Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

INSPECTION & METROLOGY / GEAR APPLICATIONS

COVID-19'S EFFECT ON PRI/NADCAP

COMPANY PROFILE ///

ECM USA

DECEMBER 2020
thermalprocessing.com

AMG ENGINEERING

ald

Global service centers

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- PORT HURON, MICHIGAN, USA
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- Prototype and trials

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ANDREW STOREY

FIELD SALES SPECIALIST FOR MATERIALS ANALYSIS /// LECO CORPORATION

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FROM THE EDITOR ///

Getting ready for 2021

It's December, and, boy, has 2020 been a year to end all years.

It goes without saying that the last 12 months have been a rough time for everyone, and the heat-treat industry has been no exception.

But as we enter 2021 and beyond, let this note not only serve as a season's greeting, but also as a promise that *Thermal Processing* will continue to explore ways to enhance our products with the ultimate goal to getting the best and latest information about the heat-treat industry in your hands — whether that be virtually or literally — just as we did this year and in years' past. It's even more important than usual when we remember the challenges 2020 brought to practically every facet of our personal and professional daily lives.

As we reflect on all the events of 2020, it's been a challenging year where we worked hard to bring you even more of the best heat-treat information you can use, whether it was in the form of detailed technical articles and columns or it was with the latest news within the heat-treat industry.

We really hope you've enjoyed the heat-treat coverage, and we plan to work even harder as we jump head first into the new year, because we have a lot of new and exciting endeavors in the works. We refuse to let COVID put a damper on our plans.

And as we close out this year here, and I'm sure I speak for everyone when I say, "Good riddance," you'll discover this month's issue of *Thermal Processing* has quite a bit to take in.

Speaking of COVID, the pandemic has definitely affected how inspections are being done. They're necessary and essential to ensuring equipment is meeting the strict standards to manufacture parts properly. So, what's happening to make sure those inspections are being performed efficiently?

Frequent contributor Jason Schulze has put together a comprehensive deep-dive into how the industry is coping and adjusting to the challenges the pandemic has thrown at it.

We also take an annual look at gear applications within the heat-treat industry. In an article from Lily Kamjou and Joakim Fagerlund, they share their insights on the performance and properties of a new, alternative gear steel.

You'll find that and much more in our December issue. And keep in mind that we are always looking for interesting and educational editorial content, so if you have a technical paper or other heat-treat-related articles you'd like to see published, please contact me. I'd love to hear from you and be given the opportunity to share your unique knowledge with our readers.

Happy holidays from all of us at *Thermal Processing*! Stay safe, and, as always, thanks for reading!

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OPERATIONS

Pomini Tenova designed equipment for JW Aluminum's new mill with the aim of combining the highest accuracies and quality required by the aluminum industry. (Courtesy: Pomini Tenova)

Tenova commissions JW Aluminum's new hot rolling mill

Tenova, a leading company specialized in innovative solutions for the metals and mining industries, has successfully commissioned the roll grinding machine and roll shop equipment for the new hot rolling mill for the expansion plant of JW Aluminum — a leading producer of flat rolled aluminum products — in Goose Creek, South Carolina, USA.

Pomini Tenova, the Tenova brand worldwide leader in production of roll grinders, was chosen by the American manufacturer in 2018 for the supply of a new fully automatic grinding machine for work rolls and back-up rolls, of a combined chocking-dechocking machine for work rolls and back-up rolls, and for a chock tilter. All equipment was designed to be used also with the rolls of the cold rolling lines already in operation at JW Aluminum.

Pomini's equipment was designed with the aim of combining the highest accuracies and quality required by the aluminum industry with the flexibility required by the extended range of dimensions, surface requirements and materials of rolls to be taken care of. For this reason, the roll grinding machine features an advanced wheel load control system, for increased stability of roughness finishing along the roll barrel; the Pomini Continuous Profile Compensation system (CPC), for true and undisturbed in-process measurement and correction of roll profile during grinding; and the hydrostatic steady rests used for back-up rolls are equipped with a single hydrostatic pad set, which can be changed quickly and does not require roll alignment after a roll type change. The chock changer features two back-up roll stands with rotation system, for ease of chock insertion and extraction.

"The effective collaboration between Tenova and JW Aluminum has made it possible to overcome the significant hurdles posed by the ongoing COVID-19 pandemic. By means of goodwill and cooperation, the installation and commissioning of the equipment have been carried out without compromising equipment performance and – most importantly – the safety of all personnel involved on site," said Livio Taccani, Pomini Tenova commercial director. "This success is a further confirmation of the high quality and performance of Pomini's roll grinders in the aluminum field, as well as of the high design flexibility of our equipment."

MORE INFO www.tenova.com

Solar Atmospheres successfully vacuum hardens large H13 liner

Solar Atmospheres of Western PA successfully vacuum hardened one of the largest aluminum extrusion liners.

The massive H13 liner measured over 100 inches overall length and weighed 16,000 pounds. The liner was turned on Lake Park's new large capacity lathe with 34-inch max diameter and 200-inch max length.

This H13 liner arrived at Solar Atmospheres of Western PA one month after the fastest cooling large vacuum furnace in the industry was completed and ready to run. This recently built Solar Manufacturing 10 bar vacuum furnace is equipped with a newly designed hot zone measuring 48" wide X 108" overall length. Additionally, the furnace has a 600 HP blower motor for increased cooling power. The critical cooling rate, to obtain optimum properties for H13 hot worked tool steel, was achieved as evidenced in the as-quenched hardness of HRC 54-55. The part was then double tempered to the customer's specification of HRC 46 to 48.

"This large, rapid cooling vacuum furnace provides us continued diversification to our vacuum heat-treating repertoire and capabilities," said Bob Hill, president of Solar Atmospheres in Western PA. "We're proud of this partnership with Lake Park Tool and Machine and to assist our customers in

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.

vacuum heat treating one of the largest air hardening dies that I have personally heat treated over my 40-year career."

MORE INFO www.lakepark.com
www.solaratm.com

The Mint of Poland orders 2nd furnace from Seco/Warwick

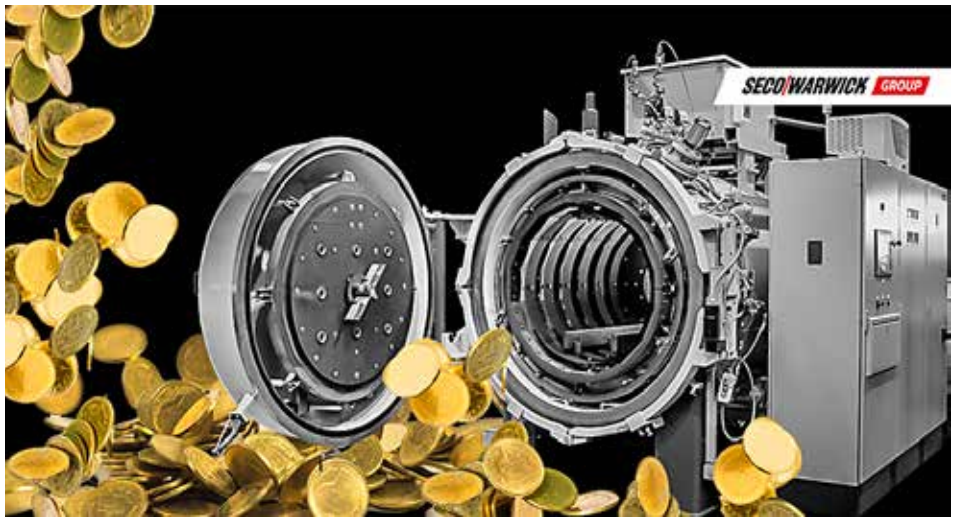
The Mint of Poland, a producer of circulation and collector coins for the National Bank of Poland, has purchased a second Vector® vacuum furnace. The historic 250 year-old-plus institution will begin producing stamps and coins with the latest Seco/Warwick solution.

The new Vector vacuum furnace with Seco/Warwick quality is a symbol of the highest craftsmanship in the field of minting. Equipped with 15 bar high pressure gas quenching (HPGQ) capability, this is the second furnace of the same type purchased by the Mint of Poland. The first device, purchased in 2012 has continued to provide quick hardening in the most optimal floorspace for the customer throughout the past eight years in its Warsaw facility, considered one of the three most valued and technologically advanced mints in the world.

The latest Vector vacuum furnace is primarily intended to increase the efficiency of the Mint of Poland. It is also a back-up resource in the event of failure or downtime due to service inspection of the current unit.

"Considering the nature of the mint's operation, including the security of the coin and tool production process, an important aspect is duplicating the device in order to maintain the continuity of heat treatment in any situation and to ensure that the entire technological line is carried out on the premises of the Mint. The second device from the same supplier, Seco/Warwick, secures our capabilities in this area," said Piotr Kraszewski, director of the production department at Mennica Polska SA."

The distinguishing feature of this new design is the additional option of high vacuum, convection heating and its PreNITLPC® technology, which opens up new possibilities for thin layer nitriding tests. This is an innovative application in the technological testing phase.



The new Seco/Warwick Vector vacuum furnace is equipped with 15 bar high pressure gas quenching (HPGQ) capability. (Courtesy: Seco/Warwick)

As emphasized by specialists in the heat-treatment industry, mints around the world are very demanding customers who pay close attention to the technologies used in the production of coins, numismatics, medals and stamps. It is an elite club of recipients of heat-treatment technology, in which opinion and recommendations are taken very seriously and are often the first criterion for choosing a partner. Seco/Warwick has for many years been on the list of the most recommended manufacturers of solutions for mints, not only state-owned, but throughout the world.

The Mint of Poland started cooperation with Seco/Warwick at the turn of 2011/2012, based on the recommendations of other mints and very good opinions of Polish users. One of the biggest initial challenges was to install and commission this full-size vacuum furnace on one of the floors of a skyscraper located in the very center of Warsaw. It involved not only logistics issues, but above all the operating conditions of the device in such a demanding external environment.

Another challenge was the relocation of the furnace from this difficult restricted access location in the center of Warsaw to the new production site of the Mint of Poland.

Over the years, Seco/Warwick has participated in numerous technological trials of mint products, dies, and their heat treatment. Many of these tests represent unique technologies not available anywhere in the world at the moment.

MORE INFO www.secowarwick.com

Graphalloy® introduces 327 lower profile pillow blocks

Graphite Metallizing Corporation, the manufacturers of self-lubricating Graphalloy® bushing materials for high temperature, low temperature, submerged, food, and other tough applications adds a new lower profile 327 pillow block.

The 327 pillow blocks are Graphalloy self-lubricating bushings mounted in stainless steel pillow blocks. This series combines the corrosion-resistant and self-lubricating properties of Graphalloy with the application and installation versatility of pillow blocks. These pillow block assemblies are self-aligning and can withstand temperatures up to 1,000°F.

The new lower profile 327 pillow block

Graphalloy® type-327 lower profile pillow blocks expand the opportunity to use Graphalloy bushings for high temperature and other extreme environments. (Courtesy: Graphalloy)

has a center line height of 1 3/32" versus the original profile center line height of 1 11/32". With both pillow blocks in the Graphalloy catalog, there are now more opportunities to solve tough bearing problems for a variety of equipment. Graphalloy stainless steel pillow blocks work exceptionally well when submerged in water, water-soluble chemicals, and other corrosive or hostile liquids such as acids, alkalies, hydrocarbons, black liquor, and liquid gases. In these environments, plastic bearings may fail because of their tendency to soften or swell when submerged.

These pillow blocks are available in industry standard two-bolt configurations, come in a range of base dimensions, and can accommodate shaft diameters from 0.5" (12.7 mm) to 1.5" (38.1 mm).

Graphalloy, a graphite/metal alloy, is formed from molten metal, graphite, and carbon. It is a uniform, solid, self-lubricating bushing and bearing material that offers superior performance in hundreds of applications. Graphalloy is well-suited for submerged or high temperature applications where grease, oil, and plastics fail.

MORE INFO www.graphalloy.com

IMAT ASMS 2021 issues call for abstracts

IMAT 2021 will co-locate with Heat Treat 2021, North American Cold Spray Conference 2021, and Motion + Power Technology Expo 2021. ASM is the only society that unifies different market segments that cross the entire materials world and connects industry, academia and government to solve global materials challenges.

The conference and expo will feature:

› In-person networking opportunities with 200+ exhibitors and 9,000+ attendees.

› 800+ technical presentations, keynotes, and panel discussions.

› Four days of technical programming and three days of expo.

› 300+ students interested in materials engineering for recruitment programs.

› A global reach to more than 300 countries.

Registration opens in spring 2021. Deadline for abstract submissions is February 19, 2021.

Abstracts are being solicited in the following topic areas:

› Additive Manufacturing.

› ATI Specialty Materials.

› Artificial Intelligence and Machine Learning.

› Characterization of Materials and Microstructure through Metallography, Image Analysis, and Mechanical Testing - Fundamental and Applied Studies.

› Corrosion and Environmental Degradation.

› Emerging Technologies.

› Failure Analysis.

› Functional Materials and Structures –

Solving barriers to adoption.

› Joining of Advance and Specialty Materials (JASM XXII).

› Light Metal Technology.

› Materials 4.0: Materials Information in the Product Life Cycle.

› Materials Behavior & Characterization.

› Materials for Energy & Utilities.

› Medical / Biomaterials: Driving for delivered patient value.

› Materials & Processes for Automation.

› Metals, Ceramics and Composite Materials (raw materials, processing, manufacturing methods, applications, environmental effects).

› Processing and Applications.

› PSDK XV: Phase Stability and Diffusion Kinetics.

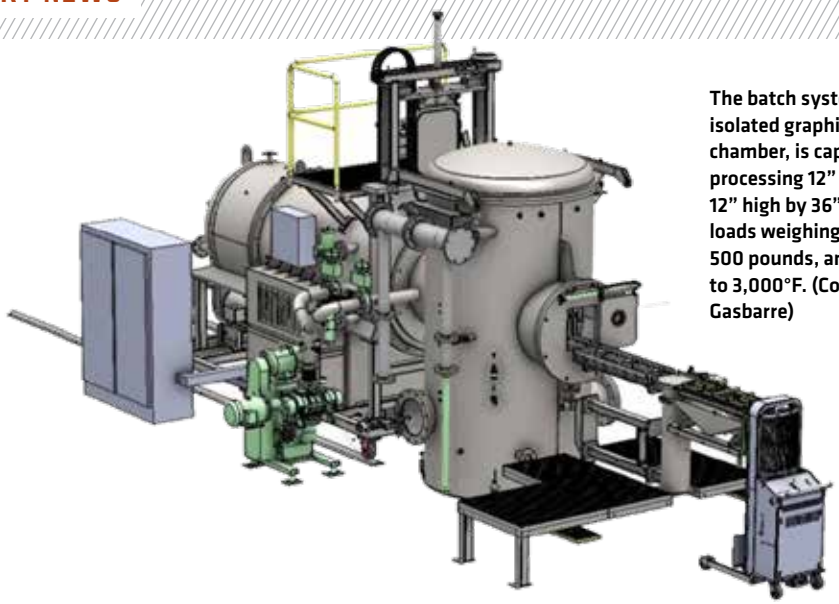
› Sustainable Materials & Processes.

