Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

FORGING / MAINTENANCE

THE CUTTING EDGE OF THERMAL PROCESSING IN A FORGE ENVIRONMENT

COMPANY PROFILE ///

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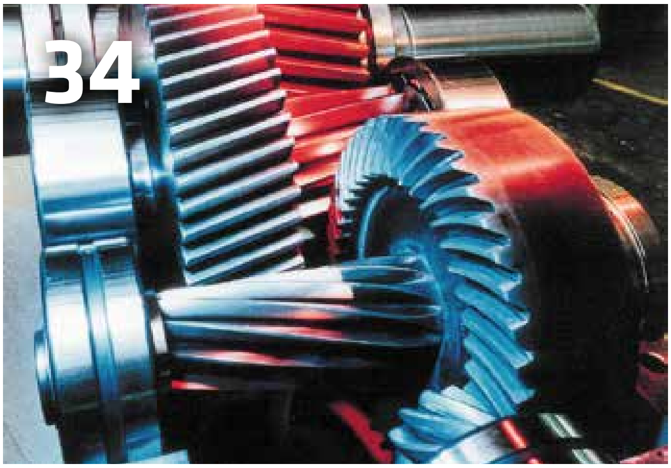

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COMPANY PROFILE ///

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Messer may be a new name for many in the metals industry in the U.S. and Canada, but the company has more than 120 years of global experience in gases and gas technologies, and many of its people should be familiar.

COVER PHOTO: SCOT FORGE

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Thermal Processing is published monthly by Media Solutions, Inc., 266D Yeager Parkway Pelham, AL 35124. Phone (205) 380-1573 Fax (205) 380-1580 International subscription rates: $105.00 per year. Postage Paid at Pelham AL and at additional mailing offices. Printed in the USA. POSTMASTER: Send address changes to *Thermal Processing* magazine, P.O. Box 1210 Pelham AL 35124. Return undeliverable Canadian addresses to P.O. Box 503 RPO West Beaver Creek Richmond Hill, ON L4B4R6.

FROM THE EDITOR ///

Industry keeps adapting to the new normal

The craziness that seems to be the driving force of 2020 has affected almost every part of our lives — from the tiniest things we may take for granted to the larger health issues that keep us up at night.

As we try to make sense and adapt to what has become a new normal, *Thermal Processing* has tried to adapt as well.

Our August issue and our September issue were originally scheduled to be a springboard for the Furnace North America tradeshow. But like so many other 2020 tradeshows, the organizers were forced to shift gears due to coronavirus pandemic.

I must applaud FNA for working toward making the best lemonade out of the lemons COVID-19 has thrown at us. After rescheduling the event to the end of September, the virus forced FNA to shift gears again. Now, the organizers are taking the tradeshow virtual. Even though a virtual experience won't replace the face-to-face camaraderie of past shows, attendees will still get the benefit of FNA's expert panelists and presenters. And I suspect no one is going to really miss their annual soft pretzel food run. (OK, full confession: I do love a soft pretzel.)

It is somewhat of a relief to know that technology has been an awesome tool in keeping a lot of our business going in these weird times.

With physical tradeshows on hold, please take time to see how *Thermal Processing* can also be your ally in getting your message to your customers. We offer many ways in which to connect your products and services to the industry.

That's good news for your audience in search of the very services and products that you can provide every day. And with the world trying to cope with economic and medical hardships, the deep reach *Thermal Processing* can provide is more important than ever.

With that in mind, I hope you find the forging and maintenance articles in our August issue of interest.

In our cover article, Joe Weaver from Scot Forge takes a look at the cutting edge of thermal processing in a forge environment. And Stephen L. Feldbauer with Abbott Furnace Company reviews lubricant removal systems and the latest technology behind them.

That's just a taste of what August's issue has in store for you.

Thermal Processing is here to serve you. With that in mind, if you have any suggestions or would like to contribute, please contact me. I'm always looking for exciting articles to share.

Stay safe and healthy out there, and, as always, thanks for reading!

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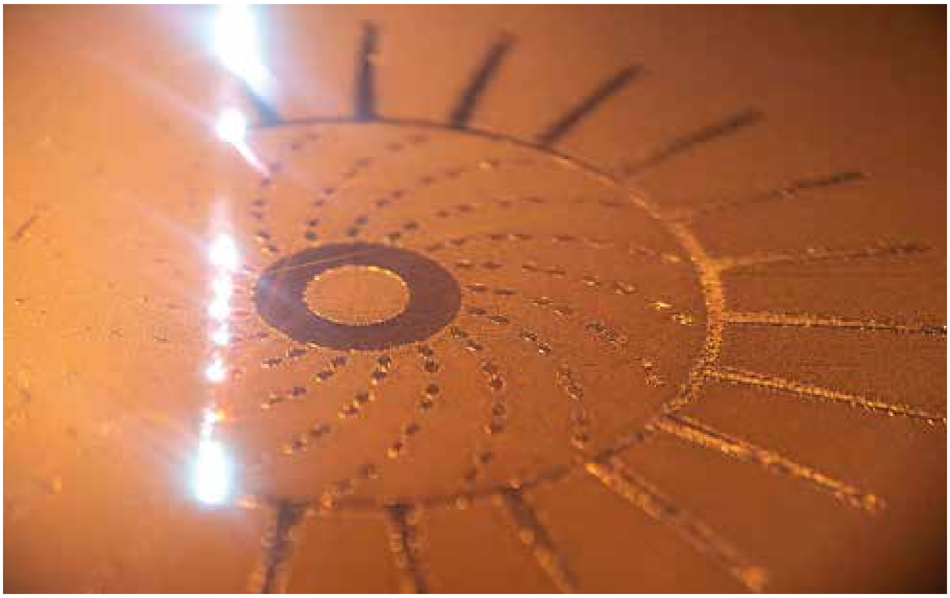

Wayland Additive has launched a new website to highlight its new electron beam (eBeam) powder bed fusion (PBF) process for metal Additive Manufacturing (AM). (Courtesy: Wayland Additive)

Wayland Additive launches new website

Wayland Additive has launched a new and comprehensive website.

Wayland's NeuBeam technology offers an innovative alternative to the two existing powder bed fusion (PBF) technologies — laser and EBM — both of which have fundamental limitations which compromise the actual benefits of using AM in the first place.

Will Richardson, CEO at Wayland said, "Across many industry sectors, there is a continued drive to adopt metal AM for production applications as an alternative to traditional fabrication processes. A key driver in this respect is the ability to produce geometrically complex and innovative products more efficiently and cost-effectively than with the laborious, time consuming, restrictive, and cost prohibitive conventional manufacturing processes. At Wayland we feel that this is a pivotal moment for considering the ways in which manufacturers apply metal AM to harness its advantages, and the only way to accelerate its adoption is to overcome the inherent issues with existing processes. Our new website explains in detail not just our new NeuBeam metal AM system, but also alerts manufacturers to the critical pit-falls to avoid and opportunities to exploit when assessing the incorporation of metal AM processes."

Across all relevant sectors of industry, OEMs are aware of the trade-off between laser and EBM metal AM processes. While laser PBF has traditionally held the advantage in terms of fidelity and surface finish (due to the precise nature of the laser(s)), eBeam PBF gains significant advantage in terms of speed and productivity as a result of the more efficient way that electrons transmit energy to the powder bed, and through-thickness heating of the entire layer. In addition, eBeam PBF can process multiple melt-pools simultaneously, further contributing to increased productivity.

However, the laser PBF process causes internal residual stresses that require extensive structural supports to be built to prevent the parts distorting or cracking during printing. These supports require a significant amount of material, and removing them is costly and time consuming. The laser PBF process also suffers from the production of highly-oxidized particles ("spatter") being ejected from the melt pool. Despite countermeasures, a minority of these particles land in the powder bed and cause localized contamination, which can compromise part integrity.

Traditional eBeam processes are characterized by inherent instabilities caused by charge accumulation within the build chamber, which can result in powder scattering or a so-called "smoke event" that distorts the current layer of the build and therefore compromises the entire build. To avoid this, the process has to be operated in a very specific way, and has a steep learning curve. Particularly, it is critical to maintain the temperature of the powder bed between strict limits, which is required to cause the powder bed to sinter so that it isn't disturbed by powder charging. This unreliability means that eBeam PBF has typically been considered less favorable than laser-based PBF.

The traditional eBeam process effectively entombs the parts in a sintered powder "cake," which makes part removal and post-processing very difficult, time-consuming and expensive. The challenge of removing unused powder from the parts also imposes geometry limitations on parts, for example with enclosed regions such as cooling channels on a turbine blade.

Peter Hansford, director of business development at Wayland said, "As a team we have been working tirelessly over the last few years to develop our NeuBeam technology to overcome the problems that manufacturers have to grapple with as they navigate around the limitations of existing metal AM processes. It is extremely exciting to see all this work pulled together and presented on

SEND US YOUR NEWS Companies wishing to submit materials for inclusion in Thermal Processing's Update section should contact the editor, Kenneth Carter, at editor@thermalprocessing.com. Releases accompanied by color images will be given first consideration.

our new website, which explains in detail where our technology fits as manufacturers look for future proof, blue ocean metal AM technologies. We invite all interested parties, or any manufacturers that have struggled to justify the business case for metal AM to engage with us and find out about the possibilities that now exist through NeuBeam."

Unlike the traditional eBeam PBF process, the charging issues that make EBM so unstable have been fully neutralized with NeuBeam using core physics principles developed in the demanding semi-conductor industry. Moreover, NeuBeam is a hot "part" process rather than a hot "bed" process. This efficiently creates parts that are free of residual stresses because the high temperatures are only applied to the part and not the bed, ensuring free-flowing powder post-build (no sinter cake) and stress-free parts with reduced energy consumption.

The NeuBeam process is capable of producing fully dense parts in a wide range of materials, many of which are not compatible with traditional eBeam or laser PBF processes such as refractory metals and highly reflective alloys. As a result, the process can demonstrate vastly improved metallurgy, without many of the compromises that existing metal AM processes necessitate.

NeuBeam also offers significant advantages over other technologies with built-in real-time in-process monitoring, allowing for rapid material development or tuning of microstructures by adapting the solidification during manufacture.

MORE INFO www.waylandadditive.com

SuperSystems makes management changes


Jim Oakes


Bob Fincken


Steve Thompson

Super Systems Inc. promoted Jim Oakes from vice president of business development to president. Oakes has been with SSi for 15 years with various responsibilities, but has focused on positioning SSi as a leader of sensors, controls, and software in the heat-treating industry. Oakes has served the industry not only at SSi but through volunteer work on the board of trustees and as board president for both the Metal Treating Institute (2019-present) and ASM Heat Treating Society (2017-2019).

Super Systems Inc. has also appointed Bob Fincken to vice president of sales for North America. Fincken has been serving SSi in sales for 14 years with a pursuit of delivering solutions to customers. His experience in the industry provides him with all the tools to lead SSi's effort to always provide customers with the best products and service in the industry.

Steve Thompson, Super Systems president, is moving to the position of chief executive officer (CEO). Thompson will continue to be a hands-on leader, providing guidance based on a clear vision of the future of heat treatment, along with experience gained since starting the company with his father Bill Thompson in 1995. Bill Thompson has officially retired.

With these changes, customers can expect the same level of service and commitment to customer support and technology innovation — the fundamental values that Bill Thompson has instilled in SSi since its founding.

Super Systems Inc., based in Cincinnati, Ohio, has been developing and manufacturing products for the thermal-processing industry since 1995. SSi's products include probes, analyzers, flow meters, controllers, software solutions, and engineered systems. With more than 100 years of combined experience, SSi continues to satisfy industry demands with innovative technology, enabling customers to be more efficient and to produce higher quality products.

MORE INFO www.supersystems.com

Solar Atmospheres celebrates AS9100 anniversary

Melissa Gruszka prepares for AS9100 audit virtually with Ed Engelhard, vice president of corporate quality at Solar Atmospheres. (Courtesy: Solar Atmospheres)

Solar Atmospheres of Western PA celebrated 13 years of AS9100 certification. Like the complexities of ever-changing customer needs, 2020 proves to be challenging for businesses. Impacts to daily routines, course of business, personal liberties, and even audit scopes bear a brunt of ushering in a new era.

This new era is intricately woven with COVID-19, populous instability, and intertwined with increasingly stringent standards, revised industry specifications, and customer requirements.

Even with these new complexities, Solar passed this milestone for more than a decade of accreditation without any major findings. The live audit, which was conducted for the very first time, used a combination of email, telephone, and video conferencing to grade Solar's QMS on recent aerospace work. The comprehensive review addressed recent events as risk and Solar's response as effective.

Melissa Gruszka, quality manager and a recent addition to Solar Atmospheres of Western PA, said, "We have a great team that can pull together, under any circumstances, to get work done. Solar maintains the highest standards by keeping safety, quality, and efficiency in check and our customers in the foreground. Solar exercises a proven value system, integral to society, and empowers people, shaping a bright future."

MORE INFO www.solaratm.com

Graphalloy® updates pillow block, flange block catalog

Each catalog page includes a picture, diagram, sizes, and common applications for a particular assembly. (Courtesy: Graphite Metallizing Corp.)

Graphite Metallizing Corporation, the manufacturer of self- lubricating Graphalloy® bushing materials, released an updated catalog for high-temperature pillow blocks and flange blocks. This catalog provides engineers and distributors with detailed views and information on the various types of pillow block and flange block assemblies made with the Graphalloy bearing material. Each catalog page includes a picture, diagram, sizes, and common applications for a particular assembly. Applications for Graphalloy bearing assemblies include ovens, dryers, dampers/louvers, kilns, conveyors, submerged, and more.

"This updated pillow block and flange block catalog reflects our expanded range of products, sizes, and applications," said General Manager Eben Walker. "Our Graphalloy bearing assemblies now solve even more problems in high temperature and other extreme applications, places where traditional lubricants can't go."

Graphalloy, a graphite-metal alloy, is available in more than 100 grades with specific properties that meet a wide range of engineering solutions and specifications. Graphalloy bearings have operated for 20 years and longer in some applications.

