that combine hydrogen and oxygen to produce electricity, water, and heat. Yet unlike batteries, they continuously generate electricity as long as a source of fuel is supplied. Fuel cells do not burn fuel, making the process quiet, pollution-free, and up to three times more efficient than combustion.



Source: Navigant Research; DOE's 2012 Fuel Cell Technologies Market Report.

Three main markets exist—stationary power, transportation power, and portable power. Stationary power includes any application in which the fuel cells are operated at a fixed location for primary power, back-up power, or combined heat and power. Transportation applications include passenger cars, buses, and other fuel cell electric vehicles (FCEVs), specialty vehicles, material handling equipment (e.g., forklifts), and auxiliary power units for off-road vehicles. Portable power applications use fuel cells that are not permanently installed or fuel cells in a portable device.

According to the report, industry trends were encouraging in 2012: Total fuel cell shipments increased in terms of both units and megawatts while costs continued to decline, especially for light duty vehicle applications. For example, the DOE notes that the cost per kilowatt for high volume production of transportation fuel cells moved closer to its target of $30 per kW.

In addition, government policies continue to favor light duty vehicles. The Obama Administration doubled the fuel economy standard in the U.S., California enacted the Advanced Clean Cars Program, and the U.S., Germany, Sweden, Denmark, Finland, Japan, and other countries increased efforts to deploy hydrogen fueling infrastructure. There were also several collaboration announcements between automakers regarding FCEVs, including Toyota and BMW's long-term strategic collaboration to jointly develop a fuel cell system, and Daimler, Ford, and Nissan joining forces to jointly develop a common fuel cell system and launch commercial FCEVs as early as 2017.

The report was a collaborative effort by staff of the Breakthrough Technologies Institute Inc., Washington, and funded through Argonne National Laboratory by the DOE's Fuel Cell Technologies Office. *For more information, visit www1.eere.energy.gov/hydrogenandfuelcells/pdfs/2012_market_report.pdf.*

feedback

The beauty of boron

I recently read the article regarding boron on ASM's Facebook page and found it very interesting. Apparently it was not reviewed by a metallurgist because I did not see any reference to the importance of boron in metals. Here are just a couple: Boron is critical for high temperature ductility and strength in nickel-base superalloys, i.e., one could not fly in a jet plane without boron. With regard to steels, ships could not operate in the cold of winter without boron. Remember why the Titanic sank?

Don Muzyka

Asking the right questions

Regarding the January letter "Put materials specification where it belongs," the whole world is like this: People ask questions of the wrong people because they think that is what they know. Yet when you finally know to ask the right question to the right person, you are one step away from arriving at the answer. On another note, I really enjoyed the "Science and Selfies" editorial. I hadn't heard about either the NASA vs. NSA news item, nor the Boeing vs. Airbus story.

Roy Salkus

Metallurgy Lane fan club

I greatly enjoyed the first article in the new series on metallurgy history. ("Iron in America," January issue). The piece mentions a number of the original iron processing plants and indicates that several of these are either historical sites or may be preserved or restored. Is there a source that could tell me where these sites are? We are planning a summer trip and would enjoy visiting some of these.

Lois and Jim Rawers

[A single reference does not exist, but one good source is the National Park Service at www.nps.gov/sair; use Google for other sites listed here. The earliest and best restored iron plant in the U.S. is Saugus Iron Works just north of Boston. Other sites showcasing iron making history include Lackawanna Iron and Steel in Scranton, Pa., Cornwall Iron Furnace* in Cornwall, Pa., Cambria Iron Works in Johnstown, Pa., Burden Iron Works* in Troy, N.Y., and Joliet Iron Works in Joliet, Ill.—Charles R. Simcoe]*

**ASM Historical Landmarks. See more at www.asminternational.org/membership/awards/historical-landmarks.*

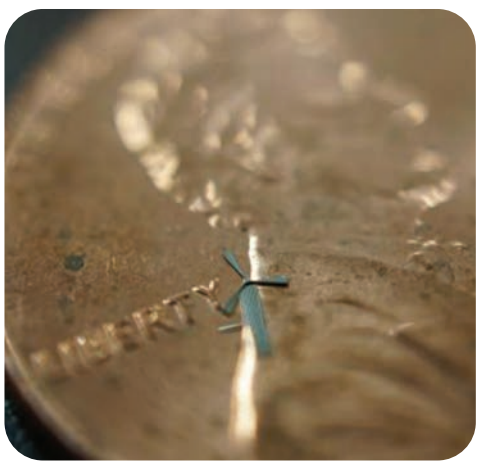
We welcome all comments and suggestions. Send letters to frances.richards@asminternational.org.

3D printed horseshoes

3D printed titanium horseshoes.

Researchers at the Commonwealth Scientific and Industrial Research Organization (CSIRO), Australia, used 3D modeling software to design a lightweight racing shoe with a perfect fit for a racehorse nicknamed "Titanium Prints." Traditionally made from aluminum, horseshoes can weigh up to 1 kg, but horse trainer John Moloney says that the ultimate race shoe should be as lightweight as possible. "These titanium shoes could take up to half of the weight off a traditional aluminum shoe, which means a horse could travel at new speeds," explains Moloney. The precision scanning process takes just a few minutes and shoes can be made to measure for each hoof and printed the same day.

CSIRO's titanium expert, John Barnes, says that 3D printing a race horseshoe from titanium is a first for scientists and demonstrates the range of applications the technology can be used for. "There are so many ways we can use 3D titanium printing. We are helping companies create new applications like biomedical implants and even things like automotive and aerospace parts. The possibilities really are endless with this technology," says Barnes. *www.csiro.au.*



A micro-windmill is pictured on the face of a penny. Courtesy of UT Arlington.

Micro-windmills to recharge cell phones

A University of Texas-Arlington research associate and electrical engineering professor designed a micro-windmill that generates wind energy and may become an innovative solution for cell phone batteries constantly in need of recharging. The device is roughly 1.8 mm at its widest point—so hundreds of them could be embedded in a sleeve for a cell phone. Wind, created by waving the cell phone in air or holding it near an open window on a windy day, would generate the electricity that could be collected by the cell phone's battery. Smitha Rao designed the windmills and blended origami concepts into conventional wafer-scale semiconductor device layouts. The result is that complex 3D moveable mechanical structures can self-assemble from 2D metal pieces using planar multilayer electroplating techniques optimized by WinMEMS Technologies Co., a Taiwanese fabrication foundry. *www.uta.edu.*

K-23 insulated firebricks are suitable for the ceramics market, including kilns, furnace linings, and cyclical furnaces.

Insulating firebricks

Morgan Advanced Materials, Windsor, England, recently introduced a full product range of insulating firebricks (IFBs). Manufactured by its Thermal Ceramics business, 10 different grades are available to meet the temperature needs of multiple applications, from 2300°-3300°F. The K-23 IFB is manufactured with a unique slurry casting process that produces low thermal conductivity and good thermal shock characteristics. Rated at 2300°F, the brick has low density, high hot strengths, good thermal stability, and ultra-low thermal conductivity. It experiences much less shrinkage than competitive products, significantly improving its lifetime. A variety of other low temperature options are available that offer tile brick in a large shape format with low shrinkage and insulation stability. For high temperature kiln linings, Insalcor is a high temperature firebrick with a use limit to 3250°F. The bubble alumina brick is produced by a manufacturing process that features excellent strength and thermal stability at high temperatures and great thermal shock resistance for high temperature cycling furnaces. *www.morganadvancedmaterials.com.*

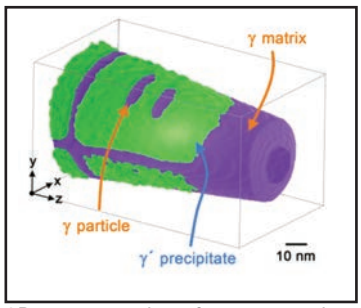
briefs

Duke University's Pratt School of Engineering, Durham, N.C., researchers used computational methods to identify dozens of platinum-group alloys with databases and algorithms that took years to develop. Using theories about how atoms interact to model chemical structures from the ground up, thousands of potential materials were screened for high probabilities of stability. After nearly 40,000 calculations, results identified 37 new binary alloys in the platinum-group metals, which include osmium, iridium, ruthenium, rhodium, platinum, and palladium. These metals are prized for their catalytic properties, resistance to chemical corrosion, and performance in high-temperature environments. www.pratt.duke.edu.

Porous Power Technologies LLC (PPT), Boulder, launched Symmetrix NC2020, a ceramic battery separator designed to improve thermal stability and safety of large-format lithium-ion batteries. The separator is nonflammable and more resistant to shrinkage than conventional separators, making cells more stable when damaged or abused. The ceramic particles are blended with PVDF polymer to form a flexible, ceramic-rich microporous membrane. Ions flow freely through the open pore structure, enabling cells with good power over broad temperature ranges. The sponge-like membrane conforms to the electrode surface to prevent dead spots and ensure reliable performance, even as electrodes expand and contract over many cycles.

Improving superalloy performance

Work from Helmholtz-Zentrum Berlin für Materialien and Energie (HZB), and University of Münster, both in Germany, shows how new phases in a nickel-base alloy form and evolve, offering clues to how high-performance alloys could be improved. Researchers combined transmission electron microscopy (TEM) and atom probe tomography (APT) to accomplish this. The microstructure of nickel-base alloys changes under controlled aging or heat treatment and in the classical two-phase microstructure new phases are initially formed. Researchers precisely observed the phase separation process on the atomic scale for the first time.

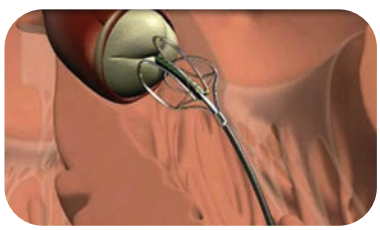


3D reconstruction of an atom probe measurement. The γ matrix (purple) is surrounding the cuboidal γ′ precipitates (green). Only a few nanometer-sized γ platelets are seen in the γ′ precipitates. APT allows site-specific analysis of the structure at the atomic scale and reveals the chemical composition in measurements of individual areas. Courtesy of HZB.

To do so, they simulated the aging process of the alloy by heat treating it for different periods. They documented how the microstructure changed during aging by using micrographs from the TEM. Whereas the classical two-phase microstructure consists of cuboid γ' precipitates embedded in a so called γ-matrix, during heat treatment, spherical γ particles initially form in the γ' precipitates of the alloy, and then further coalesce into plates that finally split the γ' precipitates. The thermo-mechanical properties of these types of alloys depend largely on the stability of this γ/γ' microstructure. *www.helmholtz-berlin.de/index_en.html.*

FDA approval for guidewire

MediValve Ltd., Israel, received 510(k) pre-marketing clearance from the U.S. Food and Drug Administration for its acWire guidewire, intended for use in peripheral vascular and heart catheterization procedures, to introduce and assist in positioning diagnostic and interventional devices. The guidewire may also function as an alignment tool by providing a reference plane of the anatomical structure of interest. It is a single-use, fully disposable medical device that uses shape-memory alloy technology to enable identification of cardiovascular structures using existing imaging methods. The device is intended for implantation plane acquisition, during trans-catheter aortic-valve implantation (TAVI) procedures using fluoroscopic imaging. *www.medivalve.com.*



MediValve receives FDA 510(k) approval for acWire guidewire. Courtesy of MediValve Ltd.

Plastics machinery safety standards update

The Plastics Industry Trade Association, Washington, and the American National Standards Institute (ANSI) announce the publication of two recently revised and approved American National Standards on plastics machinery safety: ANSI/SPI B151.20 - 2013 Safety Requirements for Plastics Sheet Production Machinery, and ANSI/SPI B151.27 - 2013 Safety Requirements for the Integration of Robots with Injection Molding Machines, both of which address detailed safety requirements for the specific machine or group of machines.

B151.20 specifies requirements for the manufacture, care, and use of plastics sheet production machinery to minimize hazards to personnel associated with machine activity. B151.27 addresses the integration, care, and use of robots used with injection molding machines to minimize hazards to personnel associated with robot and machine activity. *www.plasticsindustry.org, www.ansi.org.*

Study explores aging of pressure vessels in nuclear power stations

German scientists participated in the LONGLIFE project funded by the European Union and coordinated by the Helmholtz-Zentrum Dresden-Rossendorf (HZDR) to investigate how pressure vessels of nuclear power stations age. The embrittlement during long-term operation was investigated using many material samples in different irradiation conditions. The mechanical properties of the irradiated materials can only be tested in hot cell testing facilities like those at the HZDR. Researchers are particularly interested in the influence that the intensity of the radiation (neutron flux) has on the materials over a certain time interval. Materials that have been irradiated at a low neutron flux over many years exhibit different changes at the atomic level than materials exposed to a higher neutron flux over a shorter period of time. This effect and others that are significant during long-term irradiation are now being taken into account during monitoring of the materials' aging. *www.hzdr.de.*

Hot cell testing facility at the Helmholtz-Zentrum Dresden-Rossendorf allows analysis of irradiated material samples.

ArcelorMittal, Chicago, plans to reopen their long product finishing facility in Harriman, Tenn. With a goal of fully operating by April, the company will hire 61 new employees over the next two years. The facility, which closed in 2011 due to poor market conditions, receives billets from ArcelorMittal LaPlace, La., reheats them, and rolls them into light structural shapes and merchant bars for the construction market. The reopening will enhance the company's long product portfolio by producing 1-3-in. angles and 1-4-in. flats. http://corporate.arcelormittal.com.

QuesTek Innovations LLC, Evanston, Ill., announced that its ultrahigh-strength, high-toughness Ferrium M54TM steel was approved for inclusion in the aerospace industry's *Metallic Materials Properties Development & Standardization (MMPDS) Handbook.* The company accelerated M54 steel from a clean sheet design to a precise chemical composition in less than one year, and produced the first 10-ton ingot the next year. SAE International issued an Aerospace Material Specification (AMS 6516) two years later. With the MMPDS approval, M54 steel reached full flight qualification from clean sheet design in less than six years. www.questek.com/ferrium-m54.html.

briefs

Shimadzu Scientific Instruments Inc. (SSI) opened its new **Shimadzu Solution Center** in Columbia, Md. The 4100-sq-ft facility will enable the company to quickly respond to needs for new scientific instruments, software platforms, and applications. The center showcases more than 30 scientific instruments highlighting SSI's full range of products, including molecular/atomic spectrophotometers, mass spectrometers, liquid/gas chromatographs, x-ray spectrometers, balances, TOC analyzers, and materials testers. www.ssi.shimadzu.com.

Lake Shore Cryotronics Inc., Columbus, Ohio, announced that the **Air Force** intends to award the company a $750,000 Phase II Small Business Technology Transfer (STTR) grant. In early 2013, the Air Force awarded Lake Shore a Phase I grant to assist with development of a system prototype. This latest funding supports further application development for the 8500 Series THz system for materials characterization with the main development work performed on the prototype system installed at **Wright Patterson Air Force Base.** Lake Shore will work with researchers at the **University of Arizona** to develop techniques to improve the integrity of the THz signal. www.lakeshore.com.

Lake Shore's 8500 Series THz system.

Swivel device enables multifunctional profile measurement

The CALIPRI profile measurement device developed by NextSense GmbH, Austria, uses three laser lines to scan profiles, allowing the device to swivel and measure from different perspectives. Due to the swiveling capability, the device can be used to analyze the folded edges of sheet-metal body parts that form gaps. Traditional methods record gaps from only a few perspectives and must calculate missing data by mathematical approximation methods, and due to the missing perspectives, they cannot analyze folded edges at all.

Patented tilt correction leads to reproducible results when evaluating folded edges.

In premium-class vehicle construction, less gap clearance translates to reduced road noise and improved appearance. However, with "invisible" gaps and more hidden and more complex gap contours, measurement requirements are more stringent. The swiveling device makes it possible to spatially scan complex gaps. Regardless of whether it is handheld or installed on a robot arm, the tool can be moved freely over the component and combines segments recorded by the laser into a complete profile.

Measurement results are free from mathematical extrapolations and within a few seconds, the system reportedly delivers greater accuracy than alternative methods. A crucial element of the tool's flexibility is its patented tilt correction, which automatically compensates for any tilts and twists of the measurement sensor. Because of this feature, the device can be moved freely over any gap and fold contour throughout the production process. *For more information: Christoph Böhm, +43/(0)316/232400, office@nextsense.at, www.nextsense.at.*

2014 Image Contest now underway

FEI's (Hillsboro, Ore.) 2014 Image Contest began February 3. Categories include: The Natural World, The Human Body, and Around the House. All FEI instrument owners are invited to submit their best images through the end of the year, and some of them will be included in the free National Geographic iPad app called *Mysteries of the Unseen World.*

FEI's 2013 Image Contest winner is Marcos Rosado of the Electron Microscopy Division of the Catalan Institute of Nanoscience and Nanotechnology (ICN2), Spain, for his "Acacia Dealbata Flower" image shown here. *www.fei.com/image-contest.*

This SEM image shows an Acacia dealbata (yellow mimosa) flower, 4.5 mm across, about to open. The flower was removed from the tree and put into the microscope in a fresh state and the image was taken as soon as possible to avoid structural damage. False color was added to the gray scale image.

Robots and x-rays boost Norwegian fishing industry

Unlike farmed salmon, white fish varies significantly in size and weight, making it difficult to develop an automated system capable of processing it. However, a new filleting machine was recently invented that could boost the Norwegian fishing industry. The system resulted from collaboration between Nordic Innovation, SINTEF, Marel, Faroe Origin, and Norway Seafoods. White fish is complicated and time-consuming to fillet because bones are difficult to find and remove. As a result, 3-7% of the most valuable part of the fish is cut away unnecessarily. Researchers at SINTEF ICT conducted laboratory x-ray tests and used scanners at Oslo University Hospital to learn more about where fish bones are located. The technology focuses on image analysis and recognition. The new machine locates fish bones using x-ray technology, and then fillets the fish quickly and precisely with a powerful jet of water. Fish are guaranteed to be boneless with considerably less waste than manual filleting.

"Norway only exports 10-25% of processed products, depending on whether it is white fish or farmed fish," explains Marit Aursand, research director of SINTEF fisheries and aquaculture. "Most of our important seafood products—such as salmon, cod, and herring—receive only minimal processing or treatment before they are sent abroad. In other words, there is huge potential for carrying out more processing in Norway."

The new invention makes it possible to send fresh fish direct to shops from Norwegian facilities. *www.sintef.no.*

AMETEK Inc., Berwyn, Pa., acquired **VTI Instruments,** Irvine, Calif., a manufacturer of high precision test and measurement instrumentation for $74 million. VTI makes signal conditioning and switching instruments, data acquisition products, and integrated test systems for demanding electrical and structural testing applications where high measurement accuracy is critical. www.ametek.com.

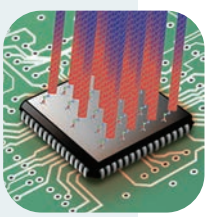
A new machine uses x-rays to locate fish bones then quickly and precisely fillets the fish with a powerful water jet.

briefs

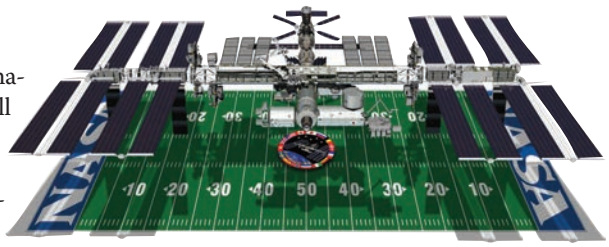
Element Six, Santa Clara, Calif., announced that its high purity, single crystal chemical vapor deposition (CVD) diamond material can be used in intracavity cooling of disc lasers, and was recently used in development of the first tunable diamond Raman laser system. The CVD diamond has the highest thermal conductivity of any material at room temperature (up to 2200 W/mK), according to researchers. Combined with a low absorption coefficient at a number of key wavelengths, the material gave the **University of Strathclyde,** UK, the ability to demonstrate this continuous-wave, diamond Raman laser for the first time. www.e6.com/optical.

High purity, single crystal CVD diamond used as an enabler in the first ever tunable Raman laser.

Researchers at **Kyoto University's Institute for Integrated Cell-Material Sciences (iCeMS),** Japan, succeeded in creating a rare metal alloy used for industrial purposes. Palladium and ruthenium were combined, which typically behave like oil and water and will not mix even when liquefied at 2000°C. This was overcome by mixing the metals at the atomic level. The alloy may be substituted for rhodium, normally used for automobile exhaust pipes. With a cost one-third that of rhodium, the new alloy is reportedly just as robust and has many of the same characteristics, such as eliminating nitric oxide from exhaust. www.icems.kyoto-u.ac.jp.



NASA seeks next-gen microgravity research concepts



The International Space Station's length and width is about the size of a football field. Courtesy of NASA.

NASA's microgravity materials science program supports materials research conducted aboard the International Space Station (ISS) and will hold a materialsLAB Workshop April 15-16 in Arlington, Va., to explore next-generation experimental concepts. The ISS is essentially an orbiting laboratory, and the only such facility to offer this unique microgravity setting. The orbital conditions onboard provide an environment where gravity-driven phenomena—such as buoyancy-driven fluid flows and sedimentation—are nearly negligible. This enables scientists to study the effects of sedimentation and buoyancy-driven convection on the formation of materials when comparing flight and ground samples. It also allows for study of the often obscured effects of things like diffusive transport and surface-tension-driven convection on the formation of materials. Measurement of properties such as liquid diffusion coefficients obtained in the absence of gravity-related heat and mass transport is another area of materials research enabled by the unique ISS environment.

Marshall Porterfield, division director, NASA Space Life and Physical Sciences, says that a vital part of facilitating future research directions is a new Physical Science Informatics System that provides global access to all past, present, and future ISS Physical Science experimental data for the first time. The system enables an open source approach to scientific data analysis and will become a gateway to hundreds of new ISS-based scientific investigations that will define the next generation of ISS experiments.

Following a half-day plenary session on April 15, workshop participants will be placed into working groups based on area of expertise, including metals, semiconductors, ceramics, glasses, polymers, biomaterials, nanomaterials, and others. NASA has released a Request for Information (RFI) to solicit ideas on materials research on the ISS. Submitting a response to the RFI will facilitate organization of the breakout sessions and ensure that your ideas will be given the opportunity to be discussed in the forum. The full RFI and submission instructions can be found at http://tinyurl.com/mrhxt9g. In addition, visit the workshop registration website at: http://icpi.nasaprs.com/NASAmaterialsLABWorkshop2014. *For more information: Francis Chiaramonte, 202/358-0693, francis.p.chiaramonte@nasa.gov, www.nasa.gov.*

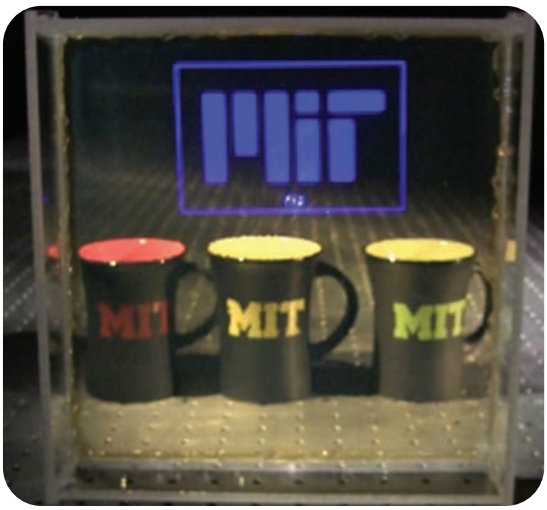
NCMS launches nanomanufacturing survey

The National Center for Manufacturing Sciences (NCMS), Ann Arbor, Mich., partnered with the National Science Foundation under the National Nanotechnology Initiative (NNI) to launch its latest study of commercialization trends in nanotechnology and nanofabrication. Themed "Achieving Sustainable Nanotechnology Products," the goal of the study is to document best practices in nanoproduct development and integration, and identify common challenges faced by organizations (academia, government labs, startups, and established corporations) in transitioning nanoscale advances from the laboratory into sustainable commercial applications.