MORE INFO www.asminternational.org

Gasbarre delivers vacuum oil quench furnace system

Gasbarre Thermal Processing Systems commissioned a vacuum oil quench furnace which included two bar gas quench capabilities to an international manufacturer. The batch system, with isolated graphite heating chamber, is capable of processing 12" wide by 12" high by 36" long loads weighing up to 500 pounds, and is rated to 3,000°F. The modular furnace design gives the customer the capability of using the two bar gas quench in the heating chamber, or transferring through internal doors to the oil quench module. The Gasbarre designed Allen-Bradley control system ensures precise control to the customer's strict requirements. Gasbarre was chosen as the equipment supplier based on the unique modular design that achieves both process flexibility and maintenance ease.

With locations in Plymouth, Michigan; Cranston, Rhode Island; and St. Marys, Pennsylvania; Gasbarre Thermal Processing Systems has been designing, manufacturing, and servicing a full line of industrial thermal processing equipment for nearly 50 years. Gasbarre's product offering includes batch and continuous thermal processing equipment for both atmosphere and vacuum applications as well as a full line of alloy fabrications, replacement parts and auxiliary equipment which consists of atmosphere generators, quench tanks, washers and charge cars.



The batch system, with isolated graphite heating chamber, is capable of processing 12" wide by 12" high by 36" long loads weighing up to 500 pounds, and is rated to 3,000°F. (Courtesy: Gasbarre)

MORE INFO www.gasbarre.com

Gasbarre names Fleming as manager to grow business

Gasbarre hired Keith Fleming as business development manager for Gasbarre Thermal Processing Systems. Fleming's experience and knowledge will support existing customers and advance Gasbarre's growing footprint in the continuous annealing, brazing, and sintering markets.

Fleming brings more than 25 years of industry experience to Gasbarre, having previously worked with powder materials, powder metal parts producers, and investment castings. Fleming is also dedicated to advancing the industries he is in by serving on Penn State DuBois' Industry Advisory Board, MPIF's Industry Development Board, and the Marketing and Membership Committee of the Investment Casting Institute. His experience demonstrates Gasbarre's commitment to having personnel who understand customer challenges and can provide proven solutions.

Keith Fleming

"With the addition of Keith, we have added yet another team member to our organization that brings many years of experience. Keith's work in the powder metal industry and beyond has given him the tools necessary to support our growing customer base as well as advancing our products into new markets. We are excited to have him on board," said Mark Saline, president of Sinterite & C. I. Hayes divisions.

MORE INFO www.gasbarre.com

Turkish company adds Nitrex system to expand production

Turkish aluminum extrusion company Alugen Aluminium expanded its production capabilities with the addition of a new Nitrex NXK series nitriding system. Founded in 2012, Alugen is a young, dynamic company and the only business of its kind in Turkey to operate in a free trade zone. The distribution of its range of aluminum profiles is designed for Europe where they do business with construction market and other sectors.

"Utku Inan, Nitrex sales representative serving Turkey, led the discussion with Alugen about the strategic decision to bring nitriding operations in-house for more cost-effective handling of nitriding and increasingly better-quality control. Over the years, Alugen has expanded production to meet demand, and the addition of a Nitrex system will allow the company to indepen-

dently control the entire manufacturing process onsite from end-to-end and ensure that extruded products are delivered to the customer faster and with consistent quality," said Marcin Stoklosa, project manager at Nitrex Poland.

"Alugen provides mass production extrusion services as well as boutique production to its clients; therefore, Nitrex had to consider the performance benefits of a single system that can handle both custom and mass production requirements. The multipurpose NXK-612 batch-type furnace was a clear choice," said Inan. With a compact footprint, a work area of 23.5" x 47 " (600 x 1200 mm), and a load capacity of 1,700 lbs. (800 kg), the NXK system allows Alugen to mix special dies with regular production dies for a faster turnaround of product-specific production plans.

Die shop manager Özcan Sürücü said, "In partnering with Nitrex, we (Alugen) have become self-sufficient from an operational point of view, no longer relying on external contractors to fill this work gap. This allows for more effective planning and ensures that all projects, whether big or small, are done on time and on budget. Moreover, I cannot say enough about the technical support we receive from Nitrex and locally from Uktu Inan towards improving our heat treating and extrusion operations as well as our product quality. We are extremely satisfied with the performance and results of our Nitrex system."

Nitrex supplied a small footprint nitriding/nitrocarburizing system to Alugen Aluminium to bring all manufacturing operations in-house for more optimal work planning and quality control. (Courtesy: Nitrex)

The Nitrex turnkey system was delivered with Nitreg® potential-controlled gas nitriding and Nitreg®-C potential-controlled gas nitrocarburizing technologies. Process recipes are optimized to improve the performance of aluminum extrusion dies and increase throughput. The service life of dies is also extended through periodic nitriding, which helps to control the high heat and impact pressure that dies undergo during extrusion cycles.

MORE INFO www.nitrex.com

Get to know IHEA's new member: DELTA H TECHNOLOGIES

IHEA's newest member, DELTA H TECHNOLOGIES, is a growing family business that prides itself on quality and performance. The company was originally established as DELTA H SERVICES in 1990 by Richard Conway while he was finishing his degree in Industrial & Systems Engineering from The Ohio State University. Conway, a United States Air Force veteran, scheduled work around his busy class schedule. After graduating from OSU in 1993, he formed DELTA H SYSTEMS INC. DELTA H initially specialized in servicing combustion and control systems on industrial furnaces, ovens, and kilns. The company continued service-related projects but also performed control system upgrades, used equipment sales, and design and assembly of specialized furnace and oven systems.

In 1998, as the result of a consulting project with an aircraft maintenance company, DELTA H SYSTEMS INC. developed the first dual-chamber aerospace heat treating (DCAHT®) system, which became its flagship product. DCAHT systems are widely used by the U.S. Armed Forces, defense contractors, and commercial aviation companies around the world. DELTA H SYSTEMS INC. was reorganized and renamed as DELTA H TECHNOLOGIES in 2009 and became a family business when Conway's oldest children, twins Neal and Ellen, joined the company. Growth has been steady ever since the reorganization.

DELTA H serves the aerospace, automotive, defense, and medical industries, focusing on processes including additive manufacturing, heat treating, and composite curing. It tends to concentrate its efforts on niche thermal-processing applications within these markets. The company boasts unrivaled quality and performance for its customers, along with excellent service and support.

DELTA H is distinctively known for "DELTA H FEVER," a highly contagious passion that comes with the realization of the purpose of the types of systems it builds and meeting the expectations of the clients it serves. DELTA H FEVER encourages employees to bring the full depth of their skills, knowledge, and experience to any and every project. The company fosters an environment of achievement and accomplishment for employees, making it a rewarding place to contribute.

The future for DELTA H is a bright one. Its plans include expanding its product lines over the next five years while continuing to focus on niche and emerging technologies. The company has nearly doubled its workforce and is seeking additional engineers and technicians to help maintain its growth. Even with the current COVID-19 pandemic, DELTA H has been able to secure government contracts as well as "too-big-to-fail" commercial projects to remain busy.

In the longer term, DELTA H aims to continue being entrepreneurial and grow the business, while taking advantage of any opportunities that may materialize. Visit www.delta-h.com for more information on DELTA H Technologies.

DELTA H serves the aerospace, automotive, defense, and medical industries, focusing on processes including additive manufacturing, heat treating, and composite curing. (Courtesy: DELTA H TECHNOLOGIES)

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WHY JOIN IHEA?

IHEA member benefits:

- Monthly Executive Economic Update.
- Discounts to attend all IHEA Educational Seminars & Webinars.
- Discounts on IHEA On-Line Training Courses.
- Discounts to attend IHEA's Annual & Fall Business Meetings.
- Participation on IHEA committees.
- Company listing on IHEA's website.
- For more info, go to www.ihea.org/page/Benefits

MEMBER TESTIMONIALS

Bob Fincken: IHEA offers many benefits for Super Systems Inc. We have had the opportunity to send engineers to the training seminars, which are offered with a discount for members. Also, our participation on the committees is very valuable — specifically the Safety Standards and Codes committee has kept SSi informed and has offered a platform for discussion of requirements. I also can't leave out the great locations and networking that takes place with other companies at the Annual Meeting.

Alberto Cantu: We certainly get much value from our IHEA membership. For instance, the economic update is shared between our C-level executives. We find it very useful because it offers valuable information in a condensed format. In addition, many of our engineering positions have, as a requirement, to be trained in IHEA's NFPA86 and Fundamentals of Industrial Process Heating courses. We think IHEA's courses are a great way to get them started in their positions. But perhaps the most valuable of all, is to be able to network with colleagues who are experts in their fields.

GET INVOLVED

IHEA committees are a great way to connect with industry peers on significant topics to you and your company. Involvement at the committee level will ensure your voice is being heard in areas of importance. Each committee meets during the spring and fall. Get involved and be a part of IHEA's growing mission to provide the knowledge base and authoritative voice for industrial heat processing. You can join a committee any time by contacting Kelly LeCount, kelly@goyermgt.com or log into your IHEA profile and click Edit Bio to select a committee.

EDUCATION COMMITTEE

The Education Committee assists in the development of the Combustion and Safety Seminars conducted annually. It also oversees the Online Distance Learning courses, new education, and training opportunities, as well as the coordination of any educational materials produced as a part of the programs. The committee is also engaged in the review and updating of IHEA's educational resources.

GOVERNMENT RELATIONS COMMITTEE

IHEA's Government Relations Committee works closely with government agencies to ensure the industry is being represented and heard.

MARKETING COMMUNICATION & MEMBERSHIP COMMITTEE

The MCM Committee is involved in the communications and public relations activities of the organization, covering the association's publications, association online website activities, media relations, membership promotion, educational seminars promotion, and other related industry programs.

SAFETY STANDARDS AND CODES COMMITTEE

The Safety Standards & Codes Committee reviews all standards — standing and proposed — by the National Fire Protection Association (NFPA) and other organizations relating to industrial furnaces and ovens. Changes to the NFPA 86 Series Standards proposed by the Committee are submitted to the NFPA 86 Committee for review and approval. A current program of a special sub-committee involves a review of U.S. and European industrial heat-processing standards to determine possible differences and effects.

INFRARED EQUIPMENT DIVISION (IRED)

The IRED works to expand the market for, and the use of, electric and gas infrared (IR) heating equipment. To accomplish this mission, the IRED organizes and conducts activities that increase understanding and awareness of IR technology among potential users, provides members with easy access to technical literature and published papers, provides members with a database of current IR applications, promotes state-of-the-art equipment design and utilization, promotes the development of new applications utilizing IR, represents the goals and concerns of the IR equipment industry before the public, and adheres to a "Code of Conduct" as established by the IRED.

INDUCTION HEATING DIVISION

The Induction Division represents another critical heat technology process. This Division focuses on educating both the induction OEMs and end users on best practices such as safety and operations, electric permitted for installation, and other important processes and materials that are relevant to this technology. The Induction Division allows IHEA to expand its reach in the heat-processing industry to provide critical information and education on induction technology. The addition of induction companies will also benefit all IHEA members by providing great resources and knowledge of numerous innovative areas for our members.

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

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JUSTIN SIMS
MECHANICAL ENGINEER /// DANTE SOLUTIONS

Simulation can show how carbide size, heating rates, and holding times during austenitization can have a significant effect on the amount of carbon entering the austenite matrix before quenching.

Evaluating a material's response during austenitization

Carbon content in steel has a direct correlation to the hardness and overall strength of a component after heat treatment. Carbon can take many forms in the steel alloy, but during austenization, generally the goal is to place all available carbon into the austenitic solid solution.

Three main factors affect the amount of carbon entering into solid solution: 1) The form of carbon at room temperature, 2) The heating rate from room temperature to the austenitizing temperature, and 3) The soaking time at high temperature. In order to understand whether the requisite amount of carbon has entered the austenite matrix, hardness testing would need to be performed on samples processed at different heating rates and soaking times. This type of evaluation can be expensive and time consuming. A simpler way to ensure all carbon has entered the austenite matrix is to use heat-treatment simulation software, such as DANTE, to evaluate the effects of different parameters quickly and cost effectively.

Of course, this requires accurate material data, and simulation can help dramatically reduce the amount of physical testing required after the material data is known. DANTE provides a material database with many common steel grades already characterized.

DANTE Solutions has developed a material simulation software tool, called Mat_Simulator, that uses the DANTE material models and material database to predict phase transformations, strain, hardness, carbon dissolved in austenite, and carbon in carbides from heating and cooling schedules provided by the user. It is a powerful tool that can be used to evaluate a material's response to defined temperature changes. These heating and cooling rates are representative of different locations through a component's cross-sectional thickness. Mat_Simulator is used in the following discussion to show the effects of different parameters on the amount of carbon in austenite at the time quenching begins when carbides are present in the material. The material examined has a total carbon content of 0.8 percent.

As previously mentioned, carbon can take on many forms in a steel alloy. It can take on the form of cementite layers of varying thickness in pearlite, spheroidal carbides from thermal processing, carbides from a carburizing process, etc.

Carbides come in many shapes and forms, with some dissolving more quickly than others. Understanding the initial microstructure is important if a proper austenitizing cycle is to be determined. Figure 1 shows the carbon simulation results in austenite for three different carbide sizes, given an identical heating rate, austenitizing temperature, and processing time. A quenching step would immediately follow this austenitizing step.

Figure 1 makes it clear that the size of the carbides can have a significant effect on the material's hardenability by limiting the amount of carbon available in the austenite matrix at the start of quenching.

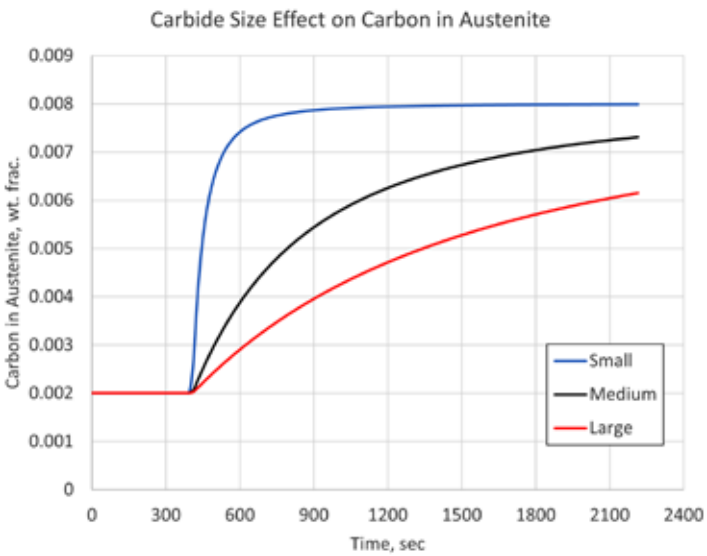

Figure 1: Simulation results showing effect of carbide size on the amount of carbon in austenite.