FDA acceptable grades of Graphalloy are available for use in food service equipment. NSF® International has certified two grades of Graphalloy material for use in municipal well pumps and water treatment plant applications.

MORE INFO www.graphalloy.com

Dante Solutions releases Dante 5.0 software

Dante Solutions, Inc. has released Dante 5.0, the most advanced heat-treatment simulation software from Dante Solutions. Included in Dante 5.0 are several new features designed to describe the physics of steel heat treatment more accurately; they include:

› **Carbon Separation Model:** This model describes the rejection of carbon as the steel transforms to ferrite from austenite. The additional carbon then enters the surrounding austenite matrix, increasing the local hardenability of the steel.

› **Carbide Decomposition Model:** This model describes the decomposition of primary carbides during heating processes. The amount of total carbon (carbon in the matrix and carbon in primary carbides), carbon in primary carbide form, and a carbide size factor are defined as initial conditions to the model. The carbon and carbide values can be uniform throughout the material or as a profile, as from a carburizing process. The carbon in carbide form will enter the matrix during heating and soaking at high temperature, increasing the carbon in the austenite matrix and the hardenability of the steel. The decomposition rate is a function of time, temperature, and carbide size factor.

› **Residual Stress Relaxation Model:** This model describes the relaxation of residual stresses during heating and holds at high temperature. The model is intended to predict stress relaxation during a stress relief processing step, annealing step, normalizing step, or during the austenitizing process. The relaxation rate is a function of time, temperature, and stress.

› **Alloy Composition Variation Modeling:** Dante 5.0 introduces the ability to model slight variations in steel alloy composition and its effect on the material's hardenability. The model is intended to capture the variation witnessed in production. The model affects the transformations to ferrite, pearlite, and bainite.

› **Liquidus/Solidus Latent Heat Model:** This model describes the latent heat released as a steel transforms from the liquid state to the solid state and the latent heat absorbed as a steel transforms from the solid state to the liquid state. The model is intended to be used when modeling any phenomena involving a melt pool, such as welding or additive manufacturing.

› Abaqus Plug-In: Dante Solutions has developed an Abaqus Plug-In designed to aid in Dante model setup. The Plug-In includes means to define material, initial conditions, boundary conditions, and much more. Abaqus users no longer need to manually modify input files. The entire Dante model can now be easily constructed within Abaqus CAE using the Dante Plug-In.

› Dante Utility GUIs: Dante Solutions has developed Graphical User Interfaces (GUI's) for all of its utilities offered to aid in material, model, and process development. Please contact a Dante Solutions engineer for more information on the type of utilities offered.

› MatSim Utility: Dante Solutions' latest utility combines the power of the Dante phase transformation models into an easy to use utility. Predict volume fraction of phases from defined heating and cooling rates, plot temperature-strain curves, and much more.

Several bugs were removed from the software, improving stability. Several mathematical algorithms were also modified, improving convergence and robustness. Dante 5.0 is now available for installation.

MORE INFO www.dante-solutions.com

Metlab hires DiMascio as VP of operations

Metlab Heat Treat provides heat treating-services to a wide range of industries. Aiming to elevate Metlab's quality and efficiencies, the company hired Chris DiMascio as the vice president of operations.

"My goal is to strengthen the core business from an operations perspective," DiMascio said. "Processes need to be solidified, and new ones need to be put in place. This includes having the right people working on the right things. To accomplish this, we will be implementing Lean principles throughout the organization. The first year will be the equivalent to 'polishing the apple.' As an example, we are already beginning to establish ownership and accountability throughout the organization."

Chris DiMascio

Mark Podob, Metlab's president and owner said, "His work with us over the past few months has resulted in many major improvements to our operation. We are looking forward to the great experience that he brings to Metlab as we seek to grow our heat-treating operations."

DiMascio has more than 30 years of broad experience (including plastics, metals, and chemicals) in engineering and operations. He was most recently principal of OpX partners, his consulting firm and, before that, COO of the process technologies division for Johnson Matthey Inc., a British company with nine facilities worldwide.

He has a Bachelor of Science Degree in mechanical engineering and an MBA in business management from Penn State University.

MORE INFO www.metlabheattreat.com

Groundbreaking with, from left, Tom Cooper (vice president of business development); Bill Walter (facility manager); and Raja Gumber (senior account manager). (Courtesy: Nitrex)

Nitrex's Aurora plant expansion heads to phase four

Nitrex, in Illinois, USA, is set to start the fourth phase of its plant expansion that will house low-pressure carburizing operations as well as provide space for additional growth. The new LPC furnace and secondary heat-treating equipment will enter production by April 2021.

Jason Orosz, president of Nitrex Heat Treating Services, announced a new plant investment aimed at expanding the Aurora, Illinois, commercial heat-treat facility located just west of Chicago. The production expansion will add a fourth building on the property to house a new low-pressure carburizing (LPC) system and secondary heat-treating equipment.

The new ECM vacuum carburizing furnace with oil quench capabilities will help meet growing demand from makers of high-end critical parts within the automotive, aerospace, and tooling industries. The 20-bar dual-chamber furnace has a workload size of 40" L x 24" W x 28" H (1,000 x 600 x 715 mm) and a load capacity of 1,500 lbs. (680 kg).

Nitrex broke ground on the new building in July to connect to an existing structure, Building 3. According to Bill Walter, facility manager of Nitrex Aurora, the construction project will be completed in January 2021, and production on the LPC furnace is expected to begin in April 2021. The expansion will increase the production footprint by 11,000 square feet, a pre-requisite to support current demand as well as future growth. Once this building is completed, the total floor space will be more than 50,000 square feet.

Nitrex first put down its roots in Aurora in 2000 after acquiring Alliance Metal

Treating from owner Tom Cooper, who stayed on following the acquisition to run operations and to help position the company for future growth. Initially, the plant offered heat-treating processes focusing on annealing, carburizing, carbonitriding, neutral hardening, and normalizing. During the preceding decades of expansion, Nitreg® nitriding and Nitreg®-S nitrocarburizing capabilities were added to its production operations; the larger footprint also supported more vacuum carburizers, tempering furnaces, and post-finishing equipment.

"Nitrex is proud of its longstanding history in Illinois. This latest expansion reaffirms our tradition of growth here as well as our long-term commitment to supporting customers with value-added solutions that meet the development needs for automotive, heavy equipment, defense, commercial, and other industrial applications," said Tom Cooper, vice president of business development.

MORE INFO www.nitrex.com

AEM hails USMCA for benefits to equipment makers

Association of Equipment Manufacturers (AEM) President Dennis Slater issued the following statement as the United States-Mexico-Canada Agreement (USMCA) entered into force :

"The USMCA entering into force today is great news for equipment manufacturers and our industry's 2.8 million men and women working across the United States and Canada. This marks the start of a new chapter for North American trade. USMCA expands agricultural market access, establishes rules for e-commerce, strengthens labor and environmental protections, and updates customs rules that will cut red tape and make it easier for U.S. manufacturers to sell to their Canadian and Mexican customers. We applaud President Trump, Vice President Pence, Senate Majority Leader McConnell, and House Speaker Pelosi to get this agreement to the finish line."

AEM was an ardent supporter of the USMCA since it was first proposed. The association actively advocated for the industry's priorities with U.S. and Canadian government stakeholders, participated in the USMCA Coalition, co-hosted U.S. Vice President Mike Pence at an equipment manufacturing facility in August 2019 to raise public support for the agreement, supported the work by Chairman Richard Neal (D-Mass.) and the nine members of the House Democrats' Trade Working Group, and ran an ongoing public education campaign on the various benefits of a ratified USMCA.

The International Trade Commission reported last year that the implementation of the USMCA could add up to$68 billion to the U.S. economy and create 176,000 jobs.

MORE INFO www.aem.org

Graphite Metallizing solves issue with cam followers

A vehicle suspension products manufacturer in the automotive industry was having problems with its automotive suspension stabilizer water quench line. When the production line was set up, the stabilizer bars were solid bar material and were quenched in oil. The line makes stabilizer bars from tube steel, which requires a water quench. Due to this change from oil to water, the grease-lubricated cam followers on the tooling fixtures locked up in less than eight weeks due to constant cycling through the water bath. The cam rollers would then flat-spot and wear additional components on the line — tracks and radius wheels.

The company turned to Graphite Metallizing for a solution. The company replaced those cam followers they were using with its Graphalloy Type 1217 bronze-grade cam followers, installed on three tooling fixtures (four on each) and a trial was conducted.

After 12 weeks, the Graphalloy was considered a success and they converted the rest of the fixtures, installing an additional 400 Graphalloy cam followers. More than two years later, the original 12 Graphalloy cam followers are still in operation. This shows an improvement in life from eight weeks to over two years.

MORE INFO www.graphalloy

After a quench change on its automotive suspension stabilizer water quench line, cam followers lasted eight weeks. Replacement Graphalloy cam followers lasted two years in a quench tank application. (Courtesy: Graphite Metallizing)

Oven manufacturer Grieve updates website

The Grieve Corporation, experts in industrial manufacturing of ovens and furnaces with a history of 70-plus years, launched an updated website with new features and enhancements to existing capabilities.

"As our company continues to grow, we look for our new website to offer the digital tools necessary to better serve our customers," said Tony Caringella, COO.

The website details Grieve's entire selection of ovens and furnaces in a digital catalog that is easy to navigate. With hundreds of different models, customers can help narrow down the right equipment for their process by using the oven finder tool by applying filters such as workspace area, operating temperature, loading method and more. Although the company offers hundreds of standard models, Grieve also has unique customization abilities to engineer the best equipment for one's application; the site details many custom ovens and furnaces as well.

Site visitors can browse Grieve's selections of ovens and furnaces and submit a request for a quotation, find the equipment that fits their process needs (along with compatible modifications and accessories), and submit a message directly to Grieve for a customized quotation that can be tailored to a specific process or application.

Ordering replacement parts is made simple with the Ecommerce platform. Customers can search by part type to find parts needed for their equipment, and order directly from the website. The Grieve team will verify the item with the customer's equipment to ensure compatibility. Customers are also encouraged to create an account that will hold their information for ease of checkout for future purchases.

Grieve works with sales representatives throughout the country (as well as globally) to support customers who would like assistance at their workspace to determine the best equipment for their needs. A local sales representative can be found using the Locate a Rep tool. Another resource for customers is the extensive resource library, housing hundreds of manuals, component literature, safety information, and more.

MORE INFO www.grievecorp.com

Magnetic Specialties launches new website

Magnetic Specialties (MSI) now offers a redesigned website, www.magspecinc.com.

The new site features a new look and layout, more detailed information, and photos of its custom-engineered magnetics. The website also adds customer-friendly specification forms for use on desktop or remote device.

The focus on the new website is to provide visitors with a roadmap to follow to discover more about the company's engineering services, transformers, reactors, and custom power supplies.

MORE INFO www.magspecinc.com

Registration open for aluminum extrusion seminar and expo

Registration for the 12th International Aluminum Extrusion Technology Seminar & Exposition – ET '21 is open. The 2020 ET Seminar was postponed due to restrictions. ET '21 is scheduled for May 11-13, 2021 in Orlando, Florida. An early discount for ET '21 registration fees is applicable through March 26, 2021. Teams of five or more registrants from the same company can receive an additional team discount by registering at the same time.

The ET Seminar will celebrate its 50th anniversary during ET '21, and as such, the ET Foundation and the Aluminum Extruders Council will be planning a special celebration to commemorate the occasion. In addition to providing a forum to present cutting-edge aluminum extrusion research, ET '21 will include the ET Expo, an exhibition featuring extrusion industry suppliers, and the Extrusion Showcase, a special exhibit that highlights the best and brightest application designs featuring aluminum extrusions. Add-on educational workshops will be held before and after the event to provide a well-rounded learning and networking experience. Those interested in attending one of the industry workshops may add a workshop to their ET registration or register to attend only a workshop during ET '21 week.

Abstracts for technical papers currently accepted for presentation are available to review on the ET '21 website.

"The ET program remains essentially intact after having to postpone the event this year due to the effects and circumstances surrounding the coronavirus pandemic," said ET seminar committee chairman Craig Werner, Werner Extrusion Solutions in Libertyville, Illinois. "We are eager and determined to deliver the exceptional program that ET delegates deserve and have come to expect. We are optimistic that global events will cooperate with us in 2021 so that the world's aluminum extrusion professionals can experience the technical advancements achieved by our industry."

The ET Seminar, which is held once every four years, addresses a variety of relevant and timely topics covering aluminum profile production, die design and technology, metallurgy, equipment, product applications, and more. The multi-day educational event attracts a worldwide audience of more than 1,300 industry professionals eager to discover the latest technical information about aluminum extrusion and network with industry peers from all over the world.

MORE INFO www.et-21.org

IHEA offers hands-on training with Powder Coating and Curing Processes Seminar

Scott Bishop explains infrared technology with an interactive classroom demonstration.

The Industrial Heating Equipment Association (IHEA), the Chemical Coaters Association International (CCAI), *Products Finishing* magazine and Southern Company have teamed up to provide a comprehensive training course. The Powder Coating and Curing Processes Seminar is scheduled for October 20-21, 2020, at the Alabama Power Technology Application Center (TAC) in Calera, Alabama.

The day-and-a-half introductory course includes classroom instruction and hands-on lab demonstrations. Attendees benefit from personal interaction with the speakers who are seasoned experts in all aspects of powder coating and curing processes. Attendees also receive technical resources to complement the program and gain valuable experience by spraying and curing a part during the course.

The classroom agenda will cover a variety of topics presented by members of the organizations who are dedicated to the education and growth of the industry. This seminar also includes a section on curing that reviews the basics of infrared technology, several useful electric and gas applications, and helpful case studies to prove the benefits to those who use it. Members of IHEA's Infrared

Attendees examine different infrared emitters.

Equipment Division will lead the curing segment and demonstrate the technology in the lab:

- Curing: Infrared Basics — Scott Bishop, Alabama Power Co.
- Curing: Applications/Case Studies — John Podach, Fostoria

Curing in action: Attendees powder coat an item and cure it in the lab.

