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Thermal processing

ISSUE FOCUS ///

HEAT TREAT EXPO PREVIEW

TROUBLESHOOTING CRACKING IN INDUCTION HARDENING OF STEELS

COMPANY PROFILE ///

Cyprium Induction

SEPTEMBER 2019
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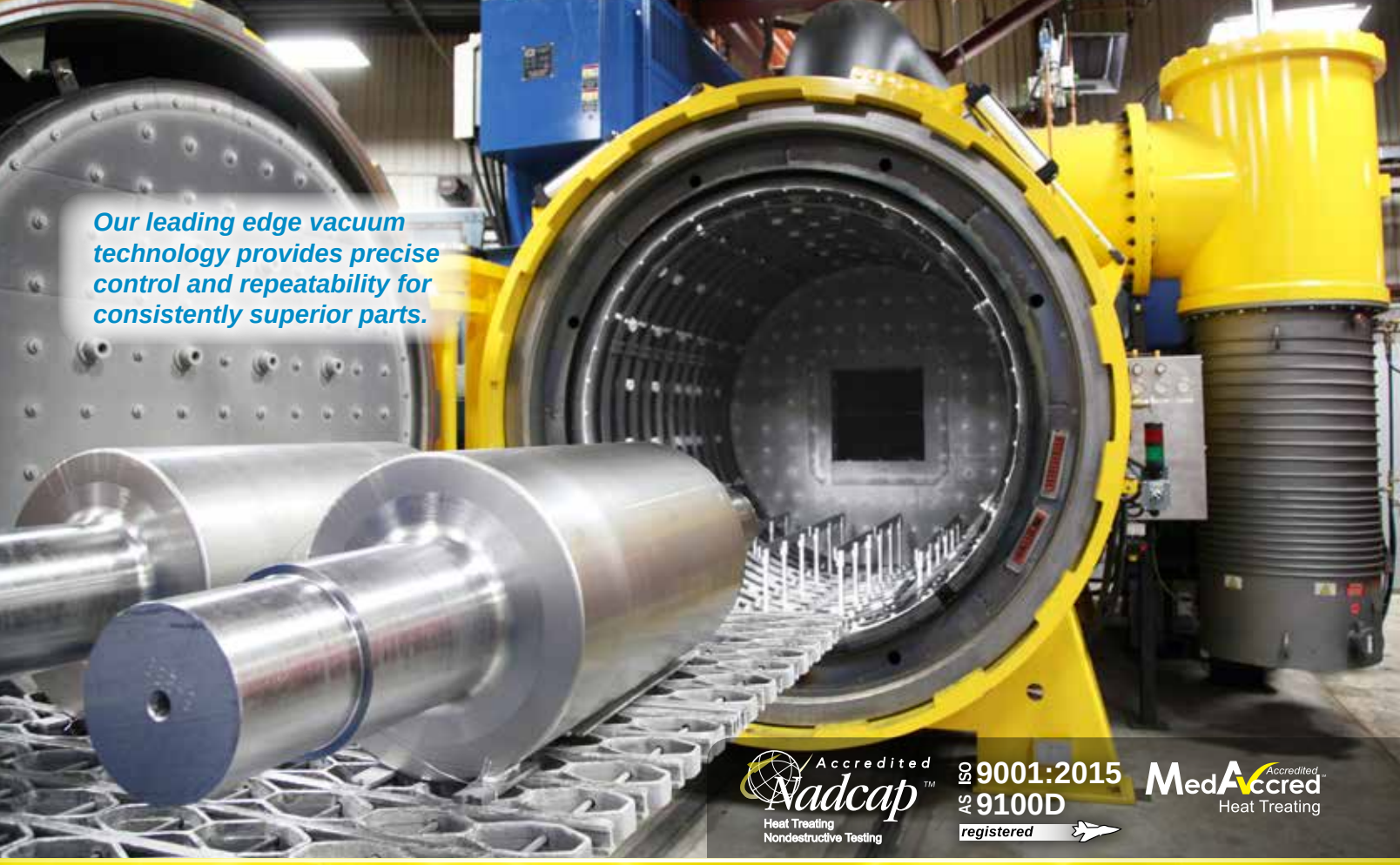

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DEPARTMENTS ///

SEPTEMBER 2019 VOLUME 8 / NUMBER 9

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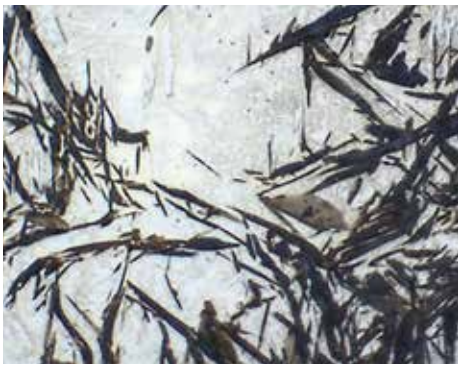
Industrial Heating Equipment Association (IHEA)

In this section, the national trade association representing the major segments of the industrial heat processing equipment industry shares news of the organization's activities, upcoming educational events, and key developments in the industry. **20**

METAL URGENCY ///

Equations analyses indicate austenite carbon content is the main controlling factor in a cold treatment process while the cold treatment temperature is secondary. **22**



QUALITY COUNTS ///

For those involved in monitoring quality as it applies to heat treating, it's important to have a solid understanding of the full process. **24**

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

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Enrique Lopez – Sales and Marketing
Email: sales@aldtt.net
Phone +1 (810) 357-0685

ALD Thermal Treatment, Inc.
2656 24th Street
Port Huron, MI 48060, USA

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FROM THE EDITOR ///

We're getting excited about Heat Treat 2019

Things are definitely heating up as we get closer and closer to Heat Treat 2019 in Detroit, Michigan, October 15–17. No doubt you're all excited about connecting with your colleagues in the industry.

All of the top companies and big names are expected to be there while hundreds of heat-treat exhibitors will crowd the floor of Detroit's Cobo Center.

Thermal Processing will have a booth there as well, so please drop by and introduce yourself. I'd love to meet you and discuss editorial opportunities with the magazine. I'm always looking for new and exciting ways to pass on important industry knowledge and expertise.

So, consider this issue of *Thermal Processing* a primer to get you in the mood, because we've packed our September issue with a lot of articles you will definitely find interesting.