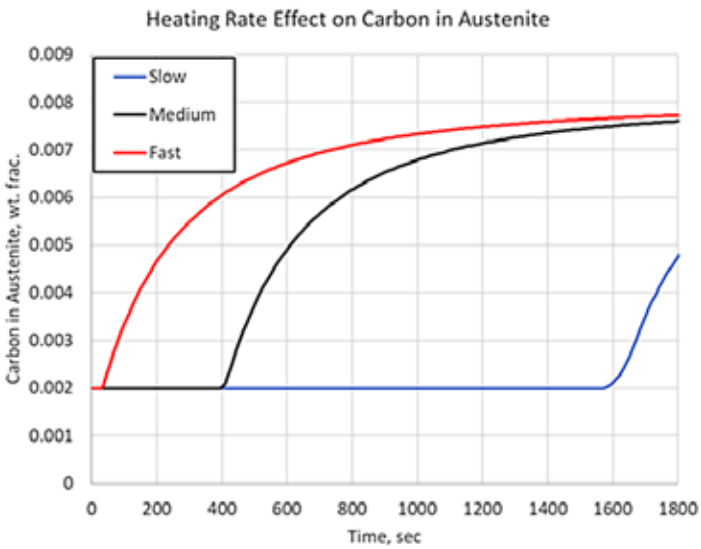

Figure 2: Simulation results showing effect of heating rate on the amount of carbon in austenite.

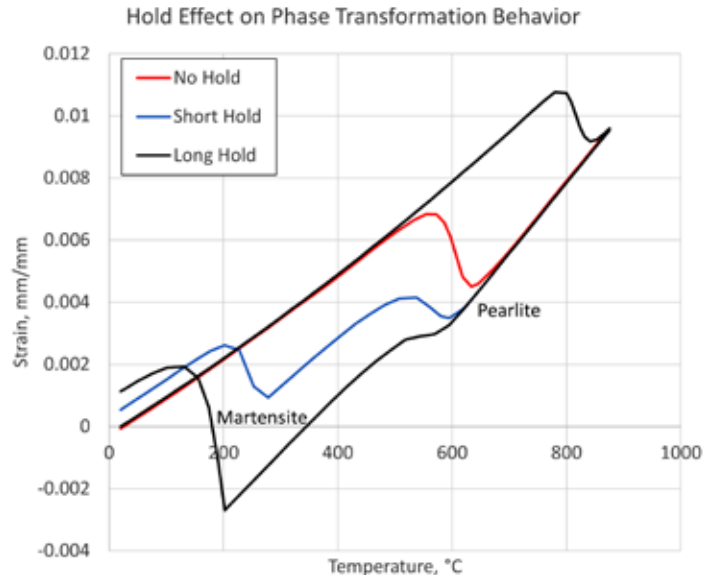

Figure 3: Simulation results showing effect of holding time on the phases obtained after quenching.

In this example, any section of a component with large carbides and exposed to the relative slow heating rate used, would behave as though it contained 0.6 percent carbon, not the 0.8 percent that is stated as the carbon content.

So, even though standards are in place for holding times with respect to cross-sectional thickness, it is still important to understand the initial microstructure of the material being heat treated. Once characterized, the initial microstructure can be used in conjunction with simulation to determine optimum heating cycles for a given component.

A faster heating rate will require a longer soak time to allow carbon to enter into solid solution for the same part cross-sectional thickness. There are two reasons for this: First, a faster heating rate delays the austenite transformation (the Ac_3 temperature is effectively raised) and carbon does not begin to efficiently enter solid-state solution until the material has transformed to austenite. Second, a faster heating rate means less time above the Ac_3 temperature, meaning the carbon has less time to enter the solution before reaching the target hold temperature.

Figure 2 shows the carbon in carbide form for three heating rates, representing various cross-sectional thicknesses, given identical carbide size, austenitizing temperature, and processing time. The slower the heating rate, the longer it takes for the carbide to begin to dissolve. Given identical parameters of carbide size, austenitizing temperatures, and hold times, there would be no difference in the amount of carbon dissolved. However, where heating rates begin to play a significant role is when the holding time is not designed properly for the center of the part, and processing times are kept constant between various geometries. If a larger-than-normal cross-section is treated, then the holding time must be adjusted accordingly because of the decreased heating rate at the core of the component. For example, if the total processing time from the fast heating rate is used on a cross-section that experiences the slow cooling rate at its core, the surface of the component would act like a material with 0.8 percent carbon, but the core would act like a material with 0.5 percent carbon, with respect to hardenability, as shown in Figure 2.

For a process with the aim of transforming a particular steel alloy to a known microstructure, the amount of carbon in the austenite solution can have a significant effect on the phases obtained. Figure 3 shows simulation results of strain vs. temperature for a steel containing 0.8 percent carbon, assuming medium-sized carbides. The simulation also assumes a medium heating rate and a fast quenching rate. Three holding times are then examined for their effect on the phases obtained after quenching. The length of time the material is held at the austenitizing temperature determines the amount of carbon that is able to dissolve into the austenite matrix, which in turn affects the hardenability of the material.

As can be seen in Figure 3, the situation in which the material was quenched immediately upon reaching the austenitizing temperature, labeled "No Hold," results in a microstructure of 100-percent pearlite. The short hold time results in a mixed structure of pearlite and martensite, whereas the long hold time contains a microstructure consisting of mostly martensite with a small amount of pearlite. The temperatures of the phases are shifted slightly due to the different amounts of carbon present in austenite at the time of quenching.

Holding times can have a significant impact on short time processes, such as induction heating. While the goal is high throughput, it is critical to ensure there is enough time for the carbides to dissolve. This is particularly important for subsurface material that may have a slower heating rate due to the reduced Joule heating occurring at that location and being dependent to some extent on thermal conduction to increase the temperature. Simulation can also be a powerful tool when examining an induction-hardening process.

In conclusion, it has been shown through simulation that the effect of carbide size, heating rates, and holding times during austenitization have a significant effect on the amount of carbon that can enter the austenite matrix before quenching. The carbon in austenite has a significant effect on the hardenability of the material and must be considered when designing austenitization cycles. It has also been shown that heat-treatment simulation software, such as DANTE, can be used to successfully evaluate and design heating cycles to ensure all carbides have dissolved and the material will behave as expected.

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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.

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The use of polyalkylene glycol in concentrations from 10-40 percent are used to quench aluminum sheet metal, extrusions, and forgings of all the heat treatable aluminum alloys.

Heat treatment of aluminum, quenching Part III

In the last article, we discussed quenching of aluminum, and the importance of rapid quenching to prevent the formation of precipitates at the grain boundaries. Water is often used as a quenchant but can cause high residual stresses and distortion.

To eliminate or reduce distortion and minimize residual stresses, many companies have used polyalkylene glycol to dramatically reduce distortion and residual stresses.

POLYALKYLENE GLYCOL

Polyalkylene glycol (PAG) quenchants are the most used polymer quenchants on the heat-treating market today. Polyalkylene glycols (PAG), or polyalkylene glycol ethers, were first introduced as quenchants in the early 1970s. PAG quenchants are an example of a copolymer. This quenchant is derived from two monomeric units — ethylene oxide and propylene oxide — to form polyalkylene glycol (Figure 1).

$$-[(CH_2CH_2O)_n(CH_2\underset{\underset{CH_3}{|}}{C}HO)_m]-$$

Figure 1: Chemical structure of polyalkylene glycol.

By varying the molecular weights and the ratio of oxides, polymers having broad applicability may be produced. Proper selection of the polymer composition, and its molecular weight, provides a PAG product that is completely soluble in water at room temperature.

PAG quenchants are used widely as an alternative to water or oil for the quenching of aluminum parts such as thin-section airframe and skin components, castings and extrusions for aerospace applications, and engine blocks, cylinder heads, and wheels for the automotive industry.

Quenching speed is critical to prevent the precipitation of intermetallic compounds which would have an adverse effect on mechanical properties and corrosion resistance.

The controlled uniform quenching characteristics of PAGs can significantly reduce or even eliminate the distortion often associated with water quenching without impairing mechanical properties or corrosion resistance. This is particularly important with thin-section sheet aluminum airframe components in the aerospace industry and complex castings and forgings, which are often quenched into boiling water or mineral oil to minimize distortion.

PAG quenchants are generally used at a concentration of 10-20 percent for heavy-section castings and forgings, and at 25-40 percent for thin-section sheet components. Figure 2 shows the effect of concentration on the cooling curves of a typical PAG quenchant.

PAG quenchants can be used in conjunction with both recirculating air furnaces and molten salt baths. However, with molten sat

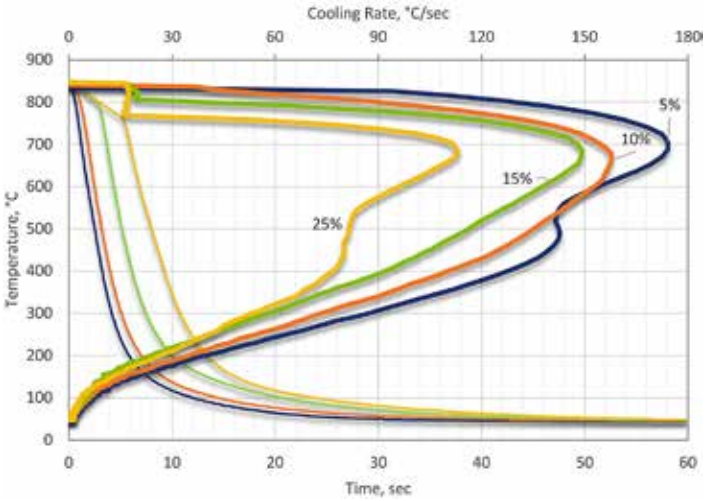

Figure 2: Effect of concentration on the cooling curves of A PAG quenchant.

Figure 3: Comparison of distortion using different quenchants for two different aluminum alloys, AA 2024 (top) and 7475 (bottom). From top to bottom, for each alloy, the quenchants are cold water; hot water at 60°C; 12 percent PAG, and 20 percent PAG. Same agitation was used for all samples [2].

baths, special precautions must be taken to compensate for salt carryover and to maintain the polymer solution at the correct working concentration.

These quenchants are available in a wide variety of viscosities and molecular weights. Commercial quenchants also contain additional additives such as corrosion inhibitors, defoamers, fungicides, and bio-

cides to enhance performance in service.

Polyalkylene glycols exhibit inverse solubility in water [1]. They are completely soluble at room temperatures but become insoluble at elevated temperatures. This inverse solubility can range from 60°C to 90°C depending on the molecular weight of the polymer. This phenomenon of inverse solubility modifies the conventional three-stage quenching process and provides great flexibility in controlling cooling rate.

PAG quenchants are approved by major aerospace manufacturers worldwide and are used extensively for critical applications in aircraft manufacture (Figure 3).

Polyalkylene glycol polymer quenchants are used in the aerospace industry to control and minimize the distortion occurring during the quenching of aluminum. Typically, these quenchants are governed by AMS 3025 [3] and are either Type I or Type II quenchants. Type I quenchants are single polyalkylene glycol polymers, while Type II quenchants are multiple molecular weight polyalkylene glycol polymers. Each offers different benefits. Because of the higher molecular weight of the Type II PAG quenchants, lower concentrations can be used.

Application of polyalkylene quenchants, such as Aqua-Quench® 260, are effective in reducing the residual stresses (and distortion) after quenching. The effect of quenching aluminum on residual stresses in Aqua-Quench 260 is shown in Figure 4.

The concentration of the polymer influences the thickness of the polymer film that is deposited on the surface of the part during quenching. As the concentration increases, the maximum rate of cooling, and the cooling rate in the convection phase, decrease. As the concentration of PAG is increased, the maximum cooling rate also decreases. This is shown in Figure 5 for sheet metal, and for forgings and wrought plate.

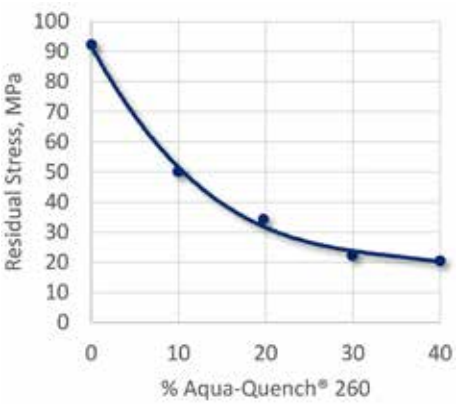

Figure 4: Measured residual stresses in 25 mm thick 7075-T6 plate quenched in different concentrations of Aqua-Quench 260.

Agitation has an important effect on the quenching characteristics of the polymer quenchant. It ensures uniform temperature distribution within the quench tank, and it also affects the quench rate. As the severity of agitation increases, the duration of the polymer-rich phase decreases and eventually disappears, and the maximum rate of cooling increases. Agitation has comparatively little effect on the cooling rate during the convection stage for polymer quenchants.

The refractive index of PAG polymer solutions (in the range employed for quenching) is essentially linear with concentration. Thus, the refractive index of a PAG quenchant solution serves as a measure of product concentration. Industrial model optical refractometers that employ an arbitrary scale may be calibrated. Whereas such instruments prove invaluable for day-to-day monitoring of the quenchant concentration, the refractometer also will register other water-soluble components that are introduced to the used quenchant. When the indicated refractometer reading begins to provide erroneous numbers, some other analytical test is required to define the "effective" quenchant concentration. With PAG quenchants, kinematic viscosity measurements (which are correlated with concentration) have proven to be most useful.

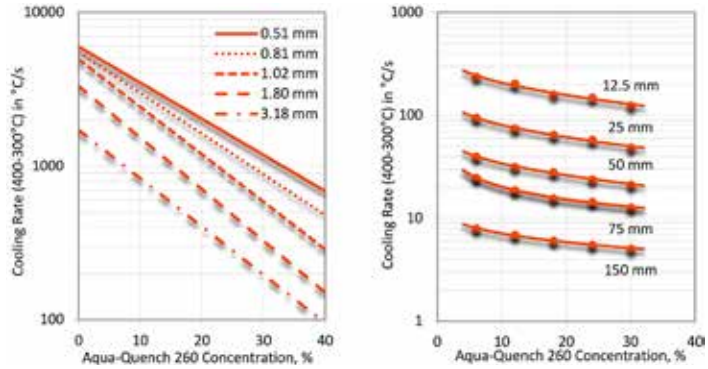

Figure 5: Cooling rates as a function of PAG concentration and product thickness.

As required, additional analytical tests for pH, inhibitor level, and conductance may be useful adjuncts to a successful monitoring program. If the level of contaminants in the PAG quenchant becomes excessive-where these contaminants may be, in part, the same undesirable constituents that are detrimental to water alone, or oil-quenchant recovery can be affected thermally. By heating the quenchant solution (in whole or in part) above the separation temperature, a more-dense polymer-rich layer is obtained. Much of the water-soluble contamination can be withdrawn with the supernatant water layer. Solid contaminants such as scale or carbon would require settling, filtration, and/or centrifugation.

Because PAG quenchants are, for the most part, resistant to bacteria and fungus, the addition of a bactericide to the as-supplied quenchant is not required. Further, biochemical activity in use is traceable not to the PAG polymer itself but to the introduction of nutrient contaminants. Microbiological treatment such as is employed with other aqueous metal working fluids generally will keep under control this foreign biological activity.

CONCLUSIONS

In this short article, the benefits of the use of PAG quenchants in reducing distortion and residual stress was illustrated. Concentrations from 10-40 percent are used to quench aluminum sheet metal, extrusions, and forgings of all the heat treatable aluminum alloys to reduce distortion and subsequent check-and-straighten activities.