Process Equipment, a Division of TPI Corp.; Eric Bellon, Heraeus Noblelight America LLC.

› Curing: Interactive Demonstration — Scott Bishop, Alabama Power Co.

The seminar combines the perfect mix of technical information, classroom involvement, hands-on practice, and social interaction for attendees to receive the best overall training value. You won't find a more cost-effective powder coating and curing training seminar anywhere else. Learn from industry experts in this state-of-the art facility.

Registration fee includes classroom and lab sessions; breakfasts, breaks, and lunch and a networking reception, CCAI's Powder Coating Training Manual ($65 value), and the newly revised *Infrared Process Heating Handbook* ($20 value).

This seminar always receives outstanding reviews from attendees. Feedback from previous participants include:

› "Speakers are very knowledgeable and helpful. Very impressed."

› "I am new to the industry, and this course provided very good information and perspective to me."

› "I really enjoyed the reception. It was nice to talk with others in the industry and find out what they do and how they do things. I learned a lot from other attendees."

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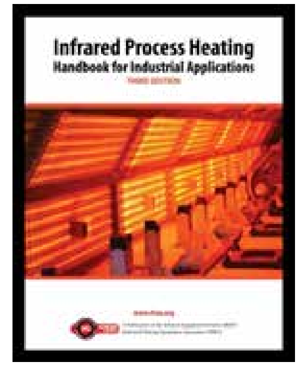
(IHEA members can also redeem vouchers for the registration fee. Contact Leslie Muck at leslie@goyermgt.com for assistance in using vouchers for this event.)

Infrared Process Heating Handbook



IHEA's Infrared Equipment Division recently completed revisions to its popular *Infrared Process Heating Handbook for Industrial Applications.* This quick introduction to the many applications of infrared heating in industrial processes has been updated to include new information, additional application examples, and new case studies. Learn how IR heating has been successfully applied to hundreds of different process heating applications such as curing metal finishes and protective coatings, fusing thermoset and thermoplastic powder coatings, forming molded plastics, bonding adhesives and metals, drying papers, inks and fabrics, and processing foods.

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JUSTIN SIMS
MECHANICAL ENGINEER /// DANTE SOLUTIONS

Using heat-treatment simulation software can be a powerful tool when determining the correct process for a particular component.

Process comparison to improve fatigue performance

Bending fatigue and contact fatigue performance can be improved by the presence of residual compressive surface stresses [1-2]. Many processes can induce these compressive residual stresses, including carburizing and quenching, induction hardening, and nitriding [3]. However, choosing the proper process, or processes, can be intimidating given all of the available processes currently being used to induce surface compressive stresses in steel components. While the residual stress profile is an important outcome of any hardening process, the resulting distortion must also be considered. Generally, distortion must be corrected, and as such, will reduce the residual compressive surface stresses if shape correction, such as straightening or machining, is performed. This is where heat-treatment simulation software, such as DANTE, can be used to evaluate several processes and determine the optimum with respect to residual stress and distortion for a given part geometry.

This article will use the heat-treatment simulation software DANTE to explore several processes and their effect on distortion and residual stress of a bevel gear. Figure 1 shows the CAD model of the bevel gear used. The gear has an outer diameter of 205mm, a bore diameter of 37.6mm, an axial length of 94.1mm, and 40 teeth. The processes and materials examined will be gas carburization/oil quenching and low-pressure carburization/high-pressure gas quenching of AISI 4320, and induction heating/spray quenching of AISI 4340. Assuming symmetric boundary conditions, only a single tooth is modeled. Figure 2(A) shows the CAD model of the single tooth used in the study, Figure 2(B) shows the single-tooth model meshed for finite element analysis (FEA), and Figure 2(C) shows a section view of the tooth, revealing the fine mesh layer near the surface required to properly capture the steep chemical, thermal, stress, and phase transformation gradients which occur near the surface of the component during a quench hardening process.

Figure 3 shows the predicted as-quenched hardness profile through the root of the tooth and reveals that the hardness profiles are similar, though not identical. This is due to the differences in carbon concentration, with the gas carburizing process producing the highest hardness due to the slightly higher carbon concentration from the uniform carbon potential applied to the model. In reality, the carbon potential may be reduced in the root area of the tooth due to poor gas circulation, reducing the surface carbon slightly in these areas. Low-pressure carburization can result in reduced carbon on concave surfaces and increased carbon on convex surfaces due to differences in surface area but can also suffer from poor gas circulation in the root area. The induction process produces the lowest hardness as a result of the 0.4 percent base carbon resident on the surface, whereas the carburized gears have surface carbon concentrations between 0.7 percent and 0.8 percent. For the application, all surface hardness values are deemed adequate and within specification. Since all processes produce acceptable hardness profiles, the residual stress profiles should be examined to ensure all three processes produce similar stress profiles, in terms of depth and magnitude. A tempering step would also need to be performed to stabilize the martensite but would only reduce the hardness and residual stress slightly and

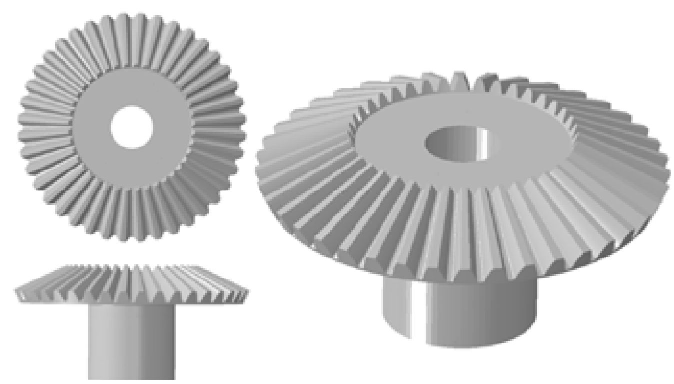

Figure 1: Top, front, and iso-view of bevel gear used in modeling study.

Figure 2: (A) CAD model of single tooth model, (B) single tooth model meshed for FEA, and (C) section view of tooth showing fine mesh layer near the surface of the tooth.

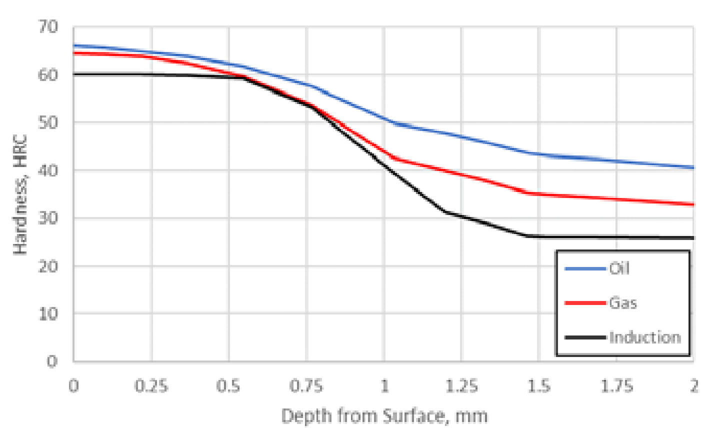

Figure 3: Hardness comparison in the root for the three processes.

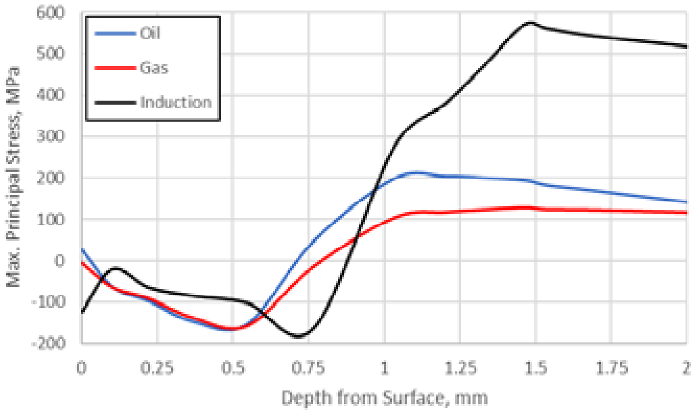

Figure 4: Maximum principal stress comparison in the root for the three processes.

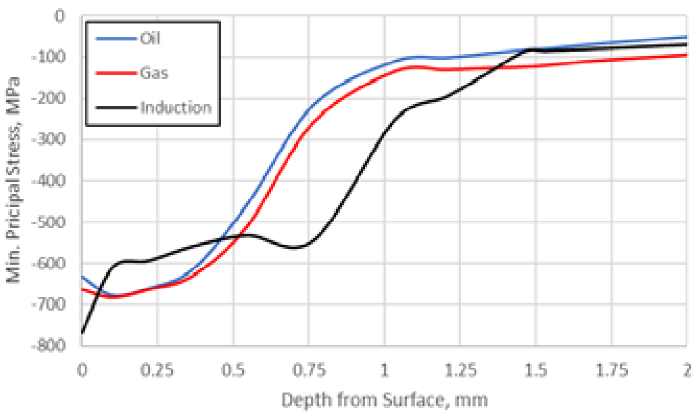

Figure 5: Minimum principal stress comparison in the root for the three processes.

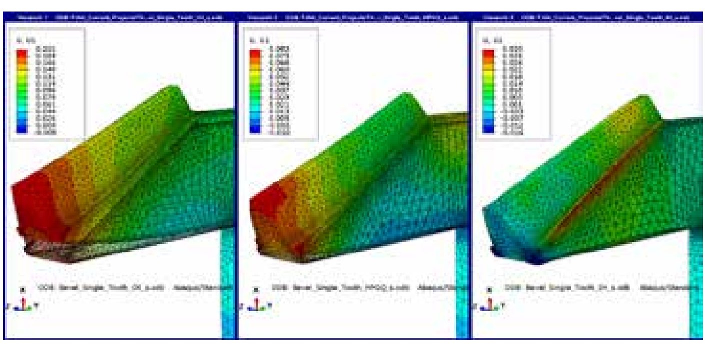

Figure 6: Axial distortion comparison of the tooth for the three processes.

is not needed for this comparison.

While the hardness is required for the gear to have the required strength, the residual stress in the root-fillet area is of the upmost importance when discussing bending fatigue performance. Any compressive residual stress will, in effect, offset the load experienced in the root-fillet of the tooth, effectively lowering the actual stress seen at the root-fillet of the tooth and improving bending fatigue performance. Figure 4 shows the predicted Maximum Principal stress profile plot through the root-fillet of the tooth. Figure 5 shows the predicted Minimum Principal stress profile through the root of the tooth. As can be seen in Figure 4, The Maximum Principal stress is approximately equivalent through the case for all three processes, but the induction hardening process generates a high tensile stress under the surface. The high stress may cause cracking if any type of defect is present in that location, creating a stress concentration. The higher tensile stress in the induction-hardened tooth is a result of the deeper compressive stresses and the sharp transition from transformation products to the base microstructure.

Although the surface hardness and residual stress are extremely important, the final distortion is also critical since any distortion may require post-heat treatment finishing operations. These finishing operations will alter the hardness and residual stress profiles. Figure 6 compares the predicted deformation of the gear in the axial direction for the three processes. The original shape of the mesh is overlaid to help with visualizing the amount of distortion. The distorted shape has also been magnified 25X to help show the distortion better. As can be seen in Figure 6, induction heating and spray quenching produces the least amount of distortion, approximately 15μm of deflection and almost no taper. This is due to only the surface layer being heated and transformed to austenite, and then to martensite. For this geometry, oil quenching caused the most distortion, approximately 200μm of deflection and 100μm of taper, though this is not always the case. Distortion is dependent on cooling uniformity, which is dependent on cooling rate and geometry [4]. This also helps explain the small distortion from induction hardening; since there is only a thin layer heated, the uniformity during quenching is easier to maintain, regardless of geometry. However, induction tooling comes at a great cost and must be justified. High-pressure gas quenching also comes with a high capital investment. So, even though these two processes produce less distortion than oil quenching, and as such will require fewer post-heat treatment finishing operations to correct the distortion, they come at an increased cost.

In conclusion, using heat treatment simulation software, such as DANTE, can be a powerful tool when determining the correct process for a particular component. Modeling can also be used to optimize a process for a given part geometry. For example, the process timing, with respect to heating rates and dwell times, may be able to be modified to reduce the high tensile stress in the induction-hardened gear. A different heat transfer coefficient in the oil quench, realized by changing the quench oil, could possibly reduce the distortion of the tooth during oil quenching. While there is no clear answer as to which process should be chosen, this will be dependent on application and specifications, heat-treatment simulation modeling can help designers understand how the distortion will affect fatigue performance by evaluating the residual stress profile and comparing it to the amount of material which must be removed due to distortion.

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Justin Sims is a mechanical engineer with Dante Solutions, where he is an analyst of steel heat-treat processes and an expert modeler of quench hardening processes using Dante software. Project work includes development and execution of carburization and quench hardening simulations of steel components and analysis of heat-treat racks and fixtures. He has a mechanical engineering degree from Cleveland State University.

D. SCOTT MACKENZIE, PH.D., FASM
SENIOR RESEARCH SCIENTIST–METALLURGY /// QUAKER HOUGHTON INC.

The basic principles of the solution heat treatment of aluminum, from problems to corrective actions.

Heat treatment of aluminum – Part II

In my article last month, I discussed the alloying elements used in aluminum alloys. In this article, I will be discussing the solution heat treatment of aluminum. In subsequent articles, I'll discuss the other unit processes of aluminum heat treating.

HEAT TREATING ALUMINUM ALLOYS

Aluminum alloys are classified as either heat-treatable or not heat-treatable, depending on whether the alloy responds to precipitation hardening. In the heat-treatable alloy systems such as 7XXX, 6XXX, and 2XXX, the alloying elements show greater solubility at elevated temperatures than at room temperature. The general sequence of heat-treating aluminum is shown in Figure 1. The temper designation describes fully the process sequence. The temper designations will be discussed in a later article on aging.

SOLUTION HEAT TREATMENT

The purpose of the solution heat treatment is to obtain the maximum practical solid solution concentration of the hardening solutes such as copper, magnesium, silicon, or zinc. The solubilities of these elements increase markedly with temperature, especially just below the eutectic melting temperature. Consequently, the most favorable temperature for solution treatment is close to the eutectic temperature, typically only 5° to 8°C (10° to 15°F) below the eutectic temperature.

