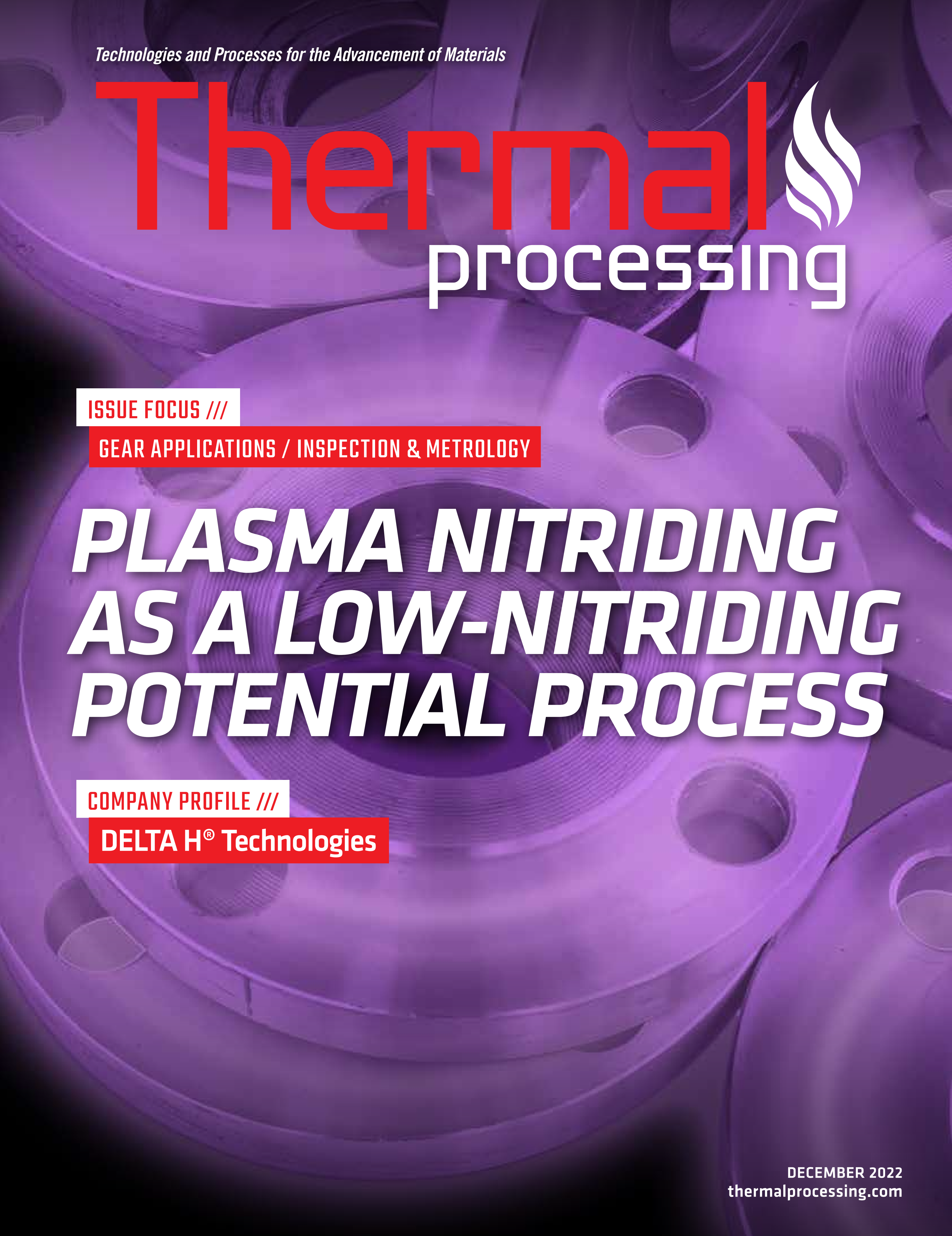

Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

GEAR APPLICATIONS / INSPECTION & METROLOGY

PLASMA NITRIDING AS A LOW-NITRIDING POTENTIAL PROCESS

COMPANY PROFILE ///

DELTA H® Technologies

DECEMBER 2022
thermalprocessing.com

CONTENTS ///

COVER PHOTO: SHUTTERSTOCK / ILLUSTRATION BY RICK FRENNEA

DEPARTMENTS ///

DECEMBER 2022 VOLUME 11 / NUMBER 12

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FROM THE EDITOR ///

2022 was a mixed bag – to say the least

The year 2022 took some odd turns before it got ready to cross the finish line, but at least we can be thankful that it wasn't a repeat of 2021, or worse, 2020.

On a positive note, with the country and the world still trying to pull itself from the grip of inflation, it looks like the heat-treat industry is still showing every sign of returning to normal.

But as we enter 2023 and beyond, let this 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-treating industry in your hands — whether that be virtually or literally — just as we did this year and in many years' past.

But before we say a final goodbye to 2022, make sure you take some time to discover this month's issue of *Thermal Processing*, which contains quite a bit of information.

December's topics are gear applications as well as metrology and inspection.

With our sister publication being *Gear Solutions*, it only makes sense that we tackle how those gears need some type of heat treating before they are able to perform their delicate, often complex, tasks.

In our cover article, Edward Roliński and Mike Woods with Advanced Heat Treat Corp., share their insights on plasma nitriding, and how it can be used to prevent the formation of brittle layers when surface hardness is increased.

On the subject of metrology and inspection, an article from Athanasios K. Zois looks at some laboratory case studies where experiments were conducted to measure the effects on different steel samples as they underwent various types of heat treatment.

As electric vehicles become more prevalent on the roads, making that technology more efficient will be on everyone's constant to-do list. In an article from Andy Richenderfer, he investigates a new cooling technology for electric vehicles.

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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IFHTSE

Solar Manufacturing's third-quarter furnace orders ranged in size from the compact Mentor® and Mentor® Pro series to a large production furnace with a work zone of up to 72 inches in length. (Courtesy: Solar Manufacturing Inc.)

Solar Manufacturing posts successful third quarter

Solar Manufacturing Inc. had a successful third quarter this year, acquiring purchase orders for 10 vacuum furnaces. The types of new furnace orders ranged in size from the compact Mentor® and Mentor® Pro series to a large production furnace with a work zone of up to 72 inches in length. The furnaces will be shipped to companies across North America in the following market sectors: aerospace, commercial heat treating, and additive manufacturing.

"With the unknown business and political climate next year, we are fortunate to be building a healthy backlog of furnace orders to weather any potential economic storm that may lie ahead," said Trevor Jones, president of Solar Manufacturing. "Additionally, strong quotation activity levels seem to indicate customers are optimistic to expand after the pandemic ramifications continue to ease."

Solar Manufacturing designs and manufactures a wide variety of vacuum heat treating, sintering, and brazing furnaces and offers replacement hot zones, spare parts, and professional service.

MORE INFO www.solarmfg.com

L&L ships furnace to ceramic matrix parts manufacturer

L&L Special Furnace Company, Inc. has delivered a Model XLC3672 to a Midwest manufacturer of ceramic matrix parts (CMCs). CMCs materialize when nano fibers of silicone carbide or other ceramic nano threads are wound together, forming various sheets and 3D-printed shapes deployed in aerospace and military applications. The resulting finished product is lighter and stronger than titanium.

The nano threads in the CMC process are coated with proprietary resins that need to be completely removed from the substructure using heat. It is also important that there is no oxygen present during the process as this will significantly weaken the part structure.

The Model XLC3672 has a work zone of 32 inches wide by 32 inches high by 66 inches deep. It has a single zone of control with a temperature gradient of ±20°F at 1,100°F using four zones of temperature control with biasing to balance any temperature gradients.

The furnace is constructed of low-mass insulating firebrick, which allows for quicker cooldown times. A venturi cooling blower is included that also aids in cooling. The Model XLC3672 is controlled by a Eurotherm Nanodac Mini 8 program mechanism with overtemperature protection. There is also a programmable flow panel to manage the nitrogen flow throughout the process.

The parts are heated to 1,220°F in a retort chamber that is pressurized with nitrogen. The byproducts of the outgassing part are directed by pressure and flow out of the rear

Model XLC3672 atmosphere-controlled burn-off furnace by L&L Furnace. (Courtesy: L&L Special Furnace Company)

The Lenox Group, an aluminum extrusion profiles company, bought a Nitrex turnkey nitriding system. (Courtesy: Nitrex)

of the furnace. The parts are then heated in a vacuum furnace to temperatures in excess of 2,300°F. The result is a super-strong component that is lighter than titanium.

An independent flow panel is provided with an oxygen analyzer that monitors the oxygen content of the atmosphere on exit. This data is recorded electronically on the data acquisition station.

Options include a variety of control and recorder configurations. A three-day, all-inclusive startup service is provided with each system within the continental U.S. and Canada. International startup and training service is available by factory quote.

MORE INFO www.llfurnace.com

Lenox Group buys compact Nitrex nitriding system

The Lenox Group, an aluminum extrusion profiles company, decided to buy a Nitrex turnkey nitriding system after expanding operations with the addition of a second extrusion press to its plant in Bulgaria. Faced with increased production and disappointing nitriding results from third-party processing services, Lenox opted to bring operations in-house to improve die reliability through more stringent quality control.

"Previously, the company sent extrusion dies for salt bath nitriding and gas nitriding, but there were quality issues and results were inconsistent, never living up to customer expectations," said Marcin Stokłosa, project manager at Nitrex. "Lenox Group experimented with various case hardening technologies in search of the best one, the results of which would be repeatable and consistent with their expectations."

In the end, the choice fell on the N-EXT 412, a compact-size Nitrex gas nitriding furnace for low volume quantities best suited for Lenox's production needs. The plug-and-play N-EXT is a turnkey nitriding system built on a self-contained platform that includes the furnace, control system with Nitreg® technology, and an exhaust neutralizer for clean and green processing. Its small footprint allows it to fit into limited spaces within a plant.

The new Nitrex system complies with AMS2750 for pyrometry and AMS2759/10 for controlled nitriding standards. With a temperature distribution of ±5°C, it is suitable for nitriding H11 and H13 extrusion dies.

With Lenox Group, the need for a fast delivery also weighed in heavily when choosing Nitrex. The system was delivered and started up in the first quarter of 2022.

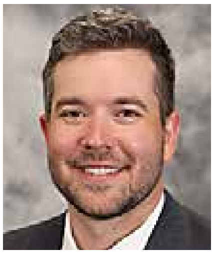
"Lenox Group could always count on our guidance and involvement through every stage of the project," said. "This is the story of a long-term relationship, and an experience rewarded with a signed contract after talks spanning several years."

MORE INFO www.nitrex.com

Gasbarre hires product development manager

Gasbarre Thermal Processing Systems has hired Bryan Stern as product development manager to support existing customers and advance its growing footprint in the vacuum furnace market.

Stern brings nearly 10 years of industry experience to Gasbarre and is a graduate of the Georgia Institute of Technology with a bachelor's degree in mechanical engineering. Stern will be focusing on equipment design, technical sales support, and technology advancements of Gasbarre's products. Stern is a 2018 MTI YES program graduate and is a member of ASM International. He is based in Eastern Pennsylvania with his wife, Megan, and daughter, Naomi.



Bryan Stern

"We couldn't be more excited to have added Bryan to an already stellar technical team at Gasbarre," said Ben Gasbarre, E.V.P. of sales and marketing. "In the short time I've worked with Bryan, I've already been thoroughly impressed by his technical knowledge and how well he's fit into the culture of Gasbarre. I look forward to seeing Bryan's growth within our organization and the benefits he will bring to our customers."

With locations in Livonia, 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.

MORE INFO www.gasbarre.com

PMEA elects Alex Gasbarre new president

Alex T. Gasbarre, CEO, Gasbarre Products, Inc., DuBois, Pennsylvania, has been elected president of the Powder Metallurgy Equipment Association (PMEA). PMEA is one of six trade associations under the Metal Powder Industries Federation, a not-for-profit association formed by the powder metallurgy industry to advance the interests of the metal powder producing and consuming industries.

Alex T. Gasbarre

His two-year term began at the conclusion of the Federation's annual Powder Metallurgy (PM) Management Summit and 77th Annual MPIF Business Meeting in October.

Alex, a graduate of Penn State University, has spent his entire professional career in the PM industry. Over the years, he has served on the MPIF Industry Development Board, PMEA Board of Directors, and chaired the MPIF PM Parts Compacting & Tooling Seminar.

MORE INFO www.mpif.org

Seco/Warwick furnace headed to Indian manufacturer

Ecocat India, a leading catalyst manufacturer whose mission is to purify air by supplying the market with innovative catalysts for the automotive sector, has ordered an advanced technology vacuum gas cooling furnace from Seco/Warwick. The furnace, which will be delivered to Ecocat India in the second half of 2022, is a vacuum design adapted to complex brazing processes. The solution is based on a single chamber, standard vacuum furnace with gas cooling. Thanks to the dedicated modifications, the system will carry out efficient and precise brazing and annealing processes that are necessary for the catalyst production process. The process takes place in a large working space with the ability to adjust to an oversized load by using the advantages of the round heating chamber.

"The furnace for Ecocat India is quite a large piece of equipment that will enable our customer to process more elements than previously," said Maciej Korecki, vice president of the Seco/Warwick Vacuum Segment. "This in turn will significantly increase the hardening plant efficiency and, consequently, will result in increased production capacity. The solution uses a high vacuum system based on a very powerful diffusion pump and a medium vacuum system. This furnace, although based on our standard solution, has been fully adapted to the needs and requirements of our customer."

Good temperature control is essential when brazing components in vacuum furnaces. The Ecocat India furnace is equipped with an inverter-controlled cooling system. As a result, it has better control over the cooling power within the furnace chamber. The furnace is also characterized by a complex temperature control system. The purpose of the latter is to obtain better heating temperature control and uniformity while protecting the load from overheating during the brazing process. Low heat losses and good temperature distribution in the heating chamber are also the great advantages of this type of furnace.

High vacuum brazed joints are considered to have very good quality when they are free of oxide inclusions, dispersed gases, and bubbles. For this reason, the vacuum brazing technology has become competitive with other joining methods when manufacturing highly loaded components with complex cross-sections. It is more widely used by catalyst and heat exchanger manufacturers.

Catalyst manufacturers are demanding customers who produce a product with very complex shapes using the difficult process of element joining (brazing). A vacuum furnace that will work in this industry must meet a number of criteria that will allow for a precise, repeatable, and safe brazing process. A good vacuum furnace designed for catalyst brazing should have a pumping system that is more resistant to dirt. It should also be equipped with a complex temperature control system that prevents load overheating, an efficient vacuum system that ensures a faster evacuation process, and inverter-controlled cooling to accelerate the safe cooling process. Thanks to this, the highest cooling power turns on at the moment of gas-forced cooling after stabilizing the brazed joint by means of static cooling.

Ecocat India is world-renowned as one of the leading manufacturers of catalysts and exhaust emission control systems for passenger cars, heavy commercial vehicles, off-road equipment, and stationary engines. These manufactured products allow end users to meet the Euro IV, V, and VI emission standards. The company provides complete catalysts for various applications, including gasoline, diesel, CNG, LPG, biofuel, SCR and urea mixers, VOC catalyst, particle oxidation catalyst, and DPF filter.

"Our superior mission is to purify the environment by providing innovative technological solutions to reduce pollutant emissions from automotive systems," said Alok Trigunayat, executive director of Ecocat India. "Ecocat India represents advanced technology, high quality, and compliance with environmental policy. The new vacuum furnace, which is our third Seco/Warwick solution, will significantly increase our production capacity. Vacuum brazing is a key process for us, and thanks to the purchased furnace, it will be precise and efficient. Seco/Warwick is the first-choice company when it comes to supplying equipment for metal heat treatment."