In the next article, we will discuss natural aging of aluminum and the various precipitation mechanisms that enable aluminum to harden to the desired strength after solution heat treatment and quenching. Should you have any suggestions for any articles or comments regarding this article, please contact the writer, or the editor.

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Measuring quality: Quantitative and qualitative assessments and their roles in getting results.

'Say what you do, do what you say'

In the special process world of the aerospace industry, companies with requirements of aerospace manufacturing must rely on the accreditation of AS9100 and the Nadcap requirements to process parts for airplanes. SAE, the body that developed the AS9100 requirements for aviation, space, and defense organizations, encompasses more the measurement of the quality management system, whereas the PRI body that manages the Nadcap requirements for special processes is more technical in the details of the process.

The principles of AS9100 define the quality management principles of customer focus, leadership, engagement of people, process approach, improvement, evidence-based decision making, and relationship management. These principles, such as leadership and relationship management, are not best measured with quantitative approaches.

The Nadcap technical requirements of specifics of correction factors, instrument calibration frequencies, and surface contamination checks for microstructure are all quantitative measures that can be tracked toward the quest to quality.

Regardless of the more philosophical approach to business compared to the technical "nitty-gritty" approach to establishing a quality process, both requirements abide by the common phrase heard in the industry: "Say what you do, do what you say." That phrase is likely on a banner in every quality manager's office.

Quality is not only a measure of key process indicators or numeric goals to hit and sustain. It's a cycle of continuous improvement where we experience a problem or success and reflect on it to then take the necessary action. This requires quantitative measures to help structure the process and create a language for the company to all speak to achieve the quality goals.

QUANTITATIVE ASSESSMENTS

Major/minor findings in the audit: These assessments are discovered during an audit, which can be nerve-wracking. It can be an AS9100 audit, where they can choose anything in your system to investigate. Or it can be the Nadcap audit, with the black and white rules that must be followed with no deviations. Those who do not prepare, who don't attempt to embrace the system, fret and worry the most. Audit findings usually are an indicator of how well the quality system is performing at a company and whether or not the technical details are being met. After so many majors and a combination of minor findings, the audit can be deemed a failure, indicating that quality must be improved to minimize these findings.

Key process indicators: Another method of quantitative assessment involves the goals being measured at the company. Even though there's a section in AS9100 that requires them, goals are important to have — required or not. They chart success and failure in a visible way, with graphs trending upwards or downwards with respect to the goal. It's an indication of whether all the elements are aligned at the company in such a way that they work in unison to achieve the set number defined as the goal. Whether that means on time delivery or scrap reduction, these set numbers simplify the language communicated to the team of quality system and technical detail alignment

in that everyone can be on the same page.

QUALITATIVE ASSESSMENTS

Let's face it, not every procedure will be written to define every movement at a company. Beyond the standard operating procedure for loading and unloading a furnace or grit blasting a part, there are aspects of the process for which a procedure is not a practical tool nor is it worth tracking how many words or letters are written in a given day to chart quality at the company.

Willingness to learn: What happens when you get a corrective action? Not surprisingly, most people hate it. With the corrective action come the dreaded tools of "Five Whys" or Fishbone Diagrams to reach the root cause of 'why' did it happen? Whichever tool is used, the activity itself requires a gathering of the team and a willingness to realize the opportunity that was missing in the process. And what is interesting throughout the process of 8D or other formal corrective action process is that this system forces communication amongst the team. Forces the employees to all get on the same page and work together to solve the problem. With this, team members are quickly identified as either seeing failures as opportunities or as just a way to complain more about their job. It is the willingness to learn that is really being measured.

Human relations: I've had opportunities where I worked at both large and small companies. And the one thing I often take inventory on is the overall attitude of the workplace culture. One of the simple measures that resonates with me in measuring overall quality at an organization are the human relations. How many of your bosses call you by your name or even remember your name? Upper management talking to the shop floor workers is a good sign a company has a great overall team working together. How many small conversations can you have, but still be productive in a workday? These all add up as well to the bigger picture of getting product shipped out the door on time, and with the highest of quality.

CONCLUSIONS

Quality is not only a measure of key process indicators or numeric goals to hit and sustain. It is even beyond the "say what you do, do what you say," as no procedure can always capture all the things being performed at the company. The presence of promoting quality-type practices is beyond how many pieces of scrap to count or how many corrective actions you have. Nadcap and AS9100 hold companies accountable.

As each production day shifts from one to the next, each crew is expected to maintain this level of quality every day. It's a cycle of continuous improvement where we experience a problem or success and reflect on it to then take the necessary action. This requires quantitative measures to help structure the process and create a language for the company to all speak to achieve the quality goals.

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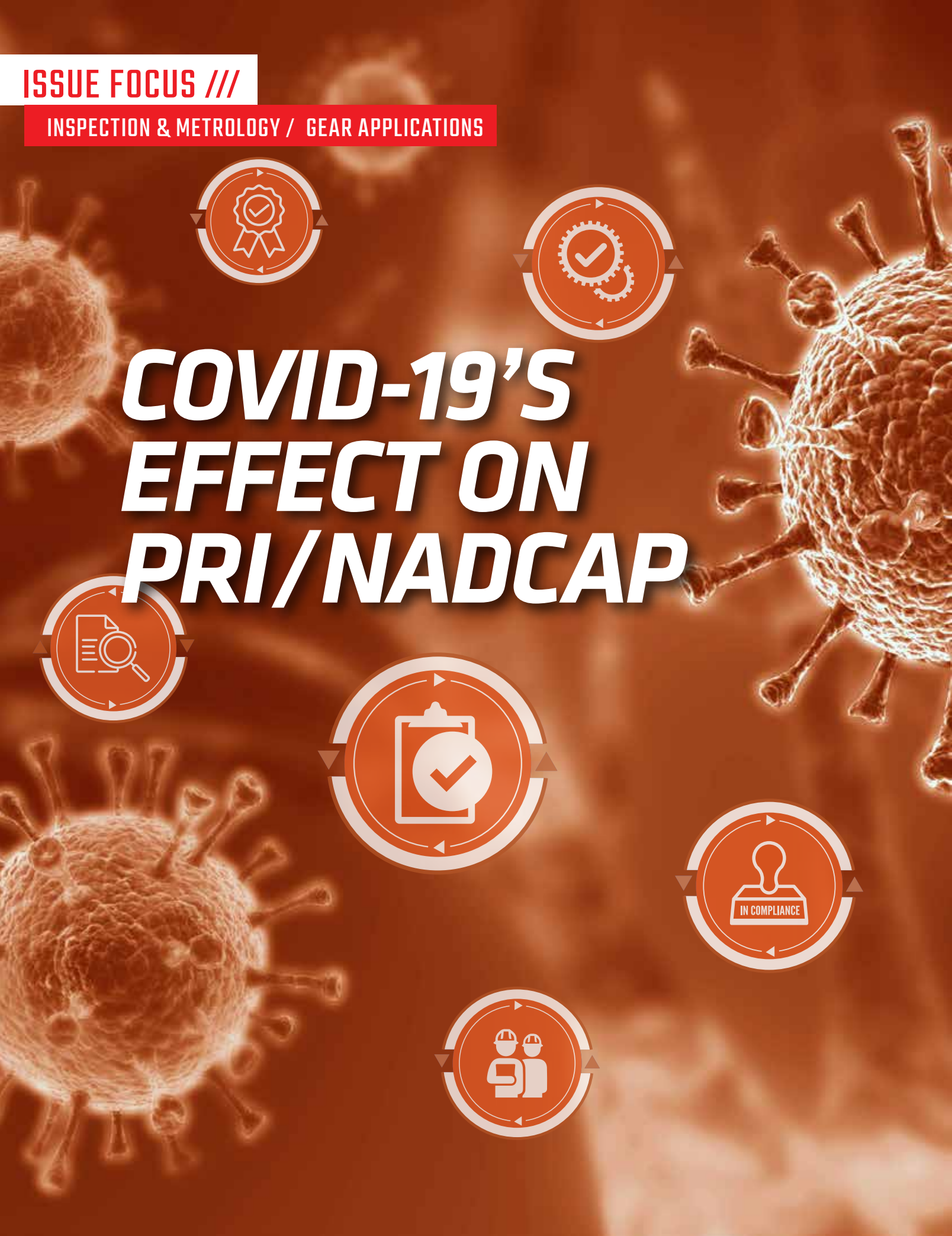
COVID-19'S EFFECT ON PRI/NADCAP



While the aerospace industry pushes through the coronavirus pandemic, it is important that the highest levels of quality are maintained throughout all Nadcap-accredited processes.

By JASON SCHULZE

At this point in 2020, we have all felt the effects of the COVID-19 pandemic both personally and professionally. As of the writing of this article, there have been nearly 10 million cases with more than 220,000 deaths in the U.S. alone [1], and, according to the CDC, cases in the U.S. are rising. For more than nine months now, we have seen its effect on our economy and business alike. For thermal processors in the aerospace industry who are Nadcap accredited, there have been frequent questions regarding anything from audit scheduling and auditor/supplier safety to audit extensions. With that, PRI and its staff have not been immune to the effects either.

I recently spoke with Scott Klavon, the director of the Nadcap Program and Aerospace Operations at Performance Review Institute about the effect the COVID-19 pandemic has had on PRI and Nadcap as well as suppliers. We discussed ways to mitigate potential issues as we work through this pandemic.

How has COVID affected the Nadcap program?

COVID-19 has had a profound impact on the number of Nadcap audits conducted in 2020. Despite the challenges presented by COVID-19 such as governmental travel/access restrictions, auditee site access restrictions and auditor cancellations, the Nadcap program is on track to successfully conduct more than 4,000 face-to-face audits in 2020.

How has the COVID situation affected audit scheduling? What sort of actions has PRI had to take to mitigate scheduling issues?

The COVID situation has had a significant impact on audit scheduling with the need to reschedule audits coming from a number of directions:

› Travel restrictions imposed by regional or national authorities, making journeying to the auditee facility impossible.

› Quarantine rules imposed by regional or national authorities, making the impact of conducting a particular audit so significant on the rest of the audits scheduled that it is impractical to carry out.

› Auditees experiencing operational issues requesting audits to be rescheduled/canceled.

› Auditors unable to travel due to being located in places with shelter-at-home orders or similar, having recently traveled to locations that subsequently declare high transmission rates or with concerns related to travel.

PRI scheduling has had to be creative in their approach to find workarounds and satisfy as many of our customers as possible, while prioritizing the safety and wellbeing of all Nadcap audit participants. This has necessitated measures such as rescheduling audits to group them according to location and relative to the auditor's prior location. With the situation evolving rapidly around the world, even within national borders, this requires continual focus and audit schedule adjustment.

If audits need to be delayed, what is the typical extension period (i.e. three months, six months, etc.)?

At this time, the process defined in Operating Procedure (OP) 1107 is being followed. The staff engineer has the ability to grant up to a three-month extension, and the task group can grant additional extensions up to a year total from the original expiry date.

A key point, however, is that extensions do not change the scheduling quarter or expiry date of the next audit. For example, if an accreditation is set to expire on April 30, 2020, and a six-month extension was granted due to the next audit being audit of quarter, the expiration would still be April 30, 2021 if the audit received a 12-month accreditation; it's not based on the extension date.

If suppliers need to reschedule their audits due to COVID related issues, is the reschedule fee being waived?

Between March and October 2020, the reschedule fee was waived

SCOTT KLAVON BIO

Scott Klavon is the director of the Nadcap Program and Aerospace Operations at Performance Review Institute.

Klavon has overall management responsibility for the Nadcap program as well as responsibility for identifying additional aerospace sector needs and creating industry managed solutions.

Prior to joining PRI, Klavon held a broad variety of positions at SAE International over a 22-year career culminating with a position as part of the executive management team. During Klavon's tenure at SAE, the majority of his time was spent focused on management of SAE's Aerospace Standards program.

Klavon helped lead the SAE aerospace standards program to become the largest aerospace consensus standards development program in the world. Prior to joining the staff at SAE, Klavon was an aviation maintenance engineer at the Naval Aviation Depot Pensacola supporting U.S. Navy and Marine Corps H-1 aircraft. Klavon began his professional career as a commissioned officer in the U.S. Navy.

Klavon holds a Bachelor of Science degree in Aerospace Engineering from The Pennsylvania State University and is a graduate of the University of Pennsylvania Wharton School Executive Development Program.

Klavon is an Associate Fellow of the American Institute of Aeronautics & Astronautics, a Fellow of the Royal Aeronautical Society, and served as a Board of Director for the American National Standards Institute. Klavon is a Chartered Engineer in the United Kingdom.

for all COVID-related Nadcap audit rescheduling and cancellation requests. In October, an adjustment was made, permitting only audits that had to be rescheduled or canceled due to governmental or travel restrictions to be exempted from the reschedule fee.

In addition, COVID-19-related requests to reschedule audits prior to 30 days of the audit start date, where there are no governmental or travel restrictions, will incur a reduced fee to cover the associated costs. Meanwhile, COVID-19-related requests to cancel audits within 30 days of the audit start date, where there are no governmental or travel restrictions, will incur the standard fee as defined in the Auditee Agreement (s-frm-1103).

Are virtual audits being discussed?

PRI is working with the Nadcap Management Council to explore how we can continue to meet the needs of our customers during these challenging times. Virtual audits are one potential solution.

The Nadcap Management Council continues to drive toward identifying the optimal solution for the current circumstance. In the meantime, companies holding Nadcap accreditation have been able to request an accreditation extension of up to 12 months. This prevents accreditations lapsing, but it can only be a temporary answer as it extends the period of time where the facility has not had a Nadcap audit. This obviously creates risk for all stakeholders — from the special processors to the OEMs — so it is not ideal. It is also accreditation time "borrowed" against the next accreditation period, meaning that the time between the next two audits will be reduced. Again, this is not desirable in ordinary circumstances, but these are unusual times.

Some auditors are of retirement age and are at higher risk. Being that auditors are a major resource, has PRI seen a decline in auditors accepting assignments? If so, how has PRI managed this?

Nadcap auditors are independent contractors who have spent their careers developing their expertise within their special process field in the aerospace industry. They enjoy the opportunity that the Nadcap program provides: to travel, to maintain their industry knowledge and professional network, and to control their own work schedule.

PRI has coordinated with them to ensure that they, along with other Nadcap audit participants, are as safe as possible. A number of factors are taken into account, such as the availability of the qualified auditors, location of the auditors relative to the auditee, local and national COVID-related restrictions, and pre- and/or post-travel quarantine requirements.

Has the COVID situation affected staff engineers in any way, and if so, how?

There has long been a goal to have PRI staff engineers qualified as Nadcap auditors, and many of them are. They are subject to the same requirement to conduct a minimum number of audits per year in order to maintain their qualified auditor status, as the other auditors are. During this COVID period, they have been fulfilling that requirement and supplementing the existing auditor capacity as needed. With fewer Nadcap audits being conducted compared to recent years, they have also had the opportunity to spend time on process improvements and other value-added activities.

What can auditees do to ensure the audit scheduling and auditing process run smooth through the COVID situation?

As the COVID-19 pandemic evolves, the safety and wellbeing of all our stakeholders remain our highest priority.