Solution treating is done close to the eutectic temperature (Table 1), therefore good control, and uniformity of temperature within furnaces are essential to avoid incipient (eutectic) melting in grain boundary regions. This can result in a decrease in both strength and ductility. In addition, quench cracking is sometimes encountered when the normal solution temperature is exceeded.

Tight temperature control is particularly critical for 2xxx alloys such as 2014, 2017, and 2024, for which the initial eutectic melting temperature is only a few degrees higher than the recommended maximum solution temperature. More latitude in the solution heat-treating temperature is generally permissible with the 7xxx series than with the 2xxx series alloys.

Increasing the solution heat-treating temperature from 350°C up to the limit of solubility, then quenching and artificially aging, tends to increase the mechanical properties of the alloy. After the solubility limit is reached, there is little benefit to increased solution heat-treating temperatures [1] [2] [3]. However, increasing the solution heat-treating temperature has been reported to accelerate aging [4], and provide an increase of hardness [5].

The time required at the solution heat-treating temperature depends upon type of product, alloy, casting, or fabricating procedure used, and section thickness. Typical soak times are shown in Figure 2. Air is the usual heating medium, but molten salt baths or fluidized beds are advantageous in providing more rapid heating.

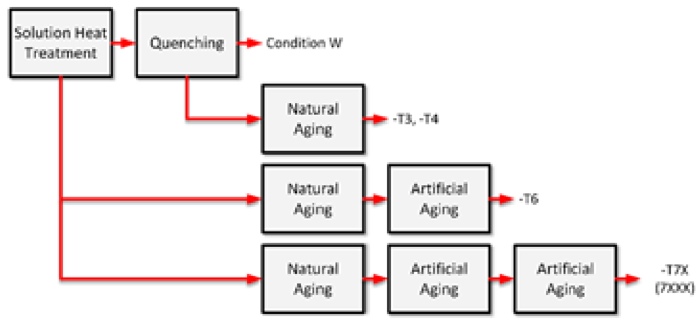

Figure 1: General sequence for heat-treating aluminum alloys.

Alloy	Solution Heat Treatment Temperature Range, °C	Initial Eutectic Melting Temperature, °C
2014	496-507	510
2017	496-507	513
2024	488-507	502

Table 1: Solution heat treatment temperatures and eutectic melting temperatures for 2XXX alloys.

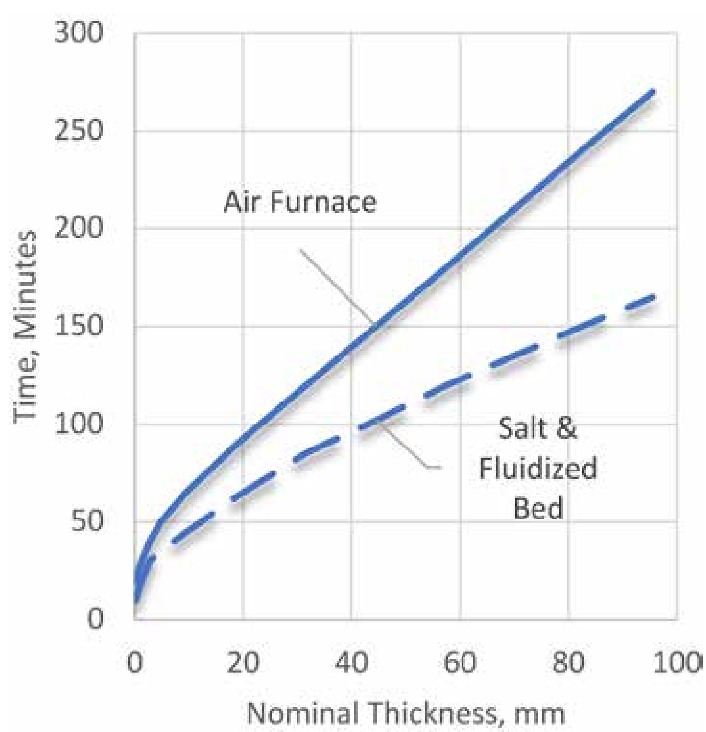

Figure 2: Typical soak times of wrought aluminum in air furnaces and salt or fluidized bed furnaces.

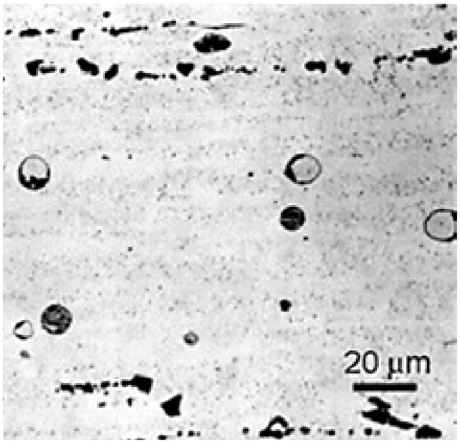

Figure 3: Incipient melting in a 2024 alloy due to excessive solution heat treating temperatures.

Figure 4: Blistering occurring in a 7XXX alloy.

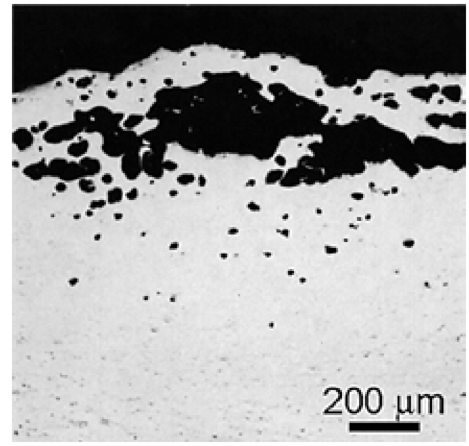

Figure 5: Typical porosity from High Temperature Oxidation.

High-temperature oxidation, evidenced by the formation of small rounded voids or crevices within the metal and by surface blisters, may occur because of heating aluminum products at solution heat treating temperatures in moisture-laden atmospheres.

The effect of time at the solution heat-treating temperature on increasing mechanical properties has been studied extensively [1] [6]. There is little benefit to extended solution heat-treating times. The long times generally cited in product heat-treating specifications are to ensure that the entire product with a given heat-treating load reaches the process temperature. Increased time can cause increased oxidation, blisters, and a decrease in properties from grain growth [7]. Excessive soak times can also lead to excessive diffusion of the aluminum-clad surface [8]. Reheat treatment of clad products thinner than 0.75 mm (0.030 in.) is generally prohibited by specifications.

Heating rate is often cited for causing incipient melting [9]. This is related to the S Phase (Al_2CuMg). The S phase is slow to dissolve. This can result in local non-equilibrium melting at temperatures from 475° to 490°C if the product is heated rapidly [10] [11] [12]. At slow heating rates, the S phase (Al_2CuMg) has time to dissolve in the matrix, and incipient melting is not observed. Incipient melting in an aluminum alloy is shown in Figure 3.

Eutectic melting is often not apparent until tensile testing or metallographic examination is performed. This is usually manifested by low elongation or poor ductility. Luckily, eutectic melting is often accompanied by high-temperature oxidation.

High-temperature oxidation is a misnamed condition of hydrogen diffusion that affects aluminum surfaces at elevated-temperature [13]. When moisture encounters aluminum at high temperatures, atomic hydrogen is formed. This hydrogen can diffuse into the metal and collect at grain boundaries and lattice defects. This results in surface blistering and porosity (Figure 4 and Figure 5).

Not all alloys and product forms are equally vulnerable to this type of attack. The 7xxx series alloys are most susceptible, followed by the 2xxx alloys. Extrusions are the most susceptible form; forgings are second. Low-strength alloys and alclad sheet and plate are relatively immune to high-temperature oxidation.

Moisture can be minimized by thoroughly drying parts and racks before they are charged. Drain holes often are needed in racks of tubular construction to avoid entrapment of water. Another common requirement is adjustment of the position of the quench tank with respect to furnace doors and air intake to reduce moisture entrainment by the furnace.

The most common method to alleviate blistering is use of a protective compound such as ammonium fluoroborate in the furnace [14]. Such a compound usually is effective in minimizing the harmful effects of moisture and other undesirable contaminants because it forms a barrier layer or film on the aluminum surface. Other methods include anodizing the aluminum surfaces.

CONCLUSIONS

In this short article we have described the basic principles of the solution heat treatment of aluminum. Several problem areas have been identified, and possible corrective actions have been detailed.

Should there be any comments on this article, or suggestions for other articles, please contact the editor or the author.

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JASON SCHULZE
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Whether it's the wide range of uses and sensitivities or its path from discovery to wide industrial use, aluminum is an interesting metal.

A brief history of the non-ferrous alloy aluminum

Non-ferrous alloys have caught my interest throughout my career, particularly aluminum. From its resistance to corrosion to its sensitivity at elevated temperatures, it is an interesting material. Moreover, it changed the aerospace and other industries due to the material properties of aluminum.

Following are some of the more interesting aspects of aluminum.

A HISTORY

Aluminum is not a rare metal; it constitutes around eight percent of the Earth's crust. Its late appearance on the metals scene can be attributed to its strong attraction to oxygen. It binds itself tightly in chemical combinations that are extremely difficult to break down from composites such as clays, schists, and mica (types of minerals). The oldest known of these composites — for centuries referred to as "earths" — is alum, which was used in China 3,800 years ago in the preparation of medicines and tanning. In the centuries after that, "earths" took on the name "pure clay," then "alumina," from which the name "aluminum" comes.

SLOW DEVELOPMENT

In 1807, five new metals were discovered by British chemist Humphrey Davy (1778-1829). One of these five was aluminum. Due to aluminum's strong attraction to oxygen, he was unable to isolate the aluminum using an electric arc. In Paris, 1854, Henri Sainte-Clair Deville (1818-1881) (Figure 1) continued experiments to isolate aluminum. He was convinced electrolysis was the most efficient way to produce high-volume pure aluminum. He began experiments using electrolysis, but soon found the cost of battery power was too expensive and had to end his experiments.

BEGINNING OF THE ALUMINUM INDUSTRY

In 1860, Sainte-Clair Deville partnered with Henry Merle, the founder of the PCAC, which produced soda. This plant had the necessary raw materials (bauxite) in place to launch aluminum production. Sainte-Clair Deville was the first to introduce bauxite (15-30 percent aluminum) into the process. Bauxite gets its name from the village Baux-de-Provence, where it was discovered in 1821.

Figure 1: French postage stamp from 1955 commemorating Henri-Étienne Sainte-Claire Deville's work with aluminum.

Due to the red color of bauxite, it was originally thought that it would be good for the steel industry. Analysis showed that it was low in iron content but had high alumina content. Forty years later it would be the raw material of the aluminum industry. In 1887, Karl Bayer (1847-1904) patented a process that would be adopted in 1893. The first refinery to purchase the license was Gardanne in the Bouches-du-Rhone region of France. The process uses bauxite mixed with caustic soda, dissolved by heating at high pressure to 250°C (482°F) in autoclaves, then decanted and filtered. The hydrated aluminum oxide is separated from the cooled filtrate and calcined (dried) to obtain an alumina suitable for electrolytic process (Figure 2). This process was adopted in the 1950s following technological advances, particularly the development of an automated chain of operations.

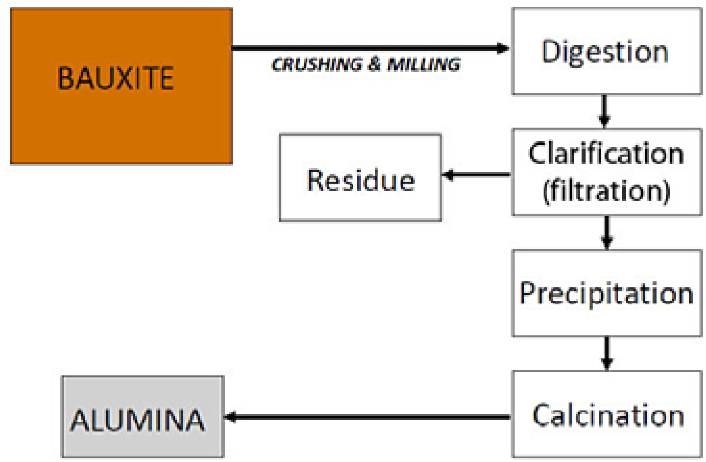

Figure 2: Karl Bayer's process was adopted in the 1950s following technological advances, particularly the development of an automated chain of operations.

MINING RESOURCES AND CONTROL

It takes four tons of bauxite to produce two tons of alumina, which is needed to produce one ton of aluminum. Controlling mining resources was of primary concern in the aluminum industry. Small-scale production sites were opened in various areas that were subsequently bought by larger entities in the highly competitive industry. France held the top position in bauxite mining until the end of WWI. Today, known reserves are estimated at more than 20 billion tons, representing three centuries of production at the current rate. The principal production zones are Australia, Africa, China, India and subtropical America (Figure 3). The last French mine closed in 1991.