Ecocat India, a leading catalyst manufacturer whose mission is to purify air by supplying the market with innovative catalysts for the automotive sector, has ordered an advanced technology vacuum gas cooling furnace from Seco/Warwick. (Courtesy: Seco/Warwick)

MORE INFO www.secowarwick.com

Delta H, Phillips Federal deliver system to Tinker AFB

Delta H® recently delivered the first heat-treating system certified to AMS2750G for heat treating aviation grade aluminum for military aircraft. The new system at Tinker AFB, Oklahoma, is the second installation at the massive depot facility and placed side by side with the previous Delta H dual chamber aerospace heat treat (DCAHT®) system installed in 2015. Third-party services for calibration and qualification were performed by Andrew Bassett of Aerospace Testing and

Pyrometry and completed within one day on site. The certifications for instrumentation, Temperature Uniformity Surveys and System Accuracy Testing were completed through ATP's new Aerospace Compliance Software (ASC) to AMS2750G.

The newly installed DCAHT features a certified TUS volume of 24 inches wide, 16 inches high, and 72 inches long, with an upper chamber convection oven operable to 500°F and a lower chamber convection furnace operable of 1,200°F. In addition to aluminum, the system can be used for PH stainless steel aging, as well as titanium and ferrous alloy processes. Both chambers qualified as Class 1, and were certified as Class 2 for aluminum applications. Honeywell controls and recorders are featured and include remote computer control, data entry, process monitoring and produce irrefutable batch records with quench delay.

Extensive training was involved not only to several operators, but also QC personnel and two individuals qualified to train other operators. Additional training was provided to USAF personnel responsible for maintaining pyrometry records to assure continued compliance to AMS2750G.

Twin Delta H dual chamber aerospace heat treating systems at Tinker AFB, Oklahoma. (Courtesy: Delta H)

Delta H manufactures heat-treating equipment designed exclusively for serving the standards of the aerospace and defense industry with guaranteed compliance to the strict and demanding requirements of AMS2750G and Nadcap accreditation.

Delta H is exclusively represented worldwide by Phillips Federal Division for all military and government sales. Phillips Federal Division is the leading service provider and manufacturing partner to the United States Government.

MORE INFO www.delta-h.com

27th IFHTSE Congress, ECHT 2022 a success

The 27th IFHTSE Congress and European Conference on Heat Treatment 2022 in Salzburg was very successful, with more than 100 papers in 16 sessions, with five keynote speakers. There were approximately 20 commercial booths. More than 250 people attended from all over the world.

Reinhold Schneider (past president of IFHTSE), chairman for the event, opens the conference. The current president, Prof. Masahiro Okumiya, and current past president, Eva Troell, are in attendance.

5TH INTERNATIONAL CONFERENCE ON HEAT TREATMENT AND SURFACE ENGINEERING OF TOOLS AND DIES (HTSE-TD)

Hangzhou, China | April 24-27, 2023

This conference in Hangzhou, China, will finally resume the HTSE-TD series. The last meeting was in January 2021 and held online. The call for papers is posted at: htse-td.allconfs.org/meeting/index_en.asp?id=6861

Abstracts should be sent to Lihui LIU, chta@chta.org.cn.

Abstracts were due October 31, 2022, with full papers due January 31, 2023.

ECHT23

Genova, Italy | May 29-31,2023

AIM is pleased to announce the ECHT 2023 Conference in Genova, Italy, at Magazzini del Cotone, May 29-31, 2023.

ECHT 2023 will cover all relevant topics for the Heat Treatment & Surface Engineering community. The Conference will have a special focus on sustainability.

Sustainability, with its three pillars — environmental, economic, and social dimensions — is playing a key role in addressing ongoing and future challenges. The metallurgical and mechanical industries are leading the way in creating a healthy development model for the environment and for future generations. Presentations and papers from industry, university. and research centers on the topic will encourage the discussion and increase awareness on the matter.

Prospective authors wishing to present papers are invited to submit a tentative title and an abstract of about 300-400 words (in English), specifying a maximum of two topics for each proposal, by December 16, 2022.

More information: www.aimnet.it/echt2023.htm

Zoltan Kolozsvary, left, receives his award for honorary IFHTSE president. Award presented by D. Scott MacKenzie.

28TH IFHTSE CONGRESS

Yokohama, Japan | November 13-16, 2023

The 28th IFHTSE Congress, to be held in Yokohama Japan, is spon-

Prof. John Speer, center, Colorado School of Mines, receives the IFHTSE Medal. The award is sponsored by SC Plasmatherm SA, Romania. Reinhold Schneider, left, conference chair, Univ. of Appl. Sciences Upper Austria, and Eva Troell, right, RISE/ivf, Sweden.

At the symposium dedicated to the late researcher Sören Segerberg (IFHTSE Bulletin 2021-05), a commemorative plaque was given to his son Peter (right) by Eva Troell and Scott MacKenzie. The award was sponsored by Quaker Houghton.

sored by the Japanese Heat Treating Society.

Important dates:

- Deadline of abstract submission: April 28, 2023.
- Notification of acceptance: May 31, 2023.
- Preliminary program release: June 30, 2023.
- Deadline of extended abstract: July 14, 2023.
- Deadline of early registration: July 31, 2023.
- Deadline of full paper submission: September 22, 2023.

More information: jsht.or.jp/ifhtse2023/index.html

FOR THE FIRST TIME: TWO TOM BELL YOUNG AUTHOR AWARDS

IFHTSE gives this award for the best paper presented at an IFHTSE Congress by a speaker younger than 35. It consists in free participation at the following Congress, including travel and accommodation. This time, two candidates were equally ranked, and the jury decided to give the award, for the first time, to both of these top candidates.

Simona Kresser of the Upper Austria University of Applied Sciences in Wels, Austria, studied "The Effect of Cooling Rate on Quenching & Partitioning (Q&P) in Martensitic Stainless Steels."

Pedro José de Castro of IWT, Bremen, Germany, presented a paper on an "Energy efficient manufacturing chain for advanced bainitic steels based on thermo-mechanical processing."

IFHTSE President Masahiro Okumiya, right, and IFHTSE Vice President Massimo Pellizzari, left, congratulate the Tom Bell Young Author Awardees.

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ONLINE www.ifhtse.org I **EMAIL** info@ifhtse.org

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

IHEA 2023 Annual Meeting returns to Florida

IHEA will hold its 2023 Annual Meeting March 13-15 at One Ocean Resort & Spa in Atlantic Beach, Florida.

The Industrial Heating Equipment Association will hold its 2023 Annual Meeting March 13-15 at the beautiful One Ocean Resort & Spa in Atlantic Beach, Florida. IHEA members look forward to the camaraderie created by the social events and the thought-provoking topics presented. The annual meeting provides plenty of opportunity to get involved with important industry-related developments while exploring new business contacts and growing relationships.

The IHEA welcome reception will kick off the event for old friends and new to meet, greet, and share stories. The meeting program will include popular economist Chris Kuehl, who will deliver his projections of the nation's economy; hot topics that include decarbonization and sustainability will be highlights of the program as well as IHEA committee meetings to discuss association business. Together with the annual president's gala and the IHEA golf tournament, this event is the perfect mix of business and pleasure. The Annual Meeting is a great way to keep current with industry developments and catch up with peers. A previous annual meeting attendee said, "The IHEA Annual Meeting is always thoughtfully structured. We learned a lot, made some new friends and business connections, and had fun doing it!"

Atlantic Beach is just east of Jacksonville, Florida. The beachfront location is perfect for morning walks and beautiful sunsets. The quaint town has several restaurants and shops within walking distance.

Meeting details and registration information will be available soon at www.ihea.org. Start making plans for IHEA's 2023 Annual Meeting. We hope to see you in March.

IHEA MEMBERSHIP HAS ITS PRIVILEGES

Don't let another year pass without becoming an IHEA member. Join now and get a multitude of benefits right from the start. The annual meeting is just one event. IHEA offers additional benefits that members enjoy all year long.

See what current members appreciate most about IHEA:

"Gasbarre Thermal Processing Systems is a long time IHEA member that finds benefits in several ways. Along with the economic reports and industry specific training, we also gain value by collaborating with industry peers to address current and future changes

in equipment safety and technology." — Ben Gasbarre, Gasbarre Thermal Processing Systems

"It's not just about business but also about people, and IHEA provides the platform to meet friends and colleagues." — Dr. Joachim Wuenning, WS Thermal Process Technology Inc.

IHEA focuses on driving its members' success by providing the knowledge base and authoritative voice for industrial heat processing. Become a member of IHEA and take advantage of these great benefits and resources:

- Monthly Executive Economic Update.
- Meeting vouchers (contingent on member category).
- Discounts to attend all IHEA Educational Seminars.
- Discounts on IHEA Online Training Courses.
- Discounts to attend IHEA's Annual Meeting.
- Ability to participate on IHEA committees.
- Subscription to IHEA's INSIDER newsletter.
- Company listing on IHEA's website.
- Ability to post resumes and job openings online in the Career Center.
- Discount on IHEA publications.

JOIN NOW at www.ihea.org.

IHEA CALENDAR OF EVENTS

MARCH 13–15, 2023

IHEA 2023 Annual Meeting

One Ocean Resort & Spa | Atlantic Beach, Florida

The Industrial Heating Equipment Association's Annual Meeting is your way to keep current with industry developments and network with peers in the industry.

MARCH 21–22, 2023

Powder Coating & Curing Processes Seminar

Alabama Power Technology Applications Center | Calera, Alabama

The day and a half Introduction to Powder Coating & Curing Processes Seminar will include classroom instruction and hands-on lab demonstrations.

Registration fee: IHEA Members: $325 / Non-Members: $425

JUNE 12–16, 2023

Therm Process 2023

Dusseldorf, Germany

The world's leading trade fair for industrial thermal processing technology.

For details on IHEA events, go to www.ihea.org/events

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

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JUSTIN SIMS
MECHANICAL ENGINEER /// DANTE SOLUTIONS

Tools now available to simulate complex gear measurements after heat-treatment simulation.

Gear inspection methods from heat-treat simulation

Gear design is a complex process, involving dozens of parameters, tolerances, and relationships to mating components. Generally, professional standards guide the gear designer to the appropriate gear dimensions, given mating and loading requirements. [1-2] After heat-treatment, gears are inspected using a slew of methods, depending on the particular gear geometry and critical locations of interest. [3-5] Heat treatment simulation provides a cheaper and faster alternative to physical testing but is lacking capabilities to relate the predicted distortion back to gear measurements made on the shop floor or in the metallurgical lab. In general, diameter distortion predictions are easily understood and correlated back to actual measurements, but simulated predictions on parameters such as tooth thickness, tooth profile, and runout can be more daunting to evaluate and are often ignored in published analyses. [6-8]

Since simulation predicts displacements at points relative to the original position of the gear, while physical measurements are relative to a distorted gear surface, confusion can arise as to whether or not the simulation matches reality. To bridge this gap, and help alleviate the confusion, two software programs are used in the following case study to provide common gear measurements on a simulated, heat-treated gear. Integrated Gear Design (IGD), developed at the Rochester Institute of Technology, is used to design the gear geometry and post-process the heat-treatment simulation results. DANTE, developed by DANTE Solutions, is used to simulate the heat treatment of steel components.

IGD is a computer program used for the design and simulation of gear drives. The software provides various tools for analysis and simulation, including, but not limited to, tooth contact analysis (TCA), finite element modeling of gear drives (FEM), and gear geometry comparison. An important feature of IGD is the automatic generation of finite element models for Abaqus or Ansys, allowing finite element analyses of complex gear drives without the tedious process of building the finite element model or being an expert on the particular finite-element software being used.

IGD takes advantage of geometric parameters commonly used in industry to construct the virtual gear geometry, including tip and root diameters, form diameters, circular tooth thickness, ball/pin diameter, and distance over balls/pins. Table 1 shows the parameters used to construct the two gear geometries for the simulation case described here — heat-treatment configuration (green shape) and the in-service configuration; Figure 1 shows IGD's definition window with the settings for the pre-heat treatment geometry.

After constructing the geometry, IGD can define cyclic symmetry (if applicable) and reduce the full gear to a single tooth, mesh the gear/tooth, and define the nodes and surfaces required for post-processing. Figure 2 shows the meshed gear and post-processing surface definitions generated in IGD, which is ready for heat-treatment simulation using DANTE.

Parameter	Heat-treatment geometry	Finished geometry
Number of teeth	59	
Module	1.25 mm	
Pressure angle	25°	
Face width	9.6 mm	
Tip diameter	76.40 mm	76.20 mm
Root diameter	71.025 mm	70.60 mm
Edge radius of hob	0.12 mm	0.312 mm
Pin diameter	2.3 mm	
Distance over pins	77.885	77.010 mm

Table 1: Gear geometry parameters for the heat-treatment and finished geometries.

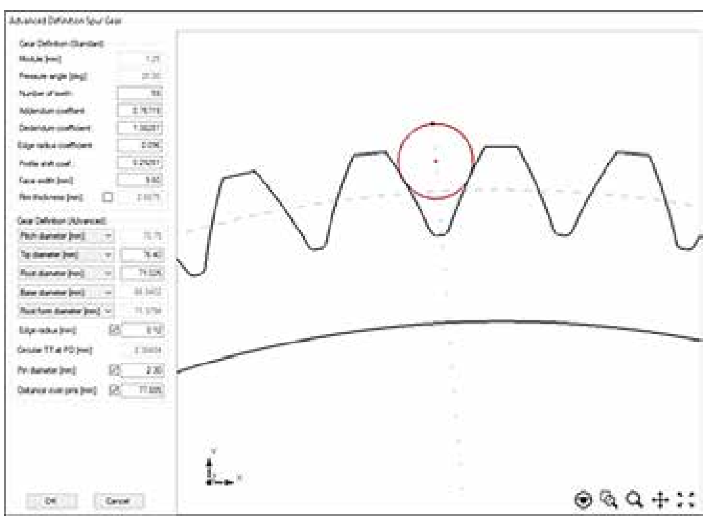

Figure 1: Definition of the heat-treatment geometry of the gear.

The gear described above is an actual component, with a heat-treatment process consisting of austenization, carburization, transfer from the furnace to the quench tank, quenching in oil, deep freezing, and tempering. Figure 3 compares the measured and simulated hardness profiles at the flank and root, revealing good agreement between experiments and simulation.