Where it becomes apparent to the auditee that the audit will not be able to take place as scheduled, we are asking that they communicate that to PRI as soon as possible. This not only facilitates our audit administration but means that we may be able to offer the auditor replacement work and satisfy another customer by offering them that audit slot.

As we continue to conduct onsite audits in locations where the situation permits, we have a shared responsibility with the auditees to do as much as we can to mitigate the risk to all audit participants. We have asked that auditees assure the following measures are in place while the auditor is onsite:

› Require anyone who will be in contact with, or working close to, the auditor to wear face masks.

› Maintain social distancing; ensure that meeting rooms and the shop floor permit adequate spacing.

› Respect the request of the auditor to social distance; the auditor must be able to move around freely on the shop floor to conduct the audit.

› Wash hands frequently with soap and water; use an alcohol-based hand sanitizer if soap and water aren't available.

› Minimize the need for the auditor to handle physical items such as documents; provide them electronically where possible.

› Provide a clean work area for the auditor that should be re-sanitized at least once every 24 hours where possible.

What sort of safety precautions are auditors taking on site?

We have asked our employees and independent contractors who are conducting Nadcap audits to observe the following precautions:

› Wear a face mask while onsite.

› Maintain social distancing.

› Respect the request of the auditee to social distance.

› Adhere to travel restrictions and quarantine rules.

› If they feel ill or have flu-like, respiratory, or other symptoms, consider self-quarantine and/or stay at home; avoid exposure to those presenting the above symptoms.

› Avoid large-scale gatherings.

› Avoid contact with livestock and wild animals.

› Wash hands frequently with soap and water; use an alcohol-based hand sanitizer if soap and water aren't available.

› Handle physical items such as documents as little as possible; request them electronically where possible.

Is the COVID situation affecting suppliers' ability to respond to audit NCRs?

NCR responses are required to follow the requirements of OP 1106, which does not allow for extensions on response time. The cumulative delinquency day system — which permits up to 45 additional days — is available for those who are unable to respond by the required due date. This system is used in place of the ability to grant extension.

However, exceeding seven cumulative days of delinquency prohibits the ability to achieve 24-month merit, exceeding 14 cumulative days of delinquency restricts the ability to obtain 18-month merit, and exceeding 30 cumulative days of delinquency could result in failure. However, Nadcap Task Groups have the ability to consider the current pandemic situation when making determination on merit and failure.

I am a PRI Training Lead Instructor and teach multiple courses. So far this year, I have had the opportunity to facilitate two online courses for Introduction to Pyrometry, which went well. Has PRI seen a decline in PRI Training course attendees through this COVID Situation?

As with the Nadcap program, PRI Training has been affected by the inability of individuals — both instructors and learners — to travel due to restrictions related to COVID. As you indicate, PRI Training was able to pivot relatively quickly to virtual training where the trainer and the learners are in separate locations, and the training is conducted live online. We are pleased to report that overall, demand for our training has remained high, and, in some cases, offering the courses online has allowed us to support a broader global audience.

Face-to-face training is still taking place where circumstances allow. We are being guided by local and governmental rules and guidance. Our customers and instructors and venue support are able to offer training with comprehensive social distancing measures in place. Private in-house training, where a number of people from the same company are trained at the company site, provides an even safer option, as only the instructor is new to the venue.

We recently also piloted a blended model where some of the learners were in the same room as the instructor, and others were participating virtually. This is, in a way, the optimal solution as it allows people to benefit from the training in the way that best meets their own needs while complying with COVID-related restrictions.

Being that the annual PA PRI/Nadcap meeting was held virtually in 2020, did PRI see any challenges when compared with the face-to-face meeting normally held?

Conducting Nadcap meetings virtually is not a new idea. It is something that has been considered for a number of years, and in fact, the Nadcap Management Council and Task Groups regularly hold their own meetings virtually in between the face-to-face Nadcap meetings that have traditionally taken place three times per year. COVID hastened the implementation of full Nadcap meetings online. This has presented challenges, as you would expect. It is a significant shift in the organization and operation of the Nadcap meetings. In addition, Nadcap meetings are very interactive, with a large volume of subscribers and suppliers actively engaging in discussions for the betterment of the Nadcap program, the audit criteria, and much more. Facilitating these discussions online instead of face-to-face is a challenge. As Nadcap is a global program, another key challenge has been that the meeting times have not been ideal for participants in some parts of the world. We are grateful for the professionalism and support of our stakeholders as we adapt our practices for optimal online meetings.

If I can focus on a specific commodity: the Nadcap Heat Treat Task Group has been working on revising AC7102/8 due to the revision of AMS2750. In attempting to mitigate issues surrounding COVID, has PRI seen any challenges regarding Task Group discussions for the revision of AC7102/8 as well as its release?

The COVID pandemic has not affected the revision of the pyrometry audit criteria — AC7102/8 - to bring it in line with AMS2750 Rev F. The checklist is being reviewed and modified by a Nadcap Heat Treat Task Group sub-team which meets between Task Group meetings, either by call or virtually or similar. This working practice has not been changed by COVID, and the sub-team support remained strong. The Task Group then has the chance to review the checklist and make comments via a formal ballot process and at Task Group meetings, which are being held virtually. The AC7102/8 checklist revision is on schedule.

This is unrelated to COVID, although a question that may come up from time to time. While suppliers should not discuss findings anywhere except eAuditNet, would PRI encourage suppliers to communicate with staff engineers when an interpretation of requirements is needed from the task group?

Absolutely. The staff engineers are a valuable resource prior to, during, and after the Nadcap audit:

› Before the audit, suppliers are expected to use the Nadcap audit criteria to conduct their self-audit in preparation for the auditor's

visit to their facility. The audit criteria are made available on eAuditNet for that purpose. If questions arise as to how to interpret any part of the audit criteria, it is far better to contact the staff engineer to assure the correct interpretation than waste time on misguided preparation.

› During the audit, if there is a difference of opinion between the auditor and the supplier, the staff engineer can be contacted to make a decision.

› After the audit, there will be contact with the staff engineer in eAuditNet, where the supplier posts responses to any non-conformances identified by the auditor during the audit, and the staff engineer reviews those and poses additional questions as needed. Just like before the audit, if there are interpretation questions, it is recommended to contact the staff engineer directly for clarification. But to be clear, the staff engineers are not able to give you the answer to a non-conformance. There rarely is one answer as so much will depend on your particular facility, procedures, capabilities, and so on.

The Nadcap auditor conference is held annually. How was this accomplished in 2020?

Due to the ongoing COVID-19 pandemic, there continued to be restrictions on travel and large gatherings in the build-up to, and at the time of, the Nadcap auditor conference. Consequently, after consultation with the Nadcap Management Council, PRI canceled the 2020 Nadcap auditor conference. There is great value in holding annual auditor conferences face-to-face, so it was disappointing to miss the opportunity to interact in person with auditors, subscriber representatives, and PRI staff members. In lieu of the 2020 auditor conference, Nadcap Task Groups provided commodity-specific refresher training online.

Is there any other information you would like to share with suppliers that may help us all through this COVID situation while maintaining quality and conformance?

In August 2020, the MedAccred program (which is like the Nadcap program but for medical device manufacturers) published the following guidance for heat treaters in Industrial Heating magazine. It is also relevant for aerospace heat treaters.

MAINTAIN YOUR SELF-AUDIT ACTIVITY

Even if it is limited to a desktop review at this point, ensuring a continued focus on your procedures and records means that they remain front of mind and may help to avoid silly mistakes once normal operations resume. This could be an opportunity for heat treaters to ensure that the following records are current:

› List of equipment.
› List of purchased services.
› List of quality personnel and approved heat-treating personnel on each shift.
› List of customers and specifications.
› List of heat-treat specifications that you work to.
› Copy of internal general procedures for heat-treat processing, pyrometry, and testing/inspection of heat-treated product.
› Organization chart.
› Personnel Training.

COMMUNICATE OPENLY AND OFTEN

Your customers, registrar, regulator, suppliers, and other stakeholders want to know how you are doing. The performance of your business affects more than your business. We are all experiencing many of the same challenges, so you may be able to obtain extensions, waivers, etc., to cover you for this period.

ADAPT WHERE POSSIBLE

When "business as usual" is just not an option, work with your customers and regulators to identify what adaptations you can make that enable you to continue to provide the service they need at the level they expect. While you maintain control of any activity granted a temporary deviation from a requirement, avoiding the disaster of not returning to compliance once this situation has passed will be critical for ongoing conformity.

UPDATE YOUR PROCESS CONTROLS

You must be able to demonstrate that you have reviewed the process control requirements for each of your customers and that you have an internal procedure and "system" that documents compliance, including to other testing and controls required by specifications.

Make sure that you have updated your internal documents to reflect any contingencies you have in place for the current situation. Some of the process controls to think about include:

› Pyrometric Testing.
› Lot Based or Periodic Tensile Testing.
› Periodic Metallurgical Testing (e.g. IGO/IGA Testing, Eutectic Melting, Cladding Diffusion, High Temperature Oxidation, etc.)
› Decarburization/Surface Contamination Testing.
› Leak Up Rate Testing.
› Hydrogen Pick Up Testing.
› First Lot Forging Qualification Testing.
› Carburizing and AC7101/4: Gas and/or Ion/Plasma.
› Metallography / Microhardness.
› Surface Contamination of Steels (IGA/IGO, Decarburization).
› Titanium Testing (Alpha case and Hydrogen pickup).

LEARN LESSONS FROM AVAILABLE DATA

The Nadcap program publishes an overview of some common non-conformances that arise in heat-treatment audits. Any heat treater looking for opportunities to assure the robustness of their operation should consider the following:

› Conduct thorough, regular self-audits covering all aspects of your heat treatment and follow up on any concerns with root cause analysis (5 why's or Ishikawa are great tools for this) and implement sustainable corrective actions. Validate that the corrective actions are actually sustainable at a later date.

› In ordinary circumstances, do not limit your self-audit activity to paperwork — spend time on the shop floor observing the operators at work.

› Make sure your internal procedure specifies the method for determining heat-up rate, start of soaking time, end of soaking time, and cooling rate; omitting these details is a common non-conformance in Nadcap audits.

› Keep the calibration of your equipment and associated records up to date. This includes things such as vacuum instruments, flowmeters, dew point meter(s), and the related master gauges.

› Check that instrument calibration records and stickers, and the calibration of primary, secondary standard and field test instruments show conformance to the requirements of AMS2750, or more stringent customer requirements.

› Verify that there is a system in place to review pyrometry procedures and the results of tests (whether performed in-house or by an outside source) to ensure that AMS2750 or more stringent customer requirements are being met.

› Ensure that the internal TUS procedure conforms to the requirements of AMS2750 or more stringent customer requirements and that temperatures indicated by all furnace thermocouples are recorded and included as part of the TUS record and that the thermocouple correction factors are stated unambiguously and used correctly.

› Validate the internal SAT procedure conforms to the requirements of AMS2750 or more stringent customer requirements and that the SATs are performed on the temperature control and recording systems as required by the applicable instrumentation type, as well as any additional recording systems used for product acceptance in each control zone of each piece of thermal processing equipment.

SUMMARY

While the aerospace industry pushes through this pandemic, it is important that we all maintain the highest level of quality throughout all of our Nadcap accredited processes. PRI staff is working hard to manage their resources and help suppliers by having an open line of communication and maintaining flexibility.

REFERENCES

[1] covid.cdc.gov/covid-data-tracker/#cases_casesinlast7days

ABOUT THE AUTHOR

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PERFORMANCE AND PROPERTIES OF A NEW ALTERNATIVE GEAR STEEL

Hybrid steels show many interesting properties relevant to gear applications, somewhat depending on the area of application and the working conditions.

By LILY KAMJOU and JOAKIM FAGERLUND

In the ongoing strive for light weighting or power densification, high-performance clean steels are showing a significant improvement. As a next step, gear steels that combine several properties, are now proving an interesting alternative. Traditional gear steels achieve their maximum hardness after carburizing and a fast quench. A fast quench usually results in distortion as the part is unavoidably unsymmetrically cooled/quenched. For many gear applications, distortion during heat treatment of final component, can add cost and unwanted hard machining operations. With many components being more sensitive to distortion, especially within electrical vehicles, where NVH becomes even more important, the potential to reduce distortion from heat treatment can be essential. With a new steel composition that hardens by precipitation hardening (aging around 500°C/950F), low distortion can be attained as a fast quench such as an oil quench is not necessary. This type of steel can be both nitrided and carburized. Costly hard machining can therefore be reduced due to the low distortion. Other interesting properties of this new steel that will be presented in this paper are: good mechanical properties at elevated temperatures and good corrosion and oxidation properties compared to traditional gear steels.

1 BACKGROUND AND INTRODUCTION

Increased demands on mechanical properties at elevated temperature set the starting point for the development of hybrid steel.

The objectives were:

› A possibility to reach a high hardness ~58-60 HRC.

› Improved mechanical properties at elevated temperatures.

› Material can be produced cost-effectively (in current process with Electric Arc Furnace EAF, Ladle Furnace & Ingot casting-route).

The strength and hardness of steels are dependent on particles that stop dislocation movement. In order to achieve good strength/hardness at elevated temperatures, these particles need to be stable at those temperatures. In a low alloyed steel (Fe-C), the hardness is dramatically reduced by increased tempering temperature. In tool steels, secondary carbide particles precipitate at about 500°C and contribute to increased strength. Another example of high-temperature precipitates are the precipitates in maraging steels (examples of precipitates: Fe-Ni-Al and Fe-Ni-Ti).

To illustrate how these types of steel respond to tempering, the Ovako Heat Treatment Guide [1] has been used (Figure 1). There it can be seen how the material strength is affected by the tempering temperature; the strength of the "engineering" steel, Fe-0.7C, drops with increasing tempering temperature. The maraging steel as well as the tool steel, both exhibit secondary hardening properties, resulting in improved elevated temperature properties.

The negative aspects of tool steel, are that the high carbon content (which is needed to achieve the desired hardness/strength) in combination with the carbide formers (e.g., Cr, Mo, V) will have a strong tendency to form large carbides during the solidification of the steel. These carbides will have a detrimental effect of the fatigue performance of the steel. The tendency to form large carbides can be reduced by fast solidification (small ingots) or by alternative steel making methods such as ESR or VIM- VAR, but this will have a large negative influence on the cost to produce the steel. Maraging steels have many attractive properties, but the very high alloying content (e.g., Ni and Co) makes it too expensive to be attractive for many applications, and also, the very low carbon content does not make it suitable for an EAF-route.