Long-time contributor Dr. Valery Rudnev and his colleagues, Gary Doyon, Randall Minnick, and Tim Boussie, share their expertise in the troubleshooting and prevention of cracking in induction heating of steels. You'll find part one of this informative article looking at the real-world necessity of having the proper experience and analysis tools. Stay tuned for part two in October.

An article from SECO/Warwick's Mark Hemsath takes a look at an innovative new furnace design that translates into safe processing with simple, advanced automation.

In our company profile, we shine a spotlight on Cyprium Induction and its broad range of products and services that include turnkey induction heat treat and induction forging equipment.

As a kickoff to Heat Treat 2019, we've expanded our monthly Q&A feature to give a shout out to several companies that are exhibiting at the show. Take a look at what they will have on display and be sure and stop by their booths for more information about what they're offering the heat-treat industry.

And last, but certainly not least, *Thermal Processing* is always thrilled to highlight the expertise our columnists bring to the heat-treating table. They continue to shine a light on all aspects of the industry.

I'm excited to bring you this issue, and I hope to see you at the show in October. Stop by booth #2119 and say hey, and maybe I can include your company in a future issue.

Thanks for reading!

KENNETH CARTER, EDITOR
editor@thermalprocessing.com
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Thermal processing

David C. Cooper
PUBLISHER

Chad Morrison
ASSOCIATE PUBLISHER

EDITORIAL

Kenneth Carter
EDITOR

Jennifer Jacobson
ASSOCIATE EDITOR

Joe Crowe
CONTRIBUTING EDITOR

SALES

Chad Morrison
ASSOCIATE PUBLISHER

Dave Gomez
NATIONAL SALES MANAGER

CIRCULATION

Teresa Cooper
MANAGER

Jamie Willett
ASSISTANT

DESIGN

RIck Frennea
CREATIVE DIRECTOR

Michele Hall
GRAPHIC DESIGNER

CONTRIBUTING WRITERS

TIM BOUSSIE
GARY DOYON
MARK HEMSATH
RANDALL MINNICK
LEE ROTHLEUTNER
DR. VALERY RUDNEV
JASON SCHULZE

Media solutions

PUBLISHED BY MEDIA SOLUTIONS, INC.
P. O. BOX 1987 • PELHAM, AL 35124
(800) 366-2185 • (205) 380-1580 FAX

David C. Cooper
PRESIDENT

Chad Morrison
VICE PRESIDENT

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OPERATIONS

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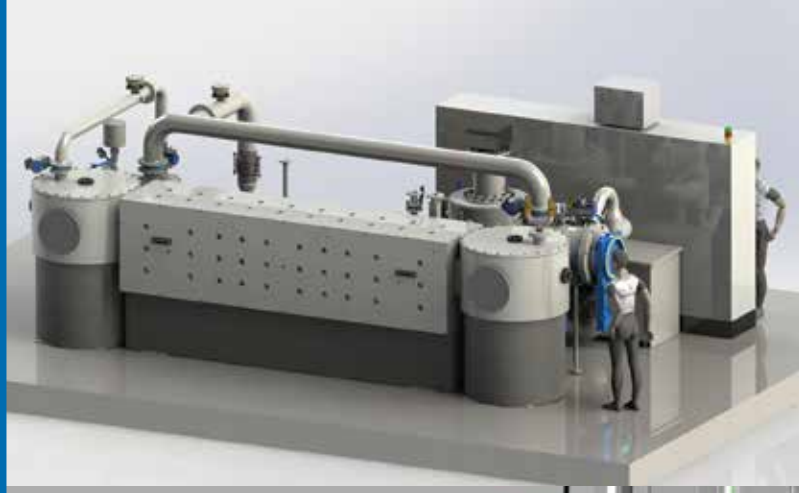

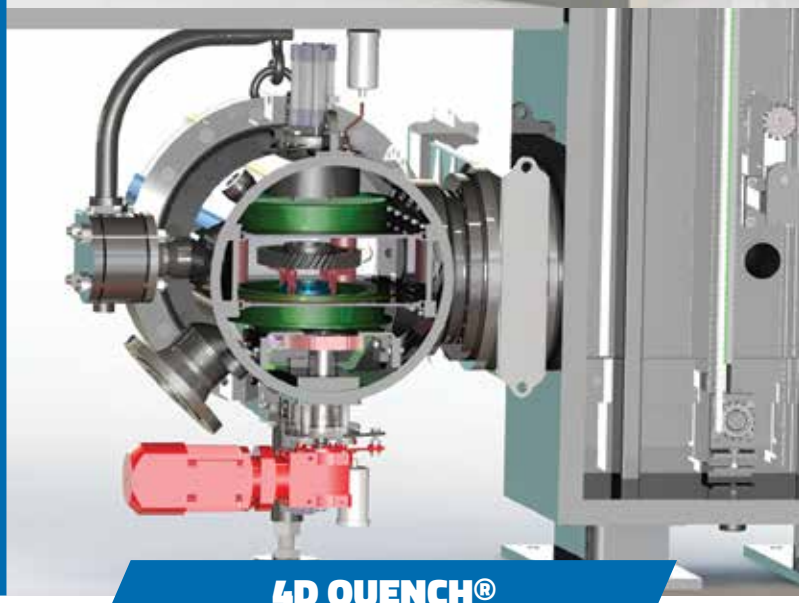

4D QUENCH®

Two super new products that take heat treating to a whole new dimension.

SECO/VACUUM is unveiling not one but TWO new products at the ASM Heat Treat show in October. We're really fired up about them and we think you will be, too!

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To learn more about these innovative new furnaces PLUS our broad array of other heat treating solutions, stop by and see us at the ASM Heat Treat Show, Booth 1207-1209 or visit us online.

SECO/VACUUM

The North American Vacuum Furnace Company

www.SecoVacUSA.com

This box furnace can be used for applications that require process temperatures up to 1,850°F under a N2/H2 blended atmosphere (96/4 blend). (Courtesy: Lindberg/MPH)

Lindberg/MPH offers electrically heated box furnace

Lindberg/MPH has a new electrically heated atmosphere box furnace with a semi-automatic powered load/unload transfer table and oil quench tank in stock. This box furnace can be used for applications that require process temperatures up to 1,850°F under a N2/H2 blended atmosphere (96/4 blend). This equipment has never shipped from our manufacturing facility, includes our full 1-year warranty, and is available for immediate inspection or shipment.