ALUMINA TO ALUMINUM – ELECTROLYSIS

The aluminum oxide is melted and electrolyzed. The anode is made of graphite, a form of carbon. Oxygen ions move to the anode where they're converted to oxygen. The anodes are gradually worn away by oxidation. The cathode is also made of graphite. Molten

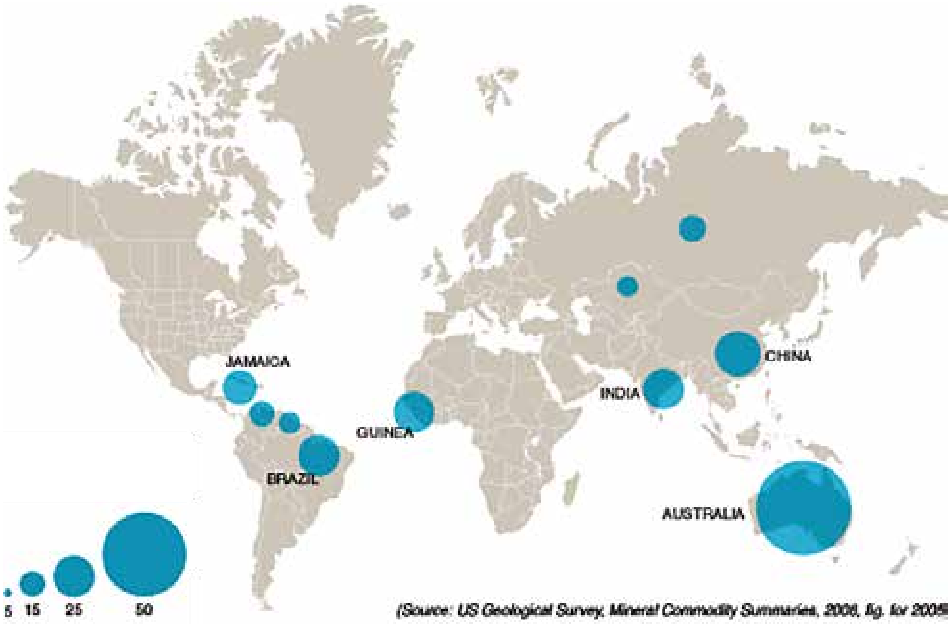

Figure 3: The principal production zones are Australia, Africa, China, India and subtropical America.

aluminum is produced there. The process requires a lot of electrical energy, which is one reason why aluminum is more expensive than steel (Figure 4).

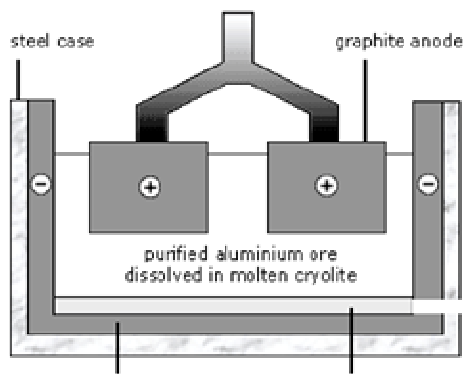

Figure 4: The electrolysis process requires a lot of electrical energy, which is one reason why aluminum is more expensive than steel.

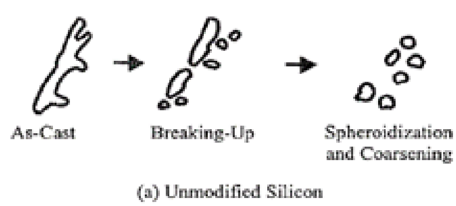

Figure 5: Silicon particles are broken down into smaller fragments and gradually spheroidized.

HEAT TREATMENT OF ALUMINUM

Aluminum is typically classified as two types: heat treatable and non-heat treatable. Following this, alloys are then classified in temper codes designated by the Aluminum Association. By definition, heat treatable aluminum alloys are those that can be strengthened by a suitable thermal process for that particular material. Let's use A356 as an example. Solubility of the alloy elements within A356.0 are directly related to temperature, although alloy element wt% is a critical factor.

In general, solution heat treating takes advantage of the precipitation hardening reaction. Its objective is to take into solid solution the maximum practical amount of the soluble hardening elements in the alloy. This process also consists of soaking the alloy at a temperature sufficiently high and for a long enough time to achieve a nearly homogeneous solid solution. Keeping with our example, solution heat treating of A356 castings produces the following effects: it dissolves Mg2Si, homogenizes the casting, and changes the morphology of eutectic silicon. One of the most important aspects of this is the dissolution of Mg2Si. Under equilibrium conditions, the solubility of the precipitating Mg2Si phase decreases with temperature. A casting removed from the mold at 800°F will have approximately 0.3 percent Mg in solution. At 700°F, approximately 0.2 percent Mg will be in solution. This means that a drop of 100°F will result in a loss of approximately one third of the strength available from dissolved magnesium.

To obtain the maximum concentration of magnesium and silicon, the solution temperature must be as close as possible to the eutectic temperature, ideally 10° – 15°F below the eutectic temperature.

Control of temperature is critical. If the melting point is exceeded, incipient melting (localized melting at the grain boundary) may occur and mechanical properties may suffer. This condition is only detectable by metallographic examination and is irreversible. Hence, most aluminum solution heat-treating furnaces must have a temperature uniformity of ±10°F.

Solution heat-treating time is critical to ensuring the mechanical properties are conforming.

As discussed earlier, this is due to the vital role that the eutectic silicon morphology plays in obtaining satisfactory mechanical properties (Figure 5). In short, silicon particles are broken down into smaller fragments and gradually spheroidized (in physical metallurgy, a process consisting of the transition of excess-phase crystals into a globular — spheroidal — form). Prolonged solution time may, in turn, lead to coarsening silicon particles.

QUENCHING

The purpose of quenching is to keep the Mg2Si from forming precipitates. If done correctly, this yields maximum strength and good elongation in castings. Two variables affect the rate of cooling: quench delay and quench medium and its respective temperature.

VERIFICATION OF PROPERTIES

Verification of properties is typically done in two ways — hardness testing and conductivity testing. This can be dependent on the material and thickness as well as state (i.e. casting, machined bar, etc.). Tensile testing may also be used depending on material process specifications.

SUMMARY

Several materials stand out, depending on an engineer's interest. Nonferrous alloys are particularly interesting due to their wide range of uses and sensitivities. I hope this article allowed readers to appreciate the different aspects of aluminum.

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ABOUT THE AUTHOR

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ISSUE FOCUS ///

FORGING / MAINTENANCE

THE CUTTING EDGE OF THERMAL PROCESSING IN A FORGE ENVIRONMENT

A 76-foot-long tip-up furnace heating hollows. (Courtesy: Scot Forge)

Keeping up with what customers seek from the thermal treatment of their forgings: more precision, more consistency, more reliability, more data.

By JOE WEAVER

Scot Forge is a 128-year-old, 100-percent employee-owned forging company that works in multiple markets from large defense, aerospace, power generation and mining projects to small machine shop and single bar orders. Over the years, our owners have made substantial investments in thermal processing equipment with nine custom-designed quenchant systems that work in tandem with more than 53 furnaces and use specialized material handling equipment. However, as customer requirements change, our company faces challenges that have never been seen before, from extreme shapes, geometries, and custom materials to mechanical properties and detailed documentation of information. Customers seek more from the thermal treatment of their forgings — more precision, more consistency, more reliability, more data. Which begs the question: How can Scot Forge keep up with the everchanging demands of customers in a matured area of the business?

EQUIPMENT: STAYING MALIABLE WITHOUT MELTING

In today's environment, technology is rapidly changing and quickly rendering new equipment obsolete. For Scot Forge, this, coupled with the financial investment of new equipment, has compelled our company to know and extensively document what can and cannot be achieved with the current heat-processing equipment. We lean heavily on our employee-owners for innovation and research and development, rather than continuously purchasing new equipment to take on the thermal processing of nonferrous alloys and nonsymmetrical forgings. To better understand the capabilities and limitations of the furnaces and quench systems, Scot Forge routinely examines the equipment, employs modeling software, uses destructive testing and documents best practices.

Most of the furnaces at Scot Forge were engineered in-house and created for the thermal processing of steel, which posed a problem when nonferrous alloys began making their way through the plants. To understand the differences between these alloys' chemical characteristics and how they would respond to different thermal techniques, Scot Forge invested in metallurgical engineers and a state-of-the-art metallurgy lab. Bringing testing in-house gives us a more reliable and better-documented analysis of forgings and how thermal treatments affect the way they react under simulated environmental conditions. The Met Lab not only serves as a conduit for quick refinement to the thermal-processing equipment and techniques, but it also helps capture the capability of the existing equipment.

Understanding if we can work with an alloy is half the battle; the other half is developing a robust and replicable process to assure meeting required properties. By using modeling software, forge engineers can run through different scenarios with customers, heat-treat operators and metallurgists to study how a forging will react to heating and cooling. The simulation outcome may lead to media-flow improvements, quench-media changes, better part placement, design or material modification recommendations, or the conclusion that there is a need for new equipment. These adjustments can help lead to better mechanical properties and minimize the risk of cracking or distortion due to quench stresses. However, the simulation results are only reliable in the real world if the equipment is operating correctly and consistently. When working with cross-sections that change from 10 inches to 40 inches or thermal treating hollows that are 200 inches long with a 30-inch diameter, it is essential to understand and maintain furnace uniformity to ensure quality. Scot Forge has invested in the capability to check furnaces by way of thermal imaging equipment to detect hotspots and monitor a forging throughout thermal processing to ensure more precise and consistent heat treatments for customers.

Finally, Scot Forge optimizes equipment through thorough documentation of testing and best practices. While this may not seem like something substantial, it is. It gives us the ability to:

› Easily pass knowledge to different operators ensuring consistency and meeting customer requirements throughout shift changes and at our other plants.

› Pass techniques to the next generation of employee-owners to build on.

› Discover trends to help establish the need for modifications or new equipment, which is just as important as knowing how to work with what is currently in place.

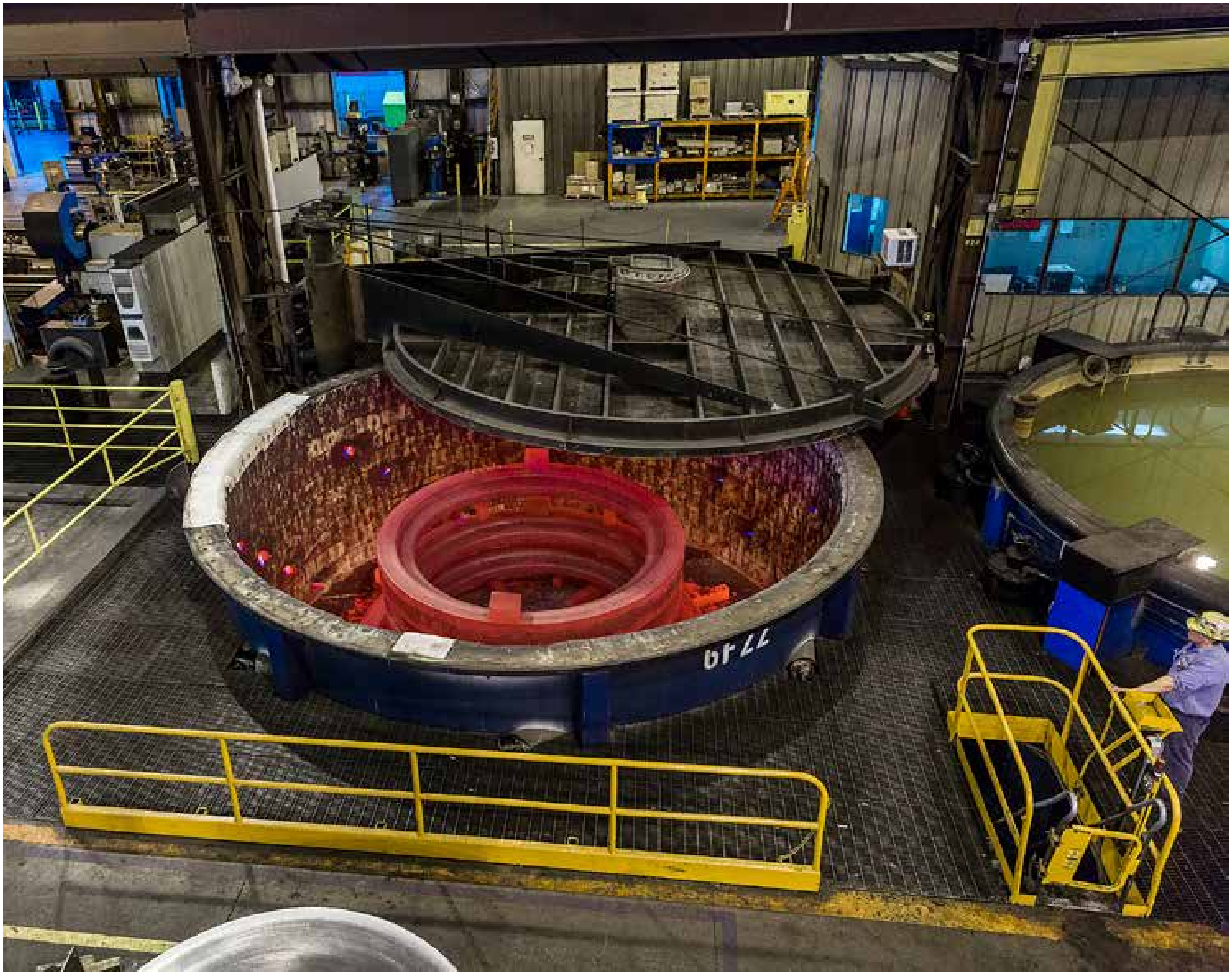
MEETING DATA AND TECHNICAL EXPECTATIONS

For many Scot Forge customers, data and documentation are more important than the part itself. They are ordering larger, more intricate forgings that demand unique alloys and considerably complex technical requirements that include thermal processing. Additionally, customers request parts that historically have come from fabrications or castings to be redesigned as forgings, creating the challenge of exceeding the established performance expectations. To meet these new demands, Scot Forge has a multifaceted approach starting with our front-line sales team, which has more than just a basic fundamental understanding of thermal processing. Many members of the sales team began their careers in the shop, giving them firsthand experience of processes, and all of them have been through thermal processing training with our degreed metallurgists. With an understanding of our capabilities and the customer's needs, the sales team can align metallurgy, forge engineering, thermal processing operators, destructive testing, third-party witness and quality/certification teams to ensure requirements are met and documented.

From billet to the final product, the forging is tracked through serialization that is stamped on a part during forging and maintained through thermal processing to ensure traceability. The heat-treat operators then implement and monitor the heating and cooling of the forging to collect and document the required data. To aid operators, increase accuracy and decrease the amount of time spent on clerical functions, Scot Forge invested in automating much of

Large spindles are water quenched in a 60,000-gallon quench tank. (Courtesy: Scot Forge)

To better understand the capabilities and limitations of the furnaces and quench systems, Scot Forge routinely examines the equipment, employs modeling software, uses destructive testing and documents best practices.