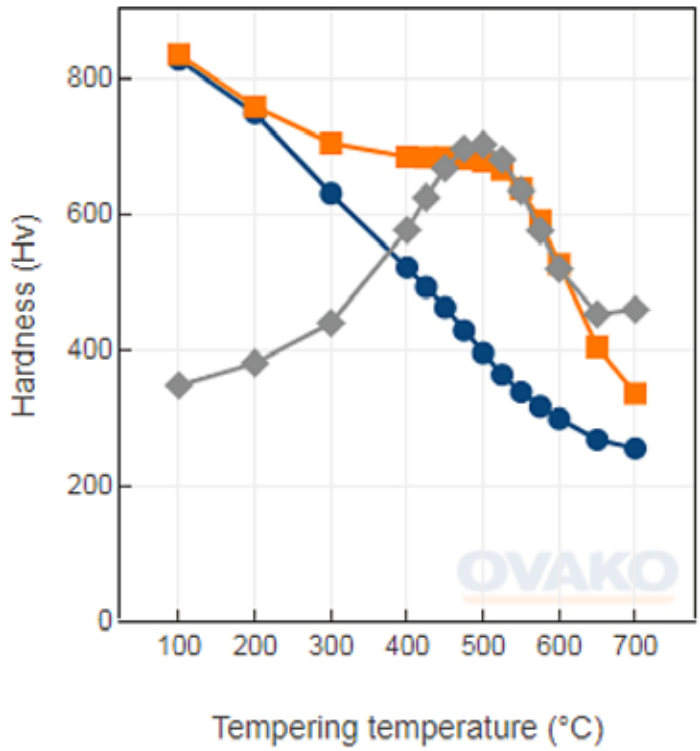

Figure 1: Example of hardness as a function of tempering temperature for three steel grades (Fe-0.7C, Fe-0.7C-5Cr-2Mo tool steel and a maraging steel (18Ni-12Co-5Mo-1.5Ti-0.1Al).

2 MATERIAL PROPERTIES

To avoid the negatives of tool and maraging steels, the aim was to keep the carbon content low, avoiding formation of large carbides and at the same time keep the alloying content, and therefore the cost, at a reasonable amount. Figure 2 shows the steel's low tendency toward segregation, which is important for the fatigue performance of the steel. As can be seen, all elements show an even distribution.

The development has resulted in two steels so far, hybrid steel 1 and hybrid steel 2. The name "hybrid" comes from the fact that the hardness is achieved from both secondary carbides and precipitated intermetallic particles. The chemical composition for the two grades

Hybrid steels require a very slow cooling rate for the martensite transformation and to reach full hardness; the steels are aged/tempered (where no quenching is needed). These facts make it possible to harden the hybrid steels with significantly lower distortion, compared to traditional gear steels, which require a fast quench (typically oil quench).

is presented in Table 1; the carbide forming elements are Cr, Mo and V and the elements that form intermetallic phases are nickel and aluminum. Oxygen, nitrogen, and sulphur in these grades are low; approximately 3ppm O, 20ppm N, and < 10ppm S.

The fact that the steel composition comprises 2 percent aluminum affects the density of the material. Common engineering steels such as the AISI 8620 have a density of approximately 7,800 kg/m^3, whereas the hybrid steels' density is 7,582 kg/m^3, i. e. almost 3 percent lower. For the automotive industry, among others, where weight reduction is in focus, lighter materials can make an impact.

Figure 3 shows the intermetallic Ni-Al precipitates (green and blue) that form at aging of the material. The average precipitate size is 5nm, which means that in 1μm^3 of the material there are approximately 500,000 of these precipitates, adding to the strengthening of the material.

The hardness after austenitization and cooling is 430 Hv for hybrid steel 1 and 550 Hv for hybrid steel 2, and it is after tempering at 500-550°C (aging) that the hybrid steel reaches its hardness; 55 HRC for hybrid steel 1 and 60 HRC for hybrid steel 2, see Figure 4.

2.1 Soft Annealing

Hybrid steels can be soft annealed; with a slow cooling from 800 to 600°C, <20°C per minute, the resulting hardness is approximately 260 HV for hybrid steel 1 and 300 HV for hybrid steel 2.

2.2 Hardenability

Due to the alloying strategy, the material has very high hardenability and can therefore be cooled slowly; no need for a fast quench to reach required properties. As can be seen in Figure 5, the hardness is the same for a bar with a diameter of 10 mm as a large bar with a diameter of 250 mm when air cooled.

2.3 Mechanical Properties at Elevated Temperature

One objective with the present steels is to increase the mechanical properties at elevated temperatures compared to engineering steels. In Figure 6, the yield strength of hybrid steel 1, hybrid steel 2, tool steel, and a bearing steel (100Cr6/52100) are compared. All steels have been hardened and tempered at 550°C (1,022°F). As can be seen, the elevated temperature properties are comparable with a tool steel and significantly improved compared to an engineering steel.

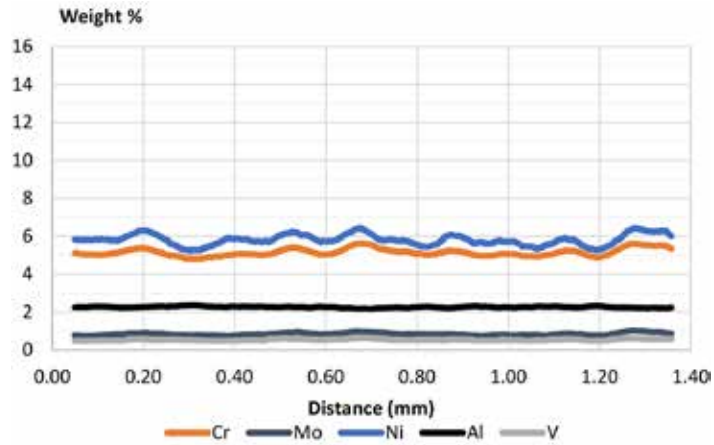

Figure 2: Chemical variation (segregation) of elements in hybrid steel. Line scan.

	C	Si	Mn	Cr	Ni	Mo	V	Al
hybrid steel 1	0.18	0.1	0.3	5	6	0.7	0.5	2
hybrid steel 2	0.28	0.1	0.3	5	6	0.7	0.5	2

Table 1: Chemical composition of the hybrid steels (percent by weight).

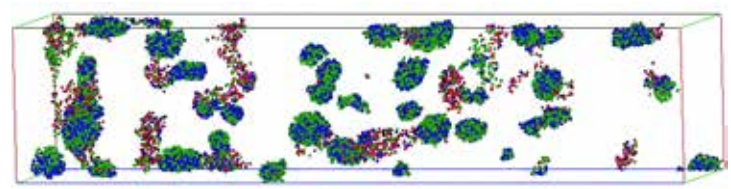

Figure 3: Atom probe tomography showing Ni-Al precipitates and carbides (volume 90x20x20nm).

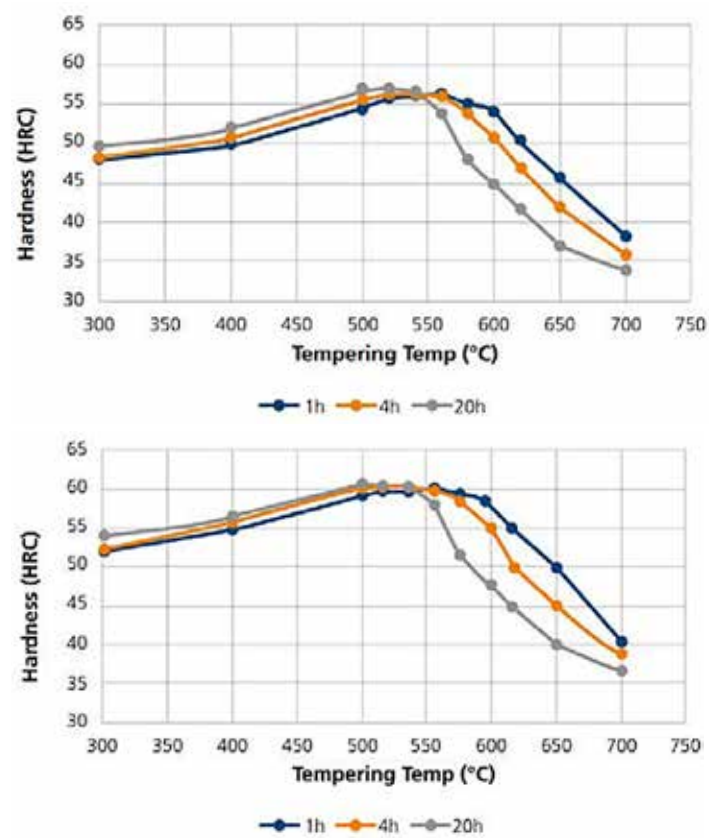

Figure 4: Tempering/aging response of the hybrid steels (left: hybrid 1 (950°C/45min), right: hybrid 2 (1020°C/45min.).

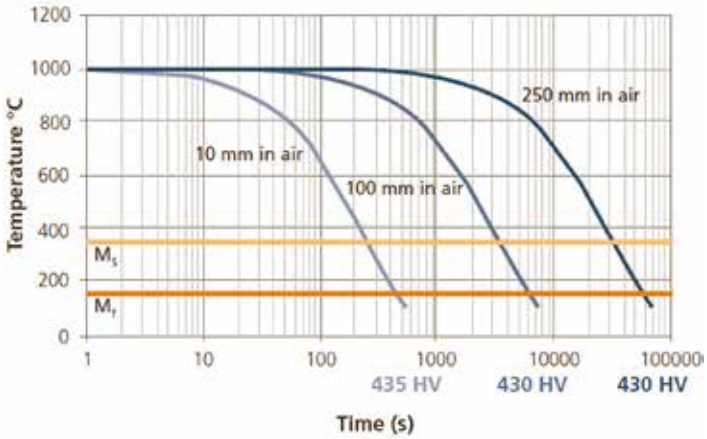

Figure 5: Hardenability of hybrid steel 1.

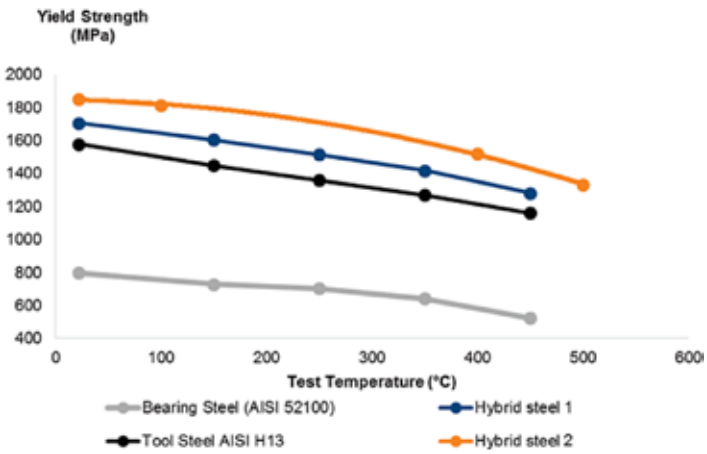

Figure 6: Yield strength as a function of test temperature (all steels tempered at 550°C for 3h).

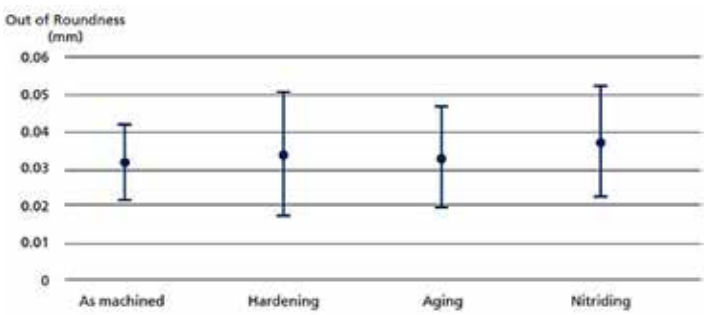

Figure 7: Out of roundness measurements of a ring, hybrid steel 1 (OD 140 mm, ID 120 mm, width 20 mm).

2.4 Distortion

Component distortion after heat treatment is quite a common issue in gear manufacturing and tends to result in cost-intense hard-machining processes such as grinding. This does, of course, depend on the type of gear, gear material, and heat-treatment process, but with standard gas carburizing and quenching processes, it is difficult to avoid entirely. Choosing a material with high hardenability and a slow enough quenching operation will reduce the distortion significantly. The hybrid steels require a very slow cooling rate for the martensite transformation and to reach full hardness; the steels are aged/tempered (where no quenching is needed). These facts make it possible to harden the hybrid steels with significantly lower distortion, compared to traditional gear steels, which require a fast quench (typically oil quench). In Figure 7, a ring has been machined in a soft-annealed condition, hardened (solution treated to approximately 450 Hv), aged to full hardness, and finally nitrided. As shown, the out of roundness is not significantly affected by the heat-treatment steps.

Reduced distortion appears to be of large importance to reduce NVH, especially in electric vehicles, and therefore materials such as hybrid steels, where the propensity to distortion is low, offer an interesting alternative to currently used common grades.

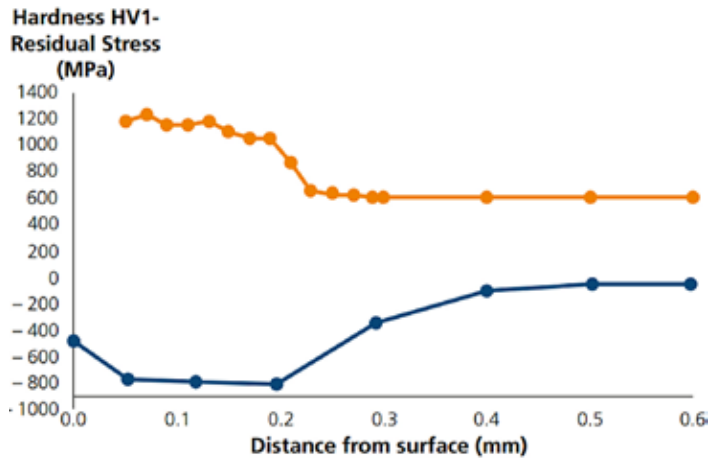

Figure 8: Plasma nitriding of hybrid steel 1.

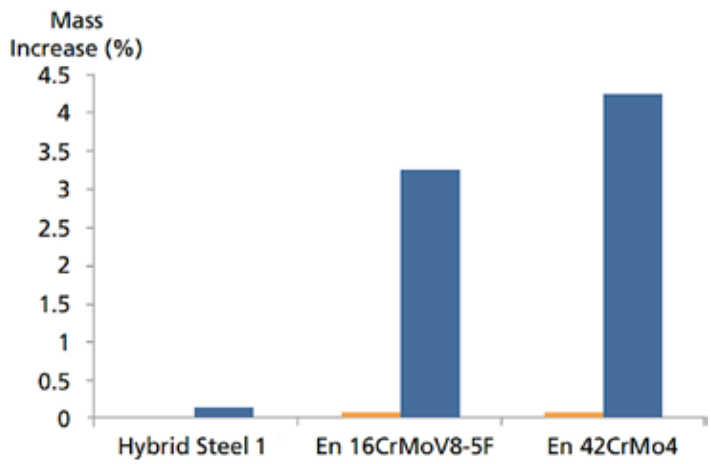

Figure 9: Oxidation resistance in air, 700°C (1,292°F).

2.5 Nitriding

The maximum hardness achieved by nitriding is strongly correlated to the amount of nitriding forming elements (e.g., Cr, V, Mo, Al); therefore, it is no surprise that the hybrid steels exhibit a high surface hardness after nitriding. As an example, hybrid steel 1 was plasma nitrided at 520°C (968°F) for 20 hours; see Figure 8. The surface hardness reached, was approximately 1,200 Hv. The nitriding resulted in a high compressive residual stress. Unlike many engineering steels, the nitriding temperature does not reduce the core hardness since it is performed in the same temperature range as where the precipitation of intermetallic particles occurs. This can be used in different ways; one possibility is that the nitriding process time can be shortened.