Specifications of this Lindberg/MPH furnace:

› Designed to accept a 24" W x 36" D x 18" H basket.

› Total furnace heat input: 45 KW with SCR power control.

› Max temperature: 1,850°F.

› Capacity (gross load): 900 lbs. @ 1,850°F.

› Furnace shell is 3/16" thick welded steel with high-temperature insulating firebrick lining.

› 2 HP recirculating fan.

› Air operated furnace door and quench elevator with 3-way hand control valve.

› Control Panel w/ PLC, HMI, & digital recorder included.

Utilities required:

› 480/3/60; Approximately 100 FLA.

› Compressed air @ 90 PSIG.

› Cooling water @ 30 PSIG (70°F).

› N2/H2 @ 30 OSIG (blending panel incl.).

› Price: $315,000.

› Model Number: 11-RO-243618-18AF.

MORE INFO www.lindbergmph.com

Gasbarre announces powder compaction promotion

Gasbarre has announced the promotion of Joseph D. Hall to Aftermarket Services Manager for Powder Compaction Solutions. The move, one of several recent, is aimed to enhance the company's aftermarket service and provide customers with unmatched technical expertise.

Hall has been with Gasbarre for more than nine years in various roles including logistics and press assembly. He has spent the last five years servicing Gasbarre aftermarket customers.

Joseph D. Hall

According to Heath Jenkins, president, press & automation, "Joe has proven himself time and again in a variety of demanding roles of increasing responsibility. Dedicated, smart, and driven to 100 percent customer satisfaction, employees like Joe are singularly important to our customers' success. His promotion is well-deserved and we look forward to what the future holds for Joe and for Gasbarre."

MORE INFO dspillane@gasbarre.com

SSi completes upgrades at Milacron in Mt. Orab, Ohio

Super Systems, Inc. recently completed major upgrades to the heat-treating assets at Milacron LLC in Mt. Orab, Ohio.

The end goal of a modern controls and SCADA infrastructure led the Milacron

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

team to SSi knowing that it had the resources and skills to tackle a job as large as this one. Included in the scope of work were new control cabinets, atmosphere flow panels, SCADA software, and a new ammonia dissociator. Equipment addressed as part of the upgrade were two pit nitriders, two pit tempers, one pit carburizer, one integral quench furnace, one batch temper, one oil quench, and the new ammonia dissociator with controls. All furnaces are capable of running recipes to automate processes, creating an easy-to-use interface for operators and centrally controlled and operated using the SuperDATA SCADA package providing proof of process and quick access to real-time and historical process and load data.

"We were very happy to be the chosen provider of the heat-treat automation project with Milacron," said Bob Fincken, national sales manager with Super Systems. "Our products and services were a perfect fit for the heat-treat department needs addressing gas flow control with our eFlo product line, recipe controls with our 9205 and 9215 products, data acquisition with SuperDATA, and all the installation and project management carried out by our field engineering team."

Jeff Bissantz, project engineer, who led the Milacron team said, "We are very happy we chose Super Systems over the competition. The quality and workmanship sets them apart from others in the industry."

Included in the Milacron job were new control cabinets, atmosphere flow panels, SCADA software, and a new ammonia dissociator. (Courtesy: Super Systems Inc.)

Super Systems Inc., based in Cincinnati, Ohio, has been developing and manufacturing products for the thermal processing industry since 1995. SSi's products include probes, analyzers, flow meters, controllers, software solutions, and engineered systems.

Milacron is a global leader in the manufacture, distribution, and service of highly engineered and customized systems within the plastic technology and processing industry.

MORE INFO www.supersystems.com
www.milacron.com

MIM2020 conference calls for presentations

An official call for presentations has been announced for MIM2020, International Conference on Injection Molding of Metals, Ceramics, and Carbides, to be held March 2-4, 2020, in Irvine, California. Potential authors have until October 4, 2019, to submit presentation abstracts on manufacturing innovations and material advancements. All abstracts accepted for presentation will

require a PowerPoint submission before the conference.

Innovation is responsible for the rapid growth of the powder injection molding industry (metal injection molding, ceramic injection molding, and cemented carbide injection molding), a nearly $2 billion advanced manufacturing industry. MIM2020, sponsored by the Metal Injection Molding Association, a trade association of Metal Powder Industries Federation and its affiliate APMI International, brings together product designers, engineers, end users, manufacturers, researchers, educators, and students for technology transfer.

MORE INFO mim2020.org

Grieve offers 650°F universal oven for variety of needs

No. 841 is a 650°F (343°C), universal oven from Grieve, currently used for a variety of heat treatments at the customer's facility. Workspace dimensions of this oven measure 36" W x 36" D x 36" H. 9 KW are installed in Incoloy sheathed tubular heating elements, while a 600 CFM, 1/2 HP recirculating blower provides universal airflow to the workload.

This Grieve universal oven features 6" insulated walls, aluminized steel exterior and Type 430 stainless steel interior with double doors. Additional features include a workspace floor reinforced for 500 pounds loading at removable subway grate and an integral leg stand.

Controls on the No. 841 include a digital programming temperature controller, manual reset excess temperature controller with separate contactors, and a recirculating blower airflow safety switch.

MORE INFO www.grievecorp.com

Grieve's No. 841 oven features digital programming temperature controller and a recirculating blower airflow safety switch. (Courtesy: Grieve)

UPC upgrades furnace controls at Woodward

United Process Controls, (UPC) recently upgraded the vacuum furnace controls and automation platform for Woodward Inc., a U.S. provider of fuel and control systems for aircraft engines. The new generation controls provide streamlined reporting for NADCAP compliance as well as seamless integration with the company's enterprise planning (ERP) system.

The control upgrades were undertaken at the company's Illinois facility and completed in a two-step approach. First, three vacuum furnaces – two Abar Ipsen and a VFS – received a full control system replacement based on UPC Protherm 710 controllers. The scope of work also included new digital heating zone trims for temperature uniformity, and multiple PID sets to minimize overshoot and meet tight tolerance requirements. Once the updated controls were installed, the second step was implementation of the Protherm 9800 SCADA and connectivity to the Protherm 710 controllers for real-time visibility of production data, including connectivity to the company's ERP system. In the latter case, the ERP interacts with Protherm 9800, managing the process recipes and feeding data to the Protherm 9800 to align the right recipe with the part or job lot entering the receiving furnace. This setup provides a redundant check and requires the operator to validate the part number or job lot number via the Protherm 9800 interface before a recipe can be deployed.