After the heat-treatment simulation is executed using DANTE and Abaqus, the position of the distorted nodes can be read in and reconstructed by IGD. Once the distorted geometry is reconstructed in IGD, it can be used for geometry comparison with the undistorted geometries, used for tooth contact analysis (reveal effects of heat-treat distortion on the contact pattern), or used for additional

ALFONSO FUENTES AZNAR
ASSOCIATE PROFESSOR ///
ROCHESTER INSTITUTE OF TECHNOLOGY

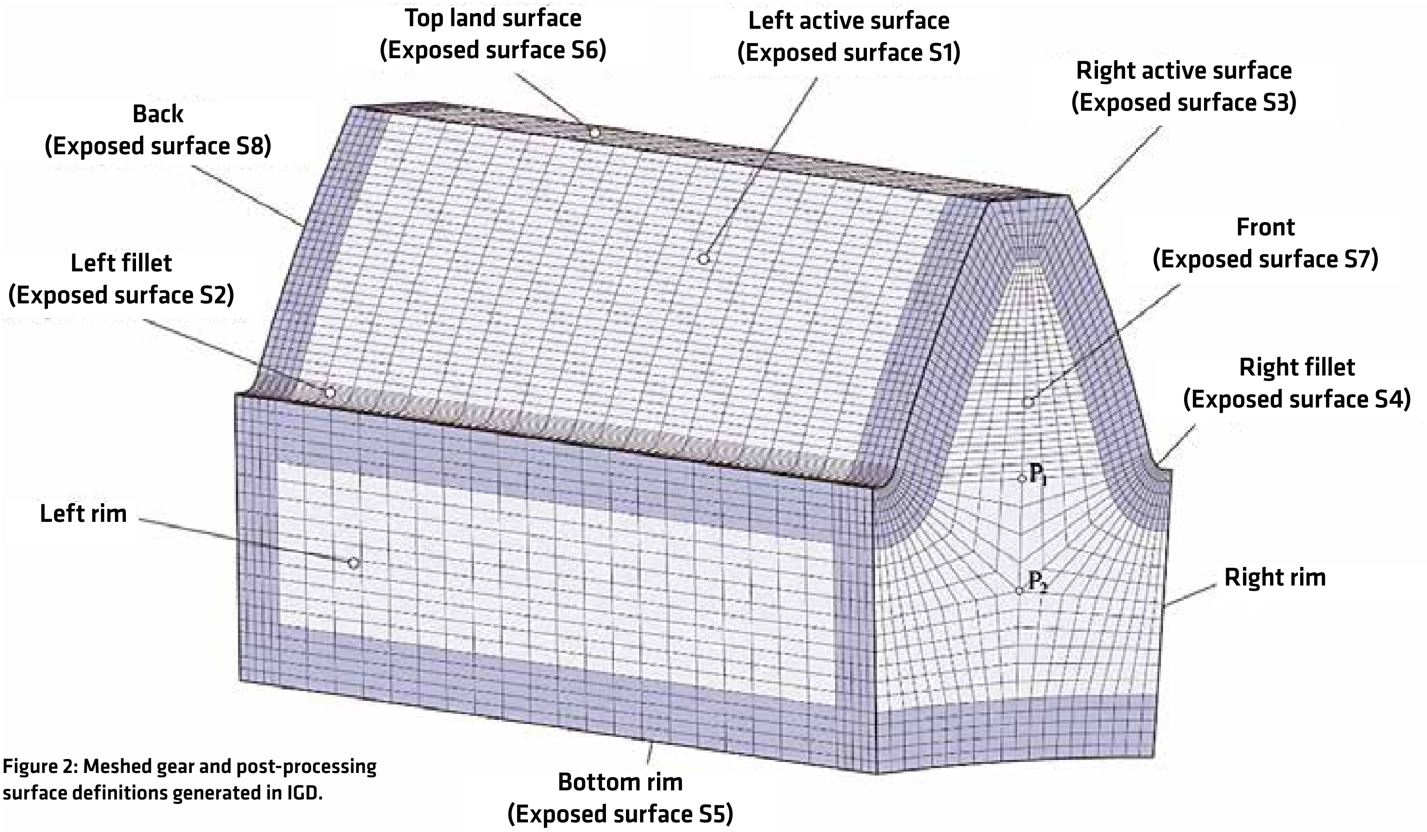

Figure 2: Meshed gear and post-processing surface definitions generated in IGD.

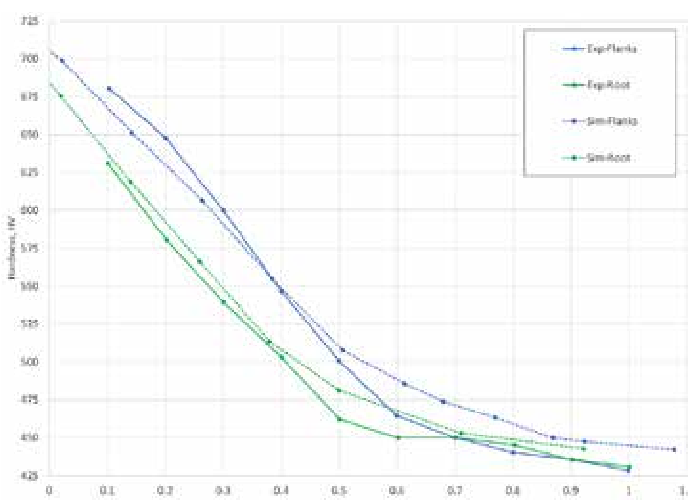

Figure 3: Comparison of measured and simulated hardness profile at two locations.

finite element analysis in Abaqus or Ansys (reveal heat-treat distortion and residual stress effect on contact and bending stresses and deflections). The additional analyses performed in IGD are carried out using the distorted geometry and residual stress predicted by DANTE. Unfortunately, detailed experimental distortion measurements were unavailable at the time of publication.

Comparing geometries is an important feature of IGD and can be directly applied to compute the deviations of the heat-treated geometry with respect to the green or finished geometries. Figure 4 compares the simulation results when (A) the global cartesian coordinates are used to evaluate the displacement along the Y-axis in Abaqus (radial direction of tooth), (B) cylindrical coordinates based on the flank geometry are used to evaluate the displacement normal to the flank, and (C) IGD is used. It should be noted that the cylindrical coordinates based on the flank and the IGD analysis are identical, with a maximum displacement of 27 μm and a minimum of 17 μm. However, these values are based on the heat-treat geometric configuration (green shape) and provide no information as to how much material removal is required, or from where, to bring the gear within the final dimensions specified on the print.

However, IGD is well suited for this type of analysis. Figure 5 shows the heat-treated distortion compared to the finished gear geometry in IGD. It can be seen that uniformly machining or grinding the gear to the final dimensions will not work, with more material needing to be removed near the tip, 222 – 229 μm, than the root, 217 – 221 μm, and not uniformly from those locations. Due to the relatively uniform carbon depth, the nonuniform material removal will result in a nonuniform hardness and residual stress distribution that may influence the gear's in-service performance, which can then be evaluated through additional analyses.

IGD also provides several features to quickly analyze tooth profiles, which is crucial to ensure that mating gears will perform as

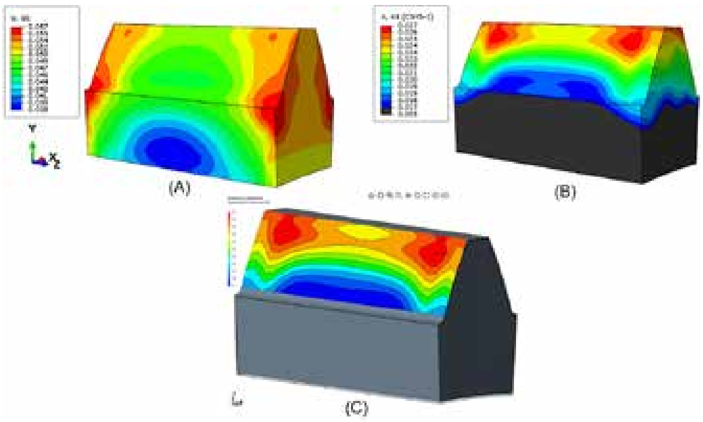

Figure 4: Predicted distortion when (A) global cartesian coordinates used in Abaqus, (B) cylindrical coordinates based on the flank geometry used in Abaqus, and (C) IGD is used.

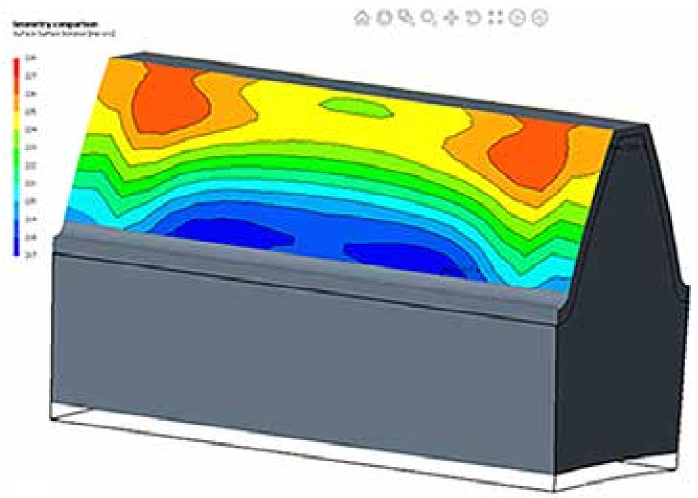

Figure 5: Predicted distortion relative to the final gear geometry in IGD.

intended. Figure 6 evaluates the entire flank profile on one side of the tooth, while Figure 7 evaluates the flank profile of both sides through a transverse cut. Additional post-processing capabilities, including the distance over pins for the distorted geometry, are being developed at this time.

In summary, heat-treatment simulation has made tremendous strides in function and accuracy over the last decade but is still lacking convenient methods to relate predicted gear distortion to measured gear distortion. The utilization of IGD and DANTE brings this much needed capability to industry.

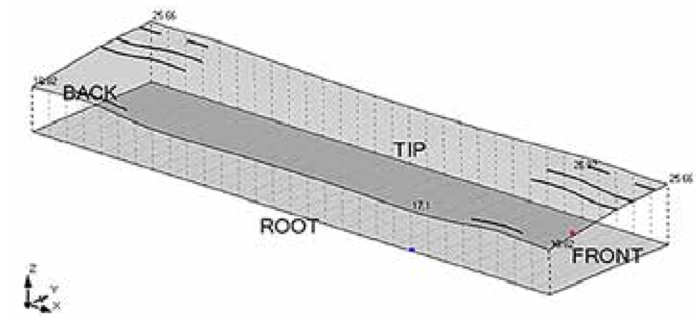

Figure 6: Distortion on left active surface of the gear tooth (values given in microns).

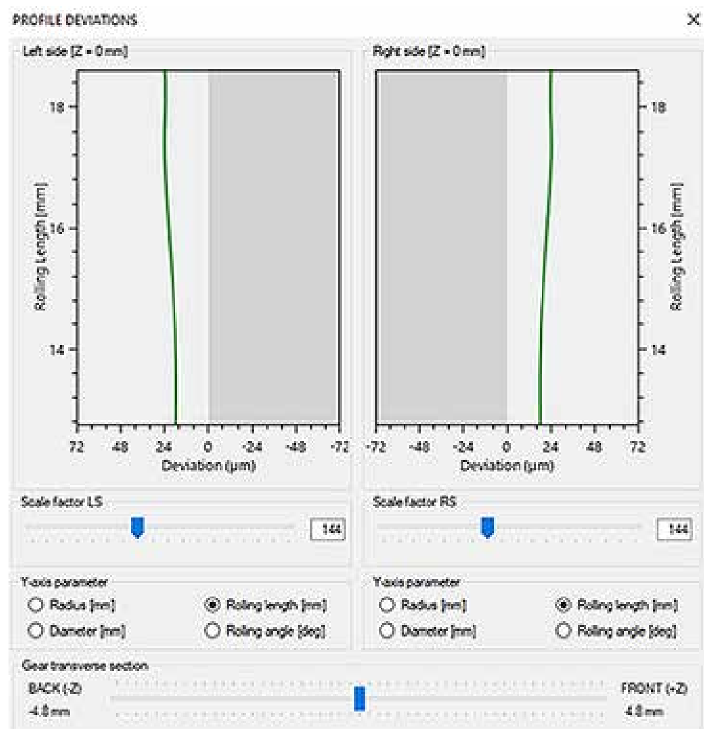

Figure 7: Profile deviations on the left and right sides of the active surfaces.

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Understanding the importance of determining the Quench Factor and the method for calculating it correctly.

Quench Factor analysis used to predict properties of quenched and aged aluminum

In this column, we will start to discuss the application of Quench Factor Analysis (QFA) to predicting properties of quenched and aged aluminum.

QUENCH FACTOR DEFINITION

Quantifying quenching, and the cooling effect of quenchants, has been extensively studied [1] [2] [3] [4]. The first systematic attempt to correlate properties to the quench rate was performed by Fink and Wiley [5] for thin (0.064") sheet. A TimeTemperatureTensile Property curve was created and was probably the first instance of a TTP diagram for aluminum. It was determined that the critical temperature range for 75S is 400°C to 290°C. This critical temperature range was later confirmed [6]. At quench rates exceeding 450°C/sec., the maximum strength and corrosion resistance were obtained. At intermediate quench rates of 450°C to 100°C/sec., the strength was lowered (using the same age treatment), but the corrosion resistance was unaffected. Between 100°C/sec and 20°C/sec, the strength decreased rapidly, and the corrosion resistance was at a minimum. At quench rates below 20°C/sec, the strength decreased rapidly, but the corrosion resistance improved.

One method that quantifies the quench path and material kinetic properties is called the "Quench Factor" and was originally described by Evancho and Staley [7]. This method is based on the integration of the area between the Time-Temperature-Property Curve and the quench path.

Historically, the average quench rate has been used to predict properties and microstructure after quenching [1] [2] [3]. However, average quench rates are not sufficient to provide accurate property data and serve as a predictive tool [7]. Quench Factor Analysis was developed to quantitatively predict properties. This quench factor depends on the rate of precipitation during quenching. The rate of precipitation during quenching is based on two competing factors: supersaturation and diffusion. As temperature is decreased during quenching, the amount of supersaturation increases, providing increased driving force for precipitation. In addition, at the beginning of quenching, the temperature is high, increasing the rate of diffusion. The Avrami precipitation kinetics for continuous cooling can be described by [7]:

$$\zeta = 1 - exp(k\tau)^n$$

Where ζ is the fraction transformed, k is a constant, and τ is defined as the quench factor, or:

$$\tau = \int \frac{dt}{C_t}$$

t is the time, and C_t is the critical time. The collection of C_t points, also known as the C-Curve or Time -Temperature-Property curve, is like the TTT curve for continuous cooling.

In general, the C_t function is described by [8]:

$$C_t = K_1 K_2 \left[exp\left(\frac{K_3 K_4^2}{RT(K_4 - T)^2}\right) exp\left(\frac{K_5}{RT}\right)\right] \quad (3)$$

where C_t is the critical time required to precipitate a constant amount of solute, K_1 is a constant that equals the natural logarithm of the fraction that was not transformed during quenching, and K_1 = ln(0.995). K_1 is chosen that for τ > 1, a decrease in properties is observed. K_2 is a constant related to the reciprocal of the number of nucleation sites, and K_3 is a constant related to the energy required

Alloy	K_2 (sec)	K_3 (cal/mol)	K_4 (°K)	K_5 (cal/mol)	Reference
7050-T76	2.2x10-19	5190	850	1.8x105	[7]
7075-T6	4.1x10-13	1050	780	1.4x105	[7]
2024-T851	1.72x10-11	45	750	3.2x104	[9]
7075-T73	1.37x10-13	1069	737	1.37x105	[10]
2219-T87	0.28x10-7	200	900	2.5x104	[11]

Note: Data for 2024-T851 was evaluated using R=1.987. All others were evaluated with R=8.3143

Table 1: Published coefficients for determining the T-T-P Curve for specific alloys and tempers.