A 20-foot diameter pit furnace heats rings next to the 42,000-gallon polymer and water quench pit tank. (Courtesy: Scot Forge)

the thermal process. Better furnace controls and apps on tablets have made it possible to capture real-time data in one step. Then, our metallurgists use the information gathered to help review test specimens for correct properties and microstructure through specimen examination under a microscope, tensile or charpy impact tests. Sometimes a third-party witness is required during thermal processing and testing to verify adherence to processing procedures. All the information gathered from thermal processing and metallurgy is then passed on to the quality and certification teams for product authentication.

For Scot Forge, staying on the cutting edge of thermal processing sometimes means reinvesting in our company with new assets, as we have purchased furnaces dedicated explicitly to specific alloys. Nevertheless, investment pales in comparison to hiring and training the right people since the equipment is only as good as the people planning, maintaining and operating it. Furthermore, capturing and disseminating more than a century of learning has proven invaluable to our ability to take on new challenges.

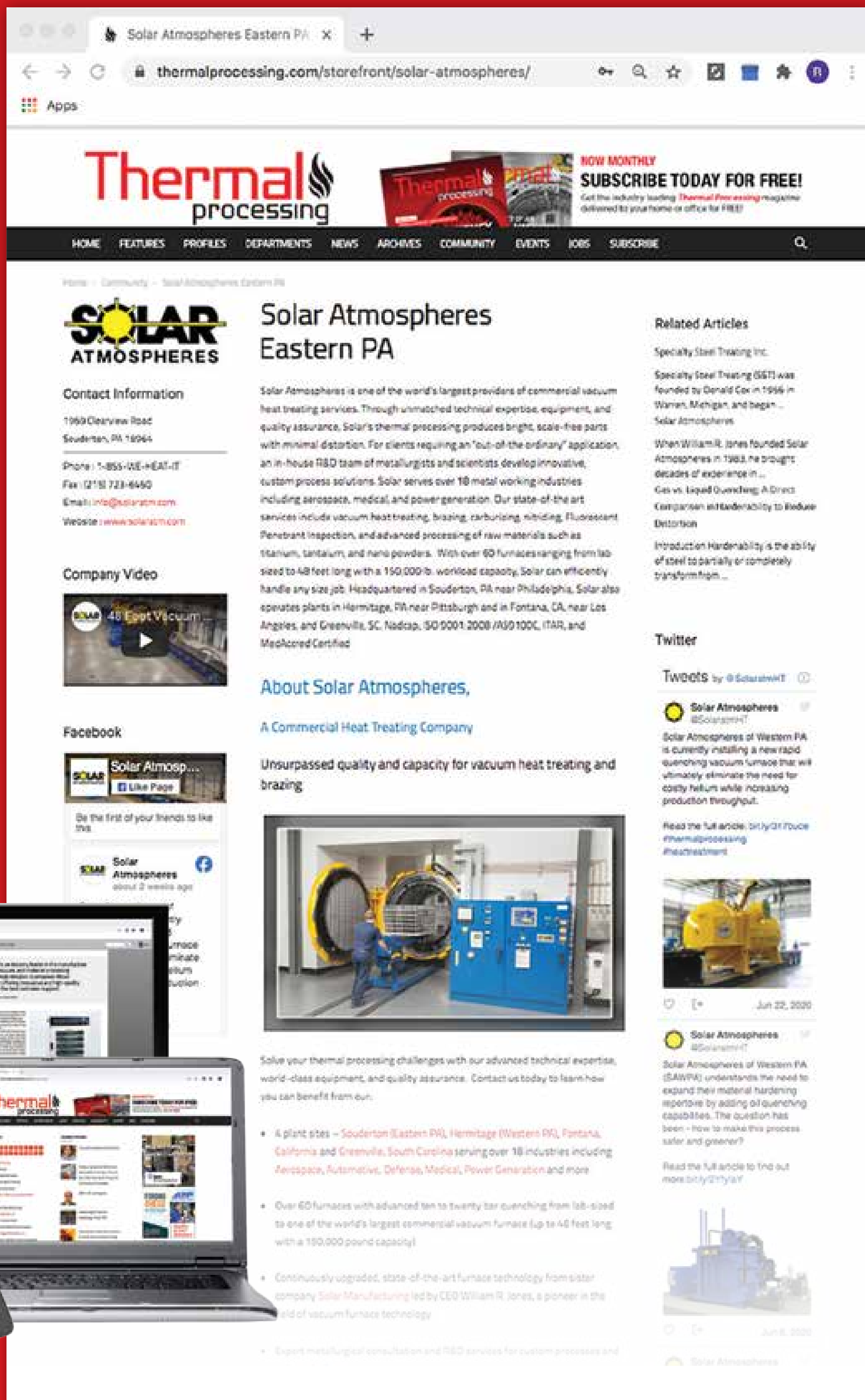
ABOUT THE AUTHOR

Joe Weaver is the heat-treat supervisor at Scot Forge and has been with the company for more than 13 years. He received his Bachelor of Science degree in metallurgical engineering from Missouri University of Science & Technology. Prior to becoming the heat-treat supervisor, Weaver held positions at Scot Forge as a process engineer and manufacturing engineer.

AT THERMAL PROCESSING, COMMUNITY IS MORE THAN A WORD, IT'S A PROMISE

Thermal Processing's online Community resource is your gateway to the manufacturers and service providers in the industrial heat-treating market.

If you're looking for a specific product or service — and the company that can fill that need — a quick-and-easy solution is just a click away at thermalprocessing.com.



A REVIEW OF LUBRICANT REMOVAL SYSTEMS AND THE LATEST TECHNOLOGY

Combining the understanding of lubricant removal with the knowledge of atmosphere control and heat can produce a system capable of functioning at an optimal level for a wide range of production levels and part sizes.

By **STEPHEN L. FELDBAUER**

Whether a component is produced through binder-jet additive manufacturing, metal injection molding, or conventional press and sintering, lubricant removal continues to be one of the most common issues in sintering. As with all technologies, new forming techniques have resulted in the development of new lubricants. The result is the need for even more understanding and process development in lubricant removal. A review of the "old rules of thumb," current solutions, and where the lubricant removal technology is headed will help to lay out a roadmap for dealing with this issue today and into the future.

BACKGROUND

There are two common steps to the manufacturing process of powder metal components, shaping the powder into the desired component geometry and sintering the component to develop the desired properties of the material. In each of these steps, the lubricant that is added to the powder is a key consideration. During the forming step, such as compaction, the lubricant provides lubrication when it melts and moves to the surfaces of the die. Lubricant is necessary for the ejection of the compact, prevents cracking of the compact, and improves tool life. Unfortunately, the lubricant that was so necessary in the shaping step must be removed from the powder metal compact before the powder metal particles may sinter together.

The lubricant that coats each particle now acts as a barrier between the particles and may hinder the sintering process. Hence, the lubricant must be removed from the compact in the initial stages of the sintering process. Failure to adequately remove the lubricant may result in a number of problems within the part and the sintering furnace.

The most common type of lubricant used in the conventional powder metal process is Ethylene Bis-Stearamide (EBS), also known as Acrawax-C from Lonza Group. This material is reported to have a melting point of 140°C (284°F) and a boiling point of 260°C (500°F). One may conclude that the lubricant should melt and boil out of the compact early on in the sintering process; however, this is not the case.

In work by Powell, et. al, EBS was observed as a function of temperature. It can be seen in Figure 2 that the EBS does not boil at 260°C (500°F). In fact, it remains as a liquid to approximately 540°C (1,000°F) and then totally dissociates to carbon and hydrogen. This solid carbon, or soot, that is formed is the root cause of lubricant removal issues in the powder metal process. Varying in degrees of severity, soot can be found on the parts, in the parts, and in the furnace.

Another important observation noted that, once the EBS melts, carbon begins to be present in the liquid as a solid until the entire solution becomes solid carbon. This was explained in a mechanism first proposed in lectures by Levanduski, et. al. of Abbott Furnace Company. (Figure 3)

Figure 1: The Vulcan.

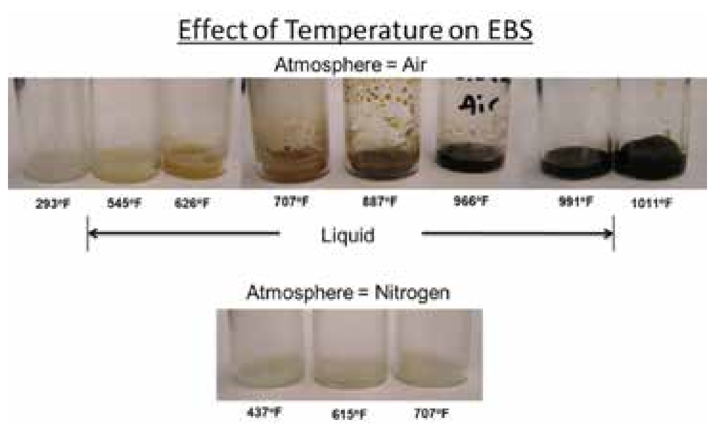


Figure 2: Effect of temperature on EBS [2].

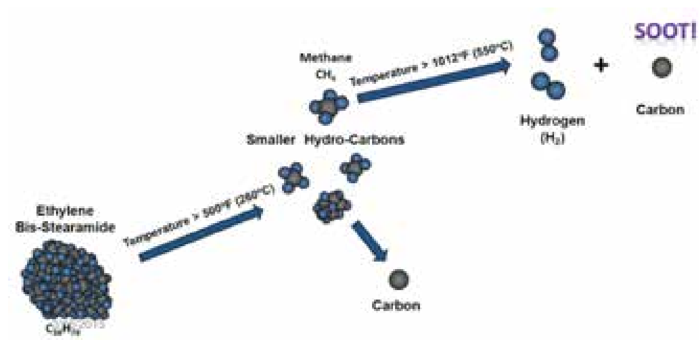


Figure 3: Sooting mechanism of EBS [1].

Like most hydrocarbon chains, as EBS is heated, it begins to break down into smaller hydrocarbon chains. It will eventually break down to become the smallest hydrocarbon, methane. Thermodynamically, methane is no longer stable once it reaches approximately 550°C

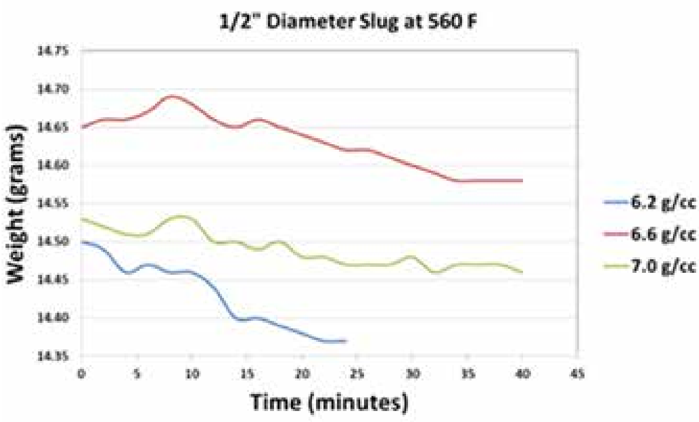


Figure 4: Time to remove EBS vs density [2].

(1,020°F), and it will dissociate into solid carbon and hydrogen. This is supported by the observation of Powell, et. al.

Powell, et. al. also note that the density of the powder metal compact plays a major role in the lubricant removal process. As the compaction technology improves to allow the production of compacts with an as-compacted density that is greater and greater, the time that is needed for the EBS to come out of the compact becomes longer. This forces us to reconsider the long-standing rule of thumb indicating 20 minutes was adequate for the removal of EBS. (Figure 4)

Here, we see the rule of thumb would work well for lower-density compacts that were common of the past; however, this is no longer a valid rule. The time for the lubricant to come out of the compact, hence the time for the compact to be between the temperatures of 140°C (284°F) and 540°C (1,000°F), must increase with the desire to compact to higher green densities.

Levanduski, et. al. point out one other important step in this mechanism: As the EBS breaks down, it cannot be divided into an even number of methane molecules. The result is carbon being left behind. This explains the presence of the carbon in the liquid of the melting study of Powell, et. al. This also points to another key aspect of the lubricant removal process: The lubricant comes out of the compact as a liquid and then boils to form a vapor; however, even though all of the liquid lubricant may be removed, there will still be solid carbon behind as the EBS dissociates.

LUBRICANT REMOVAL AIDS AND EQUIPMENT

Over the years, a number of devices and processing aids have been developed to aid in the removal of the lubricant and address the presence of carbon. The first sintering furnaces were single box designs where the compact would be preheated and the lubricant removal was to take place in the front of the heated box. It was then determined that two heated boxes on the furnace helping with the lubricant removal would allow for the rule of the thumb of 20 minutes in the first heated box to be maintained; however, as the density of the compacts increased and the sintering loads increased, this was not enough to address all of the lubricant removal issues.

The bubbler was the first device added to furnaces to help in the removal of lubricants and address sooting. (Figure 5)

The concept was to bubble nitrogen gas through water. The nitrogen would pick up moisture and carry it into the pre-heat section of the furnace. The injection location was typically placed two-thirds of the way into the pre-heat section. This coincided with the location where most products would reach approximately 650°C (1,200°F) because it could be seen in the furnace that this was the location where the soot began to form and collect. (Figure 6)

To further the capability of the bubbler, the water was then heated to accelerate the formation of water vapor that formed and was carried into the furnace.

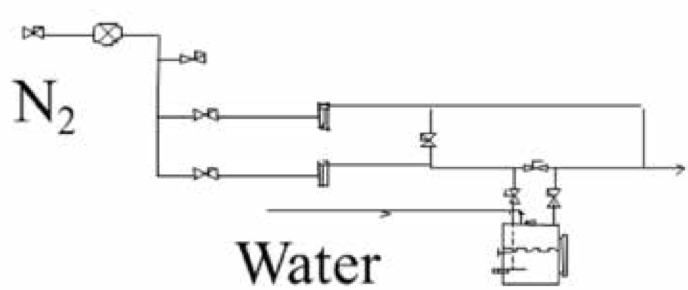


Figure 5: Bubbler and plumbing schematic.