Senior executives and researchers in stakeholder organizations are encouraged to share their experience and opinions about nanotechnology development in the U.S. Individual responses are kept confidential and the data will only be used in the aggregate. All survey respondents will receive the study results in advance of public release this summer. The 15-minute interactive survey may be accessed at www.usnanosurvey.org until March 31. *For more information: Manish Mehta, 734/995-4938, manishm@ncms.org, www.ncms.org.*

Nanotechnology has unlimited applications. Cooling microprocessor chips through the combination of carbon nanotubes and organic molecules as bonding agents is a promising technique for maintaining the performance levels of densely packed, high-speed transistors in the future. Courtesy of Lawrence Berkeley National Lab.

See-through screen could be applied on ordinary glass



Researchers at Massachusetts Institute of Technology, Cambridge, came up with a new approach for transparent displays that offers significant advantages over existing systems. Nanoparticles are embedded into the transparent material. They can be tuned to scatter only certain wavelengths, colors, or light, while letting the rest pass through.

To demonstrate the system, a blue image was projected in front of a scene containing cups of several colors, all of which can clearly be seen through the projected image. While the demonstration used silver nanoparticles, roughly 60 nm across, which produce a blue image, researchers say it should be possible to create full-color display images using the same technique. Three colors (red, green, and blue) are enough to produce what we perceive as full-color, and each of the three colors would still show only a very narrow spectral band, allowing all other hues to pass through freely. *For more information: Marin Soljačić, 617/253-2467, soljacic@mit.edu, www.web.mit.edu/physics/index.html.*

Fast ASTM test standard for transportation coatings

A collaborative 14-year effort involving BASF, Germany, automotive and aerospace OEMs, material suppliers, and test equipment manufacturers resulted in a new ASTM test standard for transportation coatings. The new method is 30-40% faster than the previous test standard, and improves the accuracy to nearly 100% in predicting coating service life compared to less than 50% before. Officially named ASTM D7869-13 Standard Practice for Xenon Arc Exposure Test with Enhanced Light and Water Exposure for Transportation Coatings, the new test simulates physical and environmental stresses that an exterior transportation coating is exposed to in a subtropical climate. These stresses include long water exposures, wet/dry cycling, and high dosages of solar radiation, all of which have been shown to cause severe coating deterioration. *www.basf.com.*

Flying with environmentally-friendly coatings

The European Union ECOPROT project aims to industrialize an innovative procedure for producing corrosion-protecting, environmentally friendly coatings for aluminum and magnesium alloys, to be used in the aeronautics market. Unlike other commercial solutions trying to penetrate the market, this coating reportedly provides a corrosion performance comparable to that of the toxic chromates, meeting the rigorous standards of the aeronautics industry. The slightly higher price of the product compared to current coatings is offset by its greener environmental impact, say researchers.

The new process was granted a patent and developed through an FP6 project called Multiprotect. While the coating has huge potential in the aeronautic market, scaling up production and achieving market penetration has been difficult. The aim of ECOPROT is to industrialize the procedure and raise industry awareness of this glasslike, environmentally friendly, and self-healing cerium-based coating. *www.ecoprot.eu.*

briefs

Axalta Coating Systems, Philadelphia, announced the publication of its annual automotive color popularity report for 2013. This year's report includes *Say it with Color!,* Axalta's forecast of four color megatrends for automotive designers around the world. White strengthened its position as the most popular automotive color among consumers worldwide in 2013, growing in popularity by 6% over the prior year. Black was the second most popular color globally, with 20% of sales, but "effect black" was preferred more than "solid black." Silver at 15% and gray at 12% waned in popularity, while red held steady at 8%. www.axaltacoatingsystems.com.

The aerospace coatings group of **PPG Industries,** Sylmar, Calif., qualified Aerocron electrocoat primer to SAE International's Aerospace Material Specification 3144 for anodic electrode position primer for aircraft applications. This qualification provides airframe manufacturers and subcontractors with third-party verification of its performance characteristics and attributes, according to company representatives. Four variations of the PPG chromate-free primer were qualified to AMS 3144 in order to meet specific customer or regional requirements. www.ppg.com.

Carboline Co., University Heights, Ohio, released Carbotherm 551, an advanced insulative coating. The water-based epoxy coating has multiple uses, from protecting workers from burns on hot surfaces to thermal insulation. It dramatically reduces the effects of solar radiation on operating vessels and storage tanks and reduces heat buildup, which can otherwise result in evaporative emissions from storage tanks containing hydrocarbon or other cargo. The coating can provide up to 60% energy efficiency when applied at only 4-6 mm. In a single coat, it can protect against heat caused by solar radiation for pressure vessels, hydrocarbon storage tanks, liquefied petroleum tanks, and other containers. www.carboline.com.

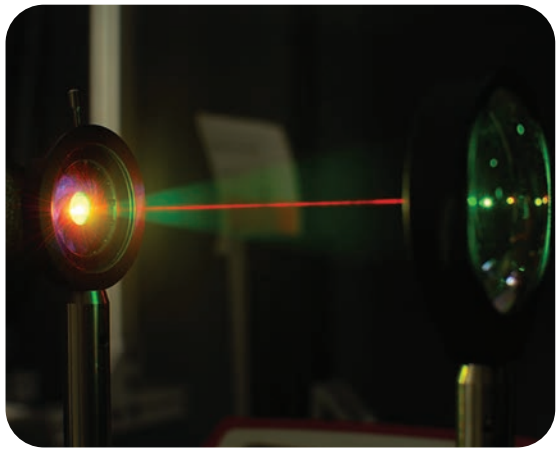
briefs

Researchers at **Kansas State University,** Manhattan, demonstrated that a composite paper—made of interleaved molybdenum disulfide and graphene nanosheets—can be both an active material to efficiently store sodium atoms and a flexible current collector. The newly developed composite paper can be used as a negative electrode in sodium-ion batteries. Synthesis of large quantities of single or few-layer-thick 2D materials is crucial to understanding the commercial potential of materials such as transition metal dichalcogenides and graphene. www.k-state.edu.

Researchers at the **University of Cambridge,** UK, developed a new method to probe silicon batteries and determined what causes silicon expansion, which degrades battery performance, to take place. Using nanoscale wires made of silicon and nuclear magnetic resonance techniques, a robust model system able to accommodate the expansion of the silicon over multiple cycles was developed and integrated with short-range probing techniques, which reveal what is happening inside the battery at the atomic level. www.cam.ac.uk.

Researchers at the **University of Liverpool,** UK, are investigating the use of ultraviolet light to create thin films that can be used on solar panels. Funding from the Engineering and Physical Sciences Research Council (EPSRC) will enable the scientists to develop new methods for atomic layer deposition using light rather than heat to create the layers. The project will replace the use of heat from below with light from above in order to create the reaction. This is significantly more energy efficient and will allow industry to use atomic layer deposition in many more applications that require larger surfaces to be covered. www.liv.ac.uk.

Silicon devices respond to infrared light



A laser beam is used in the lab to test the gold-hyperdoped sample of silicon to confirm its infrared-sensitive properties. Courtesy of the researchers.

A new system developed by researchers at five institutions, including Massachusetts Institute of Technology, Cambridge, creates detectors that are responsive to a broad range of infrared light. Silicon normally lets most infrared light pass through. The new system works at room temperature and provides a broad infrared response, say researchers. It incorporates atoms of gold into the surface of silicon's crystal structure in a way that maintains the material's original structure. It also has the advantage of using silicon, a common semiconductor that is relatively low cost, easy to process, and abundant. The approach works by implanting gold into the top hundred nanometers of silicon and then using a laser to melt the surface for a few nanoseconds. The silicon atoms recrystallize into a near-perfect lattice, and the gold atoms do not have time to escape before getting trapped in the lattice. *For more information: Tonio Buonassisi, 617/324-5130, buonassisi@mit.edu, www.web.mit.edu.*

Increasing domestic plastic production

Low U.S. natural gas prices are helping increase domestic plastic production after a decline from the 2008 recession. Because many U.S. plastic manufacturers use natural gas as their primary fuel source and natural gas-sourced liquids as a feedstock, continued low prices for those resources could boost raw plastic exports, given higher foreign energy prices. During the economic downturn in 2008 and 2009, U.S. production of plastic products declined further than raw plastic production and has been slower to recover. Demand for raw plastic from other parts of the world, such as China, remained strong, keeping U.S. plastic resin production from falling further and enabling it to recover faster. Given the inexpensive and versatile nature of polyethylene and polypropylene plastics, demand for these materials has grown rapidly since the late 1990s, both domestically and abroad. *www.eia.gov.*

Self-healing battery electrode

Researchers made the first battery electrode that heals itself, opening a new and potentially commercially viable path for making the next generation of lithium ion batteries for electric cars, cell phones, and other devices. The secret is a stretchy polymer that coats the electrode, binds it together, and spontaneously heals tiny cracks that develop during battery operation, according to the team from Stanford University and DOE's SLAC National Accelerator Laboratory, both in California.

Chao Wang, a researcher at Stanford, developed the self-healing polymer in the lab of Zhenan Bao, whose group has been working on flexible electronic skin for use in robots, sensors, prosthetic limbs, and other applications. For the battery project, he added tiny nanoparticles of carbon to the polymer so it would conduct electricity. "We found that silicon electrodes lasted 10 times longer when coated with the self-healing polymer, which repaired any cracks within just a few hours," explains Bao. The electrodes worked for about 100 charge-discharge cycles without significantly losing their energy storage capacity. *For more information: Zhenan Bao, 650/723-2419, zbao@stanford.edu, http://baogroup.stanford.edu.*

Alcoa to supply titanium and aluminum parts to Airbus

Alcoa Inc., N.Y., signed a multi-year supply agreement with Airbus, France, valued at approximately $110 million for value-add titanium and aluminum aerospace forgings. Alcoa will produce the parts using its recently modernized 50,000-ton press in Cleveland, which uses state-of-the-art controls to meet stringent aerospace specifications. The press is also reportedly capable of producing the world's largest and most complex titanium, nickel, steel, and aluminum forgings.

Alcoa signed a multi-year agreement to supply Airbus with titanium and aluminum aerospace forgings for Airbus aircraft, including the A320neo. Courtesy of Business Wire.

Alcoa will supply titanium parts, including forgings used to connect the wing structure to the engine, for the A320neo, Airbus's most fuel-efficient single-aisle jet. The agreement also includes several large aluminum forgings for the A330 and A380—including the A380 inner rear wing spar, the largest aerospace forging in the world—that will be made using Alcoa's 7085 alloy intended for large structural aircraft components. Most of these forgings support the wing structure where strength-to-weight ratio is critical to efficient flight performance. *www.alcoa.com.*

Sourcing rubber from dandelion juice

Researchers at the Fraunhofer Institute for Molecular Biology and Applied Ecology IME and Continental AG, both in Germany, built the first pilot system to extract vast quantities of dandelion rubber for making tires—an important milestone on the path to rubber procurement in Europe. The project began in October 2013 with a goal of developing the production process over the next five years so Continental can manufacture tires made from dandelion rubber.

Molecular biologists at IME and researchers at the automotive supplier built a pilot facility in Münster capable of producing natural rubber by the ton. Several hectares of a dandelion variety that is particularly rich in rubber are also being cultivated. The first prototype test tires made of blends from dandelion rubber are scheduled to be tested on public roads over the next few years. The natural rubber product exhibits the same quality as conventional rubber from rubber trees imported from subtropical countries. However, unlike conventional rubber, the new rubber can be harvested more cost effectively, better cultivated, and grown in Germany as a sustainable raw material, even on land areas not previously suited for agricultural crops. *www.ime.fraunhofer.de/en.html.*

Fraunhofer Institute scientists transformed ordinary dandelions from weeds into an agricultural crop that produces abundant natural rubber. Courtesy of Fraunhofer IME.

Conflict-free tungsten program announced

A new collaboration between the Conflict-Free Sourcing Initiative (CFSI) and the Tungsten Industry Conflict Minerals Council (TI-CMC) makes it easier for companies to source conflict-free tungsten. Through the joint development of a specialized framework, members of the TI-CMC may now choose to become validated as Democratic Republic of the Congo conflict-free tungsten smelters under the CFSI's Conflict-Free Smelter Program. This marks the first time the CFSI and TI-CMC can provide information about conflict-free tungsten smelters, just in time for reporting requirements on conflict minerals in 2014. *For more information: Julie Schindall, 571/858-5721, jschindall@eicc.info, www.conflictfreesourcinginitiative.org.*

briefs

A Tornado fighter jet fitted with metal components created on a 3D printer achieved a successful test flight in England during December, according to **BAE Systems,** London. The plane was equipped with a 3D-printed protective cover for the cockpit radio, a protective guard in the landing gear, and support struts on the air intake door. BAE says some of the parts cost less than $165 to manufacture and could potentially save hundreds of thousands of pounds every year. www.baesystems.com.

Chromalloy, Palm Beach Gardens, Fla., entered into three new long-term parts and service agreements with **Pratt & Whitney,** East Hartford, Conn., involving manufacturing and supply chain activities on the new PurePower PW1100G-JM engine and aftermarket support on legacy engines. Chromalloy will produce investment cast parts and provide advanced coatings, machining, and drilling on other components. The other two agreements cover materials and services for several aircraft engine platforms. www.chromalloy.com.

3D Systems, Rock Hill, S.C., acquired **Xerox's** solid ink engineering and development teams, labs, and related patent portfolio for $32.5 million. The company expects the acquisition of these printer design and materials science teams together with their labs and IP to catapult its printers' development and manufacturing capabilities a decade forward and substantially accelerate revenue growth. As part of the agreement, 3D Systems added more than 100 Xerox engineers and contractors specializing in product design and materials science to its global R&D team. www.3dsystems.com.

NANOTECHNOLOGY

briefs

A new microscope invented at **Michigan State University,** East Lansing, allows scientists to zoom in on the movements of atoms and molecules. An associate professor of physics and astronomy brought "molecular movies" down to the nanoscale level, where the properties of materials begin to change. The work has applications in nanoelectronic technologies and clean-energy industries. The team is said to be one of the few in the world actively developing electron-based imaging technology on the femtosecond timescale. www.msu.edu.

Researchers at **Florida State University,** Tallahassee, received more than $1.4 million from the National Science Foundation to develop a system that will produce large amounts of a state-of-the-art material made from carbon nanotubes that researchers believe could transform everything from the way airplanes are built to how prosthetic limbs fit the human body. The material, buckypaper, is a featherweight sheet made of carbon nanotubes that is being tested in the electronics, energy, medicine, space, and transportation industries. www.fsu.edu.

The frictional characteristics of nanotextured surfaces cannot be fully described by the framework of Amontons' laws of friction, according to new research from the **University of Bristol,** UK. Using a nanosized atomic force microscope tip to scan across a nanodomed surface, researchers revealed sustained stick-slip frictional instabilities under the velocity and load regimes they studied. A linear dependence between the amplitude of these frictional oscillations and the applied load was found, leading to the definition of the slope as the stick-slip amplitude coefficient. www.bris.ac.uk.

Cellulose nanocrystals potential wonder material

The same tiny cellulose crystals that give trees and plants their high strength, light weight, and resilience were shown to have the stiffness of steel, according to research at Purdue University, West Lafayette, Ind. Calculations using precise models based on the atomic structure of cellulose show the crystals have a stiffness of 206 gigapascals, which is comparable to steel, according to Pablo Zavattieri, assistant professor of civil engineering. "This is a material that is showing really amazing properties," he explains. "It is abundant, renewable, and produced as waste in the paper industry." The nanocrystals are about 3 nm wide by 500 nm long, making them too small to study with light microscopes and difficult to measure with laboratory instruments. They represent a potential green alternative to carbon nanotubes for reinforcing materials such as polymers and concrete. *For more information: Pablo Zavattieri, zavattie@purdue.edu, https://engineering.purdue.edu.*

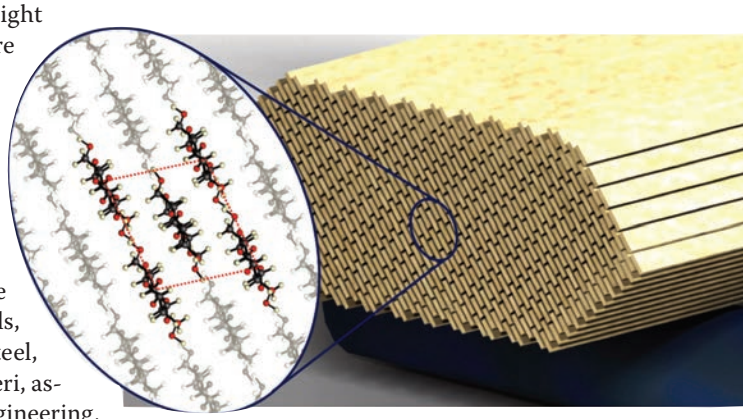
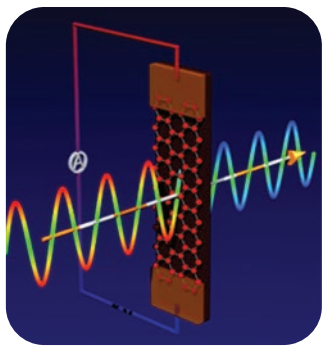


Illustration depicts structural details of cellulose nanocrystals. Courtesy of Purdue University/Pablo Zavattieri.

New de-icer is light and inexpensive

Ribbons of ultrathin graphene combined with polyurethane paint meant for cars are just right for de-icing sensitive military radar domes, according to scientists at Rice University, Houston. The researchers, in collaboration with Lockheed Martin, developed the compound to protect marine and airborne radars with a robust coating that is also transparent to radio frequencies. Because graphene is so thin, it allows radio frequencies to pass through bulky radar domes (radomes) unhindered. Radomes are used on military ships to keep ice and freezing rain from forming directly on antennas. Spray-on de-icing material that incorporates graphene nanoribbons would be lighter, less expensive, and more effective than current methods, according to researchers. *www.rice.edu, www.lockheedmartin.com.*



A new compound created by Rice University and Lockheed Martin provides a thin, robust ice-melting coating for marine, airborne, and other uses. The active element consists of carbon nanotubes "unzipped" into ribbons. Courtesy of the Tour Group.

Grant helps nanoparticle manufacturing

Making large quantities of reliable, inexpensive nanoparticles for batteries, solar cells, catalysts, and other energy applications has proven challenging due to manufacturing limits. A Cornell University, Ithaca, N.Y., research team is working to improve such processes with a $1.5 million National Science Foundation (NSF) grant to support scalable nanomanufacturing and device integration. Richard Robinson, assistant professor of materials science and engineering, and Tobias Hanrath, associate professor of chemical and biomolecular engineering, received a four-year Nanoscale Interdisciplinary Research Team grant through the NSF's Scalable Nanomanufacturing Program. Their goal is to improve large-scale, solution-phase synthesis of high-quality nanoparticles—in particular metal sulfides—and demonstrate their integration into devices including battery electrodes and solar photovoltaics. *www.cornell.edu.*

Finding and Removing Inclusions in **Magnesium Alloys**

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Sophie Lun Sin
Comondore (Ravi) Ravindran, FASM*
Centre for Near-net-shape Processing of Materials,
Ryerson University
Toronto

Understanding both the origin and procedures for removing inclusions in magnesium alloys results in castings with enhanced mechanical and corrosion properties.

Magnesium and its alloys are among the most promising lightweight materials. With a density of 1.74 g/cm^3[1] (35% lighter than aluminum), Mg alloys are attractive to both the aerospace and automotive industries due to their high strength-to-weight ratio, good castability, high impact resistance, and high recyclability.

However, its high oxidation potential usually results in inclusion contents much greater than that found in Al. Unlike Al alloys, which form a stable nonporous oxide surface, molten Mg produces a porous magnesium oxide (MgO) surface that does not protect the molten metal from further oxidation unless special precautions are taken. Inclusions in Mg alloys reduce strength and ductility, are detrimental to surface finish, increase porosity, and exhibit a tendency to increase corrosion[2]. Improving the melt quality by controlling trace elements, reducing the amount of dissolved gases, and removing inclusions could enhance the properties of Mg and its alloys.

This article provides an overview of typical inclusions found in Mg and its alloys, various techniques used to determine inclusion content, and methods employed to reduce inclusions and their influence on properties. This discussion is based on a recent review article on inclusions in Mg alloys[3].

Inclusions in Mg alloys

Typical inclusions found in Mg alloys can be categorized into either nonmetallic (oxides, carbides, nitrides, chlorides, and salts) or intermetallic (iron-based) types. A summary of typical inclusions is shown in Table 1.

Each stage of the casting process is a potential source of inclusions in Mg alloys. Melting, melt holding/transfer, and casting each exhibit conditions in which the molten Mg surface may be exposed to the atmosphere where inclusions could form:

Melting — Molten Mg reacts with oxygen to form MgO when the melt is exposed to oxygen in the atmosphere[7, 8]. In addition, all tools must be dry or preheated before immersion to remove moisture and to prevent MgO and hydrogen formation (potential fire or explosion source).

Melt holding/transfer — Actions such as stirring, charging, ladling, poor venting, removal of dross and sludge, and excessive move-

TABLE 1 — INCLUSIONS IN Mg ALLOYS [4-6]

Type	Morphology	Dimensions (μm)	Density (g/cm^3)
Oxides			
MgO	Particles, films	10-300 0.5-1 (thickness) 50-400 (length)	3.58
MgO-Al_2O_3 (spinel)	Particles		3.58
Nitrides			
Mg_3N_2	Particles, films	10-300 0.5-1 (thickness) 50-400 (length)	2.71
Carbides			
Al_4C_3	Particles	0.1-10	2.36
CaC_2	Particles	2-20	2.22
Chlorides and salts			
$MgCl_2$	Particles	10-50	2.32
NaCl	Particles	10-50	2.17
$CaCl_2$	Particles	10-50	2.15
KCl	Particles	10-50	1.98
Iron-rich intermetallic compounds			
$Al_8(Mn,Fe)_5$, α-AlMnFe, $(Mn,Fe)_5Si_3$, $Al_8(Mn,Fe)_4RE$, α-Fe, $Fe_2(Si,B)$, $Fe_3(Al,Si)$, $(Fe, Mn)_3Si$	Particles, needles	<20	4-7

**Member of ASM International*

ment of the mold before solidification is complete can promote oxide entrapment.

Casting — This process usually leads to melt turbulence to a degree dependent on the pouring technique and gating system. During casting, melt turbulence caused by poor gating design is generally associated with high surface turbulence and greater entrainment of oxide films. Entrained oxides are typically double oxide film defects (bifilms) comprised of folded MgO films[9]. A fresh melt surface is also exposed to the atmosphere, further increasing the possibility of inclusions being entrained within the melt.

Assessment of inclusions in Mg alloys

A summary of methods used or considered to assess metal cleanliness in the Mg industry is shown in Fig. 1, although none of these methods are considered standard for determining Mg melt cleanliness. Leading inclusion assessment techniques include:

Metallographic techniques — This relatively simple method uses a sectioned sample of the cast product, which is ground, polished, and examined using metallographic techniques. Metallography is usually combined with image analysis to determine particle shape, size, number, and distribution, or with scanning electron microscopy (SEM) and energy dispersive x-ray spectroscopy (EDS) to determine the nature of inclusions and possible sources of melt contamination[12]. Drawbacks associated with classic metallographic techniques include small sample sizes, which may not be representative of the entire casting, and the fact that inclusion content measurements are done "offline" after the casting has been produced.