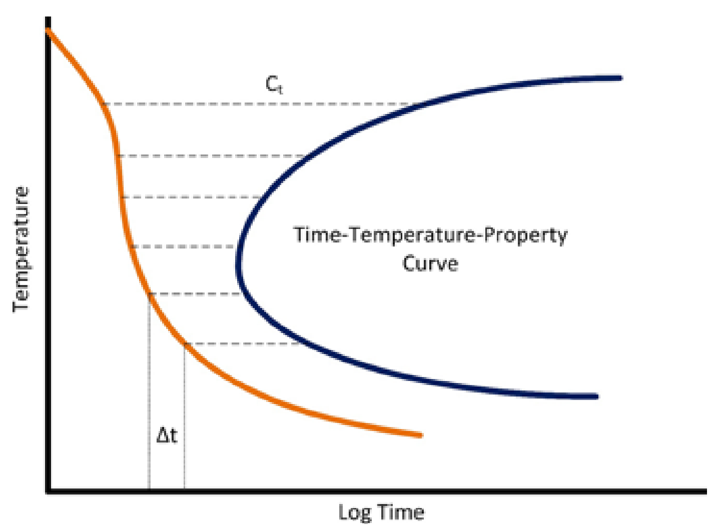
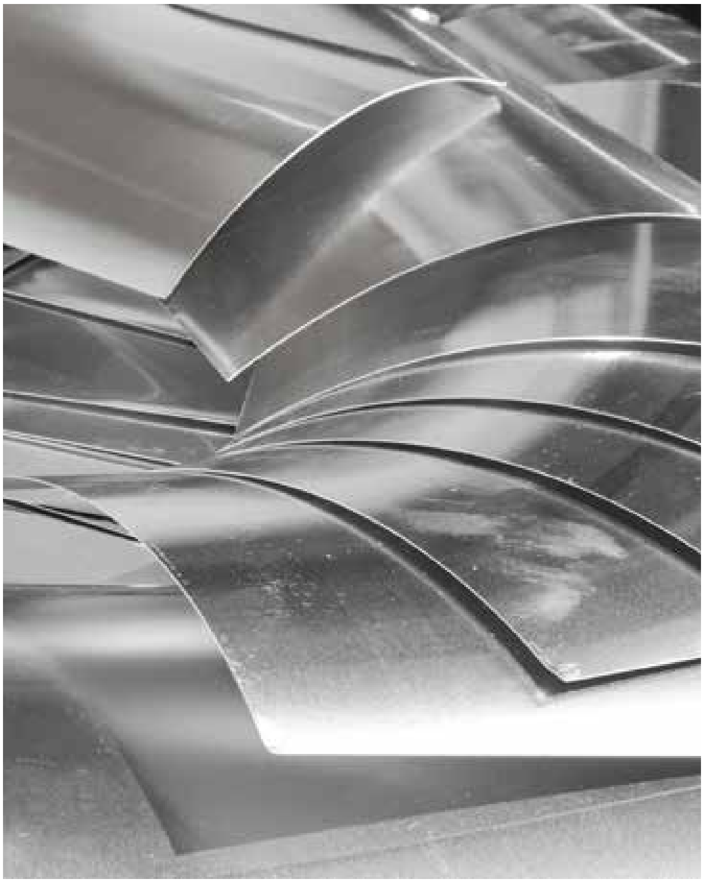


Figure 1: Schematic of the process used for determining the Quench Factor.



Quench path	Quench Factor	Measured Yield Strength (KSI)
Cold water, strongly agitated	0.464	73.4
Denatured alcohol to 290°C, then cold water	8.539	69.1
Boiling water to 315°C, then cold water	15.327	66.4
Still air to 370°C, then cold water	21.334	67.9

Table 2: Quench Factors and Measured Yield Strength for 1.6-mm thick 7075-T6 sheet [13].

to form a nucleus. K_4 is a constant related to the solvus temperature, K_5 is a constant related to the activation energy for diffusion, R is the universal gas constant, and T is the temperature in °K.

To determine the parameters K_1, K_2, K_3, K_4, and K_5, it is first necessary to have the C-Curve. C-Curve data is scarce, and of limited availability. Table 1 shows some previously published data.

To obtain the overall quench factor, Q, the incremental quench factor values are summed progressively as the probe or part is cooled through the precipitation range, normally about 800-300°F (425 - 150°C) [8]. Mathematically, this is shown by:

$$\tau = \frac{\Delta t_1}{C_1} + \frac{\Delta t_2}{C_2} + \frac{\Delta t_3}{C_3} + \ldots\ldots + \frac{\Delta t_{n1}}{C_n}$$

where $C_1 \ldots C_n$ are the critical times of the C-Curve, and $\Delta t_1 \ldots \Delta t_n$ are the incremental times described by the quench path. But, to do this integration, the C-curve must be known. This is shown schematically in Figure 1.

Typically, it is necessary to measure the quench path of several sheets of material, and then measure the properties after processing. The quench factor is determined for each quench path and associated with the measured properties. Typically, hardness and tensile properties have been used [12]. Properties are then related to the quench factor by the equation:

$$p = p_{max} exp(K_1 \tau)$$

where p is the property of interest, p_{max} is the maximum property attainable with infinite quench rate, and K_1 is -0.005013 (natural log of 0.995).

There are two difficulties with this method. First, it is necessary to know the specific quench path that the part experienced. This is often difficult to measure and requires specialized equipment to achieve repeatable results [12]. Secondly, it is also necessary that the C-Curve is known with sufficient precision. As indicated previously, this data is often not available for the specific conditions of interest. The lack of having detailed information regarding the C-Curve has limited the applicability of the use of the quench factor. Examples of measured Quench Factors are shown in Table 2.

CONCLUSION

In this column, we have defined the Quench Factor, and indicated needed data to properly calculate the Quench Factor. In the next column, methods of determining the C_t curve of an aluminum alloy will be shown, as well as the Quench Factor will be shown.

Should you have any questions regarding this, or any other column, please contact the writer or editor.

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A successful audit begins with thorough preparation that includes getting everyone ready so they are focused on performing well.

Be attached to process, not results of Nadcap audit

The dreaded Nadcap audit. The daunting AC7102 main checklist with 10 job audits. The strict requirements of AC7102/8 pyrometry adhering to AMS2750. The additional general AC7000 and supplier AC7102/S checklists. One would think that having the questions stated in these checklists would be like having the exam prior to taking it — the exam should be a breeze!

But as the saying goes in the aerospace industry, "Say what you do, do what you say." It is still a big responsibility to prepare for a successful audit, even with advance knowledge of the checklists. And it all starts with the preparation. More importantly, it starts with empowering the operators on the floor to be ready for the auditor and the types of questions they might ask so they are focused on performing well, not worried about how the results of the audit will turn out. We must be attached to the preparation of the audit and effort put in, not on the results of the audit and tallying how many findings you have.

AUDIT PREPARATION

Nadcap preparation always begins as soon as the last audit is over. Regardless whether you are on the merit program or still on the annual frequency, the preparation is critical to a successful audit. Aerospace requirements are now requiring in their respective QMS (quality management system) documentation that the Nadcap audit checklists be used for internal audits by a person not specialized in heat treat. This additional perspective can help bring clarity and opportunity to specific requirements.

Because of the daunting number of pages in each checklist, it can be all too easy to hurry through the responses. Remember even if it's N/A, the requirement now is to indicate why. This, although irritating, is a second layer of questioning to ensure that the question indeed does not apply.

One approach I have taken with the heat-treat team at Hitchiner Manufacturing Co., Inc. is to empower the heat-treat operators with both a metallurgical understanding of why parts get solution and aged or stress relieved, coupled with the stringent requirements of furnace pyrometry requirements. One of the techniques we use prior to the audit is sitting together in the classroom as a team with each qualified operator going to the white board and teaching certain aspects of pyrometry to the rest of us. This accomplishes two things. One, it allows the employee to put in their own words — on the spot — of their understanding of sensors, calibration, SATs, and TUS. Second, it allows the rest of the team to ask questions to make sure all requirements are covered. We also discuss AC7102 checklist requirements such as vacuum calibrations and even process control testing. The discussions are also opportune times for new ideas and suggestions to improve the process.

Knowing the "why" goes much further than simply stating "you turn the furnace on, pull the recipe, and take it out when the cookie timer goes off." Teaching the metallurgical phenomena of microstructure evolution to operators so they can then explain the concepts easily even to their kids provides clarity when troubleshooting misruns. When there is a power outage, the operator can visualize what internally happened to the microstructure and, along with following the requirements by the customer, help make the correct decision for what is best for the parts.

Audits are like the big championship sports games. Sports teams practice to be world champions and ranked first in their division. So, too, companies prepare for the Nadcap to be the best they can be. However, there is only so much preparation one can do so it must be done in a way to maximize efficiency.

EXPECTATION FOR THE AUDIT

Audits are like the big championship sports games. Sports teams practice to be world champions and ranked first in their division. So, too, companies prepare for the Nadcap to be the best they can be. However, there is only so much preparation one can do so it must be done in a way to maximize efficiency.

Of course, the desire is to do well in the audit. But this desire needs to be channeled all during the preparation so that during the audit the process is on autopilot. Basketball players are not trying to figure out the technique of a free throw in the middle of a game — and operators should not be fumbling on how to explain the comparison method SAT when applicable.

DURING THE AUDIT

During the audit, it is important to show up early. Earlier than you usually come to work. It allows for a little more time to settle and sort some of the daily tasks out before your day is consumed with the auditor. When you are one of the key members in the audit, you are expected to devote your time to the auditor. So, careful planning weeks prior must be made to ensure you are not pulled away.

One thing that helps in preparation is to notify key support groups such as maintenance and IT of the audit and the types of questions they might be asked (e.g. maintenance to demonstrate the PM program and how quality signs off on pyrometry requirements for maintenance activity and IT for software control and even NIST traceability for clocks if it was programmed).

It is not hard to understand why most people are afraid of audits. It's a time when supposed "weakness" or "error" is exposed. It's a time when the whole year has been going just fine, but now someone is coming in much like a police officer who catches you speeding (or you were supposed to be maintaining the normal periodic TUS schedule but decided to go extended periodic before the successful passes were completed).

However, findings are part of the audit. That is why we get audited. That is why coaches review errors with their athletes during games and practice — to improve. You want to find what is missing in your process. How can anyone learn and improve if they don't learn from their mistakes?

Being humble and open to getting a finding is what is needed, and often most difficult as there is pride in one's work. Findings are NOT ways to find out how to fire employees. It's about finding the opportunities to improve.

AFTER THE AUDIT

When there are findings in the Nadcap audit, there is a strict 21-day requirement at the time for the initial response for the corrective action. Depending on whether the staff engineer approves of the corrective action, the corrective actions can go additional rounds with 7-day extensions to resolve the issue. As soon as the audit wraps up and the task group votes on the pass or fail of the overall audit, it is back to business as normal. Preparation.

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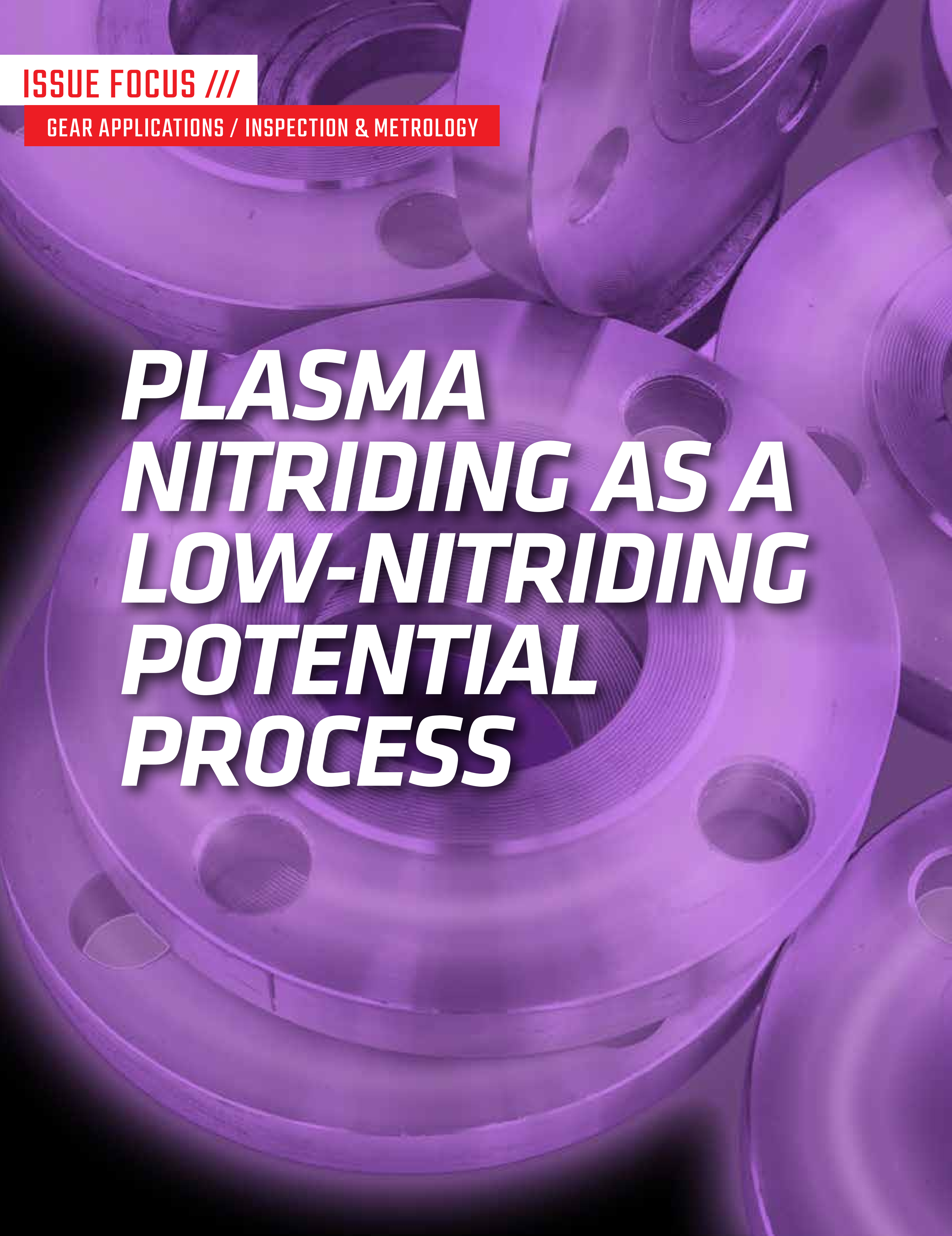


PLASMA NITRIDING AS A LOW-NITRIDING POTENTIAL PROCESS

How to prevent formation of brittle layers when increasing surface hardness.

By EDWARD ROLIŃSKI and MIKEL WOODS

Plasma/ion nitriding is a process that can be easily applied to various high-alloy steels. Some of these steels — for example M-2, S-7, D-2, 43z40 steels — nitride very well. However, applications for making various tools require the layer is hard but does not endanger their fracture-toughness properties and, therefore, must not be brittle. Although gas nitriding in this situation might also be used, control of this process would have to be at an extreme low level of the nitriding potential, which is very difficult in practice. A much easier solution is to use plasma/ion nitriding, which is, by its very nature, a low-nitriding potential process [1-7]. Plasma allows for easy control of the layer structure, which must have a very limited thickness or must be without compound zone (CZ-white layer) of nitrides.

Also, parts that require optimal bending fatigue properties, such as high-performance crankshafts, might gain significant improvement of their performance and longevity when a layer with a very thin CZ is formed.

In addition to the above-mentioned benefits, another benefit of using plasma nitriding is the ability to easily mask off specific surfaces from the treatment such as threads, which must stay soft.

PLASMA NITRIDING FUNDAMENTALS AND BENEFITS

The plasma nitriding process uses electrical-glow discharge in a mixture of nitrogen and hydrogen with an occasional addition of hydrocarbons if nitrocarburizing is needed. The glow discharge surrounds the treated parts and uniform treatment is performed as in Figure 1.

Figure 1: Plasma nitriding of stainless-steel rings. Image taken at Advanced Heat Treat Corp. Monroe, Michigan.

The cathode is bombarded by high-energy ions of nitrogen, hydrogen, and their radicals leading to chemisorption of nitrogen at the surface and its diffusion into the metal and formation of the nitrided layer [1]. The process can be controlled/monitored by conventional means: temperature, gas composition, pressure, duty cycle, etc., as well as visual observations of the near cathode regions to see uniformity of the glow discharge. See Figure 2.