2.6 Oxidation/Corrosion Properties

In some applications, the materials' oxidation and corrosive properties are important. Although those properties for normal engineering gear steels are normally not discussed much since they are poor

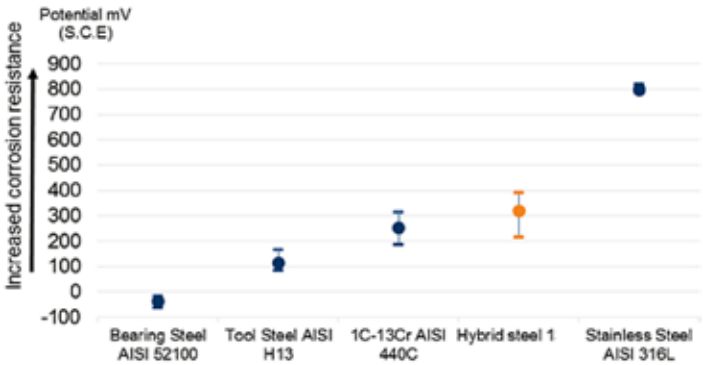

Figure 10: Measurement of pitting potential by ISO 15158 method (10 mV/min in 0.01M NaCl).

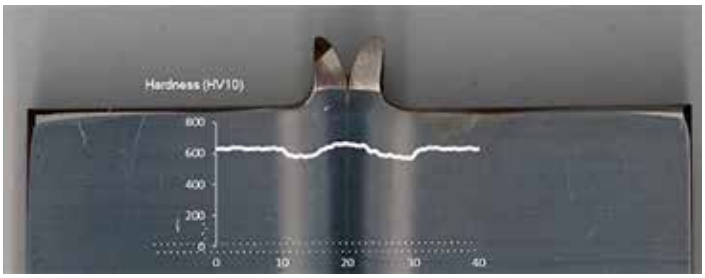

Figure 11: Friction welded hybrid steel (welded and aged).

and sometimes not needed. Due to the content of nickel and aluminum, the hybrid steels have an increased resistance to oxidation or corrosion compared to normal, low-alloyed engineering steels. In Figure 9, the oxidation behavior of the hybrid steel is compared to a carburizing grade (16CrMoV8-5F) and a quench and tempering grade (AISI 4140/42CrMo4). The test was performed at 700°C (1292°F) and in air. As can be seen, the oxidation resistance is significantly improved for the hybrid steel, which shows very little mass increase.

To evaluate the corrosive properties, a standardized test was performed (ISO 15158, [2]), where the pitting potential is measured. A high value means less sensitivity to corrosion. The result (Figure 10) showed the hybrid steel was comparable to AISI 440C (martensitic stainless steel with 17%Cr and 1%C). According to ASTM, the 440C steel is "characterized by good corrosion resistance in mild domestic and industrial environments, including fresh water, organic materials, mild acids, various petroleum products" [3].

2.7 Welding

Hybrid steels are suitable for welding, but require a different approach compared to a typical engineering steel, which reaches its maximum hardness through a fast cooling from the austenitization temperature. In Figure 11, an example where hybrid steel has been friction welded is shown. The hardness before welding was approximately 450 Hv. After welding, the hardness outside the weld increased due to aging/tempering whereas the welded zone is more or less unaffected. After aging/tempering, the hardness increased to approximately 600 Hv. In a typical engineering steel, welding would result in a hard-center portion, and the surrounding material would be tempered to a lower hardness.

2.8 Induction Heat Treatment

When progressively induction hardening a ring/gear, there is a large risk of overlapping heating of the already heat-treated part, which can result in a soft part (tempering of the already hardened steel). Tests have been performed by induction heat treating the hybrid steel and by intentionally doing an overlap.

The hardness results show minimal effect of the overlap.

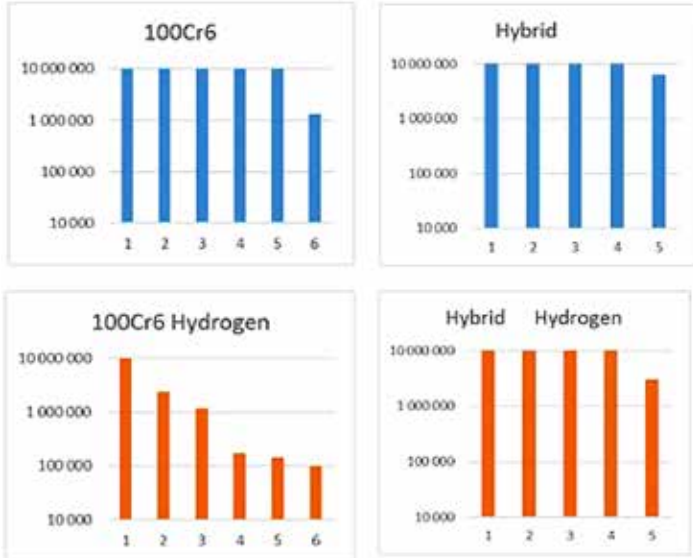

Figure 12: Rotating bending fatigue testing (725 MPa) at room temperature, hydrogen charging (0.5M Na2SO4, 5 mA/cm2, 20 hours).

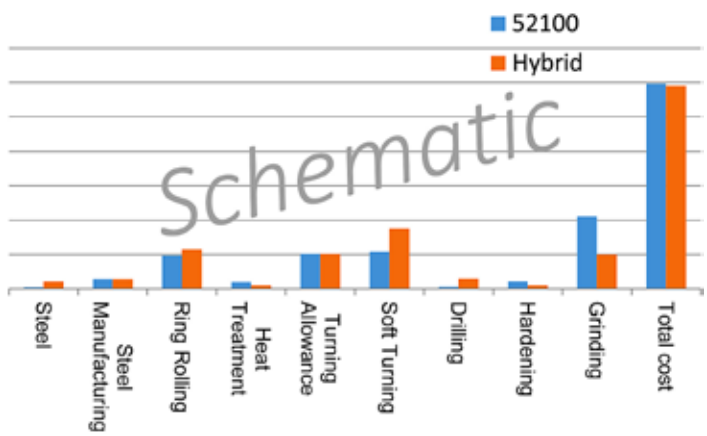

Figure 13: Schematic cost calculation for a bearing.

2.9 Influence of Hydrogen on Fatigue

The fatigue properties of steels can be severely influenced by hydrogen, observed in both bending fatigue and in rolling contact fatigue. This can affect the component and system lifetime for many different applications, from wind power to electric vehicles, where hydrogen can be an issue and where the choice of material can be crucial. Hydrogen can be an issue in gear applications, as sliding contact, together with the lubricant can introduce hydrogen into the gear (depending on lubricant, temperature, and leak currents).

Tests of hybrid steel compared to bearing steel (100Cr6/52100) indicate it is less prone to lose its fatigue strength due to hydrogen. Tests were carried out on rotating bending fatigue specimens charged with hydrogen. As can be seen in Figure 12, the hybrid steel performed better than the bearing steel, indicating it might be less sensitive to hydrogen (top two diagrams without hydrogen charging, bottom two diagrams with hydrogen charging).

3 GEAR MANUFACTURING

There are many factors that influence the total cost of a component, see Figure 13 where an example of a bearing is shown. Generally, and as seen in the example, raw material cost is a small amount

compared to other process steps. By reducing, for example, hard machining/grinding there is an opportunity to allow for a more expensive steel, also in gear applications.

To make full use of the potential of hybrid steel, machining after hardening, at a hardness around 450 HV should be done, since that enables cost-efficient production. There are, however, several possible manufacturing routes from which gears can be produced using hybrid steel.

› Through hardened gears, which are solution treated and aged, resulting in a hardness of 55 HRC or 60 HRC respectively for hybrid steel 1 and hybrid steel 2.

› Solution treated, aged and nitrided (alternatively solution treated and nitrided, with aging taking place simultaneously as nitriding), resulting in high surface hardness around 1,200 HV and a bulk hardness of 55 or 60 HRC respectively.

› Soft annealed and solution treated by induction in the surface region of the gear with additional aging, resulting in a surface hardness of 55 or 60 HRC respectively combined with a core hardness of ≥260 or ≥300 HV respectively (depending on hardening parameters).

Hybrid steels show good results in bar rolling, tube- and ring-manufacturing as well as for forgings, indicating that normal production routes for these types of steels should be very similar to standard engineering steels.

4 SUMMARY AND OUTLOOK

Hybrid steels show many interesting properties relevant to gear applications, somewhat depending on the area of application and the working conditions. Distortion and the reduction thereof, is often one of the main concerns for gears, due to cost implications or challenges in the final machining steps. Finding ways of reducing distortion through the choice of material usage as well as heat-treatment processes might facilitate the manufacturing. For applications where a higher core strength is required, as well as a high surface hardness, both hybrid steel 1 and hybrid steel 2 could be an alternative.

Some properties of hybrid steels include:

› Low microstructural segregation.
› High-volume, cost-efficient production.
› High strength, especially at elevated temperatures.
› Ultra-high strength with good weldability.
› High hardenability enabling low distortion.
› Excellent surface treatment possibilities.
› Good corrosion resistance.

In a currently ongoing project, nitrided gears will be tested for bending fatigue performance in a pulsator test rig and further on, carburizing tests on gears are also planned. To understand the machinability of the steel better, and possible production routes, there is also more gear manufacturing planned in the near future.

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ABOUT THE AUTHOR

Lily Kamjou and Joakim Fagerlund are with Ovako AB.

MAINTAINING UNIFORM TARGET TEMPERATURE

The latest design control system for batch ovens is equipped with high accuracy operating parameter requirements.

By TASHA JAMALUDDIN

There are various processes where temperatures and other operating parameters in the oven must be controlled accurately in real-time with minimal delays. Taking a metal curing process as a viable example, we must acknowledge that the production of adhesives or various polymers materials and their bonding to the metal surface is a highly temperature-sensitive process. The temperature affects the reaction kinetics and, more importantly, the atomic structure of the particular substance. The conversions of the atomic structure configurations occur at a specific temperature, and reaching the nearest temperature to target one is essential for manufacturing durable and high strength materials.

One of the most troublesome issues in industrial ovens applications is maintaining the target temperature uniformly across all oven sections. The excessive production demands and the highest quality products are followed by overwhelming operating costs, especially in the aerospace industry. Manufacturers must apply the curing process to smaller production parts to ensure that the material's target tensile strength and durability are reached. Since the curing process often represents the production process's bottleneck, there is a need for investment into multiple ovens that will make up for excessive retention times and enable continuous production.

Epcon Industrial Systems' EELV curing oven and its control system are custom-designed to secure the constant quality production with monitoring where the user is notified by alarm if any of the parameters reached the critical boundary value. (Courtesy: Epcon Industrial Systems)

THE OVEN DESIGN

Epcon Industrial Systems continues to invent solutions that meet a variety of customer's needs, which implies the highest quality production of large parts with accurate control of operating parameters and real-time monitoring. The EELV curing oven and its control system are custom-designed to secure the constant quality production with monitoring where the user is notified by alarm if any of the parameters reach the critical boundary value.

This oven is the latest technology curing system for aerospace industry. The oven is designed for operating temperatures in the range of 300 to 400°F. The electricity represents a heating utility with two 500 kW incoloy heating elements. In contrary to ovens with natural gas as a heating utility, the electricity as a fuel does not define a manipulative variable in the curing process, which means that its power is constant at all times. Therefore, using two electric heaters in two chambers within the oven, the continuous heat supply is enabled. The electric heaters allow the heat-up rate of 2°to 5°F per minute using a three-phase electric power of 480V. The main issue is the distribution of heat throughout all oven sections and the achievement of a uniform temperature.

Both chambers are supplied with two recirculation fans. They are posted at the opposite sides of the chamber where supply plenums are installed on both sides. The supply plenums are wall-mounted and shall cover a 62-foot length of the oven work chamber. Heating air is returned through the return plenum installed on top of the working chamber, creating a horizontal cross-flow pattern from both sides. The cross-flow of two air streams enables their mixing, merging into one stream, flowing vertically through the working chamber. By two-chamber assembly and four recirculation fans, sufficient airflow through all oven sections is achieved, providing a highly efficient convection heat-transfer mechanism. The nozzle adjustment of the fans' plenums and programmed RPM of the fans' motors secure the tubular flow regime of the air that additionally contributes to the airflow in every direction covering all surfaces of the material. Each fan with an airflow has a switch as an interlock. Therefore, the alarm is sent if any of the fans fail, causing other fans to stop working. To maintain a continuous flow of air through the oven and constant pressure, the four 1-inch vacuum ports are posted, one at each side of the chamber. The ports are piped to a single point connection on the customer provided vacuum source. Each vacuum port has its transducer for monitoring from the control system.

During the heating session, the recirculation fans have a primary role in maintaining the uniform temperature across the oven, while exhaust fans work slower with a minor output. On the other side, the cooling session is more complex, and it requires control of the cold air flow by two parameters. Two exhaust fans posted at each chamber are responsible for cooling the oven at a rate of 10°F per minute. Their output is 12,000 CFM during cooling mode in contrary to heating mode when it is 1,500 CFM. The exhaust fans are connected to pneumatic modulating fresh air dampers. The high-accuracy pneumatic actuator adjusts the damper opening in real-time and regulates the fresh air intake. When the oven is required to be cooled, these dampers open, and exhaust fans speed up to draw fresh air inside the oven to efficiently cool the parts. The damper opening and the RPM of the exhaust fan motors are manipulative variables, and they are finely-tuned based on the negative feedback control principle.

The curing process is often highly demanding in terms of the need

The EELV curing oven is the latest technology curing system for aerospace industry. (Courtesy: Epcon Industrial Systems)

for multiple sessions with different retention times and operating conditions. The issue with entering operating parameters manually between sessions is that it leaves a space for a human error, but more importantly, it causes that process's stages not to last as designed. If the operator needs 10 seconds to enter the new parameters between process stages and the process possesses 12 different stages, the result is two minutes where the system doesn't run accordingly, which is not acceptable in modern industrial production. The production of airplane parts needs a highly controlled production environment to ensure that part will remain stable at pressures and extremely low temperatures in the stratosphere.

CONTROL SYSTEM AND INSTRUMENTATION

Epcon Industrial Systems designed a custom PLC (programmable logic controller) connected to an HMI Rockwell Factory Talk View Site Edition Station Unlimited Display. The PLC directly controls the oven operation, including all fans, vacuum manifolds, and electric heaters. The oven-control system is designed specifically to satisfy complex batch process operational requirements. By using a human interface, the user is enabled to define 25 alphanumeric cycle descriptions and up to 11 different steps with the following:

Ramp-up Steps

1. Rate of temperature rise (min/max).
2. Oven air temperature (max.).
3. Target temperature set point.
4. Vacuum on/off and set point.

Soak Steps

1. Soak temperature set point.
2. Soak temperature tolerance.
3. Soak time range.
4. Vacuum on/off and set point.

Cool Down Steps

1. Rate of temperature drop (min/max).
2. Target temperature set point.
3. Vacuum on/off.

The additional features of the control system include:

1. Full air/part temperature control vs. time.

2. Control of max and min air heating and cooling rates with specifically designed dimming systems for electric heater output adjusting.