In addition to complying with NADCAP, the enhanced controls also meet AMS 2750E specification for thermocouple tracking. Since thermocouples have a limited life span, Woodward had to closely monitor how often each unit was used and manually record data. Now, the Protherm 710 controller tracks the thermocouple, its serial number and usage history, identifies when a thermocouple needs to be replaced based on running hours, days in service and temperatures reached, and alerts the operator when it's time to change the thermocouple. The Protherm controls also give added benefits such as monitoring and diagnostics for easier troubleshooting. Woodward also took advantage of the quality management

United Process Controls, (UPC) recently upgraded the vacuum furnace controls and automation platform for Woodward Inc. (Courtesy: United Process Controls)

module available with the Protherm 9800 to centralize metallurgical laboratory reports.

On top of these investments, UPC also equipped a number of new air-drying ovens with Protherm 470 programmable controllers with onboard input and output capabilities. Future upgrades of furnace controls and automation are planned at Woodward, and UPC will be a part of that, supplying Protherm series and Atmosphere Engineering series process controllers and connecting them into the SCADA platform.

Jason Walls, UPC engineer responsible for the Woodward project preparations and start-up, said, "The workplace at Woodward is top notch. Their commitment to ongoing improvements is an excellent example of a manufacturer understanding the potential of new technology to drive better overall equipment effectiveness, to maximize furnace availability, and to deliver well-engineered, quality products. UPC process controls and control systems add more automation and real-time visibility of production, which will ensure that furnaces continue to operate at maximum efficiency for years to come and at the same time uphold Woodward's high-quality standards of its operations and products."

MORE INFO www.group-upc.com

TigTag™ provides barcode ID for high-temp environs

InfoSight Corporation is the world leader in traceability in harsh environments and continues to meet identification needs in a variety of industries. Automated reading of barcode labels has become standard for identifying and tracking products in almost every industry.

However, some environments are impossible for even the most robust labeling to survive. InfoSight has introduced a new tag, the TigTag™, to bring barcode labeling capabilities to environments in excess of 2,000°F (1,100°C). The TigTag is a new application of its CeramiCode™ line of high temperature tags.

This identification is well-suited for pieces that experience multiple cycles of temperatures in excess of 2,000°F (1,100°C)

throughout their lifetime.

TigTag is a CeramiCode high purity alumina ceramic plate mounted to a 316 Stainless Steel baseplate. The mounting technique is designed to permit rapid temperature cycling without stress on the ceramic plate. The TigTag can be attached to metals using small TIG or MIG welds. The 2" X 3" (50 mm X 76 mm) TigTag provides a high contrast barcode capable of surviving more than 2,000°F (1,100°C). Alphanumeric characters can also be included in the laser marked message.

The TigTag provides a large, scannable barcode for traceability of pieces that experience multiple cycles of extremely high temperatures such as annealing covers, kiln cars, high temperature molds, and rolls.

InfoSight has always been committed to providing identification and traceability in the most difficult environments.

MORE INFO www.infosight.com
www.knovation.com/ceramiccodes

AHT announces new sales, metallurgy team members

Advanced Heat Treat Corp. (AHT), a leader in heat-treat services and metallurgical solutions, has added three sales employees: Tim Zemaitis, Shane Seevell, and Katie Herron.

Tim Zemaitis

The new sales and metallurgy team members will serve the AHT locations in Michigan, Iowa, and Alabama.

Zemaitis, regional sales manager for AHT's Michigan facility, joins the team with more than 30 years of experience in heat treatment, metallurgy, and engineering. Seevell, regional sales manager in the corporate office

Shane Seevell

Katie Herron

located in Iowa, brings more than 15 years of sales experience plus past heat-treat experience working at AHT. Herron, materials engineer and quality specialist in Alabama, is a recent materials engineering graduate from the University of Alabama at Birmingham.

AHT president Mikel Woods said, "We are excited about the new team members we've brought on board. They bring new diverse skillsets that blend great with our mission."

Zemaitis will focus on heat-treat needs in the Great Lakes area. The Michigan AHT facility offers ion (plasma) and gas nitriding, ferritic nitrocarburizing, UltraOx®, stress

relieve, s-phase nitriding, and more.

Seevell will cover sales in the Midwest. The Iowa AHT facilities also provide ion (plasma) and gas nitriding, ferritic nitrocarburizing and UltraOx®, in addition to induction hardening, carburizing, and more.

"With our knowledgeable staff and multiple locations, we'll be able to better serve our customers and give them the UltraGlowing® experience in every location, every time," Woods said.

Learn more about Advanced Heat Treat Corp. and its 20+ surface treatments at www.ahtcorp.com or by calling (319) 232-5221.

Lindberg/MPH ships hot stamping furnace to Gestamp facility

Lindberg/MPH announced the shipment of an electrically heated four-chamber hot stamping furnace to the Gestamp Research

This Lindberg/MPH hot stamping furnace features one stack of three high-heat chambers and one low-heat chamber. (Courtesy: Lingberg/MPH)

and Development facility in Auburn Hills, Michigan. Gestamp is an international corporation that designs, develops, and manufactures metal automotive components.

This hot stamping furnace features one stack of three high-heat chambers and one low-heat chamber. The maximum temperature rating of the high-heat chambers is 1,050°C and the low-heat chamber is 540°C. Each furnace chamber was designed with load space dimensions of 36" W x 30" D x 8" H.

The furnace is integrated at the Gestamp facility with a robotic transfer system and hydraulic hot stamping press. The four chambers operate independently with the top chamber designated for aluminum treatment. This type of hot stamping system allows the customer the flexibility to treat different steels simultaneously and takes up a much smaller footprint than a continuous system.

"This Lindberg/MPH hot stamping furnace provides uniform heating for a wide variety of high-strength steels or aluminum materials prior to hot stamping or hydro-forming applications. The team at Gestamp has been incredible to work with on this project and we are proud to be their supplier," said Bill St. Thomas, business development manager.

Features of this Lindberg/MPH hot stamping furnace include:

› Hydraulically actuated, independently controlled furnace doors.

› Exterior fans to provide cooling between the four heating chambers.

› Two heating zones of rod-overbend elements in each chamber.