HMIAM — With the hydro magnesium inclusion assessment method (HMIAM), a known volume of the melt is drawn through a stainless steel filter by vacuum. Inclusions accumulate within or on top of the filter. Once the melt has solidified and cooled, the filter and its contents are sectioned parallel to flow direction and examined with an optical microscope. The amount of inclusions in the melt is measured as the volume of particles per unit weight of metal drawn through the filter. Unlike metallographic techniques, HMIAM is performed "online"[7, 8]. One disadvantage to this method is that the quantity and morphology of oxides in ingots or die cast components may be different from those observed on the filter due to a different melt temperature[10].

Light reflectance — This technique is based on differences in optical characteristics between Mg and MgO and involves fracturing a gravity cast sample and examining it under the aperture of a brightimeter. The sample is illuminated at a 45° angle to the fracture surface and reflected light intensity is measured. Because inclusions have different optical properties compared to the matrix, incident light will be scattered at the specimen surface due to multiple reflections and refractions. In Mg alloys, MgO inclusions absorb more light than the matrix, and as a result, specimen reflectance is reduced. The reflectance should therefore correlate with the oxide inclusion content in the specimen[11]. However, this technique, while simple and inexpensive, is unable to distinguish between different inclusion types and sizes[7, 10]. Both HMIAM and light reflectance techniques are shown in Fig. 2.

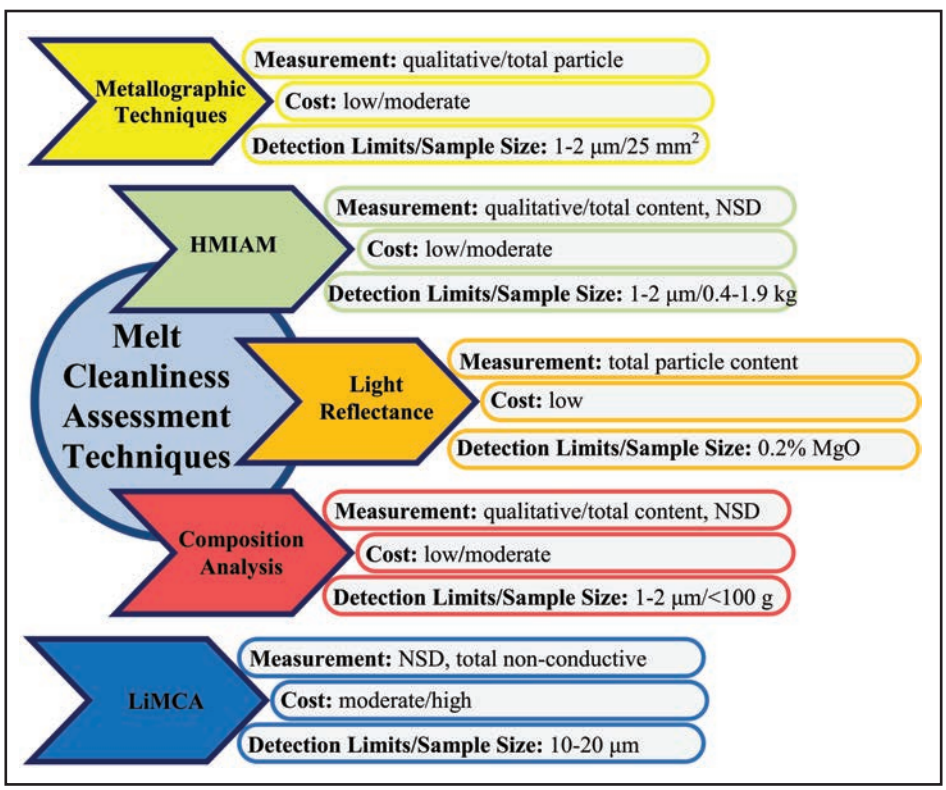

Fig. 1 — *Methods for inclusion assessment used or considered for use in the Mg industry[6-8, 10-12]. HMIAM—hydro magnesium inclusion assessment method; LiMCA—liquid metal cleanliness analyzer; NSD—number size distributions.*

LiMCA — The liquid metal cleanliness analyzer (LiMCA) instrument offers online measurement of nonconducting particles as shown in Fig. 3. The unit includes a probe, current source, and signal processing system. The probe consists of two electrodes and an electrically insulating sampling tube with an orifice through its surface. Molten metal is drawn through the aperture in the presence of a large dc current. Nonconducting inclusions as small as 20 μm are detected by measuring the change in electrical conductivity as they pass through the aperture[8]. However, because this technique operates by detecting changes in electrical conductivity, it cannot detect conductive inclusions such as intermetallic particles and fails to provide information on the chemistry, shape, or physical state of the inclusions. There are also difficulties in finding appropriate nonconductive materials for sampling tubes that are nonreactive with Mg alloys, and equipment cost is high as well[8].

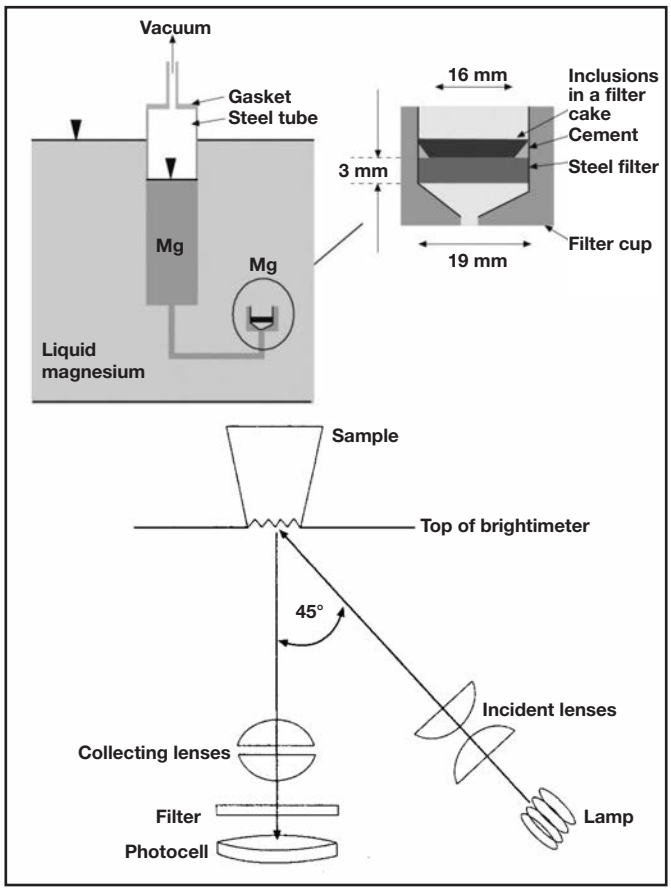

Fig. 2 — *Schematic of the HMIAM[13] (top) and light reflectance method[11] (bottom).*

Fig. 3 — *Schematic of the liquid metal cleanliness analyzer (LiMCA) technique[14].*

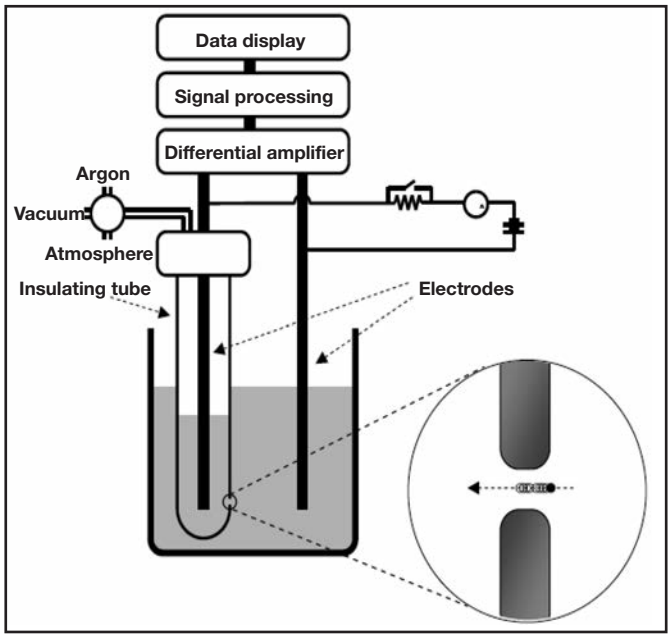

TABLE 2 — SUMMARY OF METHODS TO REMOVE INCLUSIONS IN Mg ALLOYS

Process	Description	Advantages	Disadvantages
Flux refining	$MgCl_2$, KCl, NaCl and CaF_2 based[1] Flux absorbs oxides to produce a sludge that settles to the bottom of the crucible	Simple and cost effective	Flux may become entrapped in melt Flux compositions must be tailored to alloy being melted
Protective atmosphere (SF_6)	SF_6 forms a dense film of MgO and MgF_2[15]	Very effective even at 0.1-0.2 vol.%	Potent greenhouse gas
Filtration	Ceramic foam and steel mesh types Placed in mold cavity	Can entrap MgO bifilms[9], particles and some Al-Mn-Fe intermetallics[16]	Must be incorporated into mold/casting design
Inert gas bubbling	Ar or CO_2 gas is used to float inclusions to the melt surface for skimming Efficiency depends on bubbling time, gas flowrate, bubble size and melt temperature	Can be combined with filtration Low purity gases or moisture can introduce more inclusions	Large inclusions cannot be removed Can introduce porosity Optimization of parameters required
Degassing	Cl_2 gas or C_2Cl_6 Formation of $MgCl_2$ (flux)	Very effective	Releases toxic chlorinated hydrocarbons[17]

Inclusion removal

In addition to assessing the amount of inclusions in Mg alloys, it is necessary to adapt suitable procedures and techniques to remove them. Table 2 summarizes some simple techniques to remove inclusions from Mg alloys.

Historically, Mg melts were protected during melting and casting using fluxes such as $MgCl_2$, KCl, and CaF_2[1]. While adequate at protecting Mg melts from oxidation, fluxes can be entrapped in the melt during transfer and casting and become inclusions. Since the 1970s, the Mg industry has largely used sulfur hexafluoride (SF_6) to protect Mg melts[15]. SF_6 modifies the magnesium oxide film that forms naturally on the surface of the melt, thereby suppressing vaporization. This compound is also attractive as a cover gas because it is odorless, colorless, nontoxic, nonflammable, and noncorrosive. However, SF_6 is becoming increasingly expensive and is also an extremely powerful greenhouse gas, with a 100-year global warming potential (GWP), estimated at 23,900 times that of CO_2[18]. Nonreactive gases, such as nitrogen and argon, prevent burning. However, use of such gases is impractical outside of the laboratory because they do not suppress Mg vaporization, which can result in melt loss.

Even with adequate protection, high melt turbulence increases the probability of entraining gases or oxide films during mold filling, introducing more inclusions into the casting. Incorporating filters into the casting process helps reduce melt turbulence by regulating metal flow. Filters for Mg alloys have typically been composed of ceramic (Al_2O_3, SiO_2, ZrO_2, MgO, or a combination of these oxides) in a foam-like structure with several open cells or as a steel mesh. However, ceramic filters have controversial efficiency because they may also react with the Mg melt. Tardif, et al.[16] examined the use of knitted steel mesh filters to remove melt inclusions in permanent molds. Two- and four-ply filter configurations entrap mostly MgO and some Al-Mn-Fe intermetallic particles. Griffiths and Lai[9] observed that ceramic filters in combination with a well designed gating system could reduce double oxide film defects. Filtration is a simple and effective method for removing inclusions in Mg melts, but more research is needed to optimize performance and understand the best methods to incorporate filters with the gating system.

Filtration can be combined with inert gas bubbling to further improve inclusion removal. Inert gas bubbling uses Ar or CO_2 to float melt inclusions to the melt surface where they can be skimmed away. The efficiency of gas bubbling to remove inclusions depends on bubbling time, gas flow rate, bubble size, and melt temperature[19]. Typical usage of Ar gas bubbling for 6 kg of AZ91D involves a flow rate of 1.8 l/min at a melt temperature of 740°C for a bubbling time of 30 minutes[19]. The limited availability of quantitative results on gas bubbling efficiency has sparked the need to determine optimal processing variables (e.g., Ar flow rate, residence time, bubble diameter, melt temperature) to enable efficient melt refining. A steel mesh filter with Ar bubbling treatment was as effective as degassing to improve mechanical properties and did not release harmful hydrocarbons when added to the melt[20].

Melt degassing typically uses reactive chlorine (Cl_2) gas or hexachloroethane (C_2Cl_6) to reduce hydrogen gas content within melts. Both methods promote formation of $MgCl_2$, which can remove inclusions but may become an inclusion itself if it becomes entrapped in the melt. Adding C_2Cl_6 could reduce grain size in castings, but causes environmental problems due to chlorinated hydrocarbon emissions[17].

Effects of inclusions on Mg casting properties

The influence of inclusions on mechanical properties (strength and elongation), machinability, corrosion resistance, and fluidity is demonstrated in Fig. 4. The presence

of inclusions can reduce both the corrosion resistance and melt fluidity of castings because they promote galvanic coupling with the matrix—leading to pitting corrosion—and increase melt viscosity, making castings more difficult to form. The presence of nonmetallic inclusions also prematurely degrades cutting tools, resulting in reduced machinability of Mg alloys. Results show that in all cases, removing inclusions improves the properties of Mg alloys.

Summary and perspectives

Compared to Al alloys, limited information is available regarding Mg alloy refining. Inclusions present in molten Mg can be categorized into two major groups: Nonmetallic (mainly oxides and chlorides) and intermetallic (iron-rich phases). The majority of inclusion-related issues with Mg alloys appear to originate from molten Mg exposure to moisture or oxygen, which can occur during melting, melt transfer prior to pouring, and mold filling. A better understanding of the behavior of the magnesium oxide surface is required to improve Mg melt cleanliness.

Various techniques have been developed, ranging from simple methods such as metallographic analysis to highly advanced approaches such as LiMCA. Each has advantages and disadvantages, and considerations such as cost and type of inclusion detection limits must be recognized. None of the techniques developed to assess Mg alloy melt cleanliness is universally accepted, so there is still a need for an efficient and economical assessment method. A combination of approaches may be the best solution.

Several methods to control inclusions in Mg alloys such as fluxes, protective atmospheres, filtration, inert gas bubbling, and degassing are available. Filtration and inert gas bubbling can be used in combination with relative ease and at low cost to further improve inclusion removal efficiency in Mg alloys. Properties significantly improve when inclusions are removed.

Acknowledgements

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Tensile strength and elongation

Both average tensile strength and average elongation of AZ91D increased with filtration, Ar bubbling or Ar+filtration.

Refining treatment	UTS (MPa)	Elongation (%)
No treatment	153	2.3
Filtration (steel filter, 0.81 mm square, 0.38 mm thick)	167	3.1
Ar bubbling (flowrate: 1.7 L/min; bubbling time: 5 min)	188	3.3
Ar bubbling + filtration	198	4.9

Corrosion resitance

Increasing inclusion content increased the corrosion rate of Mg-10Gd-3Y-0.5Zr alloy.

Average volume fraction of inclusions (%)	Corrosion rate (mg/cm²d)
4.07	2.0
2.84	1.8
0.87	1.3

Fluidity

The fluidity of AZ91 decreased with increasing MgO content.

AZ91 alloy	MgO content (ppm)	Average fluidity length (mm)
1	35 ± 6	225
2	42 ± 12	220
3	75 ± 19	203
4	93 ± 24	192
5	125 ± 64	185
6	472 ± 345	172

Fig. 4 — *Effect of inclusions on the properties of Mg alloys*[2, 10, 20].

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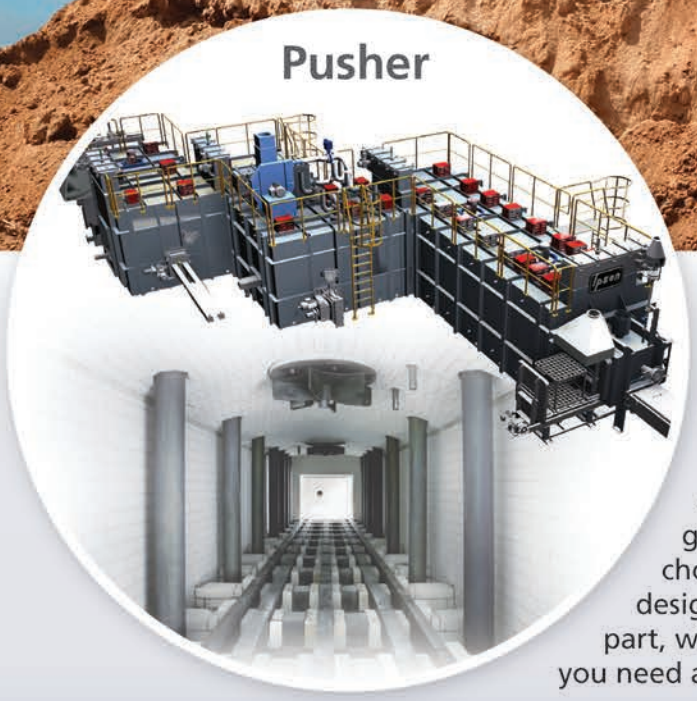

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Nondestructive Inspection of Resistance Spot Welds Using **Matrix Phased Array Ultrasonic Technology**

Jeong K. Na
EWI
Columbus, Ohio

Automobile performance and passenger safety both rely on sound welds. A new, high-frequency ultrasonic MPA probe performs nondestructive inspection of these welds, saving time and cost.

Advanced high-strength steels (AHSS) were introduced to the automotive industry to reduce vehicle weight and are gaining momentum due to initiatives that call for increased body rigidity (driving performance) and improved crash ratings and fuel efficiency. One major challenge these steels present involves the integrity of spot welds. There are roughly 4000-7000 resistance spot welds on every U.S.-made automobile and the reliability of the body structure and passenger safety both rely on sound welds.

The stress state at the weld, fracture toughness of the weldment, and presence of pores, cracks, and embrittled regions in AHSS are driving factors resulting in different failure modes compared to conventional steels—particularly interfacial type failures[1]. Traditional resistance spot weld (RSW) destructive test methods such as pry-bar or chisel check and peel tests are costly and inaccurate when applied to welds made from AHSS. The automotive industry therefore seeks nondestructive tests to ensure safe implementation of AHSS steels.

Some advanced nondestructive inspection (NDI) techniques that may provide solutions are already used in the aerospace and power generation industries. Unfortunately, transferring these techniques to the automotive industry is limited due to fundamental differences[2]. The goal is to reduce the time to validate and increase correlation methodology confidence with less engineering and laboratory time. To reduce the repeatability gap, improved robustness of NDI techniques and little or no dependence on operator skill is needed[2].

MPA probe meets the challenge

Computational modeling and simulations helped scientists develop a reliable, high-frequency matrix phased array (MPA) probe with an appropriate delay line and an optimal propagation distance for the ultrasonic beam to be focused on a spot weld. A commercially available CIVA modeling package was used to perform this modeling and simulation.

It was necessary to define parameters such as material thickness and spot weld diameter. Research revealed that the majority of spot weld applications are for materials in the thickness range of 0.7-2 mm having a nominal weld diameter of 5-7 mm. Initial beam modeling calculations helped determine general parameters for a probe capable of inspecting spot welds in the targeted range. Consideration was given to current MPA instrumentation capabilities, although many MPA instruments on the market today limit the number of elements to a maximum of 128. Figure 1 shows a schematic of a 100-element 2D MPA probe element with some probe parameters evaluated using the beam modeling tools. The same probe parameters apply to 3D probes with additions of curvature shape and radius.

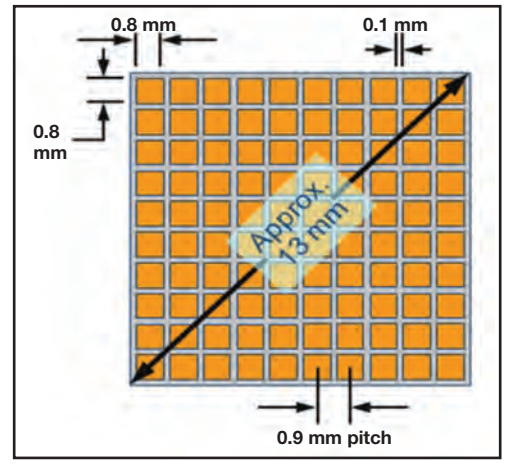

Fig. 1 — *Schematic of a 2D matrix phased array (MPA) probe element.*

To achieve good focus at a depth of 0.7-2 mm, the probe needs to have a physical delay distance between the element and part surface. The delay line tip was filled with water because it conforms to surface deformations caused by the welding electrodes. Modeling and simulation results show that a water path length of 18 mm produces a narrow beam with minimum side lobes through the interface of water and metal.

A handheld probe was designed and fabricated with an 18-mm-long water delay line cavity at the end. Subsequent modeling investigation for a 64-element probe with an 8×8 matrix configuration operating at a 12 MHz frequency proves the same water delay line could be used. In this case, the probe element was shaped to have a convex curvature with a 50-mm radius.

From simulation to reality: Portable NDI

The EWI SpotSight inspection system shown in Fig. 2 harnesses the power of MPA-based ultrasonic imaging technology to accurately evaluate the effectiveness of component joints by showing weld nugget images in real-

time with feedback. This new NDI system not only reduces the need for destructive testing of spot welds in manufacturing, but also assesses the structural integrity of products with great cost-savings and efficiency.

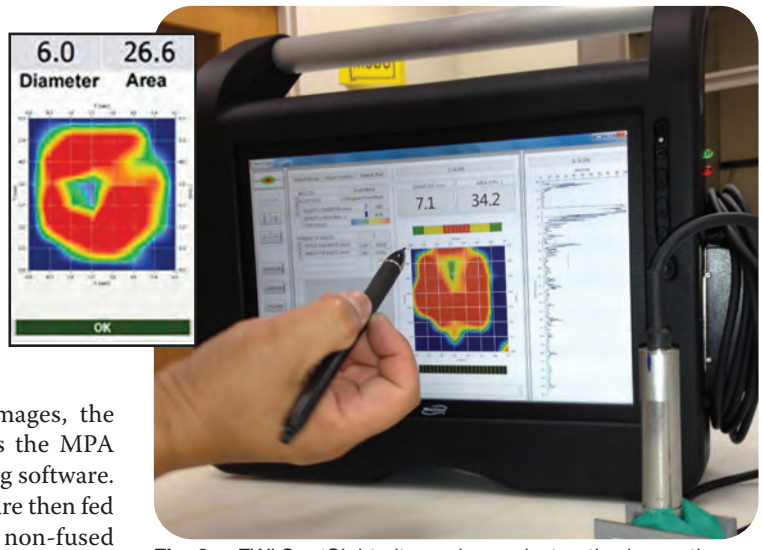

Fig. 2 — *EWI SpotSight ultrasonic nondestructive inspection system and C-scan image of a resistance spot weld nugget with porosity in the center section (inset).*

In order to generate 2D C-scan weld images, the phased array electronic circuit first activates the MPA probe with commands from the data processing software. Ultrasonic signals detected by the MPA probe are then fed into the imaging algorithm for the fused and non-fused joining areas being inspected. A color-coded ultrasonic C-scan image and additional data such as nugget diameter and fused area are displayed on the screen.

The system processes ultrasonic signals as they are detected by individual subgroups of the probe array using two electronic gates, one for the front surface reflection and the other for interface reflection. An ultrasonic image is plotted as raw ultrasonic data is processed in real-time with the dual gate imaging algorithm. Operator feedback occurs in a fraction of a second and probe adjustment is relatively fast and easy compared to other systems that require probe repositioning if results are unsatisfactory.