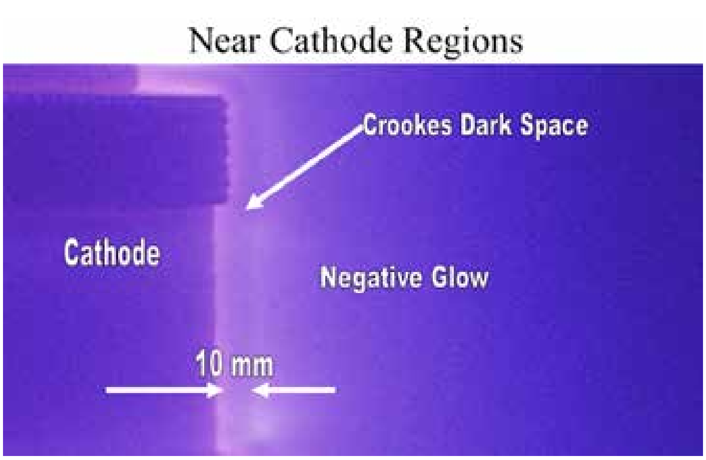


Figure 2: Near-cathode regions of the glow discharge observed through the port window during plasma nitriding. Adopted from E. Rolinski [1].

The phenomena at the cathodic surface are quite complex as can be presented in visual form/model shown in Figure 3.

The presence of sputtering at the cathode/load surface as well as low partial pressure of nitrogen result in a formation of a very thin compound zone of iron nitrides, allowing us to define the plasma/ion

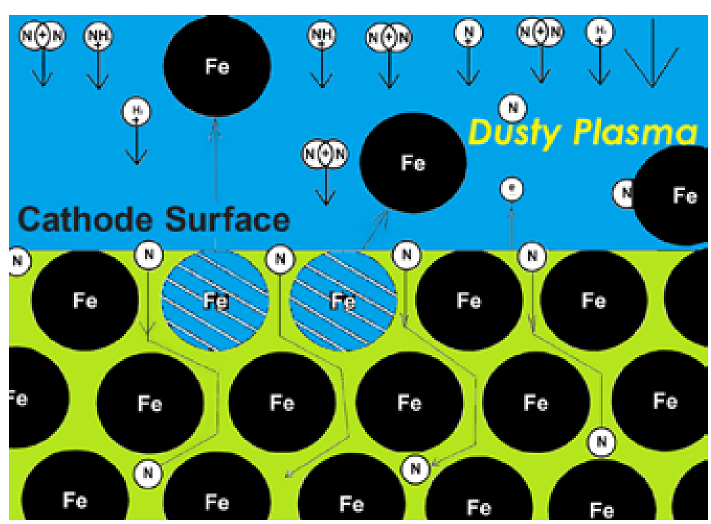


Figure 3: Interaction of the near-cathode plasma with its surface. Some of the iron atoms, Fe as well as oxides, are removed from the surface by sputtering.

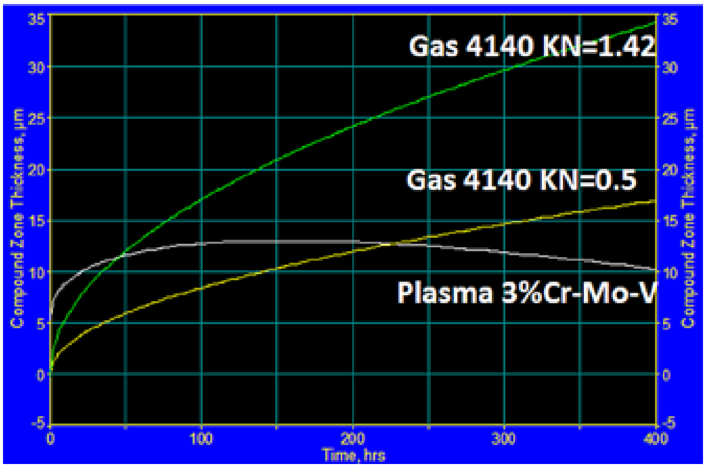


Figure 4: Kinetic of the compound zone growth in plasma nitrided 3%Cr-Mo-V steel in a mixture of 30% nitrogen+70% hydrogen and 4140 gas nitrided steel with two different nitriding potential, Kn values. All Processes carried out at 1,000° F.

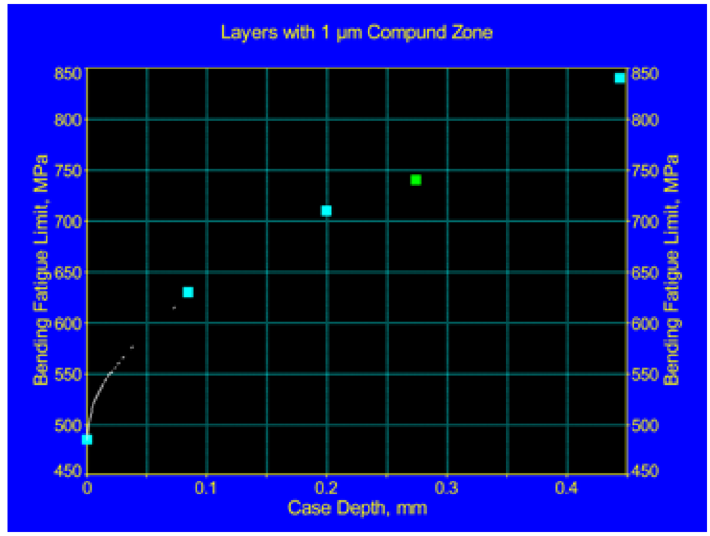
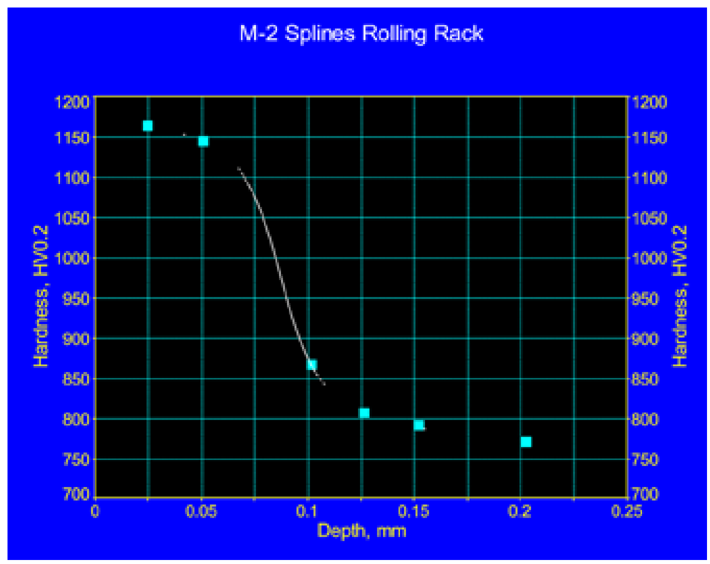


Figure 5: Effect of ion nitriding on bending fatigue of 3%Cr-Mo steel, based on T. Bell [5].

4340 Sample Surface Hardness Reading

Reading	*1*	*2*	*3*	*4*	*5*	*Average*	Total Case
HK 0.5	607	587	604			599	
HK 1.0	598	604	589			597	
HK 0.2	715	664	693			691	0.009"
HR15N	83.5	83.7	83.8			83.7	
HRC (Core)	32.7	32.3	33.1			32.7	

Figure 6: Microhardness profile in 4340-type crankshaft steel-nitrided layer and surface hardness readings.



M-2 Sample Surface Hardness Reading

Reading	*1*	*2*	*3*	*4*	*5*	*Average*	Total Case
HK 0.5	1216	1229	1191			1212	
HK 1.0	1176	1145	1134			1152	
HK 0.2	1001	1116	1398	1330	1416	1252	0.0035"
HR15N	94.2	94.3	94.2			94.2	
HRC (Core)	61.1	61.8	62.1			61.7	

Figure 7: Microhardness profiles of plasma-nitrided M-50 spline rolling racks and their surface hardness.

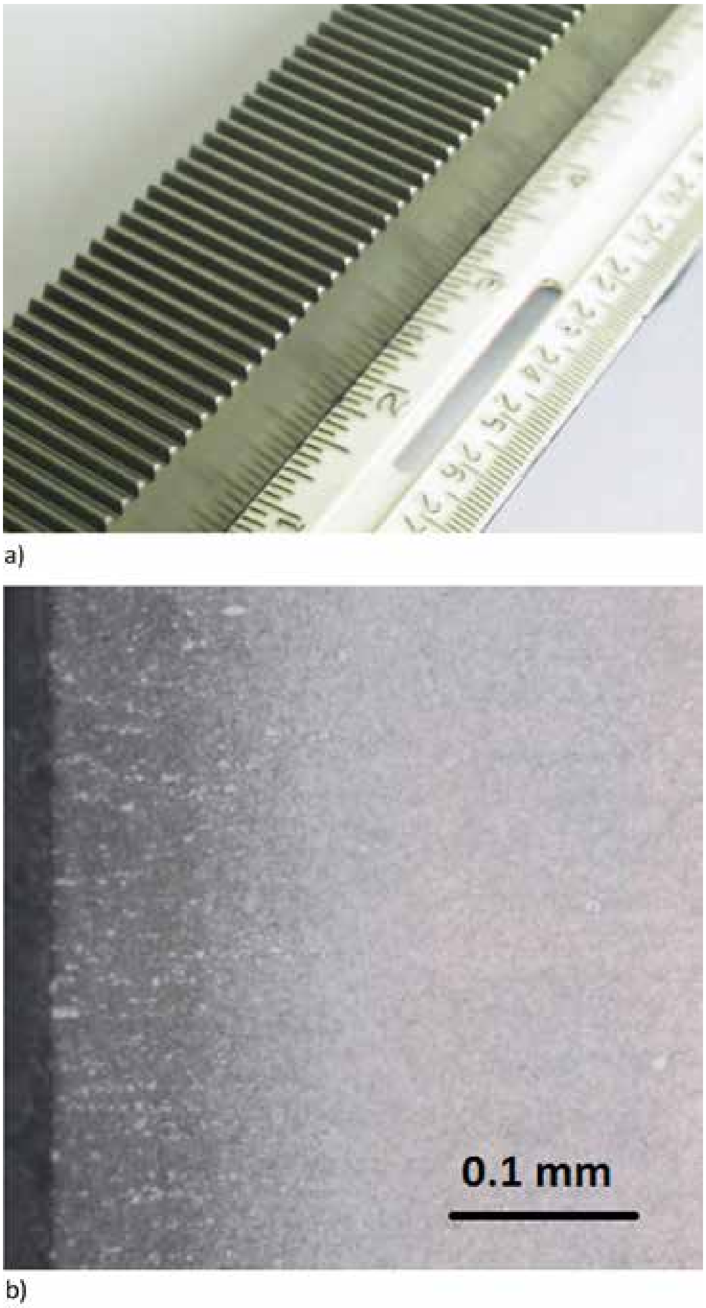


Figure 8: Rolling rack after plasma nitriding with a low nitrogen percentage a) and photomicrograph of the nitrided layer b). Etched with 3% Nital. (Images taken at Advanced Heat Treat Corp. Monroe, Michigan.)

nitriding as a low-nitriding potential process [1]. Figure 4 illustrates practical findings of the compound zone formation in two different steels when using this process.

As can be seen from the diagram, a typical gas mixture of 30% nitrogen+70% hydrogen is used and is easily controlled in the plasma-nitriding process. The process has produced a compound zone of less than 13 μm thick. At the same time, gas nitriding of similar steel carried out at very low KN values, 0.5 and 1.42 atm-1/2, produced much thicker compound zones.

A significant total case depth is needed in applications when a high bending fatigue strength is required. This can be seen in Figure 5.

Typical hardness profiles of plasma-nitrided parts requiring a good bending fatigue property are shown in Figures 6 and 7.

It should be noted that some of the nitrided tools, such as rolling racks made of M-2 steel, must not have a compound zone at all. This can be seen in Figure 8.

It is well-known from tribological research that nitrided layers used for aircraft bearings subjected to friction and rolling contact fatigue (RCF), typically made of M-50 and M50NiL steels, must have nitrided layers without compound zones and without an intergranular network of nitrides [5, 6]. Layers with this type of structure can only be formed using low-nitriding potential processes such as

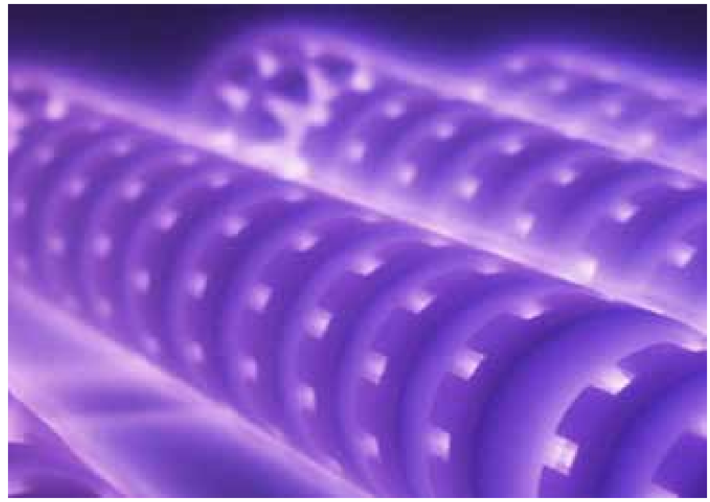


Figure 9: Plasma nitriding of rotors made of PM 316 SS. Image taken at Advanced Heat Treat Corp. Monroe, Michigan.

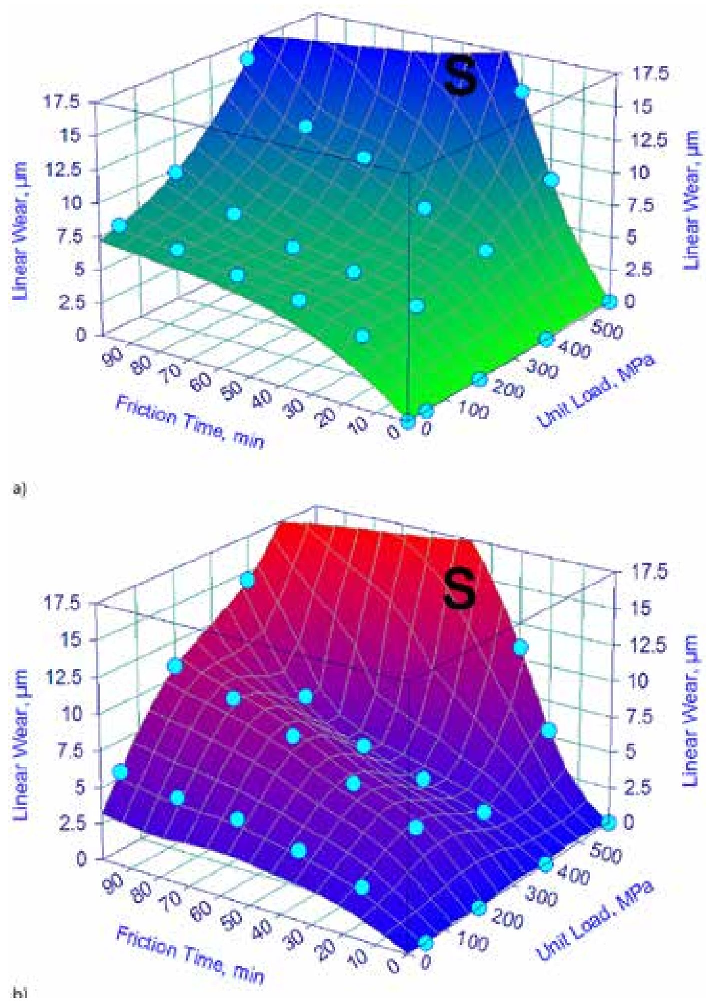


Figure 10: Linear wear of nitrided SAE 5210, total case 0.16 mm a), and linear wear of carburized SAE 5210, Total Case 0.95 mm b). Adopted from [6].