› Allen Bradley Compact Logix PLC with temperature control and logic functions.

› One dew-point monitor connected to sample tubes in each chamber.

› Ethernet and Modbus-485 communication capabilities.

› Excess temperature controller in each chamber.

MORE INFO www.lindbergmph.com

TPS ships inert gas oven to electronics manufacturer

Thermal Product Solutions, a global manufacturer of thermal-processing equipment, announced the shipment of one Blue M inert gas batch oven to a manufacturer of electronic components.

This Blue M inert gas oven has a temperature range of 15°C above ambient to 593°C. The interior work chamber dimensions are 25" W x 20" D x 20" H. All seams and entrance ports in this batch oven were welded gas tight to minimize inert gas leakage and to maintain a low oxygen atmosphere with minimum gas flow.

The Blue M inert gas batch oven features a direct drive ball bearing 1/2 Hp motor with a balanced stainless-steel multi-blade blower wheel to provide horizontal airflow, where the air moves from right to left. This type of

This Blue M inert gas oven has a temperature range of 15°C above ambient to 593°C. (Courtesy: TPS)

airflow maximizes heating rates within the oven chamber.

"This Blue M oven shipped out with two maintenance part kits in order to prevent costly maintenance in the future. This customer is supplied with spare parts to keep the oven in like-new operating condition," said Ashlee Kaczorowski, Blue M product manager.

Features of this Blue M batch oven include:

› Reinforced type 304 stainless steel interior for maximum heat and corrosion resistance.

› Direct drive ball bearing 1/2 Hp motor with balanced stainless-steel multi-blade blower wheel.

› 460V/480V 3 Phase 60 Hz electrical power.

› 21 kW heat input.

› Ethernet communications standard with controller.

› Watlow F4T with INTUITION temperature process controller.

› 4.3-inch color touch panel with high-resolution graphical interface.

› 40 ramp and soak profiles with real-time clock and battery backup.

› Ethernet Modbus TCP connectivity.

› High-speed USB 2.0 host port.

› Two preventative maintenance kits with spare parts.

MORE INFO www.thermalproductsolutions.com

Seco/Warwick to supply CAB line to Texas company

The U.S. department of Seco/Warwick Group has been selected to relocate a very large CAB line for a customer who purchased it with the intention of brazing its own heat exchangers. Built by Seco/Warwick for another Houston, Texas, OEM in 2005, the CAB line will be a first for Cold Shot Chillers, as they have not previously conducted furnace brazing in-house.

The Indexing CAB furnace has an overall load size of 48" wide x 100" long. The entire line, which measures 96 feet, includes a wet spray fluxer with blow off, load table, dry off (dehydration) oven, entrance/purge chamber, convection furnace, atmosphere air cooling chamber, final air-blast cooling chamber, and final unloading table. In addition, there is a power panel, a control panel, and an atmosphere scrubber.

The controlled atmosphere brazing (CAB) process heats a product to brazing temperatures while maintaining uniform temperatures within the product in an oxygen-free nitrogen atmosphere. The Seco/Warwick design allows OEMs and aftermarket specialists the flexibility to produce a wide variety of sizes and types of heat exchangers on a daily basis. The indexing solution allows a variety of parts to be brazed with no changes to the menus or furnace settings.

The engineering team at Seco/Warwick has the knowledge and experience to manage fleets of heat-treating equipment in a planned and professional manner regardless of the equipment manufacturer. The solutions offered by the Group are universal because they are based on best practices and its manufacturing team is available through their global network facilities (U.S., Europe, India, and China).

MORE INFO www.secowarwick.com

Wisconsin Oven ships four-zone conveyor oven

Wisconsin Oven Corporation announced the shipment of one electrically heated four zone conveyor oven to a manufacturer in the oil and gas industry.

The electrically heated conveyor oven has sufficient capability to heat 25 parts per hour with a heating time of 48 minutes and a cooling time of 12 minutes. Each chamber in this four-zone conveyor oven has a maximum temperature rating of 400°C and dimensions of 1'8" wide x 2'0" long x 6" high. The oven has a guaranteed oven temperature uniformity of ±6°C at 310°C (±10.8°F at 590°F) for a minimum of six minutes per heating chamber and with a belt speed of two inches per minute. The cool down features a 1,500 CFM propeller fan to cool the

The largest indexing CAB furnace in North America is being relocated to Cold Shot Chillers in Houston, Texas, to conduct in-house furnace brazing of the company's heat exchangers. (Courtesy: Seco/Warwick)

The electrically heated conveyor oven has sufficient capability to heat 25 parts per hour with a heating time of 48 minutes and a cooling time of 12 minutes. (Courtesy: Wisconsin Oven)

parts utilizing top-down airflow, where cooling air will be discharged into the shop from below the unit.

"Wisconsin Oven has the ability to create custom industrial ovens and furnaces that match our customer's unique needs. This specific conveyor oven was designed with four zones in order to melt a high temperature polymer into a "U" shape ring that houses electronic components," said Tom Trueman, senior application engineer.

Features of this Wisconsin Oven conveyor oven include:

› Temperature uniformity of ±6°C at 310°C (±10.8°F at 590°F).

› Manually adjustable insulated profile doors at both ends of the conveyor.

› Allen-Bradley PowerFlex variable frequency AC drive with electronic torque limiting, adjustable from 1"-4" per minute, set at 2" per minute.

› Four separate work zones.

› Eurotherm 3504 temperature controller.

› Ethernet communications.

› 1,500 CFM propeller fan with vertical top-down airflow to help cool parts.

› Barber-Colman 7SL oven high limit controller with manual reset.

› SSR power controller.

MORE INFO www.wisoven.com

Wisconsin Oven ships batch oven to aerospace industry

Wisconsin Oven Corporation shipped one indirect natural gas-fired batch oven to a manufacturer in the aerospace industry. The oven will be used to cure composite materials.

The batch oven has a maximum oven operating temperature of 500°F, work chamber dimensions of 10' wide x 16' long x 8' high, and work zone dimensions of 8' wide x 14' long x 6' high. Guaranteed temperature uniformity of ±5°F at set points 150°, 250°, 350°, and 450°F was documented with a 36-point temperature uniformity test in an empty oven chamber under static operating conditions.