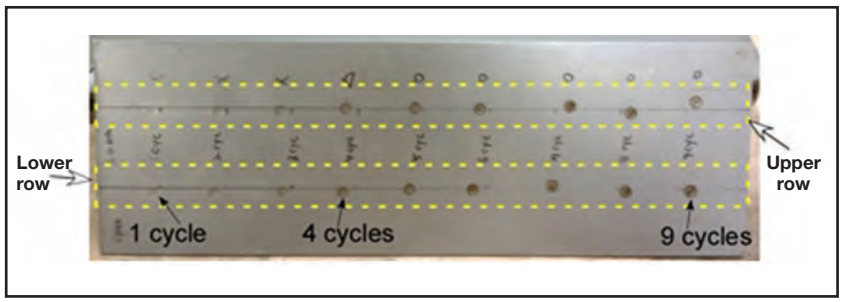

Fig. 3 — *Test sample with two rows of resistance spot welds.*

Test results

A set of resistance spot welds with two-sheet stackups and thicknesses at the lower limit of 0.7 mm were prepared. Two rows of nine spot welds each were placed on the test sample shown in Fig. 3. For this sample, a constant current of 6 kA was applied for all welds, while the number of cycles was varied from 1-9 at an increment of one cycle for each weld. Spot welds on the sample stack were tested using the SpotSight inspection system and results are shown in Fig. 3.

The number in the upper left corner of each image in Fig. 4 indicates how many electric current cycles were used to form weld nuggets. For both upper and lower rows, an acceptable spot size weld was measured after five cycles.

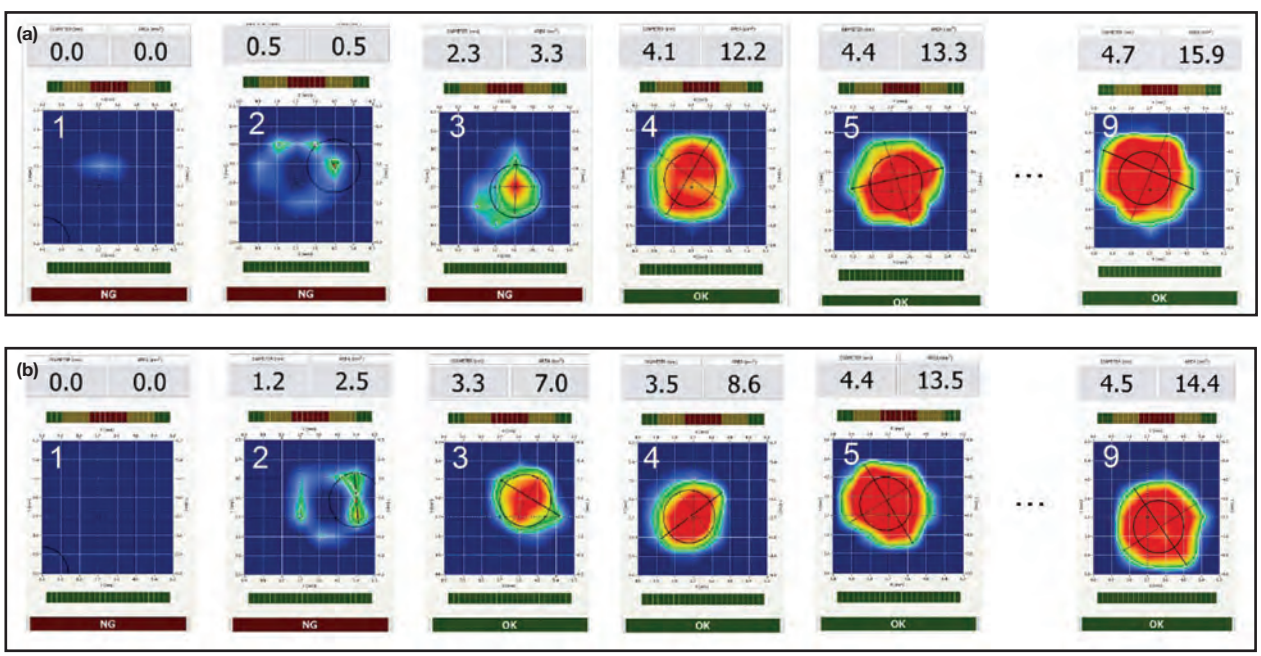

Fig. 4 — *Ultrasonic images of spot weld nuggets for the test sample plate shown in Fig. 3. Welds in the upper row (a), welds in the lower row (b).*

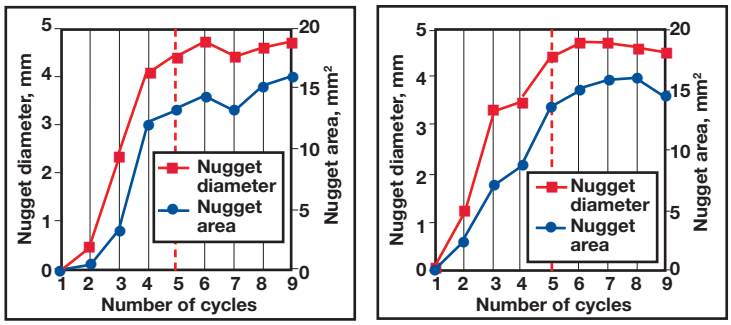

Fig. 5 — *Increase in nugget diameter and fused area as a function of number of cycles for each row. Data is based on ultrasonic image data shown in Fig. 4.*

The left and right numbers shown in the upper portion of each ultrasonic image indicate nondestructively estimated nugget diameter and area, respectively. Nugget size did not improve much after five cycles. For both rows, the overall increase in nugget size was less than 10% after five cycles.

Graphs in Fig. 5 were generated using the ultrasonic images in Fig. 4, showing improvements made to nugget diameter and fused area as the number of weld cycles increased. Diameter and area improvement start saturating once the number of cycles is higher than five at 6 KA of constant current.

Conclusions

A high-frequency ultrasonic MPA probe designed to perform nondestructive inspection of resistance spot welds on automotive chassis was developed and tested. Based on modeling and simulation results, a water delay line with a length of 18 mm produced the best penetration of ultrasonic signals at the water and metal interface, as well as throughout the metal interface where resistance spot weld nuggets form. An innovative electronic dual-gate imaging process discriminates fused and unfused sections of the weld and displays results in a color-coded C-scan format for easy interpretation. Average nugget diameter and fused area data are also displayed in real-time to provide realistic operator feedback.

NDI results of spot welds made on two 0.7-mm metal sheets with different cycle numbers at a constant electrical current level show that a good weld nugget with an acceptable diameter and fused area could be formed after four or five cycles. The number of cycles currently used on automotive chassis may be reduced to save time and cost without over-welding with additional cycles.

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Laser Beam Texturing
for Automotive Metal Forming Applications

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An alternative to traditional surface texturing processes is laser beam texturing, which offers various advantages over other commonly used methods.

In the majority of metal drawing and forming operations, a surface texture is applied to the metal to aid forming. This surface texturing, which is typically imparted as a matte finish, primarily improves the metal's drawability by creating depressions in the surface and increasing the lubrication carrying capacity. Additionally, these types of textured finishes can promote paint adhesion or enhance the appearance of components.

In North America, most textured or matte finishes are developed through either mechanical means (shot-blasting, grit-blasting, grinding) or electro-discharge texturing (EDT) of mill rolls that then impart the developed finish onto the metal surface during the final rolling operation. Asia and Europe additionally use laser beam texturing (LBT) or electron beam texturing (EBT) systems to induce a matte finish on mill rolls. The finish that these systems provide offers advantages over more traditional methods. LBT materials and how they differ from those produced using traditional surface texturing techniques will be discussed in this article.

Importance of matte/surface finishes

Lubrication is a critical factor in forming and drawing flat rolled steels. Oil (the typical lubricant) is applied to the surface to reduce friction during forming and drawing. The surface topography of steel impacts the lubricant's effectiveness during forming. The matte or textured surface finish should be consistent in surface characteristics across the width as well as along the length to be effective. It should allow for even and consistent contact pressure over the entire part, enhancing metal flow during forming and preventing localized strains that could lead to failure.

Maintaining consistent lubrication greatly reduces potential problems during forming and drawing. Issues include:

- Die damage: Excessive die wear and/or galling occurs due to localized strains, increasing die maintenance costs.
- Product loss: Galling and damage to parts can reduce yields and increase inspection costs.
- Production delays: Extra time is needed to service prematurely worn dies and to make up for scrapped parts.

Advantages of laser-beam-textured finishes

In order to adequately compare surface characteristics of various types of finishes, it is necessary to look beyond traditional profilometer traces. While this information indicates surface roughness and other parameters, each test is a single trace across the surface. 3D imaging, available through light interference technology, allows for more refined analysis over a much larger surface area, providing a more accurate picture of the material's topography. This technology plays a key role in quantifying the notable differences in the various types of matte finishes detailed in this article.

One common method, shot/grit-blasting, propels abrasive media at the roll surface at high speeds, which upsets the surface and produces a roughened texture or matte finish. This method produces a somewhat nonuniform and variable finish. Figure 1 shows the 3D surface of steel produced from blasted finish mill rolls as compared to the steel surface in Fig. 2, produced by EDT-processed mill rolls. EDT involves applying a pulsed electric field between

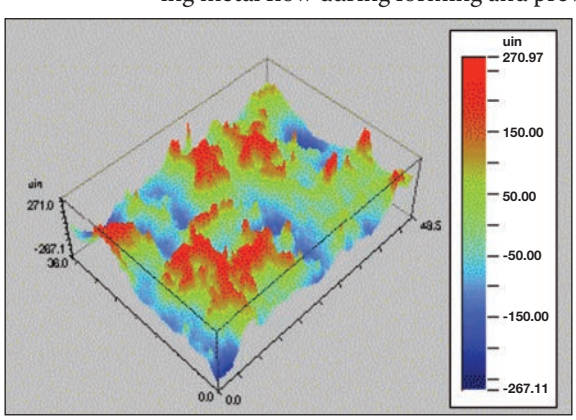


Fig. 1 – *Blasted surface finish in 3D.*

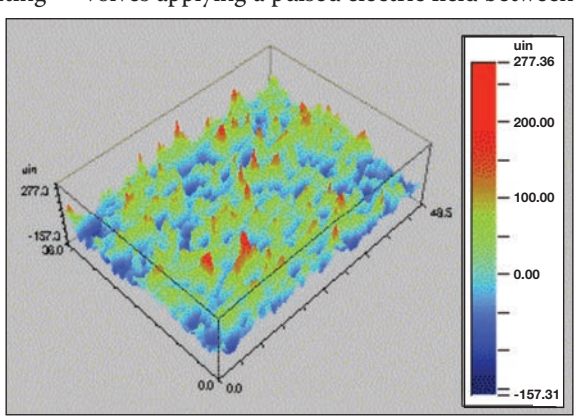


Fig. 2 – *Electro-discharge textured surface in 3D.*

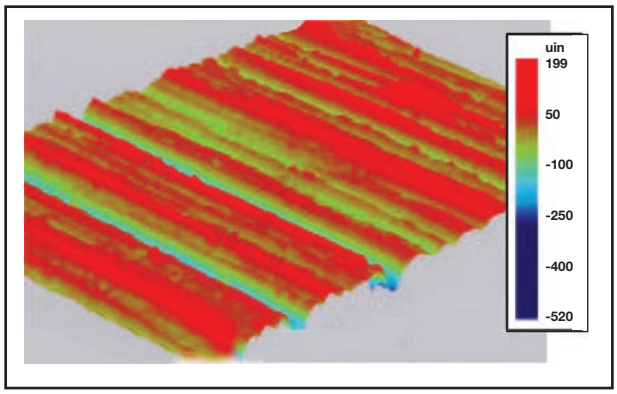


Fig. 3 – *Ground roll surface finish in 3D.*

a tool electrode and work roll, which results in tiny, random sharp craters in the surface. In the 3D images, red indicates height and blue indicates depth.

As the 3D images show, the blasted surface exhibits greater variability than the EDT steel surface, though both show pronounced peaks on the material's surface. These pinpoint peaks are prone to breaking and/or deforming during forming and drawing and can lead to galling, premature tool wear, and die lube contamination. The EDT surface is generally the more consistent type of these two traditional matte finishes.

Grinding wheels or abrasive media can be used to achieve a ground finish to enhance retention of die lube. While this method increases surface roughness, surface properties are unidirectional and exhibit notable differences in the longitudinal and transverse directions, making it unacceptable for most drawing applications. Figure 3 shows the general appearance of steel rolled with ground rolls.

When analyzing peak formations on material surfaces, the "skewness" of the surface should be measured to compare the relationship of peaks and valleys on the steel surface. If a surface is skewed toward the positive side, there is more peak than valley and vice versa. Figure 4 shows a profilometer trace of both of these surfaces, as well as a neutral surface with equal peak/valley distribution.

An LBT generated surface inherently exhibits a negative skew, while those produced with traditional finish methods tend to exhibit a positive skew. This difference in surface topography is shown in Fig. 5. Figure 6 shows an enhanced, higher magnification view of the LBT surface, further demonstrating both the lack of pinpoint peaks (undesirable in the forming and/or drawing process) and the large surface bearing area provided by this type of finish.

In addition to the negative skew imparted to materials processed with LBT rolls, the technology achieves a deterministic finish verses the stochastic or "random in nature" surface that is imparted by traditional matte finishes, enabling greater consistency and predictability during forming.

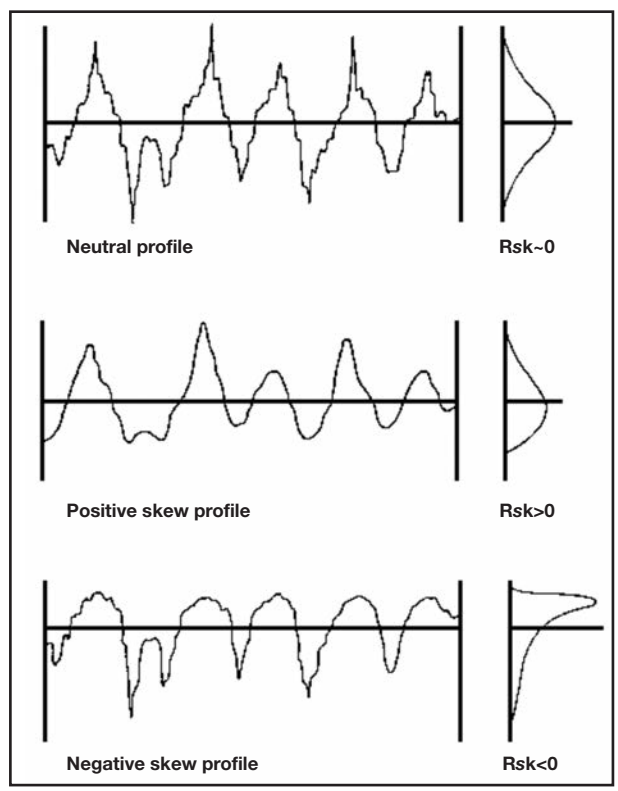


Fig. 4 – *Surface texture skew is extremely important.*

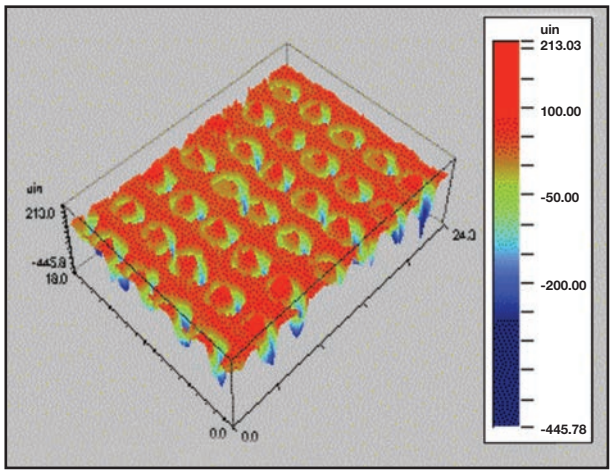


Fig. 5 – *Laser textured surface in 3D.*

Laser finish details

State-of-the-art laser texturing, such as that developed in Japan and now being produced as LaserMatte by Greer Steel in North America, creates a uniform matte finish on the work rolls by consistently imparting microcraters in the surface of the steel. These microcraters produce a relatively large, negative skew (Rsk) material at typical Ra levels of 25 to 50 µin. (Figs. 5 and 6), compared with the positive skew pattern evident in the other matte finishes. 3D imaging is used to perfect surface finishes, which provides a microscopic lubrication distribution system on the metal surface that continually feeds lubricant into the die during forming.

A 2.8-kW CO_2 laser precisely creates microcraters by using a microscopic beam of light energy that is interrupted by an aluminum chopper wheel. Highly precise teeth chop the beam into pulses. Each segment of light strikes the surface of the roll as it turns on a lathe, creating localized melting on the alloy surface. A blast of assist gas displaces the molten metal, forming a surface feature similar to a volcanic crater. Uniformity and consistency are achieved by repeating this process 40,000 times per second in a helical pattern as the laser moves slowly along a track parallel to the turning roll. Millions of small craters are precisely placed on the roll surface, with their pitch and size controlled by a multi-axis regulator.

Laser texturing creates a highly uniform, precise metal surface topography that cannot be produced by conventional methods. The predictable and repeatable surface brings numerous benefits to metal formers that extend far beyond improved lubricant-holding capabilities. Benefits of using laser-textured materials include:

- Reduced friction and galling, resulting in improved part quality
- Longer tool and die life
- Improved process yield
- Avoidance of costly tool and die coatings
- Increased productivity due to reduced press downtime
- Improved metal flow in the die, as strains that cause breakage are prevented, thus allowing the metal to achieve its forming potential

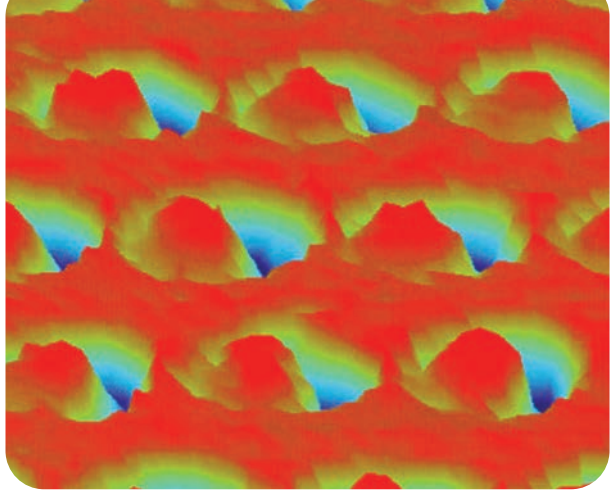


Fig. 6 – *Laser surface at high magnification in 3D.*

- Lower energy costs achieved through greater process and production efficiencies

Surface finishes affect metal formability, lubrication retention, surface contact area, paint adherence, appearance, and surface bonding area in metal forming. They also affect functionality and wear rates between mating surfaces in end-use applications. Achieving an optimum matte surface is a challenge, but laser texturing technology is providing metal formers with a reliable, cost-effective process that results in both immediate and long-term benefits.

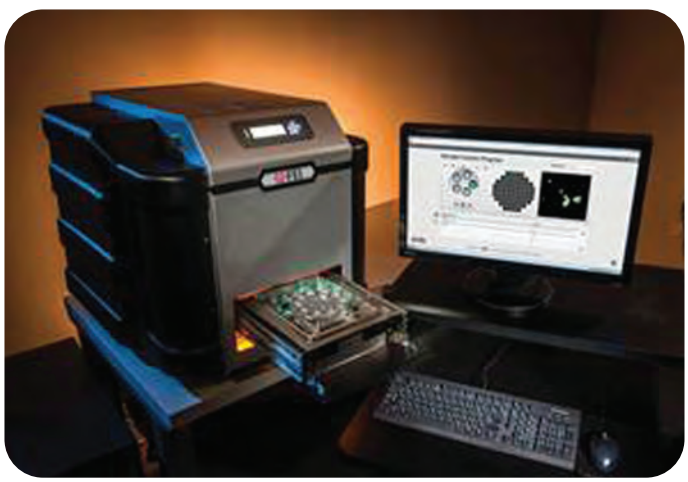
For more information: Todd Daenzer is chief operations and quality officer at Greer Steel Co., 624 Boulevard St., Dover, OH 44622, 330/343-8811, www.greersteel.com.

Faster, Automatic Identification of **Particle Contamination**

Industries such as automotive, electronics, and medical devices are particularly sensitive to the performance of precision-manufactured parts. When parts fail, sometimes due to particulate contamination that occurs in the manufacturing process, incomplete coatings or engine damage can occur.

The ability to identify particle contaminants and their origins can be an advantage in manufacturing operations. In automobile production, for example, contaminants range from metal shavings to abrasive residues to small fibers. As engine tolerances tighten, particles that impact performance have gotten smaller. Residue can remain throughout the manufacturing process, causing issues when engines are finally tested.

Traditional methods of monitoring surface cleanliness such as gravimetric analysis can calculate contaminant total bulk weight, but do not produce individual particle data. As a result, components may pass gravimetric testing, yet fail to function due to individual "killer" particles that can cause issues. Some manufacturers see dangerous abrasive contaminants, such as aluminum oxide, that are just 2 µm, which are not detected via traditional gravimetric testing yet cause engines failure.



CleanCHK system with automated sample setup.

Screenshot of sample setup screen on CleanCHK.

Traditional methods

Many options for monitoring particles on automotive component surfaces are available. It is important to thoroughly understand the features and benefits of each approach.

Bulk/gravimetric testing — Bulk/gravimetric measurements have long been used to quantify foreign material presence by measuring filter weight before and after part flushing. The part or assembly is typically flushed and residue is collected on a pre-weighed filter. The loaded filter is dried and weighed, indicating the total mass of collected debris. This method only provides a gross or an undifferentiated measure of the amount of material present. The weight or volume of filtered materials sheds no light on particle size, shape, or composition, which is necessary to improve design or control processes.

Particle counters — Particle flow-counters disperse particles in fluid. Particles are then passed through a flow cell where they are detected by an optical or laser sensor. Such devices can accurately count thousands of particles per second, and often provide a graph of particle size distributions. However, most counters assume particles are perfectly round. As a result, particle counter manufacturers report out an equivalent diameter using various algorithms, making comparisons between particle size reports from different manufacturers difficult and/or inconclusive. Particle counters also may experience false positives, which typically result from air entrapment or water in the oil. While these units are useful for monitoring trends of established particle populations, they are less valuable for understanding unknown or changing particle populations (clear signs of changes in surface contamination on a part or component).