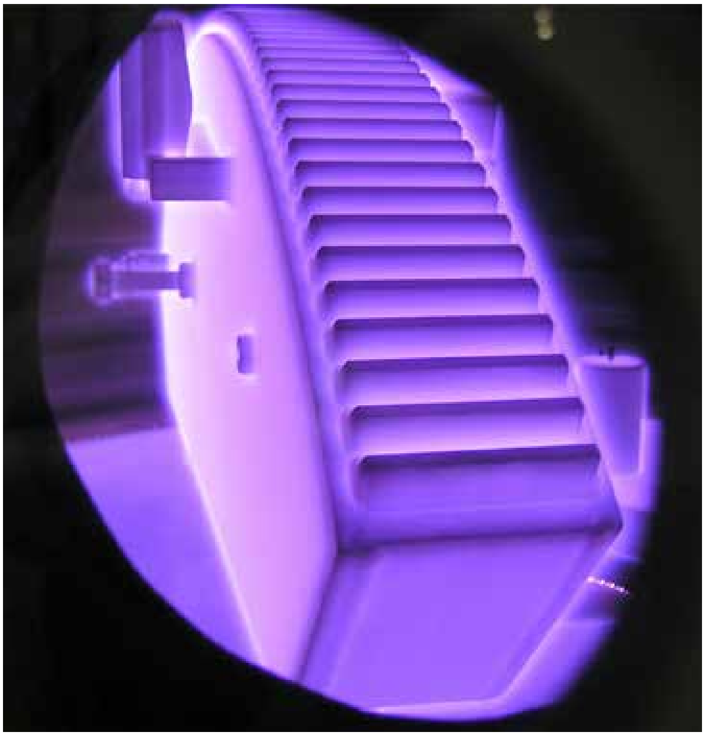


Figure 11: Gear segment during ion nitriding-mechanical masking. Images taken at Advanced Heat Treat Corp. Monroe, Michigan.

Plasma nitriding is beneficial in many of the gears' nitriding applications because of not only its low-nitriding potential but also the ability to mechanically mask the surfaces, which have to be protected from hardening.

plasma nitriding and/or a very sophisticated low KN gas nitriding.

It should be noted that applications of plasma nitriding are not limited to the low KN nitriding-type process. This method allows for nitriding austenitic stainless-steel parts, especially those made of sinter metal/powder metallurgy materials where activation of the surface is very important and penetration of the porosities, which can happen when gas nitriding is used, is not allowed [7]. See Figure 9.

NITRIDING OF GEARS

Nitrided layers with a moderate compound zone thickness are very good for enhancing tribological properties of gears when they are made of low alloy-type steels [8, 9]. Their tribological performance is excellent and may outperform carburized gears [6]. In the past, nitrided gears had to be grinded to remove the excessive compound zone. At the moment, application of the processes with the low-nitriding potential such as plasma nitriding or controlled gas nitriding allows for producing layers with proper CZ thickness. Those layers have very good frictional and RCF properties. Failure of the mechanical parts, as gears subjected to rotation and friction, can occur by different mechanism, and the most common is wear by friction. If the surface hardness is insufficient to resist friction, galling or seizure may result. Therefore, reducing wear by friction is critical in preventing the other failures. Surface hardness of nitrided or carburized components is significantly increased compared to the treated steel, and the residual compressive stress is generated through the entire thickness of such a layer. Those properties are desired in many applications. It is important to compare tribological behavior of the same low-carbon steel after two different thermochemical processes — nitriding and carburizing. See Figure 10. The samples from both treatments exhibited a linear wear rate at 50-200 MPa unit load, and the wear was similar after nitriding and carburizing, and it had a linear character. However, the wear intensity (μm/min) measure under the same unit load was about 50 percent smaller after nitriding. At 600 MPa, samples after both treatments went into seizure.

It also should be noted here that plasma nitriding is beneficial in many of the gears' nitriding applications because of not only its low-nitriding potential but also the ability to mechanically mask the surfaces, which have to be protected from hardening, see Figure 11.

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Dr. Edward Roliński, aka Doctor Glow, is the senior scientist at Advanced Heat Treat Corp. and has been studying the plasma/ion nitriding phenomenon since the 1970s. He has written countless articles and whitepapers in industry publications and manuals. Mikel Woods is the president of Advanced Heat Treat Corp. (AHT) and has been with the company since 2005. Previously to AHT, Woods worked at HUSCO International, Inc. and PricewaterhouseCoopers, LLC in finance, project management, and sales functions, respectively.

A CASE STUDY AT THE LABORATORY

HEAT TREATMENT OF STEEL

MEASUREMENT OF HARDNESS AND TENSILE STRENGTH

During a university study, experiments were conducted to measure the effects on different steel samples as they undergo various types of heat treatment.

By ATHANASIOS K. ZOIS

The heat treatment of steel changes its microstructure, its hardness, and its tensile strength. These issues are of utmost importance as they are closely related to its uses and applications. This article is an experiment, conducted at the university laboratory of physical metallurgy. It assesses the abovementioned issues in the cases of various steel samples, each of which undergoes a different type of heat treatment. Using the appropriate methodology and techniques, various conclusions are drawn. The main objective of this article is to explain this methodology.

1 INTRODUCTION

In order to be made appropriate for various uses and applications, steel has to undergo various procedures such as quenching, tempering, and annealing. Those procedures of heat treatment change the microstructure of steel. Its grade (hypoeutectoid, hypereutectoid, etc), determined by its content in carbon, is of utmost importance.

The measurement of hardness and tensile strength poses an important issue as regards the heat treatment of steel, so that various types of steel can be produced, depending on their future use.

This work is an experimental procedure that was conducted at the laboratory of physical metallurgy of the National Technical University of Athens, Greece. It is a case study on the measurement of hardness and tensile strength of steel. It is important to note that it was carried out under laboratory conditions, concerning the time sets and temperature used in the procedures. Through the use of the appropriate methodology, namely the use of the T-T-T diagram, the hardness/tensile strength conversion chart and obtaining the objective functions, the article draws conclusions on various steel samples, each of which undergoes heat treatment under different conditions, such as a different cooling rate and cooling temperature or a different tempering temperature. Consequently, the article does not discuss any innovations; it aims to explain the methodology and techniques that are applied in the various stages of heat treatment of steel.

2 EXPERIMENTAL PROCEDURE

2.1 Microstructure

The first experiment focuses on the microstructure of steel. We had four hypoeutectoid steel samples with a 0.53% carbon content. The first sample did not undergo any treatment, and it retained its initial properties. The rest of the steel samples were placed in a furnace in 900°C for 15 minutes in order to undergo austenitizing. After being heated, the second sample underwent rapid cooling in a water container. The third sample was left to cool at room temperature for approximately 20 minutes. Finally, the fourth sample was left in the furnace thats door had been left half open in order to drop the temperature from 900°C to 600°C for about 20 minutes and then it underwent rapid cooling in water.

Samples	1st measurement (HRC)	2nd measurement (HRC)	GPA (HRC)
1	19	16	17.5
2	59	59	59
3	27	27	27
4	23	21	22

Table 1: Measurement of hardness of steel samples after cooling.

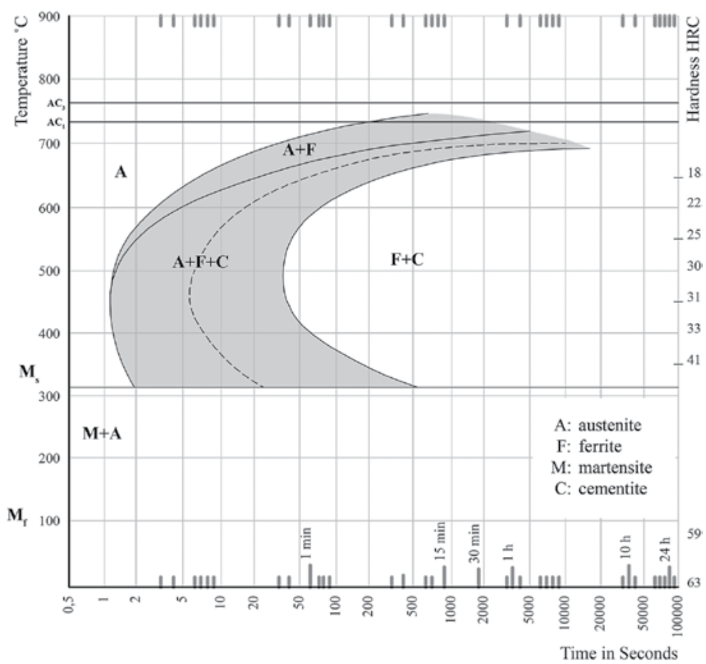

Figure 1: T-T-T diagram of steel with a 0.53% C.

After the completion of the abovementioned procedure, we conducted a test to measure the hardness of the four samples. The findings of the test are presented in Table 1.

The results of our test shall now be explained through the aid of the T-T-T diagram and any possible deviations shall be justified. (Figure 1)

1st steel sample

As we have already mentioned, the first sample did not undergo any procedure, and it retained its original properties as well as its initial microstructure. In other words, a transformation of austenite to martensite or any other transformation whatsoever was not observed. To be more specific, since the case in point is about hypoeutectoid steel with a 0.53% carbon content, its microstructure should be proeutectoid ferrite and pearlite.

2nd steel sample

The second sample was cooled rapidly from 900°C, so we observe a martensitic transformation. The hardness of the sample is estimated at 59 (HRC). Therefore, it is below the Mf in the T-T-T diagram. This means that all the austenite has been transformed into martensite. Therefore, the final microstructure is 100% martensite.

3rd steel sample

The third sample was left to cool slowly at room temperature. Its hardness measures 27 (HRC), and, according to the T-T-T diagram, it is within the F+C region. In other words, the sample consists of ferrite and cementite, i.e. pearlite. The cooling process was slow, and the austenite had not been transformed into martensite.

4th steel sample

In this case as well, the cooling process was slow, and the conditions were not appropriate for a martensitic transformation. Austenite transforms into ferrite and cementite, i.e. pearlite. Any further cooling, even a rapid one, formed. According to the T-T-T diagram, for HRC = 22, we are in the F+C region. To put it another way, the sample consists of ferrite and cementite.

The above mentioned are presented in the T-T-T diagram that concerns the transformation phase of the 2nd, the 3rd, and 4th steel samples during heat treatment.

2.1.1 Results and Discussion

Consequently, we reach the conclusions presented on Table 2.

It is observed that only rapid cooling causes martensitic transformation (2nd sample). The slower the cooling process, the more the reduction in hardness without the occurrence of martensitic transformation (3rd and 4th sample). Martensitic transformation occurs only in the case of the first rapid cooling (2nd sample vs. 4th sample). Bear in mind that, through the use of an electron microscope, we will proceed to analyze the microstructure of the samples.

2.2 Hardness and Tensile Strength

The second experiment intends to measure the hardness and the tensile strength of steel. A diagram depicting the changes in hardness and tensile strength of four steel samples of 0.53% C in relation to their tempering temperature shall be constructed. The findings we collected during tempering shall be compared and further explained.

For this part of the experiment, four samples of hypoeutectoid steel with 0.53% carbon content were placed in the furnace and heated at 900°C for 15 minutes. Afterwards, the samples were cooled in water containers.

Following heat treatment, the first sample was kept as a point of reference. The second steel sample was placed in a furnace in 200°C for 1 hour while the third steel sample was placed in a furnace in 400°C for 1 hour. Finally, the fourth steel sample was placed in a furnace in 600°C for 1 hour. Afterwards, the samples were left to cool in water containers.

After the abovementioned procedures, the hardness of the four samples was measured. The findings of this test are presented in Table 3.

In order to find the tensile strength of the samples that is equivalent to their hardness measurements, we shall go to the table depicting the hardness/tensile strength conversion chart (DIN EN ISO 18265).

In the case of hardness HRC = 66

There is no equivalent tensile strength to a HRC = 66 hardness.

Samples	Microstructure at 25°C
1	Proeutectoid ferrite and pearlite
2	100% martensite
3	Ferrite and cementite i.e pearlite
4	Ferrite and cementite i.e pearlite

Table 2: Microstructure of steel samples after cooling.

Samples	Tempering Temperature (°C)	Hardness Measurement (HRC)
1	-	66
2	200	51
3	400	44
4	600	38

Table 3: Hardness measurement of steel samples after cooling.

HRC	Tensile Strength (N/mm2)
49.1	1630
49.8	1665
50.5	1700
51.1	1740
51.7	1775
52.3	1810
53.0	1845

Table 4: Tensile strength of the 2nd steel sample according to its hardness.

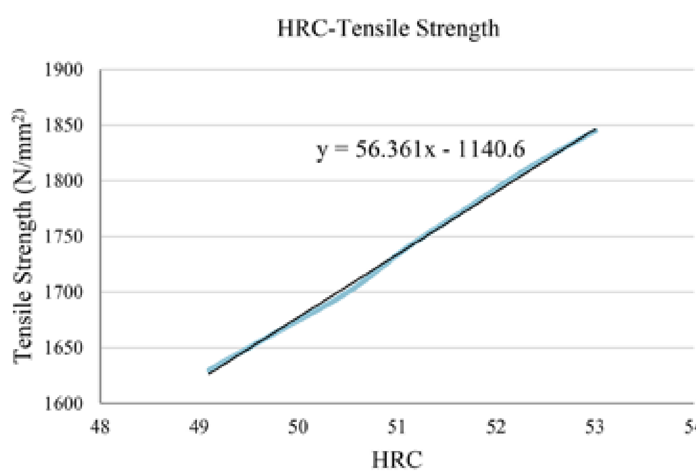

Figure 2: Curve of the objective function according to the hardness and tensile strength (2nd sample).

In the case of hardness HRC = 51

The closest value on the table is the HRC = 51.1. In this case, we take into account the three values above and the three values below our initial one, and we create a diagram and the objective function. (Table 4) (Figure 2)

Using the function y = 56.361x - 1,140.6 for x = 51, we reach the conclusion that the tensile strength is y = 1,733.81N/mm^2.

In the case of hardness HRC = 44

In this case, we work in the same way. Here, the closest value on the table is HRC = 44.5. (Figure 3) (Table 5)

Using the function y = 39.463x - 333.44 for x = 44, we reach the conclusion that the tensile strength is y = 1,402.93N/mm^2.

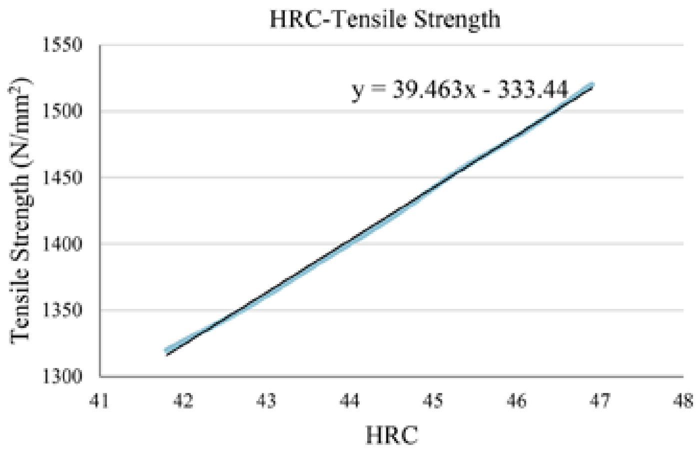

Figure 3: Curve of the objective function according to the hardness and tensile strength (3rd steel sample).