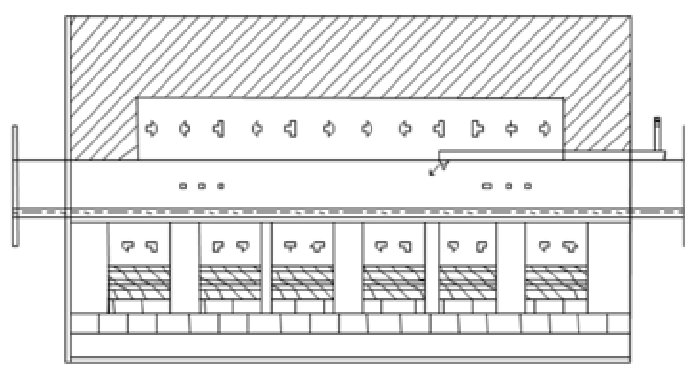


Figure 6: Injection location of moisture 2/3rds into pre-heat.

The degree of control of the bubble is limited because one only has the water temperature and nitrogen flow rate as adjustment variables; however, bubblers perform well for small to medium parts and production rates. They are capable of producing up to approximately 5 lbs/hr of water vapor. (Figure 7)

Unfortunately, the variability in the performance of the bubbler increases at the higher flow rates because the large amount of the

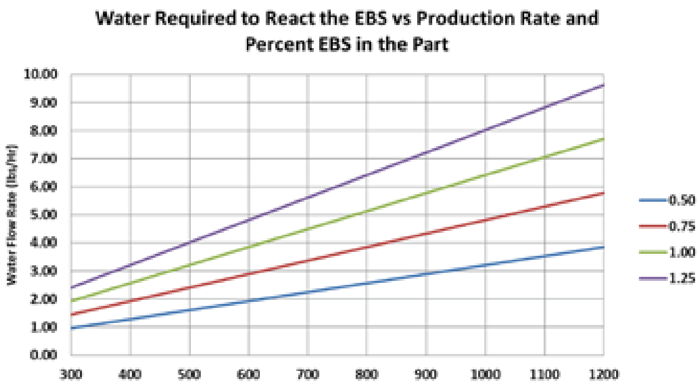


Figure 7: Water flow rate required to react EBS.

Figure 8: F.A.S.T. system and plumbing schematic.

nitrogen can often cause the water bath to become unstable and liquid water to be picked up by the gas. This liquid form of the water then causes surges in the actual amount of moisture being introduced into the furnace.

To address the control issues of the bubbler, a device was developed where water is dropped into a heater to form steam. The steam is then carried by a flow of nitrogen into the same injection location of the furnace as the bubbler. These systems are called F.A.S.T. systems. (Figure 8)

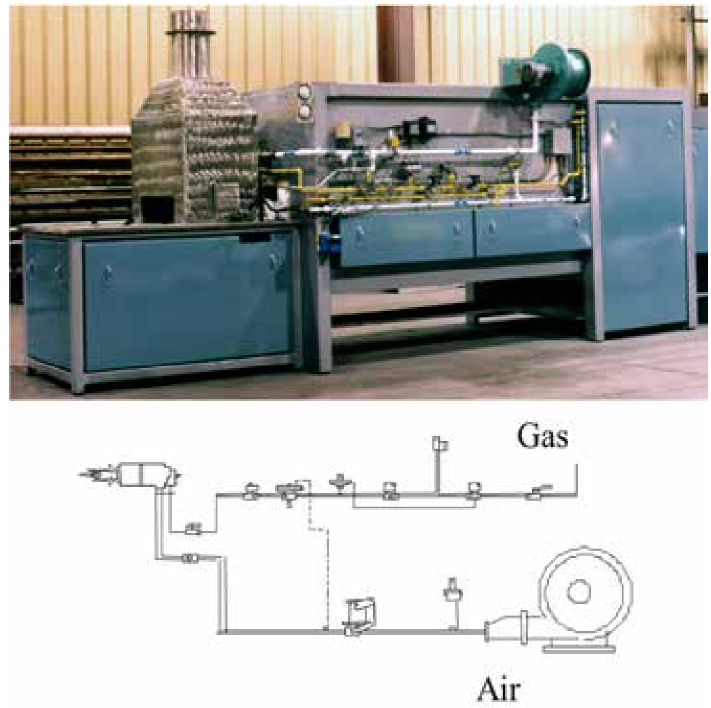


Figure 9: Q.D.P. and plumbing schematic.

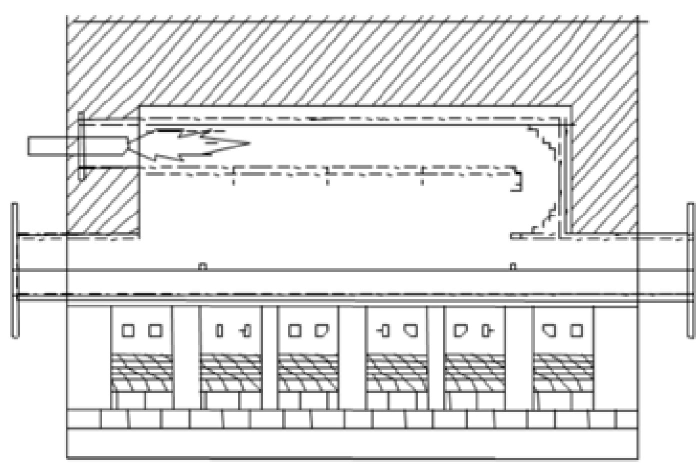


Figure 10: Schematic of Q.D.P.

Because the control variable is now the amount of water introduced to the heater, the degree of control is much better. The limiting factor is the heater size; hence, the amount of water vapor that can be produced. F.A.S.T. systems are typically limited to approximately 2.5 lbs/hr of water vapor. The systems work well for low production rates and small parts with less lubricant.

For production rates and large parts that require more water vapor to react with the lubricant, systems were developed that used a gas burner to produce the atmosphere. The air-to-fuel ratio of the burner is adjusted to produce the moisture containing atmosphere used to help in the lubricant removal process. A common example of this technology is a Q.D.P. (Figure 9)

The burner gas is produced in a chamber above the product as it enters. The gas is introduced to the product at the same location of the pre-heating step of the process as the other methods, approximately 650°C (1,200°F). (Figure 10)

Limited only by the size of the burner that is selected, the amount of water vapor that this type of system can produce is substantially larger than other systems. Due to the very large amount of moisture that is produced even when the burner is turned down to low fire, this system does not work well for small parts and light production loads.

These loads do not carry enough carbon-producing lubricant to react with the large amount of moisture produced. The result is an oxidation of the parts that is evident by frosting and decarburization.

The system is controlled by a thermocouple located in the upper combustion chamber. Since the burner produces heat while producing the atmosphere, the amount of moisture is directly influenced by the temperature of the chamber. This is a source of variability.

Another significant drawback to this type of system is the maintenance of the system. Burner performance will change over time. This requires a person knowledgeable in burner adjustment to routinely maintain the system.

Recognizing that the time to remove that lubricant from the compact continues to increase, the preheat sections of the furnace have continued to become longer, and technology has been developed to increase the time the compact is in the optimal temperature range for lubricant removal. One of these, referred to as a Zone 0, is a simple addition of an insulated neck to the preheat section of the furnace. The warm gasses exiting the furnace pass over the incoming components preheat them and help to start the lubricant to melt sooner. (Figure 11)

A further addition to this simple approach is to add the ability to inject heated air into the Zone 0. The air reacts with the excess combustible of the furnace atmosphere to produce heat. This addition to the system is called an L.B.T.

Although the Zone 0 and the L.B.T. both help to increase the time for lubricant removal, neither technology provides a means to deal with the carbon produced during the break-down of the hydrocarbon chain.

THE VULCAN

The lack of control is the underlying drawback to all of the technologies that have been developed to date. The temperature, time, sintering atmosphere composition, and moisture to aid in reacting carbon are often directly connected or limited in the degree of their control.

A recent development has been made that focuses on the need for better and independent process control. This system is called the Vulcan. It is a direct replacement for existing pre-heat box technologies. (Figures 1, 12a)

Because the optimal temperature range for lubricant removal is between 140°C (284°F) and 540°C (1,000°F), heating through radiation, as is used in conventional furnaces, is not effective. The Vulcan uses convective heating with variable speed fans to provide independent control of the heating rate and temperature profile of the compact. (Figure 12b)

The time in the optimal temperature range is controlled to 540°C (1,000°F) or less by the length of the system and the heating in each zone. This time is adjustable to match the incoming density of the compact, leaving the rule of thumb behind.

The moisture is also independent of all of the other variables. With the ability to produce from 0 to 12 lbs/hr of steam, the flow can be adjusted to provide as much or as little moisture needed to react with the carbon during the break-down of the EBS. This gives the system the ability to process small parts and loads as well as large parts and heavy loads in the same system.

Combining the understanding of lubricant removal with the knowledge of atmosphere control and heat has produced a system that has shown to function at an optimal level for a wide range of production levels and part sizes. Weight loss studies have shown 100 percent lubricant removal for Interlube E and EBS without oxidizing or decarburizing the compact.

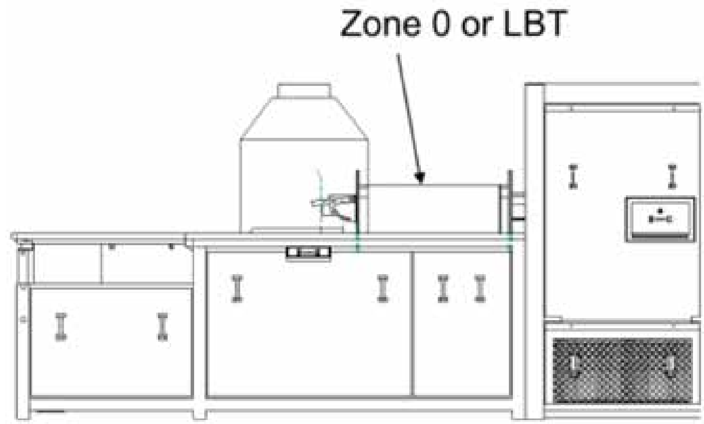


Figure 11: Schematic of Zone 0 and LBT.

Figure 12a: The Vulcan.

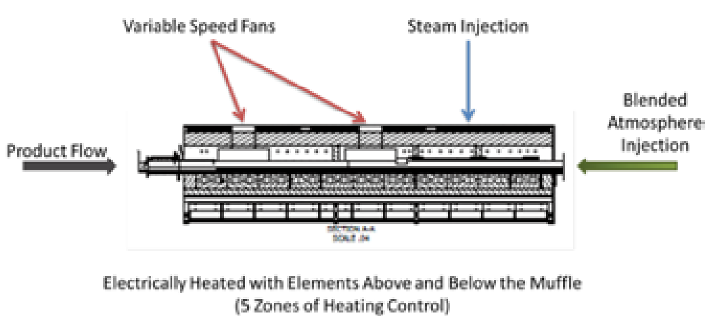


Figure 12b: Vulcan schematic.

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ABOUT THE AUTHOR

Stephen L. Feldbauer, Ph.D., is with Abbott Furnace Company in St. Mary's, Pennsylvania.

BUILDING A COMPETITIVE ADVANTAGE WITH QUALITY INDUSTRIAL GASES

Messer helps thermal processors address quality and productivity challenges of high-performance parts with proprietary gas technologies and innovative approaches. (Courtesy: Messer)

Messer may be a new name for many in the metals industry in the U.S. and Canada, but the company has more than 120 years of global experience in gases and gas technologies, and many of its people should be familiar.

Messer's heat-treatment portfolio spans industrial gases and atmosphere control systems for sintering, annealing, furnace brazing, carburizing and carbonitriding, neutral hardening, and sub-zero treatments. The company has gone through quite a few changes over the last year and a half. *Thermal Processing* had the opportunity to chat with Chris Ebeling, executive vice president, Messer (Bridgewater, New Jersey) about Messer's history and what the company can offer its customers.

Tell us a little bit about Messer and the genesis of Messer in the Americas.

Messer was founded in 1898 and today is the largest family-run specialist for industrial, medical, and specialty gases worldwide. The Messer Group has operations in Europe, Asia, and the Americas and generated consolidated sales of $1.49 billion (1.3 billion euros) in 2018. Today, following the formation of Messer Americas, the company represents a $3 billion global enterprise.

When did Messer get into the U.S. industrial gas market?

On March 1, 2019, Messer Group and CVC Capital Partners Fund VII (CVC) acquired most of the North American gases business of Linde plc, as well as certain Linde business activities in South America. We offer a portfolio of industrial gases and gas technologies developed both in Europe by the Messer Group and in the U.S. with our customers here. We are also now one of the leading privately held industrial gas companies in the region with over 70 production facilities and about 5,400 employees in the U.S., Canada, Brazil, Colombia, and Chile.

So, some Messer people will likely be familiar to our readers?

Yes. Many Messer employees joined us from Linde plc, so companies involved with metals, combustion, and metals processing, including heat treating and additive manufacturing, may already know some of our talented people. Many of us at our Americas headquarters in Bridgewater, New Jersey, work in the same offices as before only with a new corporate name on the door. Our Technical Center in Cleveland also has most of the same people in place.

Of course, manufacturers may also recognize Messer Cutting Systems (Menomonee Falls, Wisconsin), a Messer company in the U.S. since 1973, which makes laser-, oxyfuel- and plasma-cutting tools and control systems for North America. As part of our global organization, Messer Cutting Systems also has manufacturing operations in Sao Paulo, Brazil, as well as in Europe, India, and China.

Is there some synergy?

Messer already supplies the industrial gases for these cutting systems. In addition, machined parts and components are often heat-treated as part of the manufacturing process, either in-house or by a firm specializing in thermal treatment, so there is natural synergy. We also offer cryogenic cleaning systems, which can remove machine oils and other residues without water. Manufacturers with wastewater treatment systems may also benefit from Messer technology for odor control and lowering pH.