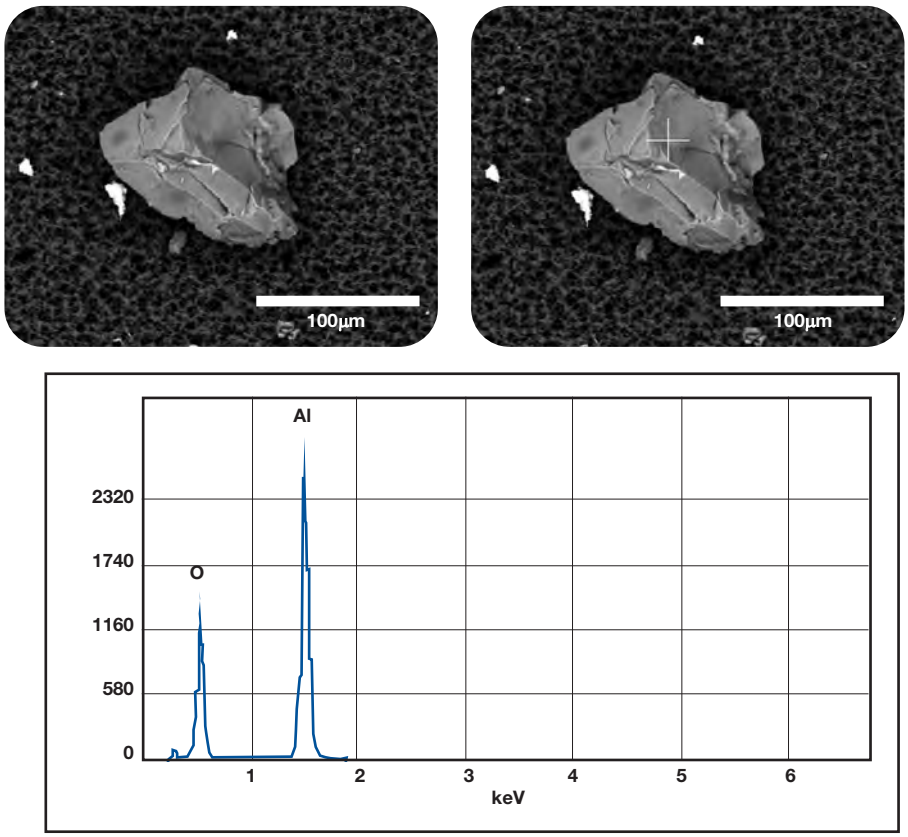
Optical microscopes — Individual particles are observed and their size is estimated. This manual particle sizing is simple to perform, but is tedious and time-consuming. In recent years, optical microscopes evolved to include cameras and motorized stages. By interfacing both to a computer, automating the particle detection/sizing process is possible. It is practical to routinely measure distributions consisting of thousands of particles and sort them by size and shape. However, the chemical composition of the particles remains unknown.

SEM image of a particle lodged inside a fuel injector.

Alternative method

Determining the elemental composition of these microscopic particles helps define the contaminant's origin and provides concrete information that allows manufacturers to conduct quality control analyses to improve production processes. When a product needs to be verified as suitably free of a specific kind or class of particulate contaminant, such as a toxic or abrasive material, other methods can waste time analyzing benign materials in the sample. Integrated microscopy allows for rapid search of large areas in a sample, targeting problem particles while disregarding empty space.

Scanning electron microscopy combined with energy-dispersive x-ray spectroscopy (SEM/EDX) provides efficient, accurate microanalysis that iden-



SEM image of aluminum oxide particle with corresponding EDS.

tifies size, shape, and chemical composition of particles. Traditionally, SEM/EDX required personnel to manage the instrument or interpret data. One alternative, the CleanCHK Analyzer from FEI, Hillsboro, Ore., requires little or no expertise to more effectively monitor particle cleanliness by identifying the source of even the smallest particle. The device monitors surface cleanliness by automatically detecting and counting particles, and analyzes their size, shape, and composition within minutes.

Designed for use on the production line floor, the system can identify particles as small as 0.5 µm so that the source of contaminants can be determined and problems can be fixed right away. The instrument allows automated sample setup, analysis, and instrument calibration and provides accurate information on particle size, shape, and chemistry. Classifications can be selected and automatically obtained based on the measured parameters.

Case study

As the automotive industry has become increasingly sensitive to part cleanliness, implementing integrated, automated, and rapid monitoring at the production level in plants helps improve part quality. One client maintains that its field failure rate (failure within the first 10,000 miles) decreased by 70% while using the CleanCHK Analyzer.

Engineers at the plant developed a study focused on understanding the levels and sources of contamination present in their manufacturing process. Within a fuel injection system, the tight tolerances between moving parts and the small dimensions of a new fuel injection nozzle led engineers to conclude that quantity, size, and shape were all critical factors in understanding their processes. A steel shaving was found to be considerably more detrimental to components than a dust particle of similar dimensions. Elemental composition of the particulate was determined to be a key factor in developing new cleanliness standards.

A cleanliness monitoring process was put in place using the CleanCHK analyzer. The system provides the means to measure performance against cleanliness standards. The process began by collecting samples using a 47-mm-diameter membrane filter with pore sizes between 0.3-20 µm. To ensure a representative sample was collected, cleaning fluid from each part was passed through the filter using vacuum filtration. Filters were then placed directly in the system using a 5-filter sample holder.

The CleanCHK reporter allowed easy management of produced data. Reporting was based on preset internal standards and presented in predetermined templates, which ensures reproducibility from user to user as well as filter to filter. Component specifications in this manufacturing plant are expressed today in the following format: Particles present should (1) have a value less then X mg/surface area, (2) no particle larger than X may be present, and (3) no more than X particles may be present with sizes between X µm and X µm. Compositional analysis for each particle was monitored based on size and shape in relation to a particular chemistry. Compositional information allowed for pinpointing issues even faster. This helps the manufacturer reduce field failure rates by 75%.

For more information: Susan Benes is Product Marketing Manager for FEI Co., 5350 NE Dawson Creek Dr., Hillsboro, OR 97124, 503/726-7500, susan.benes@fei.com, www.fei.com.

Metallurgy Lane

The Age of Steel: Part I

The second half of the 19th century set the stage for major U.S. industrial growth, and the Bessemer steelmaking process played a significant role.

Metallurgy Lane, authored by ASM life member **Charles R. Simcoe**, is a yearlong series dedicated to the early history of the U.S. metals and materials industries along with key milestones and developments.

In the latter half of the 19th century, the industrial world of wrought iron experienced a revolution: A process for making steel directly from blast furnace cast iron was being developed at two different locations. One was at a small iron mill in Kentucky owned by two brothers—William and John Kelly. As usual, the men soon encountered a fuel shortage after clearing all the timber near the plant for charcoal. With this in mind, William Kelly noticed that the cold air was not chilling the metal, but was reacting with it chemically to generate heat where the air blast impinged on the molten metal in the finery. Kelly immediately recognized the value of this reaction as a means of converting pig iron to wrought iron. Although this revelation occurred in 1847, he was delayed in building a converter until 1851.

The second location was in England where an engineer and inventor named Henry Bessemer—who had invented the artillery shell—was working on a way to replace the cast iron in cannons with steel. Bessemer's finances were much better than Kelly's, allowing him to pursue his ideas immediately.

Bessemer converter at Kelham Island Museum, Sheffield, England. Courtesy of Gunnar Larsson.

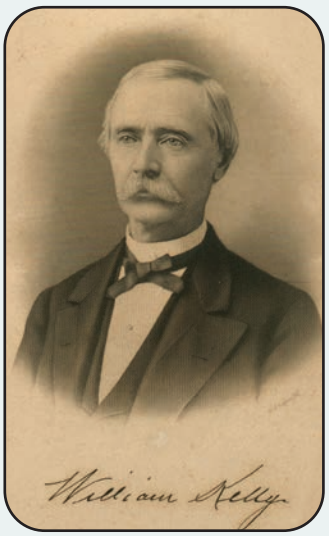
Kelly moved his experimental operations to the Cambria Iron Company in Johnstown, Pa., the company where Daniel Morrell and John Fritz were laboring to develop their three-high mill to roll wrought iron into rails. Kelly received his patent in 1857, just as a U.S. financial panic was taking hold, and went bankrupt along with thousands of other businessmen. He sold the controlling interest in his patent in 1861, and two years later a company was formed to produce steel by his process. This entity—the Kelly Pneumatic Process Company—was located in a pilot plant in Wyandotte, Mich., outside of Detroit. At this point, the operation developed the same quality problem that plagued Bessemer in England.

During Bessemer's experimental work, he had fortuitously used Swedish ore, which was low in impurities. Later, when his licensees were unable to control the carbon content and make steel that was not brittle, respected steelmaker Robert Mushet showed that manganese was a necessary ingredient to overcome the "hot shortness" caused by sulfur. He also determined that carbon content could only be controlled by blowing until it was completely removed, and then adding back the required amount. By this time, German iron and steelmakers had already developed a master alloy called "spiegeleisen" for adding carbon and manganese. Thus, Mushet was a major contributor to the success of the so called Bessemer process. However, the patent situation was now in gridlock with Bessemer and Kelly each holding a vital position in the process.

Bessemer process makes headway

During this period, America was in the throes of the terrible war between the industrial north and the agricultural, slaveholding south. Government agents as well as private individuals from both areas were combing Europe looking for armaments and other developments that would aid their cause. One such individual was a charismatic engineer and technical writer by the name of Alexander Lyman Holley.

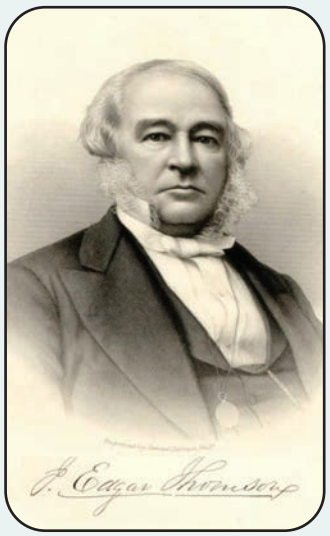
Holley was born in Connecticut in 1832. He graduated from Brown University in 1853 in the first engineering class and started working on railroad locomotives. On a trip to Europe to observe



William Kelly was an American metallurgist and inventor of a process for refining pig iron, a precursor of the Bessemer converter.

Henry Bessemer—of Bessemer process fame—was originally working on a way to replace the cast iron in cannons with steel.

The bust of Alexander Lyman Holley stands in Manhattan's Washington Square Park.



J. Edgar Thomson, president of the Pennsylvania Railroad.

the latest developments in ordnance and armor plate, he came into contact with the Bessemer steelmaking process. Bessemer had a pilot plant where he was very busy in this period showing off his process to interested parties. However, Holley realized that the patent situation needed to be resolved before the process could become commercialized in the U.S. He accomplished this task and built the first Bessemer steel plant in Troy, N.Y., in 1865.

In the meantime, the first successful steel made by this process in the U.S. was cast at the little plant in Wyandotte, Mich., at the Kelly Pneumatic Process Company. An ASM historical marker pays tribute to this event. Ingots from this heat were shipped to the North Chicago Rolling Mill Company where they were successfully rolled into the first steel rails made in America.

Patent release paves way for steel industry

The release of the patent deadlock cleared the way for the domestic steel industry and Holley was the chief promoter and designer. He either constructed or consulted on nearly all 15 Bessemer plants built by 1875. These included the very early plant of the Pennsylvania Steel Company near Harrisburg, with J. Edgar Thomson and Thomas Scott of the Pennsylvania Railroad Company as principals; the Cambria Steel Company where Kelly received support from Morrell to develop the process; the first plant in Pittsburgh built for Andrew Carnegie and named for his benefactor (J. Edgar Thomson, president of the Pennsylvania Railroad); plants at North Chicago and Joliet, Ill.; a plant for the Vulcan Works at St. Louis, Mo.; and plants for Bethlehem Steel and Scranton Steel in eastern Pa.

These early steel plants were small enterprises by later comparisons. Bessemer converters had reached only five tons by the early 1870s. Also, their supply of molten metal typically came from remelting cast iron in separate furnaces. At this stage in America's industrialization, mills simply were not equipped to handle large quantities of molten metal.

For his contribution to the development of the Kelly-Bessemer process, Alexander Holley has been called the "Father of American Steelmaking." He was elected president of the American Institute of Mining and Metallurgical Engineers as well as the American Society of Mechanical Engineers, and named vice president of the American Society of Civil Engineers. After his death from peritonitis at age 49 in 1882, these engineering societies commissioned a statue of Holley that remains standing in Manhattan's Washington Square Park. Engineers from all of the major technical societies attended the dedication, including members from France and Germany.

Future forward for U.S. steel

The U.S. was now positioned to experience an even brighter future for iron and steel. During the last 30 years of the 19th century, production would increase nearly tenfold for iron—from 1.7 million tons in 1870 to 14 million tons in 1900—and for steel, from 68,750 tons in 1870 to 10 million tons in 1900. Throughout the 1890s, the U.S. produced one-third of all the world's steel, and half of that went into railroad rails.

Bessemer steel gradually became the material of choice for rails and beams because it was stronger, harder, and far more wear resistant for rails than wrought iron. In the final analysis, however, it was the much lower costs for manufacturing Bessemer steel compared to wrought iron that tipped the scales in its favor. In the 1890s, with competition high among the mills, the price of steel for rails hit a low of $11 per ton. Low-cost steel was the force behind America's modern industrial growth, and the major force behind this growth was an immigrant Scotsman named Andrew Carnegie.

For more information:
Charles R. Simcoe can be reached at crsimcoe@yahoo.com. For more metallurgical history, visit www.metals-history.blogspot.com.

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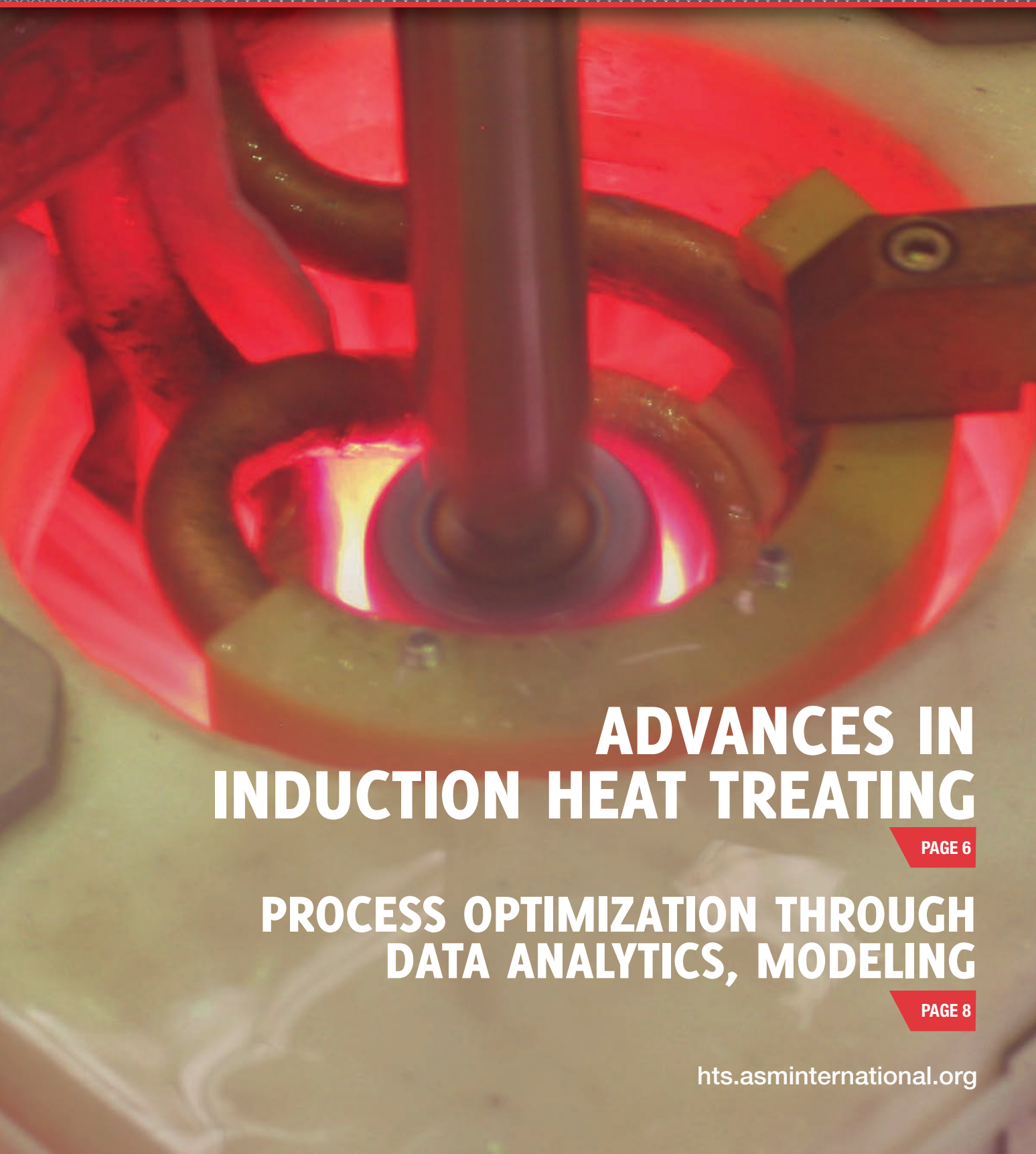

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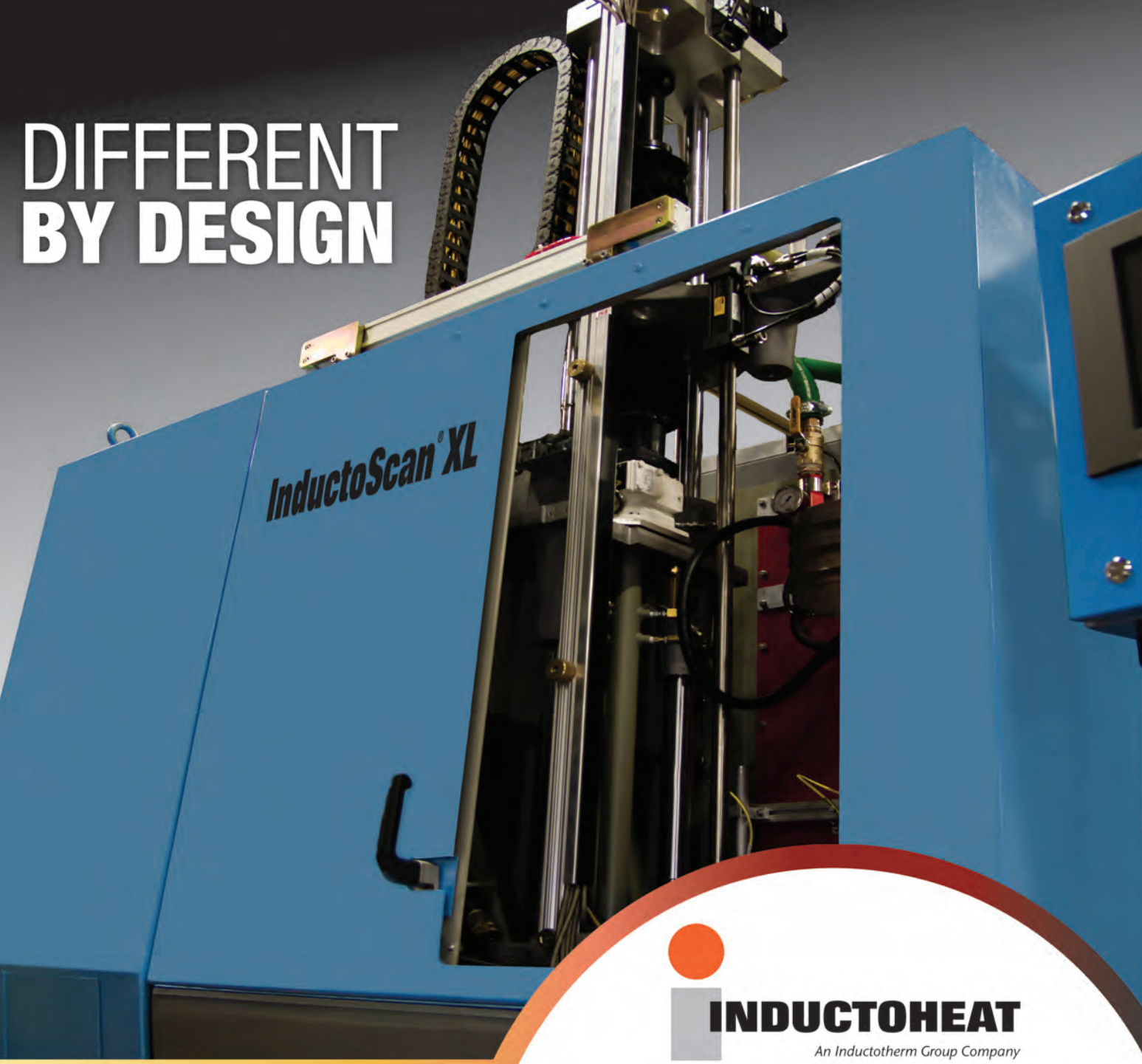
DIFFERENT BY DESIGN



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HTPRO
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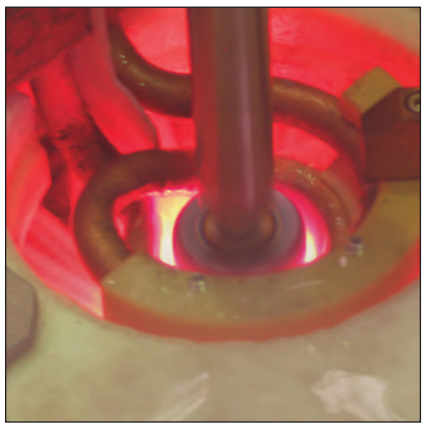
The editorial focus for *HTPro* in 2014 reflects some key technology areas wherein opportunities exist to lower manufacturing and processing costs, reduce energy consumption, and improve performance of heat treated components through continual research and development.

June	Process Control
September	Surface Engineering
November	Atmosphere/Vacuum Heat Treating

To contribute an article to one of these issues, please contact Frances Richards at frances.richards@asminternational.org. To advertise, please contact Erik Klingerman at erik.klingerman@asminternational.org.



ABOUT THE COVER:
Induction hardening of an axle. Courtesy of Ajax TOCCO Magnethermic, Madison Heights, Mich. www.ajaxtocco.com.

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We Need to Change the Perception of Heat Treating

Heat treating is an extremely important technology and is critical to help solve many engineering problems and meet industrial demands for improved materials performance. Traditionally, heat treating process development has advanced incrementally through empirical trial and error (experience-based progress), and even through serendipitous discoveries. Such advancements are very time consuming, highly inefficient, usually only marginally effective, and can be costly. In addition, it is unfortunate that manufacturers are decimating their internal experienced technologists and metallurgists; gone is the mentoring system to support the growth and capability of fresh new technical talent.

We must change this heat treating paradigm from experience-based technological *evolution* to a faster, more effective science-based technological *revolution* to meet ever increasing market demands. Traditional equilibrium and isothermal-based process systems are no longer adequate to meet desired more stringent part performance specifications.

Heat treating is a multivariant technology, and many dynamic reactions occur simultaneously, which defy simple analyses. We must drive development of science-based technology to even higher levels through the use of simulation-based engineering and science (SBES). Numerical outputs from models and simulation provide data on degrees of freedom, possibly characterizing alternative solutions. Simulation techniques lend themselves to direct animation that can provide additional detailed visualization of properties and high-speed process dynamics. We now have a far better understanding of deformation mechanisms and of the best use of optimum reaction pathways for maximum part strengthening. These smart tools provide the capability to produce tailored heat treat processes and designer-specific materials that provide product engineers even greater flexibility to handle the increasing market demand of "more for less."

How do we change the paradigm? I believe this involves two objectives:

(1) Change the design and manufacturing perception of heat treating from a burdensome and difficult part of the product manufacturing process to a clear understanding of the need for heat treatment from a technological standpoint—maybe even changing the term *heat treating* to *thermal engineering*.

(2) Foster a closer, more proactive working relationship between materials scientists and product and manufacturing engineers through better communication—creating a team approach to defining the optimum material for the application and the thermal process required to achieve required performance attributes.

The bottom line is that whatever it is called and no matter how it is perceived, we simply can't do without heat treating.

George D. Pfaffmann, FASM
Ajax-TOCCO Magnethermic Corp.

It's Not Too Early to Think About the 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-midcareer heat treating professional whose accomplishments exhibit exceptional achievements in the heat treating industry. The award was created in recognition of Surface Combustion's 100-year anniversary in 2015.

The award acknowledges an individual who sets the "highest standards" for HTS participation and inspires others around him/her to dedicate themselves to the advancement and promotion of vacuum and atmosphere heat treating technologies.