This composite curing oven has sufficient capacity to cool 440 pounds of steel and 360 pounds of composite materials from 300° to 150°F at an average rate of 5°F per minute. It also has the capacity to heat 440 pounds of steel and 360 pounds of composite materials from 130° to 300°F at an average rate of 5°F per minute. The air will be supplied to the work chamber through ductwork located along the length and on each side of the work chamber, near the bottom of the chamber, to assure that the air passes past the product on the way back to the heater house. This will maximize heating rates and temperature uniformity of the product.

The gas-fired batch oven has temperature uniformity of ±5°F at 150°, 250°, 350°, and 450°F. (Courtesy: Wisconsin Oven)

"A complete turn-key installation package was also included with this composite curing oven. This package helps our customers with unloading and reassembly/rewiring of components that are often removed during the shipping process," said Jim Lucas, senior sales engineer.

Features of this curing oven include:

- Temperature uniformity of ±5°F at 150°, 250°, 350°, and 450°F.
- 10,000 CFM @ 5 HP with VFD.
- Honeywell Model 7800 flame relay with integral purge timer and burner controls.
- 46,000 CFM plug-mounted recirculation blower.
- One vertical lift, electrically operated door.
- WOC Premium Control System (PLC controlled).
- Turn-key installation.

FOR MORE www.wisoven.com

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

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IHEA's Fundamentals of Industrial Process Heating Online Learning Course continues to provide an excellent overview of the essential areas used throughout the industrial process heating field. Students benefit from the flexible web-based distance-learning format. It's an affordable alternative to campus-based classes and allows students to go at their own pace.

The program offers a vital tool to industrial process heating operators and users of all types of industrial heating equipment. Students learn safe, efficient operation of industrial-heating equipment, how to reduce energy consumption, and ways to improve a company's bottom line.

Registration is open through October 4, 2019, and the course begins October 7, 2019. Students will learn the basics of heat transfer, fuels and combustion, energy use, furnace design, refractories, automatic control, and atmospheres as applied to industrial-process heating. Students will become familiar with a variety of oven, furnace, and kiln types used in industry. To register for the course, as well as a complete list of course topics, go to: www.ihea.org/event/FundamentalsFall19.

Jack Marino

Industry expert Jack Marino leads students in this six-week online course. Marino is a registered professional engineer with more than 40 years of experience in the heat processing business. He is a graduate of Rensselaer Polytechnic Institute with a bachelor's degree in Aeronautical Engineering and has a master's degree in Engineering Science from Penn State. Marino's knowledge and experience offer invaluable resources that online students can access throughout the course.

IHEA's online courses are a terrific value for IHEA members and non-members alike considering no travel expenses are involved and there is no time out of the office. Take advantage of the online tools provided and benefit from the ability to learn almost anywhere.

A former online student said, "Because of balancing an extremely busy workload and family life, I am not able to be on a regular schedule or take time in the evening to travel to a class. The advantage for me is that I can check in when time permits and still stay up to date on all activities. The course information is directly related to my work, and I found it to be very beneficial."

Each week, students will be assigned a chapter to read from the Fundamental of Process Heating coursebook (electronic version included with course registration) and expected to participate in on-line forum discussions and complete weekly quizzes. There is a final exam project that will be assigned during the fifth week of class. The instructor will be available through email to respond to questions and provide clarification.

IHEA's Fundamentals of Industrial Process Heating Online Learning Course offers an excellent overview of the essential areas used throughout the industrial process heating field.

The cost for IHEA members is $750 or one member voucher, and the cost for non-members is $925. The fee includes electronic course handbook, course instruction, quizzes and projects, class forums, and the opportunity to contact the instructor throughout the course. Students will also receive PDHs for successfully completing the course. Printed materials are available for an additional fee.

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› Students can take the course at home or work.
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› Instructor-led, interactive and safe.

WHAT STUDENTS ARE SAYING ABOUT THE COURSE

› "Excellent knowledge of the course instructor with an excellent and quick response."

› "I enjoyed participating in the discussion forums and found them to be a useful addition to the course materials."

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Don't let another year pass without becoming an IHEA member. Join now and get a multitude of benefits right from the start. Hear what current members appreciate most about IHEA:

"INEX Incorporated has benefited greatly since becoming a member of IHEA. Perhaps the most direct benefit has been enabling our employees to take advantage of the online training programs to broaden their understanding of how our products are utilized by our end users. On a personal note, the biannual meetings have proven to be an excellent networking opportunity. It has been very interesting to see what a diverse industry we participate in and to realize that many of our problems and opportunities are the same as other IHEA members' experience. The work of the various committees benefits each and every member as well as the industry in general." — Mike Kasprzyk, President, INEX Inc.

"IHEA is all about process heating. Whether it is a vacuum carburizing oven or an infrared powder coating curing oven, IHEA covers the spectrum of heating in manufacturing processes. IHEA members are oven- and furnace-equipment OEMs, electrical utilities, combustion-burner manufacturers, various heating-magazine publishers, and even energy consultants. The widely varied membership provides an excellent opportunity for networking and keeping up with the latest and greatest heating-technology developments. IHEA membership provides access to exceptional training opportunities, heating-related national standards updates, up-to-date economic news, and thought leaders across the process heating industry. I have made so many professional and personal contacts and new friends during my membership of IHEA. If you are in the process-heating industry and are not a member of IHEA, you are missing out on a wonderful opportunity. I never miss an opportunity to attend an IHEA event, and I always come away with new contacts and new ideas." — Michael Stowe, Advanced Energy

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IHEA 2019 Process Heating Seminar

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LEE ROTHLEUTNER
GROUP LEADER FOR MATERIAL CONVERSION ///
THE TIMKEN COMPANY

Equations analyses indicate austenite carbon content is the main controlling factor in a cold-treatment process while the cold-treatment temperature is secondary.

Achieving results through cold treatment

Cold treatment is a sub-zero thermal treatment process primarily used to reduce the retained austenite content of alloy and high carbon steels. Cold treatment covers the approximate temperature range of 0°C to 80°C, below which is considered cryogenic or deep cryogenic treatment [1]. Although cold treatment has been used to improve the performance of steel for centuries [2], it continues to be a topic of discussion in many industries [3-5]. As a result, the following discussion and analysis is intended to provide insights into the cold-treatment processes as well as provide context to identify key factors to be considered when establishing a cold-treatment process.