3. Control of cure time threshold.

4. Cure cycle data.

Hazard prevention and satisfaction of all OSHA standards are achieved by programming a system to shut down immediately if one of the following requirements is fulfilled:

1. Oven door open with oven temperature more than 150°F (Door switch).

2. Oven over-temperature state.

3. Heating/recirculation chamber over-temperature condition.

4. Loss of airflow of each fan (airflow switch).

5. PLC failure.

In addition to the regular electricity supply, the uninterruptible power supply is added to this control system. A UPS shall be provided for a 120V control circuit with the capability to operate PLC and operator interface for 60 minutes in the event of a power outage. The UPS is a true online model with field replaceable maintenance free batteries.

TEMPERATURE CONTROL AND MONITORING

The control system allows operators to monitor the oven on air thermocouples or individual part thermocouples using multiple thermocouples for redundancy. The oven is commonly supplied with 4 "J" type thermosets that continuously monitor the temperature in all parts of the chamber. According to customers' needs, the number of thermocouples and their positioning may be adjusted by Epcon's engineering team. These thermocouples shall be permanently installed in the oven through the oven walls. High sensor sensitivity at various air humidities and temperatures is enabled using the thermocouples in the form of sheathed grounded junction elements with industrial protection head. The thermocouple I/O points on the PLC are wired to a jack panel (with female type "J" jacks) mounted in the control panel with clear labels. The PLC I/O modules are designed so separate outputs such as RPM of the fans' motors and damping actuators are programmed to act according to the one particular thermocouple's response, making an energy-optimized system at all times.

CONCLUSION

The firm proof that this type of control configuration is indeed the optimal solution for large batch curing ovens is its recent application in the aerospace industry. Epcon Industrial Systems designed the system tested with 50 thermocouples at different places within the large capacity oven. During the testing, all thermocouples registered temperatures within 5°F from the set temperature, showing the uniform temperature distribution in all the chambers' sections. Another addition in the oven was a unique precise rotating device to rotate the rocket motor casing during the curing process. The rotating device was run by a rotation system servo motor drive, which presents an Allen Bradley product, and it is interfaced with a PLC and operated from panel-view. The rotating device's addition significantly contributes to equal exposure of all product parts to the direct air stream, ensuring the highest quality of every millimeter of the product unit.

ABOUT THE AUTHOR

Tasha Jamaluddin is managing director of Epcon Industrial Systems with a demonstrated history of working in the environmental services industry. She is a board member of the local HBS (Harvard Business School) Club and a longstanding member of the Environmental Technology Trade Advisory Committee (ETTAC). For more information, go to: www.epconlp.com

COMPANY PROFILE ///

ECM USA

PROVIDING GREAT EQUIPMENT WITH EXCELLENT CUSTOMER SERVICE

ECM Robotics offers a variety of robots and leading edge technologies: polyarticular, parallel and scara, collaborative integration, vision systems, and vision tracking. (Courtesy: ECM)

As an industrial vacuum furnace manufacturer, ECM USA provides high-quality low pressure vacuum carburizing, hardening, and vacuum carbonitriding furnaces, services, and spare parts for North, Central, and South America – especially in the automotive and aerospace manufacturing markets.

By KENNETH CARTER, Thermal Processing editor

When ECM USA General Manager Dennis Beauchesne first started at the industrial heat-treat supplier, he would only see one or two cars on the road with a few parts processed with ECM's equipment.

Now, more than 20 years later, that number of vehicles has grown exponentially.

"I can go down the road on any street in the U.S. today, and I would say there's a 90 percent chance that the car that passes me has parts in it that were processed on our equipment," Beauchesne said.

Processing parts for dozens of automobile companies — including the Big Three — is quite the accomplishment for a company that started out in France with about 30 or 40 employees.

Although ECM started in 1928, it really jumped into the heat-treat game in 1964 building vacuum furnaces.

"We started vacuum carburizing, and that's when we decided we required subsidiaries — until then, they were a pretty small company," Beauchesne said. "Then we started building low pressure carburizing furnaces for a lot of the large automotive companies — Fiat, Chrysler, Ford, GM. And then, of course, Tier 2 companies like Bodycote for heat treating and GKN, Axle Alliance, those kinds of companies, for systems. We grew from a single vacuum furnace kind of company, where we had standalone vacuum furnaces, to today, where we're into large-scale production, multi-chamber production, low-pressure carburizing, and automation. Now we're expanding into robotics along with advanced automation and vacuum furnaces."

WIDE RANGE OF PRODUCTS AND SERVICES

Customers who come to ECM USA for their heat-treat needs will find a gamut of products and services, including vacuum furnaces that range from single chamber systems used for brazing, vacuum annealing, hardening, and gas quenching from 2 to 20 bars, but also equipment for specialty processes such as vacuum carburizing, vacuum induction melting, and a process called vapor phase aluminization (VPA), according to Beauchesne.

"All of these pieces of equipment can be of small to large-scale or high-production type of equipment that can be equipped with specialty automation and robotics, so we can take a single piece all the way into a complete assembly," he said. "We've integrated some high-temperature sintering furnaces along with robotics for ceramic applications. I would say, if it's vacuum, high temperature, and there's automation involved, that's really our business."

Being able to supply so much to its customers is something Beauchesne said is essential to ECM's success in the heat-treat industry.

The ECM USA Synergy Center utilizes the ECM Nano vacuum furnace to provide pre-production testing and is fully equipped for metallurgical analysis including distortion and hardness evaluations. (Courtesy: ECM)

"We want to be a one-stop shop," he said. "We're not just here to supply vacuum furnaces and some automation; we'd like to also help the customer with all the fixturing that goes along with it, the water systems that they need, just a full supply. We don't like to go to the customer and say, 'Well, that's on you. You have to get that part of it. Here are the specs we need, you make it happen.' We'd like to help the customer along with everything."

AUTOMATION

Automation has been a key component of ECM's products and services for the last 25 years, according to Beauchesne.

"If the customer gives us a full load of parts — maybe 100 or 200 parts already built or maybe somebody manually built the load — then we can handle the load all through our system," he said. "Usually, we have a few processes within the range of our equipment, like washing or pre-oxidizing before it goes into our vacuum equipment to do a vacuum hardening or a low-pressure carburizing, and then we'll have tempering. What we would do is provide roller conveyors and chain conveyors that would convey the load through all those processes where they would come out so the customer could break down that load again into single pieces to get them through the rest of the plant."

For the last two years, ECM has been working with its customers on a robot that could be integrated into a single piece flow, according to Beauchesne.

"We have a new system called the Nano — which is a smaller

"They want someone that doesn't just supply a furnace and doesn't just supply a robot or a piece of automation."

ECM Nano integrates directly into the production line which allows it to reduce the cycle time while simplifying the flow between the machining and heat treatment. (Courtesy: ECM)

ECM quality service includes training, on-site preventive maintenance, remote maintenance, spare parts, metallurgical testing, retrofits, used equipment and more. (Courtesy: ECM)

load — and it will integrate very easily into single-piece flow lines, because that's where we see a lot of production going to: a single-piece flow with a higher quality on each piece, rather than having a larger load with marginal quality from one corner to the other of the heat-treated load," he said.

These are just some of the innovative achievements being developed to help customers, and Beauchesne said ECM is prepared to help customers no matter their knowledge base.

"Often, the customer has a specification on the parts they want to do, but we've also had customers that don't have a good understanding as to where they need to go with the thermal cycle," he said. "In both cases, we would evaluate the part and evaluate the process that they know and give our experienced opinion to help get to a starting point."

SYNERGY CENTER

A special feature that ECM offers its customers is the Synergy Center, located within their Wisconsin headquarters, where testing can be done before a customer commits to equipment and applications, according to Beauchesne.

"Basically, we were already doing testing for different customers," he said. "And so, we formalized it to synergize with other suppliers in the heat-treat industry, like fixtures, water systems, carbon fiber, and other lab-equipment. In the Synergy Center, you can not only talk about vacuum furnaces and the application of heating and processing, but we can also talk about the other peripheral equipment to take care of the customer."

Once ECM starts working together with a customer, the process can take several paths, according to Beauchesne.

"Typically we would look at an hourly fee for the Synergy Center or the furnace time needed to process the testing — if it's a test that we are familiar with and that we understand — then we'd give them a price," he said. "Or if they are looking for a package of testing and a furnace purchase then we would do a few tests for free."

From there, ECM would develop a test matrix that would lay out the best business plan for the customer moving forward, according to Beauchesne.

"That's pretty much how it is; it's first, one or two tests, and then we go to a test matrix," he said. "At the same time we're doing that, we're talking to them about their production needs: How does it fit into the plant? How much workspace do they have? What is the production requirement for that particular part? Where is it going to be in the world? Is it Mexico; is it Canada; is it the U.S.; is it Europe? Is it robotically loaded? Does it have to run on the weekends? We then can help them out with any of those application and production questions, and ultimately fit the process into their production needs. We're not just trying to supply a piece of equipment where you plug it in and make it work. We look at the whole picture of their production in order to get a part out the door."

All of these considerations are important when a customer is looking for a supplier that can do it all, according to Beauchesne.

"They want someone that doesn't just supply a furnace and doesn't just supply a robot or a piece of automation," he said. "We

Eco-friendly vacuum furnace system for a cleaner, safer, and more efficient heat treat operation aimed at replacing sealed quench or IQ furnaces. (Courtesy: ECM)

have a lot of customers that we're working with that want to bring heat treating in house. They don't want to send it out anymore."

Part of that means acquiring a furnace and trying to figure out how to make it work, which means a company will need the expertise necessary to understand the metallurgy, provide the equipment, provide the after-sale support, and where they can present a part and then get a heat-treated part back, according to Beauchesne.

"That's the kind of customer that we see happening in the heat-treat business, and also the kind of customers that ECM is gearing up to serve," he said.

THE ECO SYSTEM

Adding to that impressive resume of products and services is ECM's recently introduced ECO furnace line that's being developed to help the existing heat treater with replacing integral quench or sealed quench furnaces.

The new technology can offer functions such as vacuum carburizing or vacuum hardening done with a lower carbon footprint without the huge investment of replacing all of their heat-treating furnaces in order to install new vacuum furnaces, according to Beauchesne.

"This ECO line will take out a 36-by-48 IQ available by a number of global suppliers," he said. "You can place an ECO system in line with those existing furnaces, temper ovens, washers, and more."

The ECO line provides an alternative for traditional heat treaters when it comes time to upgrade their 30- or 40-year-old furnaces, according to Beauchesne.

"If they want to move into new technologies, but they feel like they don't want to get rid of all their furnaces and buy a new line, then this ECO line breaks the barrier between a standard IQ atmosphere furnace to get you into a vacuum furnace that has all the advantages of vacuum," he said. "You don't have any flames in the plant coupled with a very high level of safety, while reducing your carbon footprint by hundreds and thousands of pounds of carbon."

The ECO line, which was introduced at Furnaces North America earlier this year, already has people talking, according to Beauchesne.

With all that it offers to the heat-treat industry, it's important to note that ECM's core mission is to integrate equipment into heat-treat plants but also to keep them serviceable 24 hours a day, seven days a week — a task the company has performed exceptionally well for decades.

"That's one of our biggest achievements," Beauchesne said. "We emphasize a lot to potential customers that we have quite a bit of equipment in the automotive industry running 24/7. There's a lot of support that you need to have, not only from project management in the planning phase, but electrically and mechanically, and also, after implementation, you have to support them and never have them go down."

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ANDREW STOREY /// FIELD SALES SPECIALIST FOR MATERIALS ANALYSIS /// LECO CORPORATION

"With the bulk analysis method for carburized layers, we're seeing a lot of penetration into commercial heat treaters and the rail industry specifically."

What's a typical week like for you?

I'm the technical person who works on a specific group of products on the sales side of the business. In more normal times, I would be traveling around with our U.S. and Canadian sales teams to meet with our customers and help find solutions to their needs on three primary products: LECO's glow discharge optical emission spectrometers, automated microhardness testers, and digital microscopes. Sometimes, I would join our mobile laboratories that circle the country annually. Lately, most customer interaction has had to take place virtually. The last year has allowed for a lot of content generation for our sales team (presentations, videos, etc.)

Why is carburization important and how does bulk analysis come into play?

There are a lot of different objects in our lives that are carburized, which involves increasing the carbon content and making microstructural changes to the surfaces of materials to effectively make them more wear-resistant. Common examples of carburized parts are gears and bearings that are in your car and the threads of a screw.

A consistent and measurable carburization process makes these parts withstand the forces they encounter during use. Because of LECO's history with carbon determination with combustion, we often have customers approach us asking for ways to measure carbon in the surface layer. Bulk glow discharge analysis is often a better way to make this measurement.

What's the importance of the LECO GDS900 and performing that analysis? How does that the machine characterize carburized steel?

The GDS900 is a LECO optical emission spectrometer that is capable of full-elemental determination of conductive materials. The thing that's really differentiating about the instrument is that it has this glow discharge source, which can non-thermally remove surface layers one at a time and subsequently analyze those layers. A pre-analysis period enables the data to be collected from a portion of the sample several microns from the surface. That allows us to avoid mixing carbon from the carburized materials with surface contaminants, such as oils, dust, or even a fingerprint that all can contribute to an elevated carbon content on the very near surface. These measures collectively enable a repeatable measurement of the carburized layer alone.

That's where we're able to make that repeatable measurement at a particular depth that we know is in the carburized layer rather than combining it with either the surface or the core material. And it's a very particular measurement.

Why aren't physical tests used to determine that carbon composition?

Generally, when physical tests are used to measure carburized materials, they are measuring characteristics that correlate well with changes in carbon content. I work with our micro-hardness testers, which are very commonly used to physically test carburized materials. With microhardness, one can measure how hardness changes as a function of surface depth. However, there's no means of universally relating carbon content to that hardness because, with different materials, you're going to have different starting carbon content and non-carbon components of the material that affect its hardness. Accordingly, we can't just take a hardness value and say that equals this percentage of carbon. The glow discharge spectrometer fills in that question.

What makes the GDS900 unique with this type of analysis?

The unique part really is the Grimm glow discharge source. The GDS900 is an optical emission spectrometer, and there are many instruments that also operate under that same general principle of removing surface material, exciting it, and subsequently analyzing the emission spectrum.

But what's different here is that we have a really stable source that's removing that layer-by-layer, which enables us to characterize a more specific part of the sample. Other competitive sources offer physically fluctuating plasmas that anchor to a part of a sample and sublime and melt a surface rather than eroding a layer at a time. On top of that, the GDS900 has an automatic self-cleaning mechanism at the end that really limits the amount of moment-to-moment maintenance and cleaning that's required. Those are the underlying differences that make it uniquely able to achieve this analysis in ways that competitive equipment does not. On other glow discharge instruments from LECO, this source also enables the determination and plotting of full elemental composition as a function of surface depth.

What types of practical situations would this process be used?

With the bulk analysis method for carburized layers, we're seeing a lot of penetration into commercial heat treaters and the rail industry specifically. But what we've also been able to observe very positively is that it's not just new users saying, "Oh, I'd like to do that in my laboratory." We also have current GDS users who already have been analyzing steel conventionally, and they've been able to add this method without any new costs.

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