Rules for submitting nominations:

- Candidates must be a member and an active participant in ASM International and HTS.
- Nominees must be 40 years of age or younger and employed full time in the heat treating industry for a minimum of five years.
- Candidates must be submitted by an ASM International member.
- Three letters of recommendation must be submitted with the nomination form.
- Nominations should clearly state the nominee's impact on the industry and/or service and dedication to the future of the HTS.

The award shall be presented to one recipient every two years at the General Membership Meeting at the HTS Conference and Exposition. Recommendations must be submitted to ASM Headquarters no later than April 1 in the year in which the award is to be presented. The first award is to be presented in 2015. Winner receives a plaque and $4000 cash award funded by Surface Combustion.

A selection committee consisting of five members will be appointed every two years by the HTS Awards and Nominations Committee. Three members of the selection committee will be appointed by Surface Combustion. The selection committee will submit a report for approval by the HTS Awards and Nominations Committee and the HTS Board, which shall include the rationale and documentation used for award selection.

For rules and nomination form for the ASM HTS/Surface Combustion Emerging Leader Award, visit the Heat Treating Society Community website at http://hts.asminternational.org and click on Membership & Networking and HT Awards. For additional information, or to submit a nomination, contact Sarina Pastoric at 440/338-5151, ext. 5513, or email sarina.pastoric@asminternational.org.

Heat Treating Society Looking for Volunteers

Get Involved!
Serve on a Heat Treating Subcommittee!

The HTS Technical Programming Committee is seeking enthusiastic, committed members to serve on various technical subcommittees, which develop, promote, and execute programming for HTS events. The committee is currently looking for members in the following technical subcommittees: Applied Energy, Quenching and Cooling, Vacuum, Atmospheres, Research and Development, Cryogenics, and Brazing.

Interested members should review the Subcommittee Best Practices on the HTS website and contact natalie.nemec@asminternational.org.

5th International Conference on Thermal Process Modeling and Computer Simulation

ASM Heat Treating Society and International Federation for Heat Treating and Surface Engineering (IFHTSE) are co-sponsoring the 5th International Conference on Thermal Process Modeling and Computer Simulation (ICTPCS), which is colocated with the AeroMat 2014 Conference at the Gaylord Palms Resort & Convention Center in Orlando, Fla. ICTPCS was originated by IFTHSE.

The ICTPCS technical program consists of 64 presentations covering the broad field of thermal process modeling. Several papers deal strictly with computational issues of efficiency, accuracy, and solver methods. The majority of presentations involve modeling applications of various processes including:

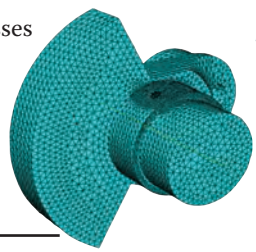
- Surface treatments such as carburizing, nitriding, thermal spraying, and cladding
- Immersion quenching processes in liquids that boil
- Gas quenching
- Phase transformations during heating and cooling
- Induction hardening and spray quenching
- Controlled cooling of castings and forgings
- Welding

Conference presenters comprise a distinguished mix of U.S. and international experts from academia and industry.

Keynote presentations include:

- Immersion quenching with transient boiling
  Dr. Sabine Denis of Université de Lorraine, Nancy, France
- Distortion, stresses, and defects in solidifying castings
  Prof. Christoph Beckermann of the University of Iowa, Iowa City
- Modeling of additive manufacturing processes
  Dr. Howard Kuhn of the University of Pittsburgh

Registrants to ICTPCS will have complete access to AeroMat technical sessions and the exposition.



TECHNICAL PROGRAM

	TRACK 1	TRACK 2
Monday, June 16, 2014		
8:00 – 10:00 a.m.	Distortion & Residual Stress I	Metal Processing I
BREAK		
10:30 a.m. – 12:00 p.m.	Phase Transformation I	Metal Processing II
LUNCH		
3:30 – 5:00 p.m.	Phase Transformation II	Carburizing
Tuesday, June 17, 2014		
8:00 – 10:00 a.m.	Distortion & Residual Stress II	Modeling Methods
BREAK		
10:30 a.m. – 12:00 p.m.	Phase Transformation III	Nitriding
LUNCH		
1:00 – 2:30 p.m.	Induction	
1:00 – 3:00 p.m.		Properties & Data
3:30 – 5:00 p.m.	Welding	
3:30 – 5:30 p.m.		Process Modeling
Wednesday, June 17, 2014		
8:00 – 10:00 a.m.	Quenching I	
BREAK		
10:30 a.m. – 12:00 p.m.	Quenching II	Coatings

For more information, to register, or to make housing arrangements, visit www.asminternational.org/htmodeling.

Demystifying Induction Tempering

The Center for Heat Treating Excellence (CHTE) at Worcester Polytechnic Institute (WPI) in Massachusetts is conducting a cutting-edge research project aimed at demonstrating the benefits and limitations of induction tempering versus furnace tempering. Results will enable manufacturers that use a tempering process for their products to choose the optimal technology required to reduce tempering cycle time and process costs while maintaining or improving product quality.

"This is the first time a project like this is being undertaken," says CHTE member Lesley Frame, manager of materials engineering and development at Thermatool Corp., East Haven, Conn. "Currently, widely available, detailed comparative data for induction and furnace tempering does not exist. The industry has been reliant on dated gas furnace-tempering data, which does not provide a sufficient guide for developing induction heat treating recipes."

CHTE member Lesley Frame, Thermatool Corp.

Tempering requires a balance between desired hardness and tensile strength, while increasing toughness and maintaining a uniform microstructure. Further, industry requires minimized residual stress and distortion in heat treated parts. Because stresses and distortion are affected by temperature changes, it is necessary to understand how internal stresses might develop during rapid-heating processes like induction tempering.

This study will provide CHTE members with information on the best recipe to maximize part performance. The expectation is that members will be able to apply the data to process designs to improve efficiency and productivity and eliminate trial-and-error experimentation.

Rick Sisson, WPI professor of mechanical engineering and director of CHTE, said the project will take the guesswork out of decision-making and help industry work more effectively. "For the first time, industry will have the answers it needs to determine when furnace tempering will best meet application needs and when induction tempering is the best process," explains Sisson.

Research objectives

One of the project's main goals is to compare induction and furnace tempering processes at a fundamental level in terms of the effects of power (kW), frequency (kHz), temperature, and time on the microstructure and hardness of quenched and tempered steel. In the study, 1 ft long by 0.5 in. diameter (300 by 13 mm) AISI 1045 carbon steel and AISI 4140 alloy steel rods are being tested. Steel microstructures will be characterized using optical and scanning electron microscopy, x-ray diffraction, and transmission electron microscopy.

Induction tempering offers an alternative to furnace tempering.

Microstructures, residual stress distribution, and mechanical properties (hardness, impact toughness, and torsional properties) of induction-tempered steel samples and furnace-tempered samples will be compared. Based on hardness test results, impact toughness and torsional fatigue behavior of selected samples will be determined and correlated with the microstructure.

Induction-tempering tests will be conducted at Thermatool Corp. and furnace tempering will take place at CHTE. Results are expected in late 2014.

About CHTE

The CHTE collaborative is an alliance between the industrial sector and university researchers to address short-term and long-term needs of the heat treating industry. Membership in CHTE is unique because members have a voice in selecting quality research projects that help them solve today's business challenges.

Member research process

Research projects are member driven. Each project has a focus group comprising members who provide an industrial perspective. Members submit and vote on proposed ideas, and three to four projects are funded yearly. Companies also have the option of funding a sole-sponsored proprietary project. In addition, members own royalty-free intellectual property rights to precompetitive research, and are trained on all research technology and software updates.

CHTE also periodically undertakes large-scale projects funded by the federal government or foundations. These endeavors keep members informed about leading edge technology.

CHTE current research portfolio

Other projects now in progress include:
Nondestructive testing, alloy life improvements, gas quench steel hardenability, and cold spray nanomaterials.

For more information about CHTE, its research projects, and member services, visit wpi.edu/+chte, call 508/831-5592, or email Rick Sisson at sisson@wpi.edu or Diran Apelian at dapelian@wpi.edu.

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- Proven Heat Processing Equipment Incorporating the Latest Product Enhancements.
- Contact BeaverMatic to find out more about how we can help your company succeed.

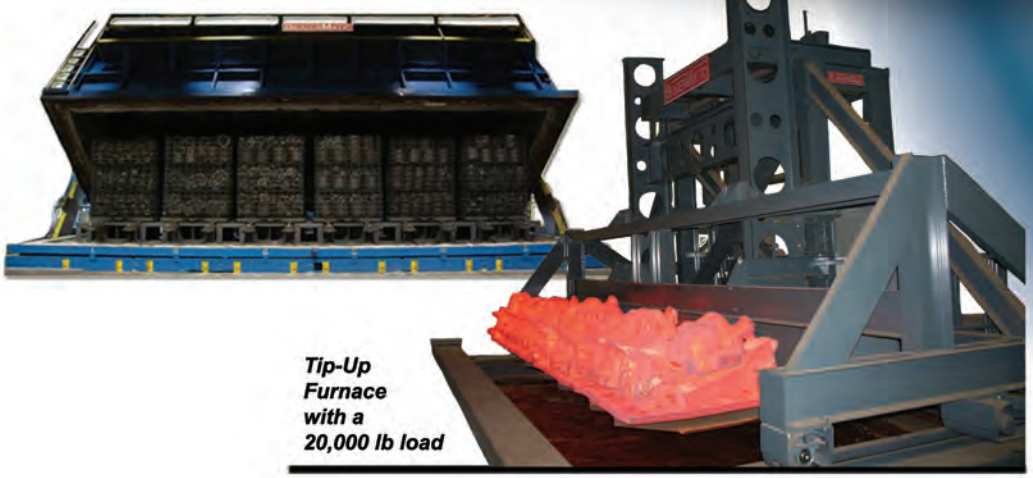
Get heat treating solutions through our simplified yet sophisticated furnace designs.

IQF Furnace

Temper Furnace

Washer

Carbottom Furnace



Tip-Up Furnace with a 20,000 lb load

Box Furnace

1715 Northrock Court | Rockford, IL 61103 | Tel: 815.963.0005 | Fax: 815.963.5673
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INDUCTION COUPLED HIGH MAGNETIC FIELD EXPANDS PROCESSING ENVELOPE FOR HEAT TREAT INNOVATIONS

TRADITIONAL HEAT TREATING PROCESSES HAVE REACHED A PLATEAU AND ARE NO LONGER GOOD ENOUGH.

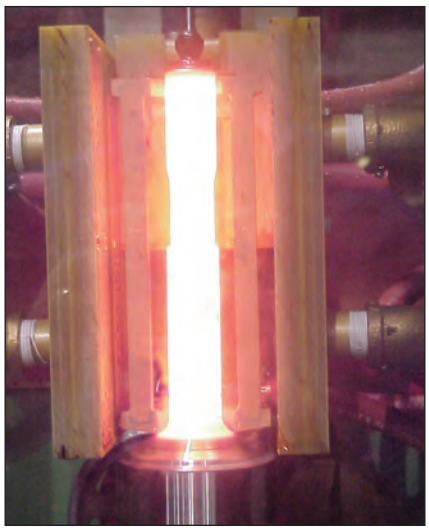
George Pfaffmann, FASM*, Ajax-TOCCO Magnethermic Corp., Madison Heights, Mich.
Aquil Ahmad*, Metallurgical Consultant, West Bloomfield, Mich.

Increasing demand from the durable goods market (e.g., automotive, agriculture, aerospace) for lighter weight, more efficient, and highly durable products requires a significant increase in material/component strength and performance capability. Traditional thermally activated processes used to improve materials strength and performance have evolved empirically and are largely isothermally based, equilibrium reactions. Using this approach, heat input, flow, and its redistribution are driven only by an applied elevated-temperature differential. Therefore, the desire to accelerate thermal transfer requires the application of higher surface temperatures and longer times, which can result in several undesirable effects and other process capability limitations.

Advanced induction thermal capabilities

Continual improvement of induction heating technology has increased the ability to selectively focus and provide a highly controlled internal thermal profile of a part, enabling optimization of specifically programmed, thermally driven metallurgical reactions for maximum strengthening results. Notably, the latest innovations in equipment versatility and FEA-modeled hardware tooling provide an unmatched, precise capability to accelerate processing speeds and produce novel metallurgical microstructurally enhanced strength (ultra-grain refinement approaching the nanoscale plus unique beneficial microstructure morphology) in a part.

Induction heating generates heat (with truly no limit on achievable temperature) within the part's subsurface. The depth of heat distribution can be programmed and dynamically profiled to produce desired metallurgical results, which are achieved by the efficient use of environmentally clean electrical energy. The part's internal heat profile can be optimized using a wide range of in-situ computerized process-control parameters. Therefore, processing can be customized to provide optimally driven reactions for improved part performance.



Induction heating a shaft.

Induction heating thermal dynamics are vastly different from those applied in traditional isothermal systems. In cases of short heating times (1 to 2 seconds or

Recognition of the need

A recent U.S. Army Solicitation for Innovative Research on High Magnetic Field Processing illustrates that there is a need for such disruptive technology. The document reads in part:

The Army is highly interested in the application of electromagnetic fields for development of ultralightweight metals with tailored microstructures and properties. The current methods used to manipulate metal properties involve varying scale, composition, temperature, and pressure to improve strength, hardness, facture toughness, elastic modulus, density, etc., but the use of these traditional techniques for tailoring a wide range of chemical and physical properties is reaching a plateau. It is worth noting that significant ongoing research is being dedicated to reengineering and exploring the creation of materials at the nanoscale, which holds potential for future applications that inherently hinge on surmounting scalability, assembly, and producibility challenges. However, there is an emerging technology that goes beyond factors of scale, composition, temperature, and pressure, and holds great promise in facilitating the realization of transformal materials with the aid of externally applied fields. The application of fields may alter phase transformation pathways, create new microstructures, shift equilibrium favoring new metastable alloys, align phases, manipulate and shape nanoscale architectures, and produce materials with revolutionary structural and multifunctional properties otherwise unattainable by conventional processing and production methods. The application of electromagnetic fields offers the unique opportunity to direct the architecture of materials features across atomic, molecular, micro, meso, and continuum levels. These fields may either be used to induce a permanent material property improvement or to selectively activate enhanced time-dependent properties via dynamic stimulation.

*Member of ASM International

Fig. 1 — *ITHMF setup at ORNL consists of a commercial prototype 9-T, 8-in. diameter by 9-in. long uniform field strength superconducting magnet to conduct large-scale experiments.*

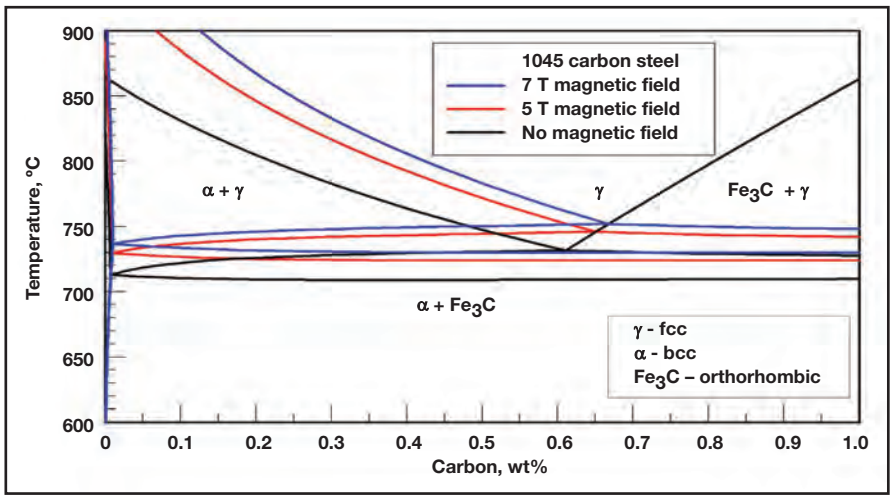


Fig. 2 — *The application of a high magnetic field on an AISI 1045 carbon steel shifts all phase equilibria.*

less) and complex dynamic thermal geometric profiles, these dynamics cannot be accurately recorded nor can they graphically display the part's internal thermal response and reactions. The dynamics inhibit a more complete understanding and evaluation of the multiple reaction issues involved, limiting the ability to establish an optimal process. However, because induction heating is electrically applied and fully electronically controlled, it can be mathematically modeled and objectively simulated (via "what if" studies). The resultant graphics display provides a detailed representation of the dynamic interactions involved to help better understand the process.

Challenges and limitations of understanding the process are fully addressed, and actual dynamics can simulated by using the latest induction computer modeling programs—including fully coupled, electromagnetic/thermal and FEA/FED modeling. This approach enables graphical display of complex thermal logistics and subsequent interreactive reactions to understand the process, make adjustments, and identify optimal reactions/process parameters/dynamics to improve part performance. Coupling material science and simulation process engineering provides an advanced understanding and review of viable alternative solutions.

High magnetic field processing (HMFP)

A new high magnetic field processing (HMFP) and thermomagnetic field processing (TMFP) facility at Oak Ridge National Laboratory, Tenn., includes an industrial-scale HMFP facility with an integrated induction heating and quenching capability for conducting industrial experiments (Fig 1). Coupling a high magnetic field environment with an applied induction elevated temperature capability offers an enabling disruptive technology. This approach enables achieving stronger, more durable components and materials with improved performance. Induction heating plus a high magnetic field processes parts much faster than thermal processing alone because the magnetic field alters the phase equilibrium diagram (Fig. 2). It shifts phase-transition temperatures, and phase solubilities increase with increasing temperature. Other benefits include:

- Accelerated phase transformations
- Enhanced nucleation and growth during phase transformation
- Smaller grain size
- Less segregation during solidification
- More homogeneous microstructure and properties
- Higher strength and plasticity
- Lower residual stresses
- Faster diffusion

Such a technology offers the means to make significant major science and technological advancements in developing the next generation of novel structural and functional materials for use in a broad range of transportation and military applications.

All materials are influenced by high magnetic fields, so all material systems from metallic through polymeric and protein will respond to an induction thermal high magnetic field (ITHMF) environment. Major improvements in performance (from 15 to 300%) can be manifested in mechanical and/or physical properties. For example, an ITHMF (9 T) processed Hy Tuf vacuum arc remelted high-strength, low-alloy steel (Latrobe Specialty Steels Co., Pa.) has an equivalent ultimate tensile strength and double the toughness of a more expensive conventionally processed 250 maraging steel grade.

Development of nanocrystalline and textured and/or novel microstructures and reaction paths is made easier and faster through the synthesis and catalytic chemical effect of the extreme ITHMF environment. In addition, the deformation behavior (magnetoplasticity) of materials appears to be influenced by high magnetic fields, potentially enabling high- and low-cycle fatigue damage mitigation (life extension), superplastic behavior at ambient temperature, residual stress relief, and other visionary applications. It might even be possible to make classically brittle materials formable under high magnetic fields. Therefore, the ITHMF environment has an impact on phase equilibria and kinetics and represents a new synthesis/catalysis paradigm and a deformation/life enhancement processing breakthrough technology. HTPRO

Acknowledgement: The authors thank Dr. Gerard Ludtka and Dr. Gail Ludtka, Oak Ridge National Laboratory, Tenn., for input from their research on this technology conducted at ORNL.

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ANALYTICS, MODELING, AND OPTIMIZATION OF INDUSTRIAL HEAT TREATING PROCESSES

MANUFACTURING DATA ARE PRIMARILY USED FOR PROCESS AUDITS AND TROUBLESHOOTING SPECIFIC BATCHES THAT HAVE QUALITY ISSUES, BUT COULD BE LEVERAGED TO GAIN INSIGHT FOR OVERALL PROCESS OPTIMIZATION AND CONTROL.

Satyam S. Sahay, FASM* and Goutam Mohapatra, John Deere Asia Technology Innovation Center, Pune, India
Robert Gaster*, John Deere Moline Technology Innovation Center, Ill.
Hema Guthy*, John Deere Coffeyville Works, Kan.

Modern industrial heat treating operations have sophisticated IT architectures, where significant amounts of data in GB/TB per year are generated including characteristics of input material (chemistry, prior material quality, charge dimensions, quantity, and configuration), process parameters (furnace temperature, carbon potential, and quenching oil-temperature variation with time) and product quality (hardness, microstructure, case depth, and distortion) are generated. These manufacturing data are primarily used for process audits and troubleshooting specific batches that have quality issues.

Much of this collected data goes unused. However, it could be significantly leveraged to generate process insight and optimize processes to improve manufacturing efficiency and product quality for an overall reduction in operational and energy costs. Figure 1 illustrates that this could be achieved in a closed loop, where the manufacturing data together with heat treating knowledge can be synthesized with physics and data-based modeling approaches to generate insight for process optimization and control. Actionable outcomes at different phases of the loop are also shown in the figure. For example, many surprises about process and product can emerge from process analysis and modeling, where the insight generated from this approach could directly impact product quality and design recommendations. This could enhance key process efficiency metrics—namely, operational and energy costs, productivity, and quality.

This approach is an expanded, generic view of a typical smart-manufacturing circle[1] comprising Data-Analyze-Model-Apply. Big data, data analytics, and data-based modeling approaches (neural network, principal component analysis, and other advanced statistical methods) are emerging as key areas to analyze manufacturing operations. Data-based approaches are effective to generate predictions within a current operating regime from which data are derived.

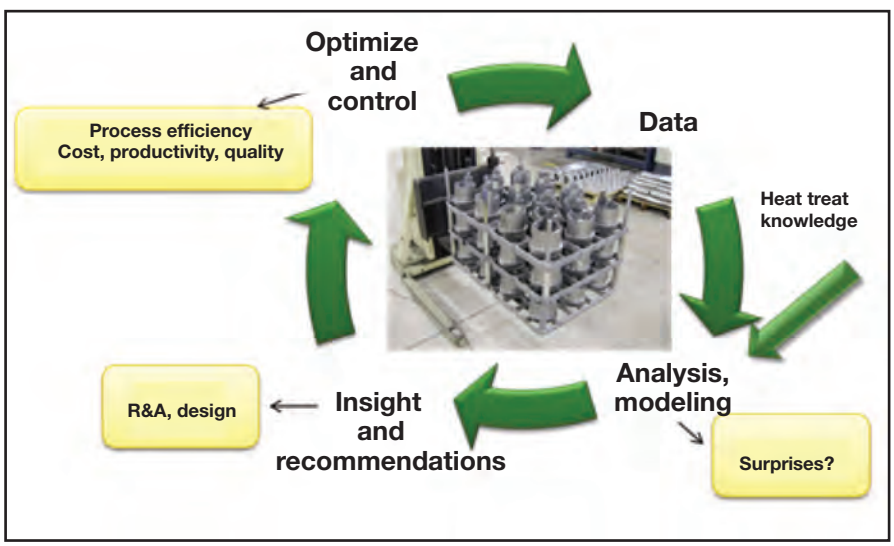

Fig. 1 — *Manufacturing data together with heat treating knowledge can be synthesized with physics and data-based modeling approaches in a closed loop to provide insight for improving process efficiency and product quality for overall reduction in operating and energy costs.*

*Member of ASM International

In contrast, physics-based models can also lead to an optimum operating condition, which is far removed from current conditions. Physics-based models for heat treating operations incorporate mass and energy conservation, laws of heat transfer, metallurgical thermodynamics, and chemical reactions and kinetics. Some important physics-based models with respect to carburizing include thermal models, diffusion kinetics, quenching models, residual stress, and distortion models. A judicious synthesis of these two approaches and modeling methodologies is far more effective than focusing on individual components of the process.