COLD-TREATMENT FUNDAMENTALS

Many steels used in a heat-treated condition are heated to form a significant fraction of austenite and then cooled to form a variety of microstructures depending on the required properties for the application. Martensite is formed during rapid cooling or at a rate sufficiently fast to avoid formation of ferrite, pearlite, and bainite. The temperature at which martensite forms is designated in literature as the martensite start (M_s) temperature. The M_s represents the thermodynamic driving force necessary to initiate the austenite-to-martensite shear transformation [6]. Chemical composition of the steel affects the M_s temperature. Carbon suppresses the M_s temperature significantly due to its ability to solid-solution strengthen austenite. The resultant is that higher carbon contents require higher shear stresses and therefore greater undercooling to initiate the martensite transformation. Empirical equations for the M_s temperature as a function of chemical composition have been developed for a variety of steel classifications; however, the Andrews linear equation

$$M_S\,(°C) = 539 - 423(C) - 30.4(Mn) - 12.1(Cr) - 17.7(Ni) - 7.5(Mo)$$

from 1965 is still one of the simplest and most widely used. In the Andrews equation, M_s has units of degrees Celsius and alloying additions of carbon (C), manganese (Mn), chromium (Cr), nickel (Ni), and molybdenum (Mo) are in weight percent (wt%) [6]. The Andrews equation was determined using steels of the following composition range, in wt%: <0.6 C, 0.6-4.9 Mn, <5 Cr, <5 Ni, <5.4 Mo. Although high-carbon steels are excluded from this chemical composition range, use of the Andrews equation as a first approximation is common. Since the M_s reflects a thermodynamic value, the extent of the athermal martensite transformation can be quantified as a function of undercooling below the M_s. The Koistinen-Marburger equation

$$f = 1 - e^{-0.011\,\Delta T}$$

relates the martensite volume fraction, f, to the undercooling below M_s, ΔT, in degrees Celsius which is equivalent to cold-treatment temperature in the present context. It is important to emphasize the Koistinen-Marburger equation is independent of time.

Figure 1 shows the plot that can be made by combining the Andrews and Koistinen-Marburger equations. Retained austenite (RA) as a function of cold-treatment temperature was calculated using the two equations along with the nominal chemical composition of 100CrMnSi6-6 [7]. Lines of constant C content for 0.6, 0.8, and 1.0 wt% C were shown to demonstrate the significant influence C content has on the fraction of retained austenite for a given alloy composition and cold-treatment temperature. At room temperature (RT, +20°C) a 1 wt% C version of 100CrMnSi6-6 is estimated to have 70 percent RA while a 0.6 wt% C version is estimated to only have 10 percent RA. In high-carbon steels, the amount of carbon in the austenite depends primarily on the temperature the steel is austenitized. Figure 2 shows published data relating the M_s temperature to the austenitizing temperature of 52100. The M_s temperature decreases as austenitizing temperature increases, approaching a constant M_s temperature of approximately 140°C at the highest austenitizing temperatures evaluated. In the range of austenitizing temperatures most relevant to industrial heat treatment of 52100, less than 900°C, the M_s temperature is very sensitive to austenitizing temperature and therefore requires strict process control.

Figure 3 shows four representative micrographs of 100CrMnSi6-6 quenched to room temperature as well as cold treated at three different temperatures. A single specimen was austenitized in a protective atmosphere furnace, oil quenched to room temperature, cut, mounted, polished, lightly etched, and cold treated at −20, −60, and −80°C to visually demonstrate the evolution of retained austenite fraction during cold treatment. The sample was austenitized at a sufficiently high temperature to allow nearly all carbon to be dissolved in the austenite before being quenched to room temperature. White areas are retained austenite, brown/tan areas are martensite, and the gray globular feature near the center of each image is a manganese sulfide (MnS) and was used as a fiducial marker to ensure image position was not lost between each cold treatment.

Figure 4 shows the hardness and visual retained austenite data collected from the specimen shown in Figure 3. Each data point represents the sample mean ±1 using five HRC measurements for hardness and five 200x magnification fields for visual retained austenite. The room temperature condition (+20°C) exhibited approximately 53 HRC at 70 percent RA while the -80°C cold-treated condition exhibited approximately 58.5 HRC at 25 percent RA.

Figure 5 compares the measured values shown in Figure 4 and the calculated values obtained using both the Andrews and Koistinen-Marburger equations shown in Figure 1. Although the data presented in this analysis is limited, it is in reasonably good agreement with the values calculated from literature.

UNDERSTANDING THE PROCESS

The above-mentioned experimental data and analysis were presented as an exercise in linking established relationships from literature

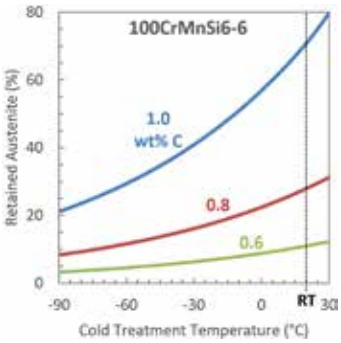

Figure 1: Retained austenite as a function of cold treatment temperature calculated using Equations 1 and 2 along with the nominal chemical composition of 100CrMnSi6-6 steel.

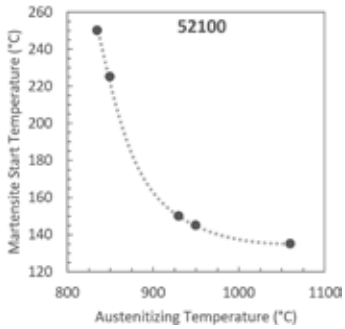

Figure 2: Martensite start temperature as a function of austenitizing temperature for 52100 steel [8].

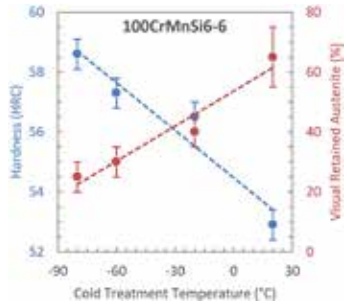

Figure 4: Hardness and visual retained austenite data from 100CrMnSi6-6 steel samples described in Figure 3.