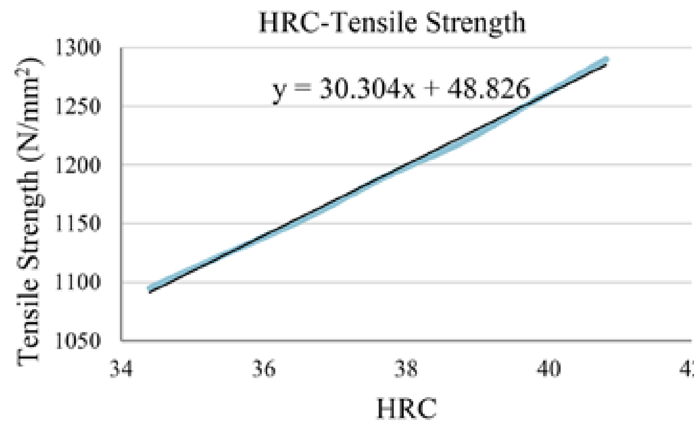

Figure 4: Curve of the objective function according to the hardness and tensile strength (4th sample).

HRC	Tensile Strength (N/mm2)
41.8	1320
42.7	1350
43.6	1385
44.5	1420
45.3	1455
46.1	1485
46.9	1520

Table 5: Tensile strength of the 3rd steel sample according to its hardness.

HRC	Tensile Strength (N/mm2)
34.4	1095
35.5	1125
36.6	1155
37.7	1190
38.8	1220
39.8	1255
40.8	1290

Table 6: Tensile strength of the 4th steel sample according to its hardness.

In the case of HRC = 38

Similarly, in this case, the closest value on our table is HRC=37.7. Therefore, using the three values below and above this one, we are able to obtain the objective function. (Table 6) (Figure 4)

Using the function $y = 30.304x + 48.826$ for $x = 38$, the tensile strength is $y = 1{,}200.38 N/mm^2$.

Bearing in mind the above-mentioned, we reach the conclusions presented in Table 7.

The abovementioned findings concerning all four steel samples are depicted in Figures 5 and 6.

3 RESULTS AND DISCUSSION

Bearing in mind the findings of our experimental study, we reach the conclusion that the second sample — the one with the 200°C tempering temperature — showed the highest measurement of tensile strength. The third sample followed as regards its tensile strength while the fourth sample shows the lowest measurement of tensile strength.

It makes perfect sense that our initial sample shows the highest hardness measurements as well as the lowest ductility measurement.

It is observed that the higher the tempering temperature, the lower the reduction in both hardness and tensile strength. We must also bear in mind that the tempering time remained the same (1 hour) in the cases of all samples so that hardness would not be influenced by the time factor.

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Samples	1st measurement (HRC)	2nd measurement (HRC)	GPA (HRC)
1	-	66	-
2	200	51	1733.81
3	400	44	1402.93
4	600	38	1200.38

Table 7. Relation of tempering temperature, hardness and tensile strength of the four steel samples.

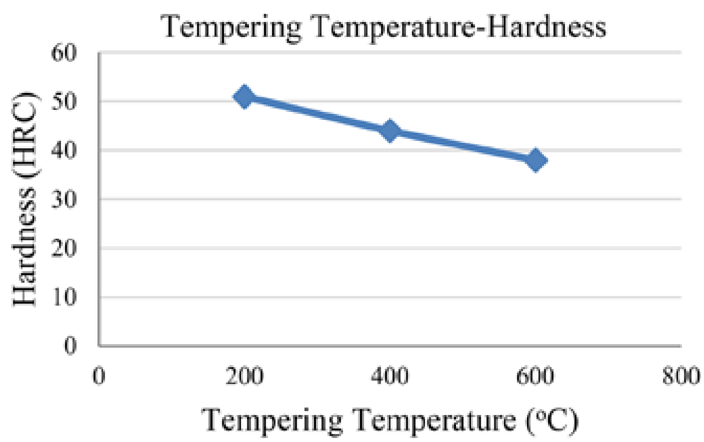

Figure 5: Curve of tempering temperature and hardness for steel samples numbers 2, 3, and 4.

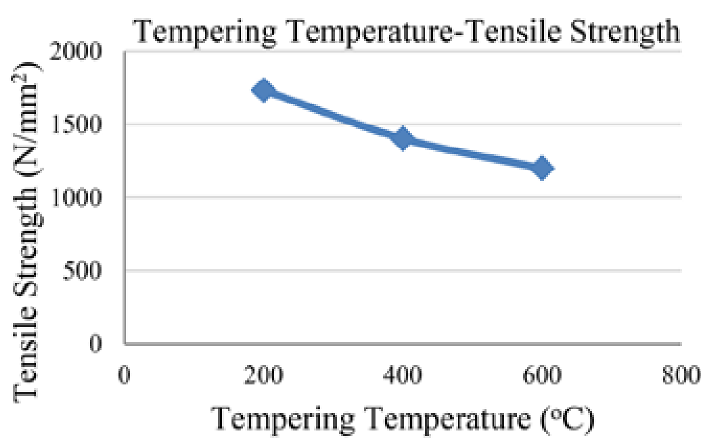

Figure 6: Curve of tempering temperature and tensile strength for steel samples numbers 2, 3, and 4.

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INVESTIGATING A NEW COOLING TECHNOLOGY FOR ELECTRIC VEHICLES

EV battery thermal management is increasingly important. Today's batteries are more powerful than ever, and that trend will continue for the foreseeable future. (Courtesy: Shutterstock)

Electric vehicles are gaining greater traction in the consumer marketplace, and more effective battery thermal management will be a major concern going forward. Immersion cooling may be the way forward for EV manufacturers.

By ANDY RICHENDERFER

The electric vehicle (EV) revolution is well underway: It's estimated the number of EVs populating U.S. roads alone will double by 2024. And though the internal combustion engine (ICE) vehicle is a long way from disappearing, it's anticipated EVs will continue to make up an increasing portion of the vehicle population around the world.

As this evolution takes place, EV manufacturers and the automotive industry at large need to answer an increasingly critical question: What is the best method for keeping increasingly powerful batteries cool enough to operate at peak performance over the vehicle's useful life?

EV battery thermal management is increasingly important. Today's batteries are more powerful than ever, and that trend will continue for the foreseeable future. Newer charging demands have thus rendered traditional cooling methods increasingly ineffective. Conventional air cooling is not quite up to the task of keeping new batteries at optimal temperatures. Water-glycol systems have since been deployed instead, but these solutions simultaneously involve some inhibitive challenges for increasingly sophisticated batteries.

This situation has left EV manufacturers searching for an answer — one that might be found in new immersion cooling systems, which have emerged as a technology with the potential to revolutionize battery thermal management. This article will further detail some of the challenges of effective thermal management in modern EVs, traditional methods' inherent limitations, and the benefits that can be had by deploying immersion cooling solutions.

COMPARING HEAT DISSIPATION IN EVS AND ICES

To best understand the challenges inherent to successful EV battery thermal management, it's useful to compare modern EV technology to traditional ICE operation. For example, ICE vehicles typically generate significant waste heat. On average, only about 40 percent of ICE heat helps keep engine components operating as intended, while the remaining 60 percent is used to help run the catalytic converter system or provide heat to the vehicle's cabin when needed.

EVs, meanwhile, generate heat much differently. While an EV is driving, it will typically run at nearly a 90 percent efficiency rate and generate far less excessive heat than an ICE. Still, even mild levels of heat excess can damage a range of sensitive electric equipment responsible for keeping the car in safe working order. More concerning is the heat generated while an EV is charging, especially in rapid charging applications. As batteries are replenished, an effective cooling mechanism is absolutely necessary to protect the rest of the engine architecture and the battery itself.

Here, the most important concern is safety. Overheated batteries are at risk for thermal runaway, a phenomenon in which the battery's lithium-ion cell enters an uncontrollable, self-heating state. Unless the battery is cooled effectively, the temperature within the battery will continue to rise and cause structural and chemical integrity to be compromised. As this happens, an uncontrolled battery fire could result.

But even outside of this worst-case scenario, batteries that regularly experience mild overheating tend to age more quickly and will provide diminished range, power, and performance across the vehicle's lifetime. Meanwhile, excessive heat generated during charging can cause damage to the vehicle's electric motor and power electronics, all of which can lead to expensive breakdowns and potential safety hazards for drivers.

LIMITATIONS OF CONVENTIONAL COOLING METHODS

To understand the need for more effective cooling methods, it's important to examine the limitations of current technology. Air-cooling methods were initially deployed in many of the first EVs on the market, but these types of systems quickly demonstrated limited effectiveness in helping to mitigate the excess heat generated by rapid charging. Not only did this pose a threat to the battery itself, but it was a fundamental hurdle to widespread EV adoption. Batteries must be compatible with rapid charging to meet consumer demands.

The migration to water-glycol cooling systems was quick. These systems were broadly adapted from technology used to mitigate excessive heat in modern ICE engines. Here, a series of tubes are filled with a cooling water-glycol solution. The tubes then surround the battery pack with the intent of keeping battery temperatures within an optimal range between 20°C and 32°C. Water-glycol cooling proved significantly more effective than air cooling, allowing for faster charging speeds and helping to extend the life of the battery.

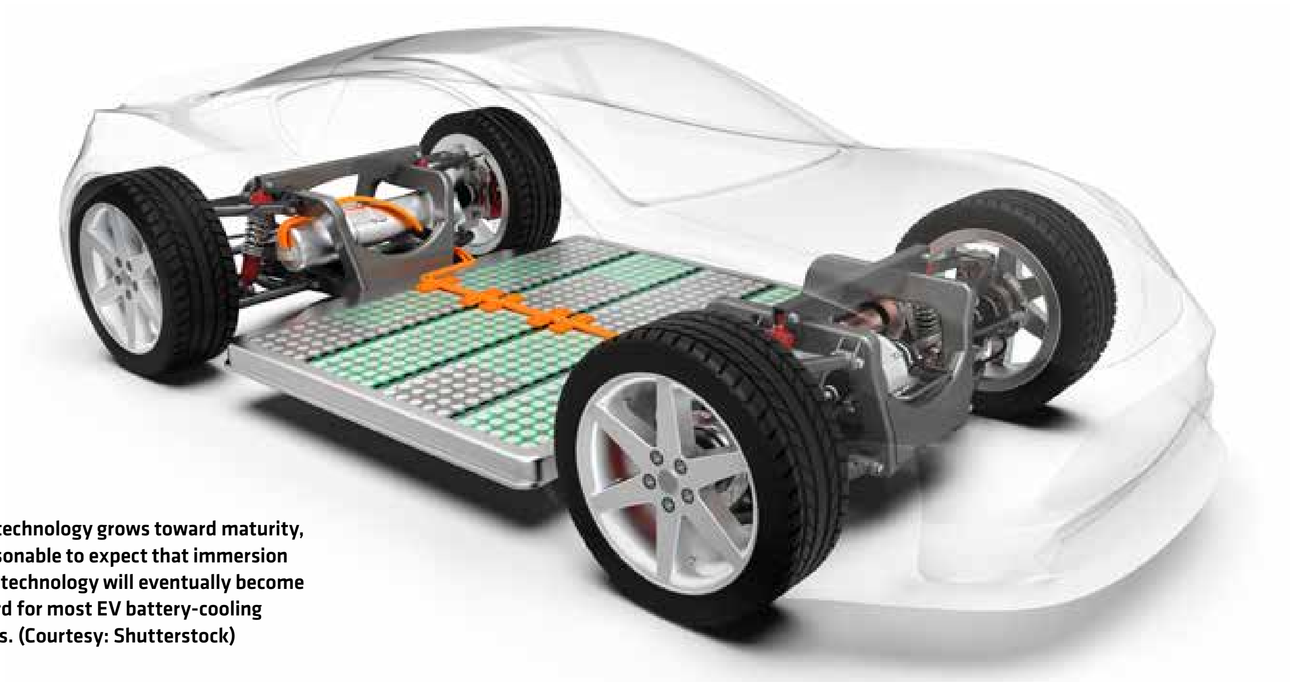
Water-glycol systems have since demonstrated their own shortcomings; however, because since they are filled with a water solution, the systems cannot come into direct contact with the electric battery. Any leaks in the system would cause potential safety issues were water to hit the battery or other electronics. For these reasons, many EV OEMs have found themselves searching for effective alternatives — and one solution demonstrating significant potential is immersion cooling.

IMMERSION COOLING AND ITS ADVANTAGES

Immersion cooling systems are not yet in commercial production, but multiple OEMs are actively exploring the deployment of these kinds of systems within their EV designs.

What is immersion cooling? In such a setup, the battery is submerged in dielectric fluid, enabling a more direct cooling approach than a water-glycol system. No complex tube system is required, as the dielectric fluid comes into direct contact with the battery. High-speed battery charging simulations have shown the differences between immersion cooling and water-glycol systems, and they demonstrate a number of benefits, including:

Greater enablement of high-speed charging. Immersion cooling



As the technology grows toward maturity, it's reasonable to expect that immersion cooling technology will eventually become standard for most EV battery-cooling systems. (Courtesy: Shutterstock)

was shown to extend the battery pack's life by 8 percent over a water-glycol system. Meanwhile, immersion cooling was more effective in controlling peak and average temperatures. Finally, immersion cooling reduced peak battery temperature by 5 percent over water-based systems and promoted more uniform temperatures throughout the pack.

SAFETY ADVANTAGES

Immersion cooling eliminates the risk of accidental water exposure to the battery because the dielectric fluid is already completely surrounding it and poses no electrical incompatibility risk. Further, if a catastrophic failure were to occur in a particular battery cell, the surrounding dielectric fluid helps prevent the spread of heat in one cell throughout the entirety of the battery pack — this would help stop other nearby cells from experiencing thermal runaway.

This kind of testing has reliably demonstrated its efficacy and advantages over water-glycol systems, and we anticipate that it will gain significant traction as the market for EVs continues to mature.

WHY CUSTOM FORMULATIONS MATTER

For immersion cooling to truly meet its potential in EV applications, the dielectric fluids must be formulated to specifically meet those needs. These fluids are not new — they have been used in wide-ranging applications for years. However, many of these have not been purpose-designed for EVs and battery cooling. Instead, custom formulation approaches are likely necessary to deliver the levels of performance OEMs are searching for.

To achieve these goals, collaborative approaches between OEMs and lubricant manufacturers and formulators can help. These relationships should grant OEMs the flexibility necessary to adapt as new EV battery and architecture design iterations are developed and brought to market.

Assistance from a custom-formulation partner can help optimize the fluid's performance properties as testing is performed through iterative tweaking and changing chemistry and additive packages. And because immersion technology is new, there are many complexities that must be worked through.

IDEAL DIELECTRIC FLUID PERFORMANCE PROPERTIES

While there are many variables to consider in dielectric fluid formulation, a few of the most important include:

» **Heat Transfer.** An ideal fluid will help warm up batteries quickly and keep them cool (below 50°C) to maximize battery life, range, and output. This helps to keep other electrical components cool to maximize efficiency.

» **Safety.** Fluids must work with the hardware to prevent battery aging and in the event of thermal runaway prevent the failure from spreading throughout the battery pack. Additionally, fluids in direct contact with electronics must have low electrical conductivity.

» **Durability.** Fluids must be selected and formulated to last the lifetime of the battery and be compatible with the polymers and seals.

CHOOSING A FORMULATION PARTNER

As the technology grows toward maturity, it's reasonable to expect that immersion cooling technology will eventually become standard for most EV battery-cooling systems.

As this happens, the fluids necessary to keep the batteries cool will also need to evolve. Fluid formulators will need to be flexible enough to customize chemistries in partnership with leading EV OEMs to adapt their fluids to this emerging technology.

And because most OEMs are only in the initial testing phases for immersion cooling in mass-market production vehicles, a formulation partner with deep expertise in fluid technology can be beneficial in overcoming some of the initial challenges and hurdles associated with early-stage development.

EV OEMs should work closely with formulation specialists to identify the right dielectric fluid performance properties for their unique systems.

With its inherent benefits for battery cooling applications, immersion cooling is a logical choice for EV OEMs. Working with the right partner can help those OEMs seize the benefits sooner rather than later.