Case studies

Coil batch annealing. This generic approach was effectively demonstrated by the significant improvement in first-pass yield of an industrial batch annealing operation in a secondary cold-rolling mill[2]. The operation had many operating challenges including the need to process coils with high variability from different sources, pressure to maintain a low inventory level, and a lack of a process model that could customize cycle design for individual coil stacks. As a result, more than 50% of annealed coils failed to meet target quality requirements, resulting in product downgrade, or rework that added significant cost to meet product quality. The situation was expected to be-

come worse as more stringent quality specifications in mechanical properties (e.g., hardness variations across the coil) were anticipated.

Three recommendations were offered after examining the operation by combining results of process analytics with process model (phenomenological and neural-network) simulations: (1) classifying coils in a different manner for stacking in the furnace charge, (2) establishing new chemical composition specifications for coils to be annealed, and (3) creating new model-based process cycles (temperature and soaking time) for different coil classes. The integrated approach reduced overall rejection rates and downgrading rates for two major products by 44 and 60%, respectively, thereby enabling the desired tightening of quality specifications. The reduction in rework and downgrading also significantly reduced the plant's specific energy consumption. Achieved benefits were monitored and sustained for more than one year[2].

Automated coil batch annealing. In another study, an automated batch annealing operation in an integrated steel plant was analyzed and optimized[3]. The modern operation was equipped with a model-based control system, which simulated the process and derived optimized recipes before heat treating individual stacks of coils. In the study, process and quality data were analyzed and compared with physics-based models, which showed that the thermal model used in the control system was very conservative in estimating heat transfer across the coils. As a result, process cycle time did not vary with the thickness of the coil stack. In addition, the control system was only based on thermal differential across the

Fig. 2 — *Representative coil batch-annealing operation.*

coils, so nonisothermal effects arising from complex recipitation/recrystallization/grain growth mechanisms were not captured. Because of the nonisothermal effect, accelerated annealing kinetics with a reduction in heating rate was observed through physics-based modeling and laboratory kinetics experiments. An appropriate thermal conductivity model and nonisothermal models were used to create transfer functions for the process recipe derived from the control system to modify the resulting recipes. This approach was validated on an industrial scale, and overall productivity of the 1-million ton/year integrated steel plant was improved by 9%[3] together with a considerable reduction in specific energy cost.

Batch carburizing. In a recent study, a carburizing operation of a modern heat treating shop was analyzed, modeled, and optimized. The heat treating operation has 12 quench-sealed furnaces for heat treating transmission components such as gears and shafts. About 500 MB of data comprising charge characteristics (dimensions, number of parts, charge configuration, and weight), process parameters (furnace temperature-time and carbon potential-time records of various segments, and oil temperature-time) and quality (case depth, microstructure, hardness, and retained austenite) were extracted for the operation for a

Fig. 3 — *Representative carburizing operation with integral quench furnaces.*

one-year period. All data were recorded with different periodicity. For example, furnace process data were recorded every minute, whereas quality data were recorded per batch. Raw process data (time, temperature, and carbon potential) were transformed from a per minute basis into a per batch basis with the mean and standard deviations values. Subsequently, process data were merged with charge

and quality data for analysis. The reconciled and merged data were used for further analyses.

Some key analyses included:

- Checking inputs and quality against specifications
- Checking the consistency of various recipes
- Principal component analysis (PCA) to find key input variables that impact quality parameters
- Using neural networks to relate input variables with quality
- Using first principle models (including diffusion kinetics) for consistent validation and selection of recipes

The operation had very high emphasis on product quality, with every normal batch meeting the specified product quality. However, minor process parameter variations were observed, which were correlated to case-depth variation (within the quality specification). Results of detailed data analysis and the diffusion model indicated that recipes with overlapping specifications could be rationalized to reduce the number of required recipes. Furthermore, principal component analysis helped in segregating process parameters having less influence on quality data. This was used to build a robust mathematical model. An artificial neural network model was built based on key parameters, which could predict 98% of the case depth for any combinations of process parameters within an uncertainty of 20%, which was consistent with the plant data. In addition, process parameters were optimized using dif-

fusion kinetics and neural network modeling.

Major deployable outcomes included a new operating regime, new recipes, and a recipe selection methodology. The study projected a 12.5% productivity increase, together with ease of operation (lower number of recipes), specific energy consumption, and 90 MT per year of carbon footprint reduction, which is equivalent to 15 automobiles with an average of 12,000 miles/year at 26 mpg fuel efficiency.

These examples demonstrate the effectiveness of the approach and the value realized at the shop floor, which justify the efforts needed for executing such projects. Better use of this methodology requires standardization of data, models, and an analysis approach. Although most modern processes have transitioned to IT infrastructures where data is collected, data consolidation and standardization remains an issue. Modeling approaches have not matured into standard software products, such as in-design, finite element analysis (FEA), and computational fluid dynamics (CFD). Selecting the right approach, developing models, and analyzing results to generate deployable solutions requires a significant level of technical expertise with an understanding of first principles and mathematical modeling. The greatest limitation in this area is finding the technical talents with the necessary level of expertise.

Conclusion

A significant amount of data is generated from modern manufacturing operations, which can be effectively leveraged together with heat treating first principles understanding for analytics, modeling, and optimization of heat treating operations aimed at reducing specific energy consumption and improving productivity and product quality for an overall reduction in operating costs. The approach is proven with value realized on the shop floor, but it has not completely matured for standard deployment due to a lack of necessary technical expertise. HTPRO

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Keep the Heart of Your Vacuum Furnace System Healthy and Pumping

The heart of the vacuum furnace system is just as critical as the heart of the human body. Just as it is important to keep your heart healthy and pumping, it is crucial to keep your vacuum furnace system healthy and pumping. Get the best performance out of your vacuum furnace by selecting the most appropriate pumping system for your process and by following simple tips.

First, the basics …
Vacuum furnace systems utilize various types of pumping system combinations to evacuate atmospheric pressure from the vacuum chamber to required ranges for specific processes. Since the heart of the furnace is the vacuum system, it is essential to maintain the pumping system as specified in the operator's manual, taking into consideration any special accommodations that the type of process being conducted may require.

There are typically three subsystems included in each vacuum furnace pumping system: the roughing pump, the vacuum booster pump and the diffusion pump. These pumps are usually classified as mechanical and diffusion vapor pumps.

Mechanical pumps and blowers, often referred to as roughing pumps, are utilized during the initial pump-down phase of the vacuum furnace from atmospheric pressure to a predetermined pressure level.

A diffusion pump is utilized to achieve a lower system pressure than what is typically achieved by a mechanical pump and booster package alone. The diffusion pump cannot operate … visit **IpsenUSA.com/Pumping** to read the rest of this article and to learn more about ***maintaining your pumping system*** and a ***pump's worst enemy***.

Read the article at IpsenUSA.com/Pumping

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Richard Blackwell to Chair 2014 Nominating Committee

Members of the 2014 Nominating Committee have been selected and **Richard Blackwell, FASM,** business manager, Buehler Canada, Whitby, Ontario, was elected to serve as chair by the ASM Board of Trustees. Rick has been a member of ASM International since 1975 and is currently president of the International Metallographic Society (IMS), having served as director and in all officer positions since 2001. In addition, he has been a member of the Ontario Chapter since 1975, serving on the Executive Committee and holding all chapter positions since 1993. Rick became a Fellow of ASM in 2007, and has served on a number of selection committees as well as the ASM Nominating Committee in 2001.

ASM Officers Appoint Members

In accordance with the ASM International Constitution, ASM president **Prof. C. Ravi Ravindran, FASM;** vice president **Dr. Sunniva R. Collins, FASM;** and immediate past president **Dr. Gernant E. Maurer, FASM,** appointed nine members to the Nominating Committee from among candidates proposed by chapters, committees, councils, and ASM Affiliate Society boards. The committee is responsible for selecting a nominee for vice president-trustee (one-year term) and nominating three trustees (three-year terms). Members do not select a candidate for president of the society, because Article IV, Section 3, of the Constitution states that the office of president shall be filled for a period of one year by succession of the vice president. The 2014 Nominating Committee's nominee for vice president will serve as ASM's president in 2016.

Nominating Committee members for 2014 include:

Richard Berryman, lead engineer, Northrop Grumman Electronic Systems Div., Azusa, Calif. (nominated by Chapter Council); **Margaret Bush,** senior materials engineer, Medtronic, Minneapolis (nominated by the Minnesota Chapter); **Pradeep Goyal,** managing director, Pradeep Metals Limited, Mumbai, India (nominated by the India Council); **Aaron Hall,** principal member of Technical Staff, Sandia National Laboratories, Albuquerque, N.M. (nominated by the Thermal Spray Society); **William Loewenthal, FASM,** lab manager/engineer, Tensile Testing Metallurgical Laboratory, Cleveland (nominated by the Cleveland Chapter); **Manish Mehta**, director, Collaboration Programs, NCMS, Ann Arbor, Mich. (nominated by the Detroit Chapter); **Joseph Newkirk**, associate professor, Missouri University of Science and Technology, Rolla, Mo. (nominated by the Technical Books Committee); **Mark Robinson, FASM,** owner, MTL Technologies LLC, Reading, Pa. (nominated by the Lehigh Valley Chapter); and **Chirag Shah**, Engineering Services Manager, Exova Inc., Glendale Heights, Ill. (nominated by the Chicago Regional Chapter).

The Nominating Committee will meet on April 24-25 and its recommended slate of officers will be published in the June issue of *ASM News*.

ASM Board of Trustees

Nominations due March 15

It's time to nominate candidates for ASM vice president and trustee. Qualifications include: materials professionals with broad experience in ASM, business, and management; experience in ASM committee and ASM chapter work; managerial experience (budgets and policy making) is most desirable; is an individual or chapter sustaining ASM member; understands the duties and responsibilities required and is willing to serve if elected; understands ASM's strategy and objectives; has knowledge of the field of materials and information technology. Vice presidential nominees must have previously served on the ASM Board of Trustees. Contact Leslie Taylor at 440/338-5151 ext. 5500, or leslie.taylor@asminternational.org. Visit website for rules and nomination form at www.asminternational.org/about/governance/nominating-committee.

...in this issue

Submit news of ASM and its members, chapters, and affiliate societies to
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tel: 440/338-5151, ext. 5662 **fax:** 440/338-4634 **e-mail:** joanne.miller@asminternational.org

Contact ASM International at 9639 Kinsman Road, Materials Park, OH 44073 **tel:** 440/338-5151, ext. 0, or 800/336-5152, ext. 0
(toll free in U.S. and Canada) **fax:** 440/338-4634 **e-mail:** MemberServiceCenter@asminternational.org **website:** www.asminternational.org

Student News

Student Board Member Initiatives


Booth


Chester


Hickey

ASM Student Board Members Jessica Booth, Karly Chester, and Ray Hickey are excited to announce three student member initiatives. Launched in February, the **ASM Student Ambassadors Program** provides the chance to share the opportunities and benefits of ASM at your next MAdvantage Chapter Meeting and receive up to $50 to cover your meeting expenses. The program is open to the first 10 chapters who apply. ASM will provide these chapters with a short presentation outlining the opportunities and benefits of ASM membership. After the meeting, submit a photograph from your meeting, a description of your chapter's ASM interactions, and receipts for your expenses. One chapter will be selected for a feature in *ASM News*. The remaining nine chapters will be featured on the ASM Student web page. Apply for the ASM Student Ambassadors Program via the link on the Student page at www.asminternational.org/students3 and ASM will be in touch with the first 10 applicants. Act quickly because the link will be closed once the first 10 applicants have been received! For more information, contact leslie.taylor@asminternational.org.

The new **ASM website** is now available and Jessica, Karly, and Ray will be working to make the Student landing page more relevant by including polls and trivia via the Student Forum, as well as links to student discounts, programs, and other opportunities. ASM's Student Board Members look forward to your interest and feedback. Please submit suggestions, questions, or input via the Student Forum at **www.asminternational.org/students3.**

ASM Dome Day Competition is the most exciting initiative due to be released in May 2014. Dome Day is a student competition where student teams build small geodesic domes and compete in a number of categories. Competition scope, rules, and deadlines will be announced in the May issue of ASM News with deadline for submission in October 2014. The competition will be an annual event celebrating the completion of the geodesic dome at ASM headquarters in 1959.

Attention Students! ASM Student Paper Contest

ASM is encouraging students to submit papers to the ASM Student Paper Contest. The contest is designed to increase interest and awareness in materials science and engineering, and also provide recognition for outstanding student efforts in the field. The contest is open to all Material Advantage student members who are enrolled at a college or university offering courses in materials science and engineering. The winner will receive a cash prize of **$500**, plus up to **$500** toward travel expenses to attend MS&T'14. In addition, a full set of *ASM Handbooks* or an online subscription to the product will be presented to the school or student chapter of the winning entry.

A full description of the contest rules can be found at: www.asminternational.org/membership/awards. For more information, contact Christine Hoover at 800/336-5152 ext. 5509, 440/338-5151 ext. 5509, or christine.hoover@asminternational.org. The deadline for entering is **April 1, 2014.**

IMS Joins ASM, HTS and TSS In Seeking Student Board Member Applications

We're looking for Material Advantage student members to provide insights and ideas to the ASM, HTS, TSS, and IMS Boards!

We are pleased to announce the continuation and expansion of our successful Student Board Member Programs. In addition to ASM, HTS, and TSS, IMS also seeks Student Board Members. Each Society values the input and participation of students and is looking for their insights and ideas.

An opportunity like no other!

- All 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
- Gain leadership skills to enhance your career
- Add a unique experience to your resume
- Represent Material Advantage and speak on behalf of students
- Work with leading professionals in the field

ASM International
- Attend four Board meetings: June 16-18, 2014, October 12-15, 2014, March 2015, and June 2015
- Term begins June 2014

International Metallographic Society
- Participate in monthly teleconferences
- Attend one Board Meeting (August 2-6, 2015)
- Term begins August 2014

ASM Heat Treating Society
- Attend two Board meetings (October 2014 and Spring 2015)
- Participate in four teleconferences
- Term begins September 2014

ASM Thermal Spray Society
- Attend one Board meeting in October 2014
- Participate in two teleconferences
- Receive a one-year complimentary membership in Material Advantage

Apply at www.asminternational.org/students3.

To read about students who made news, see story on page 54 of this issue.

Canada Council Award Nominations due April 30

ASM's Canada Council is seeking nominations for its 2014 awards program. These prestigious awards include:

- **The G. MacDonald Young Award** – the ASM Canada Council established this award in 1988 to recognize distinguished and significant contributions by an ASM member in Canada. This award consists of a plaque in addition to a piece of Canadian native soapstone sculpture.
- **M. Brian Ives Lectureship** – This award was established in 1971 by the Canada Council of ASM to identify a distinguished lecturer who will present a technical talk at a regular monthly meeting of each of those Canada ASM Chapters who elect to participate. The winner receives a $1,000 honorarium and travels to each ASM Canada Chapter throughout the year to give their presentation at the expense of the ASM Canada Council.
- **John Convey Innovation Awards** – In 1977, the Canada Council created a new award to recognize sustaining members companies' contributions for further development of the materials engineering industry in Canada. The award considers a new product and/or service directed at the Canadian or international marketplace. Two awards are presented each year—one to a company with more than $5 million in sales.

Nomination forms and award rules can be found at www.asminternational.org/membership/awards.

Contact Christine Hoover at christine.hoover@asminternational.org or 440/338-5151 ext. 5509 for more information.

ASM Debuts Revamped Website

ASM International recently rolled out a major redesign of the organization's website, www.asminternational.org, aimed at enhancing the user experience by simplifying and streamlining the information and services available online.

"Member feedback is everything to us, so redesigning the website around their needs was the natural next step in ASM's evolution," says Thom Passek, Managing Director of ASM. "We celebrated our 100th year anniversary in 2013, so kicking off 2014 with an all-new website is a great start to the next century of this society."

The major updates, based on member and customer feedback, include:

- **Simplified Navigation** –Users can find content with less clicks by hovering over the "Mega Menu" main navigation tabs.
- **New Filtering** – It is now easier to pare down ASM's huge resource collection of content by Resource Type, Subject and Publication Date.
- **Easier Reading** – Enlarged text adds to a simplified look and feel.
- **Fast Checkout** – The new checkout process is designed after well-known internet commerce vendors.
- **Enhanced Rewards** – Members can now earn points for product purchases, which can be redeemed for free content.
- **More Connections** – Profile pictures can now be uploaded to the Member Directory, which can help with recognition at networking events.
- **Convenient Searching** – The new search function for the ASM store allows users to find content to solve materials problems quickly and easily.

Users are encouraged to send feedback to ASMWebsiteSupport@asminternational.org.

From the President's Desk

Vision 101—Moving into the Next Century

We recently celebrated ASM's first 100 years with a fabulous gala and mega-conference of five technical societies in Montréal. The celebrations continued at Materials Park. On December 5, 2013, I unveiled the 100th anniversary plaque and proposed a toast to ASM in the presence of VP Sunniva Collins, managing director Thom Passek, and the entire staff. It was a great time to rejoice, as it was 100 years earlier (October 4, 1913) that William Park Woodside envisioned the value of information sharing. His vision of knowledge exchange and professional advancement resulted in the Steel Treaters Club, which eventually became ASM. Today we have 83 chapters and approximately 30,000 members worldwide.

Now is the time to surge forward with optimism and confidence. Although we face challenges, we also see opportunities. We have a loyal membership, unique volunteers, dedicated staff, outstanding managers, a committed managing director, and a pragmatic board. I dedicated the anniversary plaque to our founding fathers William Park Woodside and William Hunt Eisenman as well as this outstanding team.

At the Dome, I shared my "Vision 101"—key priorities as ASM President—with specific items for immediate consideration. These include ideas related to membership and chapter development; ASM's position as a gateway and clearinghouse for materials information; e-courses for lifelong learning; participation of student board members in Materials Camps and professional chapters; and increased visibility for our sustaining members in the digital edition of *Advanced Materials & Processes.* With our Montréal meeting as inspiration, we can plan for future collaboration with affiliate and related societies, transgressing boundaries in materials science and engineering.

During my presidency, I am traveling extensively. I was delighted to visit the Chennai, India, Pune, and Bengaluru Chapters and the India Council in December 2013 and was encouraged by their dynamism. At the IISc, I visited the IIM team led by President Prof. Kamanio Chattopadhyay with significant progress on inter-society partnerships. I also visited the Los Angeles, Orange County, Chicago Regional, and Detroit chapters. In the near future, I look forward to seeing the Montréal, Notre Dame, Ontario, North Texas, Savannah River, and Hartford chapters.

As the most visible ambassador of our great society, I am doing my best to promote ASM.

C. (Ravi) Ravindran
c.ravindran5@gmail.com

Chapter News

India Hosts President Ravi

ASM President Ravi Ravindran, made a trip to his homeland, India, to connect with members there. He visited the India Chapter on December 27, 2013, and met the Core Committee members for extensive discussion. The occasion was also used to soft launch upcoming events, MET-2014 and the Chapter's Heat Treat Show 2014 to be held in December. The dinner meeting was well attended by the industry professionals and corporate directors who enjoyed this unique opportunity to interact with the Society's president.

From left to right: Prem Aurora (vice chairman, India National Council), Jayant Jamuar (chairman, India National Council); Pradeep Goyal (past trustee, ASM International), H.M. Mehta (founder chairman, India Chapter), Ravi Ravindran (president, ASM International), Ashok Tiwari (chairman, India Chapter), I.P. Wadhwa (director, Tafcon), Sandeep Parekh (secretary, India Chapter), Rajesh Shah (public relations, India Chapter).

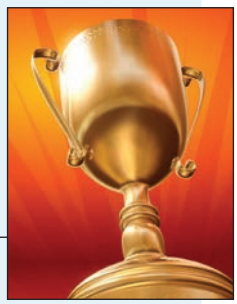
President Ravindran visited the leaders of the Bengaluru Chapter on December 28. Dignitaries included (left to right): B. Ashok, R.V. Krishnan, V. Babu Sathian (chapter vice chair), Ravi Ravindran, FASM, L.M. Kota, R.R. Bhat, and V. Ramachandran, FASM.

LA Chapter Explores Human-powered Vehicles

Mike Hahn (left), Los Angeles chapter secretary, congratulates Bill Gaines, records chairman and historian, of the International Human Powered Vehicle Association, who spoke at the January LA Chapter meeting about human-powered vehicles. His talk covered recent record achievements and the role played by materials.

Nominators... Get Your Deadlines Here!

Deadline	Award
March 15	• Bradley Stoughton Young Teachers Award • Engineering Materials Achievement Award (EMMA) • ASM-IIM Visiting Lectureship
April 1	• ASM Student Paper Contest



VOLUNTEERISM COMMITTEE

Profile of a Volunteer

Ken Davis
Special Effects Designer

It's all about materials—whether you're a rocket engineer or a special effects designer, like Ken Davis. "Whether I'm blowing something up or trying not to burn it down—it all involves materials," says Ken. He has creatively answered the question, "What do you do with a B.A. in English?" His career has ranged from electronics, designing and manufacturing custom test equipment, to working for an advanced materials company, DWA Aluminum Composites, and now designing special effects for major events and motion pictures at Artistry in Motion in Van Nuys, Calif.

Ken first joined ASM while working at DWA. "All employees were members, exhibited at ASM conferences, and encouraged to chair sessions and present papers," recalls Ken. "It was considered beneficial to the company, the employee, and ASM." Over the past 20 years, Ken has served many roles with the San Fernando Valley Chapter and began volunteering on national committees 10 years ago. "At the chapter level, it's a more personal experience, but on the national level you get a high altitude view of our common interests and issues," says Ken.

With his interest in making a personal impact on people's lives, Ken gravitates toward roles in membership and volunteerism. "There are so many opportunities to volunteer at the higher levels in ASM."

Ken appreciates staying current on the latest advances in materials through ASM, but "most important is the great network you never lose," he believes. Whatever his next step, Ken is confident he'll always have the professional and personal relationships he's built over the years in ASM.

Ken considers all ASM members to be "volunteers," with some choosing a higher level of involvement. "We're all part of this materials community. Look inside yourself and see what your interests are. Whatever your passion is, there's a way to engage it at ASM."

For a list of upcoming ASM Training Courses, see our ad on page 30 of this issue.

Members in the News

Anderson's Application to Practice Award

ASM trustee, Iver E. Anderson, FASM, senior metallurgist at the U.S. Department of Energy's Ames Laboratory and adjunct professor in the Materials Science and Engineering Department at Iowa State University, was chosen as a recipient of the 2014 Application to Practice Award by TMS, the Minerals, Metals and Materials Society. The award is given to a person who has demonstrated outstanding achievement in transferring research in metallurgy and materials into commercial production and practical use as a representative of an industrial, academic, governmental, or technical organization. Anderson accepted the award at the 2014 TMS-AIME awards ceremony held February 18 in San Diego. Anderson has a Ph.D. in metallurgical engineering from University of Wisconsin (1982); he has more than 170 publications and 36 patents.

NACE Honors Perdomo

Dr. Jorge J. Perdomo is a 2014 recipient of the 2014 NACE Technical Achievement Award. Perdomo, of the ExxonMobil Research and Engineering Company in Baytown, Texas, is recognized for his practical approach to solving corrosion-related problems of pressure equipment via failure analysis, materials selection, life assessment/prediction, and repair methods in the oil and gas, refining, petrochemical, and

IN MEMORIAM

Richard J. Coar, Life Member of Roanoke, Va., died on December 29 at age 92. An aerospace propulsion pioneer, he was instrumental in leading Pratt & Whitney into gas turbine engine design and development, and was involved with every major P&W engine program. Born in Hanover, N.H., Coar won a 4-year scholarship to Tufts University's engineering school, receiving a Bachelor's degree in mechanical engineering in 1942. He was a summer intern in the engineering department at Pratt & Whitney Aircraft, in East Hartford, Conn., later returning as a full time test engineer. In 1956 Coar became the chief engineer at the Florida Research and Development Center in West Palm Beach. In 1971 he returned to Connecticut as a vice president responsible for commercial and military engine development. In 1976 he became the executive vice president and in 1983 was named president of Pratt & Whitney. In 1984, Coar became the executive vice president of United Technologies, retiring in 1986. Coar was elected to the National Academy of Engineering, was a member of ASME, and became an ASM Distinguished Life Member in 1985. He received the Daniel Guggenheim Medal in 1998 and held more than a dozen patents.