Messer produces argon, nitrogen, hydrogen, helium, and other industrial gases for metal heat treatment processes. (Courtesy: Messer)

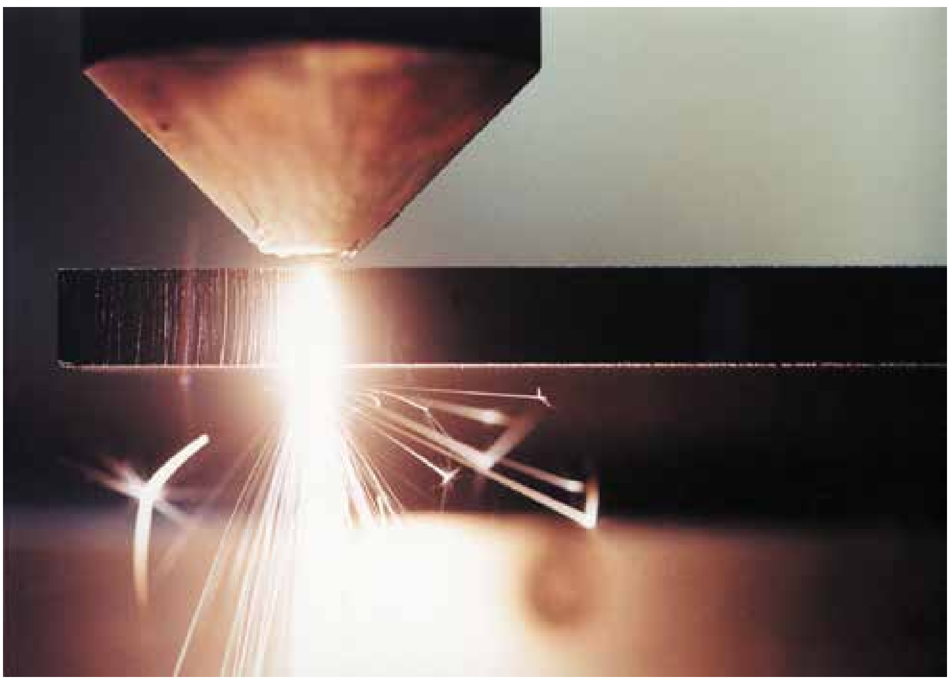
What sets Messer apart?

Our goal is to help customers build a competitive advantage through improvements in productivity, quality, process reliability, and reduced operating costs. So, it is not just the quality of industrial gas, but how the gas is supplied and applied during thermal processing that is key. Our installations include proprietary pressure-controlled gas delivery and process-control technologies. We work closely with customers and offer extensive experience with all types of combustion and heat-treatment furnaces — batch and continuous. With our technology and expertise, productivity gains of 20 to 30 percent or more are not uncommon in some applications. In other cases, it is more about repeatable quality, and improvements of 2 to 3 percent can make a major impact on throughput.

How does Messer in the Americas fit within the global organization?

As part of Messer's global organization, we adhere to core values such as customer orientation, corporate responsibility, and integrity. At the same time, we respond like a much smaller company. We encourage our businesses to be agile and entrepreneurial. Our technical experts have a deep understanding of gas processes and work with customers to identify needs and develop optimal solutions. We validate our solutions and can perform further testing and analysis at our Cleveland Technical Center.

Our goal is to help customers build a competitive advantage through improvements in productivity, quality, process reliability, and reduced operating costs.



Messer Cutting Systems (Menomonee Falls, Wisconsin), a Messer company in the U.S. since 1973, makes laser-, oxyfuel-, and plasma-cutting tools and control systems for North America. (Courtesy: Messer)

What about safety?

Safety is a Messer core value and integral to everything we do from project planning to service. Training is part of every new installation, and we train everyone at the plant in safety awareness and procedures, not just the operators.

What do you see as the trends and challenges in the industry today?

We find that each market has its own nuances. For example, aerospace and automotive sectors need lighter designs or more durable components or both. High-performance parts for defense or power generation often must withstand high torque, temperature extremes, or thermal cycling — and there is often little room for compromise. So, metal alloys and process quality must continually improve, and thermal processing is at the intersection of that challenge.

In applications such as robotics, there may also be high-performance requirements for parts such as gears. In other cases, complex designs or specialized components such as medical devices may require shorter runs or shorter design-to-manufacture cycles. Powder metals and additive manufacturing are playing a growing role in these applications. That, in turn, is fueling the need for tighter control in forming and post-treatment operations.

At Messer, we can help processors address such challenges and succeed, often with innovative solutions.

Can you summarize some processes where Messer has particular expertise?

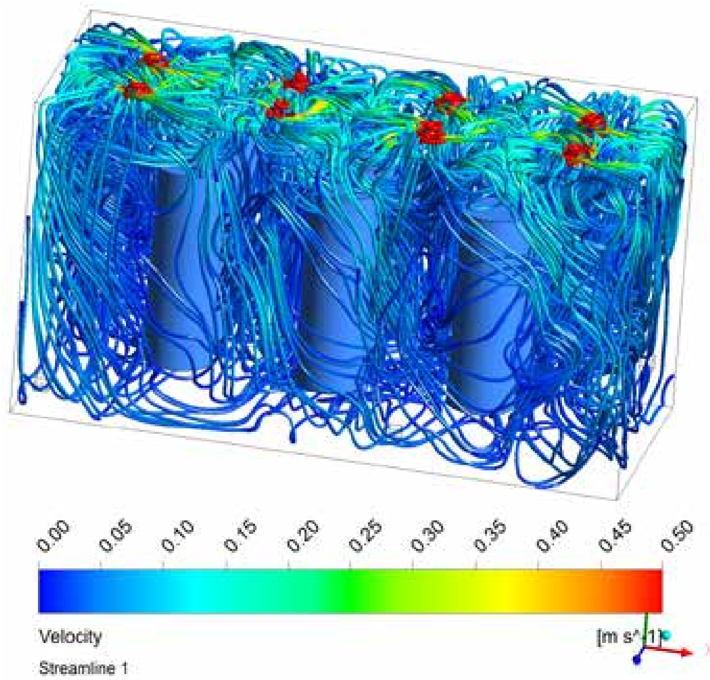
This is not a comprehensive list, but here are a few areas where we offer specialized technologies and process expertise:

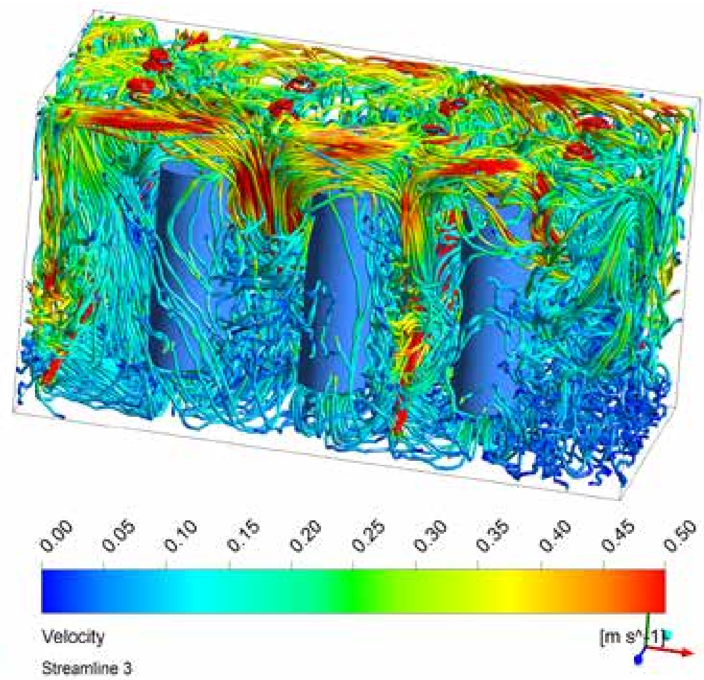
› **Furnace Efficiency & Convection:** Most types of heat-treatment furnaces — from roller hearth to pit — can benefit from improved convection, but fans are a perennial source of downtime. Fans take a beating and demand regular repair and replacement. We take a different approach — high-speed gas injection (HSGI) technology. Messer HSGI uses high-velocity injections of inert gas through proprietary injectors to improve circulation and gas interaction with parts and to promote heat-transfer efficiency, which, in the end, enhances quality and productivity.

› **Oxyfuel Combustion:** We offer customized oxyfuel and air-oxyfuel burners in all sizes and solutions for pre-heating steel for reheat furnaces for rolling mills and forges. We also offer proprietary oxyfuel technology for remelting aluminum, which greatly improves radiant heating with lower NOX — effectively improving furnace productivity and for meeting tightening state and local environmental requirements. Our new systems give secondary processors more flexibility to adapt to variations in scrap supply or changing market conditions. Globally, Messer has installed more burners and solutions in recent years than many of our competitors in Europe.

› **Additive Manufacturing (AM):** We offer a suite of AM gas technologies to help processors move from prototype to full-scale additive manufacturing of powder-metal parts. This includes the Messer ASURE3D™ atmosphere control system, which precisely monitors variables in the print chamber and ensures proper gas flows to achieve consistent results for high-performance parts. We also offer technology for hot isostatic pressing (HIP) and a range of post-processing operations.

› **Sintering:** To remain competitive and reduce costs in producing sintered parts, heat treaters must closely manage part carbon-content for consistent results. We offer consulting services to identify and resolve many types of issues. But upgrading to the Messer sintering atmosphere control system takes the process to a new level of quality with real-time monitoring and dynamic control of the furnace atmosphere.





Messer High-Speed Gas Injection (HSGI) technology greatly improves convection inside heat treatment furnaces. The images model gas velocities around coils before (left) and after installation of HSGI (right), using FLUENT computational fluid dynamics (CFD) software. (Courtesy: Messer)

› **Sub-zero Treatments:** Cryogenic hardening, typically with liquid nitrogen, goes well beyond quenching in transforming higher-alloy steels from austenite to martensite. Messer sub-zero treatment cabinets can tightly control the process for consistent results. This is especially important for tool steels and high-carbon and high-chromium steels in applications that demand superior wear resistance and extended component life.

MORE INFO www.messer-us.com

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RAYMOND DANIEL NOBLE /// VICE PRESIDENT /// NOBLE INDUSTRIAL FURNACE

"We've been a contracting company for over 47 years, and there are very few things we haven't seen."

Noble is expanding its services. In what way are you expanding?

We've been working on a service expansion called Noble 1-Stop. We have begun working in partnership with companies' maintenance and purchasing departments to oversee their heat-treat facility maintenance and inventory. Noble 1-Stop can free up their maintenance & purchasing personnel to do other jobs. We start with an evaluation of the facility, processes and equipment then identify all their consumables and critical spare parts.

It's something new that we've done, and we're having some success with it because of the list of benefits that go with it. It's convenient because your critical spares are readily available; it's efficient because you can schedule preventative maintenance and reduce unscheduled downtime; it brings cost savings. It's our way to connect with a heat-treat shop, and the big thing is that we're there to help out the customer. In the heat-treat world, reducing downtime is primarily the main objective because whenever you have downtime, costs go up.

What was involved in Noble 1-Stop's decision-making process?

It's Noble 1-Stop, one source for what you need when you need it. Things have changed with COVID and some industries have slowed down. So, it was an idea we had that started out of the necessity that customers are reducing expenses wherever they can and downsizing their workforce. We've had a preventative maintenance contract with some of them, so we could identify their needs. We want to offer our solution to current customers and to more businesses in the heat treat industry.

We track equipment operations and modify some of the procedures, suggest ways to standardize between facilities, equipment and related consumables. We put together a report. Businesses love reports that show where they're making money and if they're losing it where they can save it. So it was more or less a necessity that we recognized where they were downsizing, cutting maintenance and cutting costs. Unfortunately for many customers, that means they are cutting experience. And that's where we can help them out.

That was the decision process. You could see a hole, and we would fill it. And it works out for everybody, from major aerospace and tooling companies to smaller, family owned heat-treatment shops. Wherever you see a change in management or key facility/maintenance personnel, we can help them get up to speed and make sure important details don't get lost in the transition. We help maintain their equipment, manage their spare part and consumable inventory whether it is maintained in our shop or theirs. This ensures they have what they need to keep production up and running.

How does 1-Stop set Noble apart?

Noble, as a contracting service company, goes on the road troubleshooting and repairing equipment almost every day. You get the experiences and benefits of a quality furnace designer and manufacturer because we have an eye for flawed designs and how to correct them. We're able to recognize the science at work. We incorporate that into a design upgrade or a rebuild. I believe our experience in heat treat allows us to evaluate and look for ways to improve or streamline your thermal process. We can get in there and see what makes a good furnace run and a bad one break.

Noble 1-Stop can even help standardize across multiple facilities and all brands of heat treat equipment and related components.

We also have a good team, and I credit our success to us hiring the right people for the right job.

What does this mean for your existing products and services?

Our existing products, like our new builds, will benefit from increasing our presence on the road and out in other shops. We've been a contracting company for over 47 years, and there are very few things we haven't seen. Our business is pretty much split 50/50 with new builds and maintenance service. Servicing equipment helps us with refining our design — seeing what works and what doesn't. It gets us out of the bubble; we get fresh ideas, and it increases our exposure.

What kind of market response are you getting so far?

So far, it's been positive. A couple of the customers that we've been dealing with on a small scale, we do an inventory evaluation for them, mainly in-house where we go through and catalog everything they have, and they purchase it and keep it in-house. We're also trying to do that on a different scale where you can catalog all the perishable tooling or consumables and have it in our shop so they don't have the expense of managing it. We work with each customer on a case-by-case basis establishing the cost saving method best for them. Some shops don't have the space, or they get new management, and things get cleaned out. We can keep a better inventory.

We source multiple vendors and get competitive pricing for them. Instead of the customer trying to get the best price, we do all the legwork for them. I think it's a win-win for us and for the customer. The way of doing business is changing and this is our response. Noble 1-Stop is beneficial to our customers. With our experience, we're able to help them, and they appreciate it.

MORE INFO www.noblefurnace.com


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