ABOUT THE AUTHOR

As a senior research engineer at The Lubrizol Corporation, Andy Richenderfer supports thermal management strategic projects focusing on test design and development for fluid heat transfer performance and safety. Richenderfer joined Lubrizol in 2020 and, prior to that, was a thermal-hydraulic engineer at Knolls Atomic Power Laboratory. Richenderfer has a Ph.D. in nuclear science and engineering from the Massachusetts Institute of Technology.

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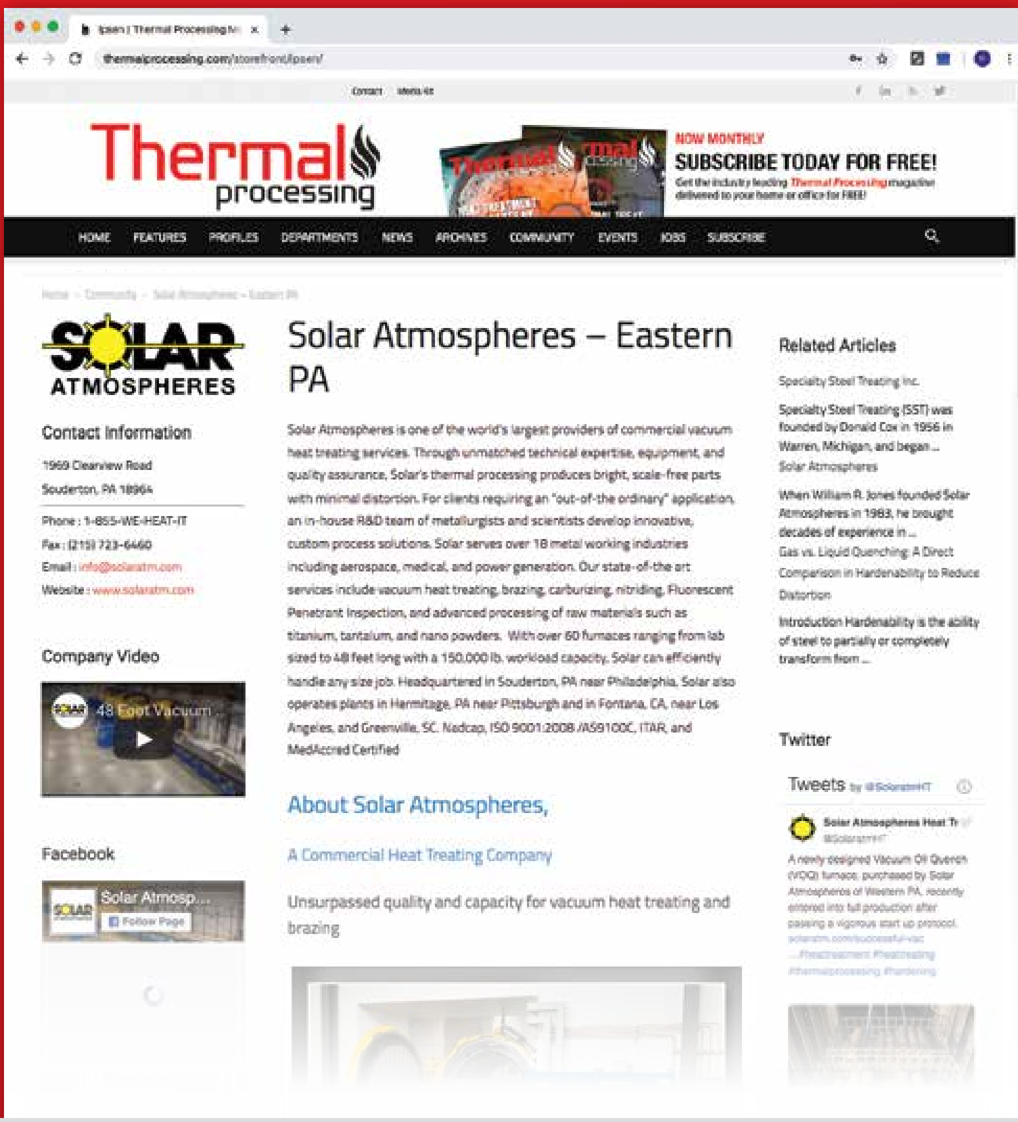

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CREATING SOLUTIONS FOR SPECIFIC NEEDS

This composite oven, which is 18 feet x 20 feet x 65 feet, is used for precision temperature control and uniformity. (Courtesy: DELTA H)

DELTA H® Technologies offers numerous types of industrial furnace and heat-treat ovens for a variety of applications, including aerospace, medical, and more.

By KENNETH CARTER, Thermal Processing editor

A change in enthalpy is the change in energy within a system. Put simply, it is the heat exchanged between a system and its surroundings.

That's exactly what happens within a heat-treating furnace, so it was an easy step to get to the origins of DELTA H® Technologies: DELTA H is the symbol for change in enthalpy. And DELTA H Technologies has endeavored to make itself a symbol of excellence within the ever-changing heat-treating industry.

"My wife, Mary, is a retired chemistry and physics teacher; she actually came up with the name," said DELTA H Technologies CTO and Founder Richard Conway. "It's kind of a cool name for anything to do with ovens and furnaces, and we've had that ever since, and it's now a registered trademark."

SINGLE AND DUAL CHAMBER SYSTEMS

The DELTA H® brand has been around for almost 30 years, but its current incarnation as DELTA H Technologies designs and builds dual and single chamber aerospace heat treating (DCAHT® / SCAHT®) systems with an emphasis on making various sizes of walk-in ovens and cabinet ovens, as well, according to Conway.

"We tend to be niche focused and watch for emerging technologies," he said. "We really like the high-demand applications — especially aerospace and defense. We also do a lot with metal additive manufacturing and out-of-autoclave or vacuum composite applications — all aviation related. Our systems will meet class one for most applications, even though it's not required. They are all about high-performance with intensive data acquisition systems."

DELTA H's wheelhouse is mostly custom designed work that builds on the company's established designs, according to Conway.

"We have a whole lot of standard designs and then we modify those," he said.

Conway emphasized that DELTA H® Technologies always strives to make the best product available.

"We focus on incomparable value and then sell for a fair price," he said. "That's kind of a big distinguishing thing with us. Our systems are typically heavy-duty steel construction, oversized blower shafts and fans, and we use Link-Belt bearings and Baldor motors, which are the best you can get, and the highest quality we can find for most anything on our units. We have an electrical house that does our enclosures and subpanels, and they do brilliant, breathtaking work. Our systems are masterpieces of craftsmanship, works of art in themselves, and people just recognize that. For the industries we serve, they generally have a very fast breakeven point, especially when it comes to aviation and medical applications."

AMS STANDARDS

Since a lot of DELTA H's work involves aerospace applications, much of what the company does revolves around AMS standards, according to Conway.

"If you would study these aerospace standards for a long time and then try to dream up the most perfect furnace system for that, it'd be one of our units," he said. "Every time we get another idea or somebody has a suggestion, we usually quickly adopt it in our designs."

In addition to aerospace, Conway said DELTA H also has a hand in emerging technologies as well as standards for the medical industry.

Since a lot of DELTA H's work involves aerospace applications, much of what the company does revolves around AMS standards. (Courtesy: DELTA H)

"MedAccred adopted AMS 2750 as their heat-treating standard, so we got into the medical side of things not even knowing much about it," he said. "Now we have projects in Malaysia and a couple other parts of the world over there that involve orthopedic-type applications and heat treating that has to be compliant with AMS 2750. That's pretty exciting stuff."

That brings home a point of pride with Conway in that, with his decades of experience, he said he can build anything.

"I'm ready to take on anything; when we get a new challenge, we welcome it even if they might have a different spec or a different parameter," he said. "We're building a system right now that's an inert atmosphere oven. It has to have rapid cooling on it, and so we have a heat exchanger inside this oven that can heat up to 1,200°F in about an hour or so, and it can also cool down to ambient again, all

DELTA H Technologies designs and builds dual and single chamber aerospace heat treating (DCAHT® / SCAHT®) systems with an emphasis on making various sizes of walk-in ovens and cabinet ovens. (Courtesy: DELTA H)

under atmosphere, in about two hours. That took some serious engineering to figure how to do that, and we're getting ready to ship that this week. That was quite a challenge."

FIRST CHALLENGE

Never backing away from a challenge is been the history of DELTA H since the beginning.

During the 1990s, Conway did a lot of consulting and technical service work, and he started building replacement control systems. In 1999, he got a call about a project at a San Antonio airfield. A customer at an aircraft maintenance-repair-overhaul (MRO) facility needed a way to heat-treat parts in order to avoid aircraft-to-ground, or AOG, situations. Sending those parts out to be heat treated had been deemed to be too expensive and time intensive.

Conway was flown in and soon informed them that the hobby kiln the facility had purchased would not work for their needs. In response, Conway designed a small, compact system that could do both solution heat treating and aluminum aging with a rollaway quench tank.

DELTA H CTO and Founder Richard Conway says working with the military is very rewarding for him. (Courtesy: DELTA H)

Since almost all of the parts the facility needed to quickly heat treat were less than four feet long and lightweight, Conway said he was able to design a dual chamber concept that met all of the facility's required specifications.

"They didn't need anything super fancy, but it just had to meet all these aerospace performance specs," he said. "That was the whole trick, and, after that, I started selling or developing them. The second one went to another customer in San Antonio, and the third one went to Boeing in Salt Lake City, and the rest is kind of history.

We've built them ever since and improving as necessary to meet the evolving specs. They're used by the armed forces all over the world, and they're used by leading aircraft OEMs, MROs, and many parts manufacturers."

A FAMILY BUSINESS

Several years after Conway had established DELTA H, Conway's twin children, Neal and Ellen, came on board with the company in 2009, and DELTA H Technologies, LLC was born. Conway said DELTA H is very much a family business — a fact he is most proud of.

"That fall in 2009, we got a whole bunch of orders for these dual and single chamber systems, and it went on from there," he said. "Being in a family business is hard to top. I spend about every day with my twins, Neal and Ellen, and my wife of nearly 40 years, Mary, is here most of the time. That's really the best thing. Our youngest son, Scott, was also involved before joining the USAF and is now a full-time engineering student in Utah."

But, if Conway had to choose a close second place, he said he also is proud of the work he does for the armed forces.

"Working with the military is very rewarding for me personally as a USAF veteran — that the military is standardizing on our equipment is very fulfilling," he said. "We also have developed a horizontal quench system that's used by the company supplying satellite parts for the Canadian Space Agency. We have our most advanced and biggest DCAHT systems at the Michoud Assembly Facility for NASA heat-treating tubes for this next generation of rockets and space-launch systems (SLS) in that rocket heading to the moon right now — cannot be more rewarding than that. Most major aircraft OEMs use our equipment at different facilities, and are 100 percent dependent on them, and that's pretty rewarding as well."

LOOKING TO THE FUTURE

Conway isn't one to rest on his laurels, and he said DELTA H will continue to grow its product line as it looks to the future.

"We are branching into some other industries," he said. "We're getting a little bit more into industry-type things, for example a project with RIDGID® Tools. Those kinds of systems are interesting and can be used in industrial applications where more standard heat treating is going on. We do have quite a bit of growth in automotive as well, but I think we're just going to keep an eye out on emerging technologies and just see what happens here over the next few years."

All in all, it's been a challenging and rewarding company for Conway where the results speak for themselves, but Conway's longevity in the industry boils down to something even more elemental than that:

"We're just having fun — I mean, it's exciting," he said. "We sometimes get crazy projects, and we never know who's going to be calling or what the challenge might be. In this industry, I've got to have a background where I can work with these engineers and scientists and understand what they're trying to do and then figure out what the best heat-processing application is and how we would apply a solution. We figure it out for them and then, if they like the idea, we calculate a price for it, build it, install it, and train the customer in how to run it, and then they're off to the races."

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MIKE LOEPKE /// HEAD OF SOFTWARE AND DIGITALIZATION /// NITREX

"Qmulus is a holistic IOT solution with the aim to facilitate and optimize the daily work of heat treaters."

What is Qmulus, and why did Nitrex feel the need to develop it?
Qmulus is a holistic IOT solution with the aim to facilitate and optimize the daily work of heat treaters. It offers different functionalities such as monitoring, controlling things, detecting anomalies, finding reasons and solutions for these anomalies, analyzing certain things, and optimizing the whole process. It also helps auditing and reporting all the things you have at heat treatment on regular base. The reasons why we thought it would be a great idea to develop something like this is that there isn't such a solution where everything is under one roof.

Nitrex has some really good digital solutions and special furnace software, but it's only ever really focused on an individual piece of equipment, an individual instrument, or a special functionality. There was a solution missing where all of these things can be brought together in one platform, and that's really what this is: It's a platform that lets you have your entire heat-treat plant at your fingertips. It is not only a visualization of furnaces, their current status, and what they're doing but also the ability to review all the documentation for those assets, whether they're manuals or spare parts lists or other things. The ability to review past heat-treatment cycle data, compare that to one another, download recipes into individual controllers, identify anomalies, all of this functionality for an entire plant or even a group of plants can be brought under one roof.

How does the cloud allow the heat-treating sites to be managed remotely? What advantages does this allow?
Many furnace manufacturers have provided some kind of remote interface in the past with varying degrees of success. But having an on-prem service that communicates and synchronizes data from furnace systems and instruments to the cloud really improves the ease with which someone can interact and access. I can sit here at my desk, and I can log in and seamlessly check on a facility in the Chicago area from my smartphone or from my laptop with a browser. There's no software to install. It's not clunky. It's user friendly.

Qmulus allows for this real-time visibility of a heat-treating plant. How does it do that?
All of the data is already available in these plants. It's in data silos and in separated systems already available. Nitrex has created its own edge device for IoT systems, which is collecting the data of different sources, aggregating this data, encrypting this data, and sending it into the cloud environment. And with the cloud environment, I do not only mean the public or private cloud environments hosted for example in AWS or Azure, but also, if needed, an on-premises cloud. The customer can even have its own cloud system and Qmulus can be installed there as well. But the beauty is that we have all the information and software services running and available in one place where it is easy to create backups, to service, and to update.

Additionally, as with any system that collects large amounts of data and with the current tools that are available to users now, like cloud computing power, we can harness this to actually crunch all of those massive amounts of data and actually draw conclusions and inferences and even enable adjustments of processes in real time based on historical trends. And this is something that really hasn't been available in our industry, although it's been made available to other industries.

Enabling this for heat treatment in order to provide a level of predictive quality, this is something that's really powerful, and we're looking forward to bringing this functionality to heat treaters.

How does Qmulus provide data protection?
Qmulus, in general, is using state-of-the-art communication protocols and also encryption modules. All data in transfer or resting is encrypted with the latest security encryption standards. We are following FIPS 140-2 or higher, which is a requirement for CMMC and ITAR, for example. We are already aiming to meet the upcoming regulations, which are not final yet.

But we also have consultants leading us in the right direction. We are making sure we are meeting the standards, and we are still compliant. If we have a cloud system running on AWS or Azure, we also rely on the security expertise of the infrastructure providers, because they know best how to secure and protect data.

Basically the takeaway is that whatever government-mandated security and data privacy regulations are in effect, Qmulus meets those. It's being constructed with the ability to host an on-prem system, if that's required, for sensitive government contractors, for example. Or you could host it in a gov cloud as well, to be defense compliant. And all the customers, even in public cloud environments, are isolated. They have their own private subnets/tenants, so the data is strictly separated. There's no way a customer can have access to other customers' data.

What has been the market reaction so far?
All the potential and existing customers we presented Qmulus to say it's definitely the right way to go and that the market was lacking such a solution. In general, I think that they are happy that finally it is going this route. In particular, the feedback was pretty good at FNA. Every major customer — I'm talking about large manufacturers that have a digitalization strategy — have said it fits with their strategy.

MORE INFO www.nitrex.com