Harold Mendell Cobb, 92, died at Crosslands in Kennett Square, Pa., on January 28. He was born February 3, 1921, in Dallas and raised in Philadelphia. He attended Philadelphia public schools, the William Penn Charter School, and graduated from Yale University with a degree in metallurgical engineering. Cobb worked in the metals industry for 22 years, followed by 18 years as a staff manager at the American Society for Testing & Materials (ASTM), in Philadelphia, from which he retired in 1983. He was a principal developer of the Unified Numbering System (UNS) for Metals and an expert on stainless steel and its history. He held a patent on an electron beam welding process for zirconium. In addition to being an ASM Life Member, he was a member of ASTM and the American Name Society. During retirement, he served for 10 years as secretary of an International Committee on the Standardization (ISO) of steel products and was the editor of 25 books on steel. Cobb considered his greatest achievement to be authorship of *The History of Stainless Steel* (ASM, 2010). His final publication with ASM was *Dictionary of Metals,* a book of metallurgical definitions and a historical overview of metals, published in 2012.

Lawrence "Larry" Kaufman, FASM, founder of the CALPHAD Community, passed away on December 2 in Israel. Kaufman received a Sc.D. in 1955 at the Massachusetts Institute of Technology (MIT) where his interest in phase equilibria was sparked by association with Mats Hillert and Morris Cohen. He joined ManLabs in 1958 as a research scientist, becoming vice president in 1973. His success in convincing the NSF to hold a session on the calculation of phase diagrams within a larger workshop on Phase Equilibria at Gaithersburg in 1975, led to the CALPHAD technique. CALPHAD Inc. was founded the same year. The acronym was also the title of a new journal published by Pergamon Press in 1977, with Kaufman as the editor-in-chief. He became an ASM fellow and president of ManLabs in1985 and was the recipient of the first Gibbs Triangle award instituted by the CALPHAD Community in 1986. Kaufman's pioneering work was also recognized when he became the inaugural recipient of the ASM J. Willard Gibbs Phase Equilibria Award in 2008.

Norbert F. Vinatieri, of Whittier, Calif., a Life Member, died January 7 at age 92. Born in South Dakota, he received a degree in metallurgical engineering from the South Dakota School of Mines and Technology in 1943. He was a lieutenant junior grade in the U.S. Navy and served in the Pacific. Vinatieri worked for several metallurgical companies in the Los Angeles area and was involved in assessing metal fatigue of the Saturn V rocket engine that launched the Apollo missions to the moon. He served as a volunteer with the Los Angeles ASM Chapter and Westec for many years.

Members in the News

pulp and paper industries. His award will be presented at the NACE 2014 meeting in San Antonio during the Awards Dinner on March 12. Perdomo holds a B.Sc. in metallurgy from Universidad Simon Bolivar, Caracas, Venezuela, and a Ph.D. in metallurgy from Case Western Reserve University, Cleveland.

Rosei Receives Two Canadian Awards

The Canadian Society for Chemistry (CSC) has bestowed its 2014 Award for Research Excellence in Materials Chemistry on **Prof. Federico Rosei,** director of the INRS Énergie Matériaux Télécommunications research center, in recognition of his exceptional contributions to the field. Rosei will be honored at the society's annual conference, June 1-5, in Vancouver. Additionally, in February, Rosei received an E.W.R. Steacie Memorial Fellowship, one of the most prestigious honors awarded by the Natural Sciences and Engineering Research Council of Canada (NSERC). Among his previous awards, Rosei received the 2013 Brian Ives Lectureship Award from ASM Canada.

Henein Named 2014 TMS President

TMS instated **Hani Henein** as its new president during the TMS 2014 Annual Meeting & Exhibition in San Diego, February 16-20. A TMS member for 31 years, Henein previously served as that Society's vice president, a member of its Financial Planning Committee, and Board Director of Programming. Henein is a professor at the University of Alberta in Edmonton, Canada. As vice president of TMS, Henein worked to foster the development and involvement of young professionals in TMS and hopes to continue that work in his new role as president. Henein earned his B.S. and M.S. degrees from McGill University and his doctorate from the University of British Columbia.

NAE Elects Pharr

George M. Pharr, FASM, Chancellor's Professor in the Department of Materials Science and Engineering at the University of Tennessee, Knoxville, and Joint Faculty Scientist in the Materials Science and Technology Division at Oak Ridge National Laboratory, was named to the National Academy of Engineering (NAE). Pharr, who is also director of the UT-ORNL Joint Institute for Advanced Materials and McKamey Professor of Engineering, has been elected for his "development of methods for determining mechanical properties of materials by nanoindentation." He studies nanoscale materials for use in high strength materials for energy production and storage, electronics, modern medicine, computer hard drives, and everyday products.

TMS Young Leader Professional Development Award Winners

TMS announced the recipients of its 2014 Young Leader Professional Development Award in January. Winners were formally recognized at the 143rd TMS Annual Meeting & Exhibition, February 16-20, at the San Diego Convention Center. The award recognizes early-career individuals, under the age of 40, for their potential as future leaders within TMS and the materials and engineering community it serves.

Congratulations to these ASM joint student members who were among those selected for the TMS award: Electronic, Magnetic & Photonic Materials Division: **Hans Shin,** Pacific Testing Laboratories

Extraction & Processing Division: **Zhiwei Peng,** Michigan Technological University

Materials Processing & Manufacturing Division: **Srinivasa Rao Bakshi**, India Institute of Technology Madras; **Amber Genau**, University of Alabama; and **Paul Gibbs**, Los Alamos National Laboratory.

Structural Material Division: **Jennifer Carter**, Case Western Reserve University; **Benjamin Morrow**, Los Alamos National Laboratory; and **John Nychka**, University of Alberta.

Suresh is Doubly Honored

Carnegie Mellon University president **Subra Suresh, FASM,** recently received two honors. Last October, he was elected as a member of the Institute of Medicine (IOM), making him the only current university president and only one of 16 living Americans to be elected to all three major national academies (along with the National Academy of Sciences and the National Academy of Engineering). Additionally, in December Suresh was elected as a Fellow of the National Academy of Inventors (NAI). NAI Fellows are recognized for their "prolific spirit of innovation." Induction of the 2013 class will occur on March 7 at the U.S. Patent and Trademark Office in Alexandria, Va.

Metal Powder Group Elects Officers

McGeehan

Bowles

The Metal Powder Industries Federation (MPIF) elected two ASM members to head up a few of their trade associations. **Patrick J. McGeehan,** vice president and general manager, Specialty Metal Products, Ametek Inc., Robesonia, Pa., was elected president of the Metal Powder Producers Association (MPPA). **David V. Bowles,** general manager and president, Pressure Technology Inc., Warminster, Pa., was elected president of the Isostatic Pressing Association (IPA). Both men were installed during the federation's annual meeting last November in Key West, Fla.

Henkel Corp., Madison Heights, Mich., announces an epoxy-based **surfacing film** for composites, which offers protection against lightning strike. Loctite EA 9845 LC Aero contains a lightweight conductive foil and was developed to improve the surface quality of honeycomb-cored composite parts while protecting them from lightning damage. The epoxy reduces surface imperfections, offers a 30% weight savings compared to current surfacing films, and minimizes pre-paint preparation requirements. www.henkel.com/aerospace.

Micromeritics Instrument Corp., Norcross, Ga., introduced the 3Flex Surface Characterization Analyzer, a **fully automated, three-station instrument** capable of high-performance physisorption, mesopore, micropore, and chemisorption analyses with superior accuracy, resolution, and data reduction. Each analysis station is upgradeable from mesopore to micropore with the option of designating one station for chemisorption analyses. All analysis stations can be configured for krypton analysis of low surface area materials. Vaporsorption capability is standard. The instrument is suited for the characterization of MOFs, zeolites, activated carbons, adsorbents, and a wide variety of porous and nonporous materials. www.micromeritics.com.

RTP Company, Winona, Minn., introduced new **ultra-performance compounds** based on carbon fiber reinforced PEEK, PPA, PPS, and PEI resin systems to create high performing thermoplastic products. Combining the higher mechanical properties and lower densities of carbon fiber with the thermal and chemical resistance by using high temperature resin systems helps these injection moldable thermoplastic materials close the performance gap between plastics and metals. Products are available in high temperature resin systems with carbon fiber reinforcement loadings from 20-40%. www.rtpcompany.com.

Hitachi High Technologies America Inc., Schaumburg, Ill., announced that its SU3500 **scanning electron microscope** is now available with a 4-axis motorized stage, in addition to the existing 5-axis motorized stage system. The new 4-axis version is targeted for smaller sample applications (max. 200 mm diameter and 70 mm height). The 4-axis motorized stage system features the same electron optics and signal detection systems as the 5-axis motorized stage system, providing excellent 3D imaging and analytical performance. Designed with intuitive logic, the user-friendly GUI provides comprehensive image observation and display functions. www.hitachi-hta.com.

products & literature

Bruker Elemental, Kennewick, Wash., introduced the second generation of its S1 Titan **handheld XRF analyzer** platform. Based on feedback, the new S1 Titan enhancements include a weatherproof IP54-rated housing and optional integrated camera and small spot collimator. S1 Titan 600 and 800 use a thin film window and Fast SDD detector for analysis of up to 37 elements, including light elements such as Mg, Al, and Si, without the need for a vacuum or helium gas flush. The analyzer is available specifically configured to analyze precious metals. www.bruker.com/s1titan.

Thwing-Albert Instrument Co., West Berlin, N.J., offers an additional **pneumatic sample preparation tool**—the Alfa Cutter 240-15B. This cutter can apply up to 15 tons of pressure allowing larger samples to be cut quickly using a steel rule die. The tool is a pneumatic press style cutter used to prepare samples for materials testing. It can cut multiple samples at once with multiple configurations on one die, and thicker and larger samples are possible with a maximum size of 10 × 22 in. www.thwingalbert.com.

HMV-G Series **Micro Vickers hardness testers** from Shimadzu Scientific Instruments, Columbia, Md., feature a CCD camera for automatic length measurement and provide simple, secure analysis with minimal risk of human error. The new G-frame design expands the workspace, dramatically improving operability while permitting effective measurement of long and large test samples. Additionally, the camera's automatic lens switching function adjusts the lens to suit the size of the indentation. Even users with limited experience can measure samples of unknown hardness easily and reliably. www.ssi.shimadzu.com.

Engineered with a silicon carbide filler material, EP21SC-1 **two-part epoxy** from Master Bond Inc., Hackensack, N.J., delivers abrasion resistance for an array of chemical and mechanical processing applications. It features a smooth paste consistency and noncritical 1:1 mix ratio by weight or volume. As a two-part system, it cures readily at room temperature or more quickly at elevated temperatures. With a Shore D hardness exceeding 95, EP21SC-1 is a rigid compound that adheres well to treated metals, ceramics, and many plastics. Its physical strength profile includes tensile strength greater than 6000 psi and compressive strength of more than 15,000 psi at room temperature. www.masterbond.com.

Materials R&D Engineer

L.E. Jones Company L.L.C., leading manufacturer of precision valve seat inserts, is seeking candidates for the full-time position of Materials R&D Engineer.

Minimum qualifications include:

1. A Master or a Bachelor of Science degree, majoring in metallurgical engineering, materials science & engineering, mechanical engineering, or chemistry.
2. Excellent verbal and written communication skills.

Duties include:

- Completion of internal materials testing projects
- Management of external materials lab testing projects
- Completion of new alloy development projects
- Development of new materials analysis and testing methods
- Assisting in new materials processing development of VSIs manufacturing
- Assisting in trouble shooting for materials processing related issues
- Assisting in Sales and Marketing projects
- Assisting in Spectrometry Lab operation
- Communication with customers on materials engineering topics
- Preparation of materials evaluation reports
- Participation with continuous product quality improvement programs

L.E. Jones Company L.L.C. is a leading manufacturer of heavy duty engine valve seat inserts using unique high alloy materials, including many new alloys and surface treatments developed by L.E. Jones Company. L.E. Jones Company is located in Menominee, Michigan. We offer a competitive salary and a comprehensive benefits package. Interested candidates should submit a resume and two references in confidence to:

Vacancy 11
Human Resources Manager
L.E. Jones Company L.L.C.
1200 34th Ave.
Menominee, Michigan 49858

L.E. Jones Company L.L.C. is an Equal Opportunity Employer
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ad index

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MATERIALS TECHNOLOGY LEAD

Job Description and Qualifications Air Products and Chemicals, Inc., a Fortune 500 manufacturer of industrial gases and chemicals, has an immediate opening for a MATERIAL TECHNOLOGY LEAD at our Corporate Headquarters in Allentown, Pennsylvania.

The Materials Technology Lead is responsible for the safe and reliable operation of our facilities through the performance of key activities including:

- Recommending materials of construction based on process conditions including fluids handled, pressure, temperature, etc.
- Conducting failure analyses to determine root causes for equipment failure in service and providing material recommendations or plant operation modifications to avoid a recurrence of the failure.
- Providing materials consulting and advice to Air Products operating facilities on issues such as welding, heat treating, corrosion performance, materials properties (e.g., high temperature creep properties and failure mechanisms, low temperature toughness), etc.
- Developing and overseeing testing protocols to determine viability and limitations of materials for new and existing process applications.
- Developing and leading research programs

Qualifications and Requirements:

- A MS/PhD degree in Materials/Metallurgical Engineering with a minimum of 15 years experience in the industrial gas, petrochemical, power, or chemical process industries is required.
- Needs to have a comprehensive understanding of basic corrosion and failure mechanisms.
- Must have the ability to identify microstructures and fracture morphologies of a wide variety of alloy systems and an in-depth understanding of alloy systems as related to materials of construction.
- Must be staying abreast of technical advances in the field, particularly those related to high temperature metallurgy. Laboratory experience is required.
- Have the ability to lead a technical team and mentor others.
- Demonstrate the ability and vision to conceive, define and champion research projects on innovative materials solutions and predictive tools to improve plant reliability and mitigate risk.
- Seeking a motivated engineer with excellent verbal and written communication skills able to interface with engineers and plant personnel and to leverage the expertise of external labs, consultants and technical organizations.

Familiarity with the following items will also be a plus:

- Risk based inspection and fitness for service methodologies
- Remaining Life Assessment methodologies
- High temperature metallurgy (above 1500F)
- Non-destructive test methods
- Nickel based alloys

Approximately 15-20% travel required, some international.

Air Products (NYSE:APD) provides atmospheric, process and specialty gases; performance materials; equipment; and technology. For over 70 years, the company has enabled customers to become more productive, energy efficient and sustainable. More than 20,000 employees in over 50 countries supply innovative solutions to the energy, environment and emerging markets. These include semiconductor materials, refinery hydrogen, coal gasification, natural gas liquefaction, and advanced coatings and adhesives. In fiscal 2012, Air Products had sales approaching $10 billion. For more information, visit www.airproducts.com.

To apply for this position, please visit the Air Products Career Center. Click on the link Search job openings from the left navigation bar. You can apply specifically to Job Req #13240BR or forward your resume directly to KaBrile Bradley at bradlek@airproducts.com

We thank all applicants in advance for their interest; however, only those applicants who are being considered for an interview, or are currently employed by Air Products, will be contacted.

Air Products is an equal opportunity employer (M/F/D/V) where diversity matters.

editorial preview

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Materials Testing & Characterization

Highlighting:
- Resonant Ultrasound Spectroscopy
- Fracture Toughness Testing of Ductile Materials
- ITSC Show Preview

Advertising closes March 4, 2014

MAY 2014
Aerospace Materials & Applications

Highlighting:
- Development of Ti_2AlNb Alloys
- Overcoming Barriers of Magnesium Ignition and Flammability
- AeroMat Show Preview

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International Thermal Spray and Surface Engineering newsletter covering coatings in the energy and power generation industries.

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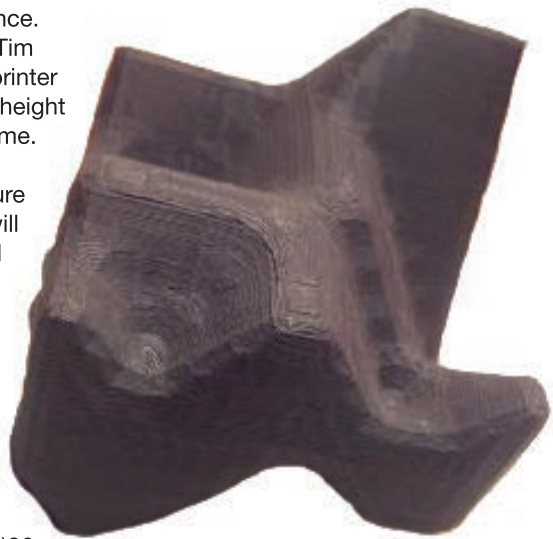
stress RELIEF

3D printing explains physics

Researchers at Imperial College London successfully demonstrated how complex theoretical physics can be transformed into a physical object using a 3D printer. In eight hours and at the cost of around $20 (15€), a commercially available 3D printer created 8-cm^3 objects based on a mathematical model that describes how forest fires can be started and how they eventually spread over time. Dubbed "sculplexity" (sculptures of complexity), the approach could also be used to produce works of art based on science.

"The basic idea is simple," says Tim Evans, theoretical physicist. "A 3D printer builds up its object in layers, so the height of the object can be thought of as time. Suppose you have a mathematical model, which defines a flat, 2D picture that evolves in time—typically this will be a grid with some squares full and some empty. The mathematical model will define at each point in time what the printer should print at one height. The next step in the model will then define what to print on top of the first layer, and so forth. The result is a 3D object that shows how the mathematical model has evolved over time." *For more information: Tim Evans, +44 (0)20 7594 7837, t.evans@imperial.ac.uk, www3.imperial.ac.uk.*



Researchers successfully demonstrated how complex theoretical physics can be transformed into a physical object using a 3D printer. Courtesy of Imperial College London/EPL.

Algorithm makes faces more memorable

Faces could be instantly transformed into more memorable ones without the need for an expensive makeover, thanks to an algorithm developed by researchers in Massachusetts Institute of Technology's Computer Science and Artificial Intelligence Laboratory, Cambridge. To develop the algorithm, a database of more than 2000 images was fed into the software. Each image was awarded a "memorability score," based on volunteers' ability to remember the pictures, which allows the software to analyze and detect subtle trends in the features that made them more or less memorable. The algorithm was programmed with a set of objectives—to make the face as memorable as possible without changing the identity of the person or altering their facial attributes, such as age, gender, or overall attractiveness. Changing the width of a nose may make a face look much more distinctive, for example, but it could also completely alter how attractive the person is, and so would fail to meet the algorithm's objectives. *For more information: Aditya Khosla, khosla@csail.mit.edu, www.web.mit.edu.*

The top left and bottom right images are the most memorable. Courtesy of the Oliva and Torralba labs.

Wearable art

Chicago-based artist and longtime proponent of 3D-printed art and sculpture, Joshua Harker made his runway debut at this year's 3D Printshow in London and Paris. His first piece of wearable art, a headdress laser sintered on an EOSINT P 760 additive manufacturing system, served as the anchor of the fashion show. The all-plastic headgear, which pays homage to traditional ceremonial headdresses of Native American and African tribes, consists of a variety of interwoven and suspended components. After Harker dedicated almost 200 hours of design time, EOS was able to print the entire piece in less than 26 hours. *For more information: Joshua Harker, 773/343-2251, josh@joshharker.com.*

The headdress material is nylon 12 (specifically EOS PA 2201), commonly used in manufacturing. Its properties are analogous to traditional nylon 12.

SUCCESS ANALYSIS

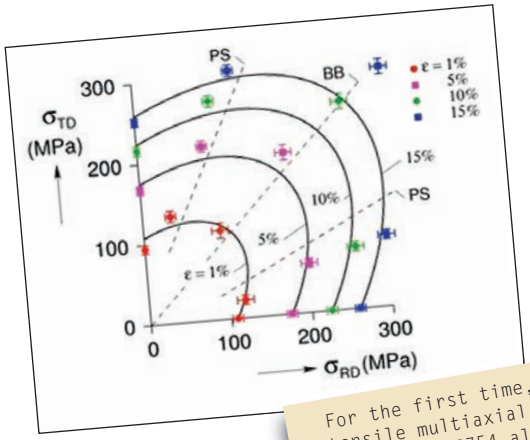
Specimen Name: NIST Center for Automotive Lightweighting (NCAL)

Vital Statistics:

Today's automakers lack the necessary tools to easily incorporate lightweight materials (e.g., aluminum alloys, high-strength steels, and polymer composites) due to inadequate data and material models. As a result, the U.S. auto industry spends hundreds of millions of dollars per year reworking metal forming dies that do not make correct parts.

NCAL is developing the measurement methodology, standards, and analysis techniques required by auto manufacturers and base metal suppliers to transition to advanced materials for auto body components.

The center developed a technique to measure the stress-strain response of sheet metal along nonlinear multiaxial paths. The team also measures the sheet's evolving crystallographic texture to develop a microstructural understanding of deformation response.



For the first time, the tensile multiaxial yield surface of 5754 aluminum alloy sheet was measured from initial yield up to failure. Graph shows the flow stress of 5754 Al as a function of strain.

Success Factors:

By directly measuring the mechanical response of sheet metal being deformed along a complex path, NCAL is providing the data needed to develop next-generation models that will accelerate the use of advanced lightweight materials in vehicles. This high strain rate data helps ensure safe performance in collisions and reduces the need for costly physical crash tests, according to researchers.

Equipment includes a high-rate servohydraulic mechanical testing machine; next-generation cruciform metal formability system designed to test sheet metal along any path in strain space relevant to metal forming operations; a Marciniak testing system with two punch sizes, x-ray diffraction, and digital image correlation; SEM, TEM, EBSD, XRD, OIM, optical and neutron diffraction; computational facilities; and a sample preparation area that includes plasma cutting and welding.

Control center and overview of NCAL's metal formability system.

Close-up of x-ray stress measurement mounted on the cruciform system, positioned above a deforming sample.

About the Innovators:

NCAL is led by Tim Foecke and NIST researchers Mark Iadicola, Thomas Gnaeupel-Herold, Adam Creuziger, Bill Luecke, Dave Pitchure, and Mark Stoudt. Consortium partners include Ford, General Motors, Chrysler, ThyssenKrupp, US Steel Corp., ALCOA, Carnegie Mellon University, and several others.

What's Next:

Beyond model generation, there is ongoing work to measure the actual stress-strain state within the neck of an ASTM E-8 tensile specimen to determine mechanical properties beyond instability. This high strain data helps forming simulations, as the constrained deformation during forming often exceeds that reached by traditional tensile tests.

Contact Details:

Tim Foecke, NCAL Director
NIST Material Measurement Laboratory
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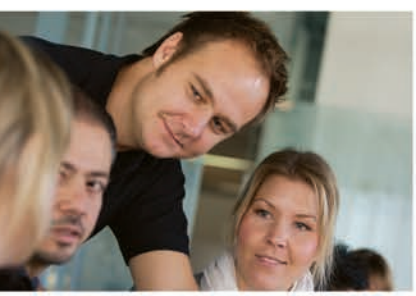

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