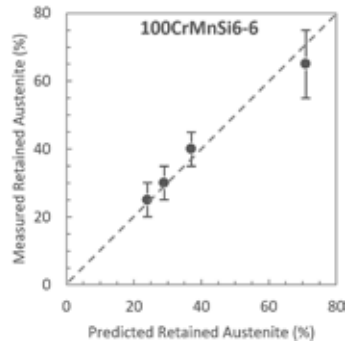

Figure 5: Comparison of measured retained austenite values shown in Figure 4 and predicted retained austenite values using the Koistinen-Marburger equation shown as Equation 2.

to results from a cold-treatment process. Although not every experiment will be in good agreement with literature, it allows for a basis of identifying and understanding the potential factors contributing to any misalignment. From the analysis above, austenite-carbon content and cold-treatment temperature can be considered critical factors to the control of a cold-treatment process. The latter of the two factors being the least significant.

CONTROLLING AUSTENITE CARBON CONTENT

The coefficient for C in the Andrews equation is an order of magnitude higher than any other alloying element in the equation. This clearly indicates the relative importance of controlling carbon content to ensure a consistent M_s is achieved. Methods for controlling austenite carbon content are provided below.

Starting microstructure: Consistency of austenitization is important to ensure a cold-treatment process provides consistent results. Spheroidized microstructures can be particularly challenging due to the potential for large variations in carbide size distribution.

Austenitizing temperature: Generally considered a coarse process adjustment. Figure 2 provided a sense as to the sensitivity of this process parameter in controlling austenite-carbon content.

Austenitizing time: Generally considered a fine process adjustment. Adjustment of the temperature should be first and then the time can be adjusted to ensure the process can accommodate small process anomalies.

CONTROLLING COLD-TREATMENT TEMPERATURE

Figure 1 showed controlling the cold-treatment temperature increases in importance as C content increases and higher temperature cold treatments can leave an appreciable amount of RA in the microstructure. The Koistinen-Marburger equation also showed the fraction of RA transformed is independent of time. The steel simply needs to uniformly get to temperature to achieve desired results.

SUMMARY

Cold treatment of steels was discussed in the context of two equations from literature, the Andrews equation and the Koistinen-Marburger equation. The Andrews equation relates chemical composition of a steel to its M_s temperature, the thermodynamic driving force for martensite formation. The Koistinen-Marburger equation relates the fraction of martensite transformed to the amount of uncooling a steel has below its M_s temperature. Experimental data was in good agreement with the equations from literature. Analysis of the equations indicates austenite-carbon content is the primary controlling factor in a cold-treatment process while the cold-treatment temperature itself is secondary.

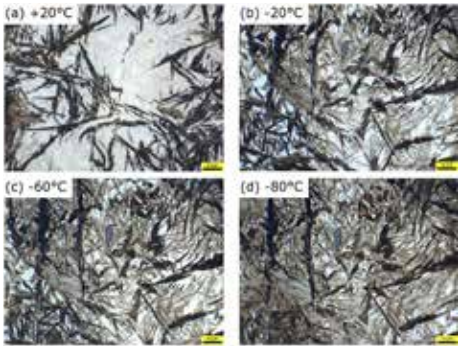

Figure 3: Representative optical micrographs of a 100CrMnSi6-6 steel specimen austenitized at a temperature and time adequate to dissolve nearly all carbides then (a) quenched to room temperature, (b) cold treated to -20 °C, (c) cold treated to -60 °C, and (d) cold treated to -80 °C. The same polished sample was used for all four conditions. The manganese sulfide (MnS) near the center of each image was used as a fiducial marker.

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ABOUT THE AUTHOR

Lee Rothleutner is the Group Leader for Material Conversion within The Timken Company's Bearing Research and Development. He received his MS (2012) and PhD (2015) in Metallurgical & Materials Engineering from the Advanced Steel Processing and Products Research Center at the Colorado School of Mines. He actively serves on various committees with the ASM Heat Treating Society and is a veteran of the U.S. Coast Guard. He can be reached at lee.rothleutner@timken.com.

JASON SCHULZE
METALLURGICAL ENGINEER /// CONRAD KACSIK

For those involved in monitoring quality as it applies to heat treating, it's important to have a solid understanding of the full process.

Quality staff: Understanding the technical side

Last month, we examined the history and heat-treatment of aluminum and how it applies to the quality functions of the industry. This month, we will do the same for the history and heat-treatment of steel. There are many roads of scientific achievement that have led to our current state (all of which will not be covered in this article).

A BRIEF HISTORY

Steel, in many forms, has a long history. From ~500bce when Egyptians austenitized steel, to sixth century BC southern India smelting "wootz" steel, to recent studies of 11th century Damascus steel containing carbon nanotubes (Figure 1), to the invention of the open-hearth furnace in 1865, steel has had a colorful history. I won't be spending too much time on its history but noting significant events which enable steel to be produced efficiently with a high grade of quality we see today.

The history of steel has several lines of lineage converging to present day. Certain significant events took place which have influenced how we produce and heat-treat steel in modern times. As stated, Egyptians' austenitization of steel did not include a carbon source. Their process was used primarily for weapons and tools. It seems the first source of carbon in steel production/heat treatment was a consequence of the first blast furnace in China around the sixth century BC. China, though, was not the only country producing steel implements and tools. In ancient India, around the sixth century BC, craftsmen in southern India used crucibles to smelt wrought iron with charcoal to produce what is called "wootz" steel. Wootz steel is a material that was admired for its sharp and tough nature. The most distinguishing feature is the swirling patterns cause by bands of clustered *Fe3C particles (Fe3C is called cementite). It is an intermetallic compound of iron and carbon (an intermediate transition metal carbide). It is 6.67% C wt% and 93.3 percent Fe wt%) (Figure 2).

By the 12th century, Sri Lanka was the world's largest producer of crucible steel. It supplied steel ingots to Asia as well as the Middle East. By the 18th century, steel was becoming widely renowned for its durability and extent of use. Due to limited production and less robust production processing, steel was very expensive. Its purchase was limited to the end use of special applications such as weapons, armor and tools. As the industrial revolution progressed, the production and advancement in steel technology moved quickly. In 1855, the Bessemer process was introduced. The Bessemer process' key principle is forcing hot air through the molten metal, which in turn removes impurities. In 1865, the open-hearth furnace was invented through a joint venture between Sir Carl Wilhelm Siemens and French engineer Pierre-Emile Martin. In this process, excess carbon and other impurities are burnt out of pig iron to produce steel. The open-hearth technique overcame the insufficient temperatures generated by normal fuels and furnaces, enabling the steel to be produced in bulk for the first time. The rest is recent history (Figure 3).

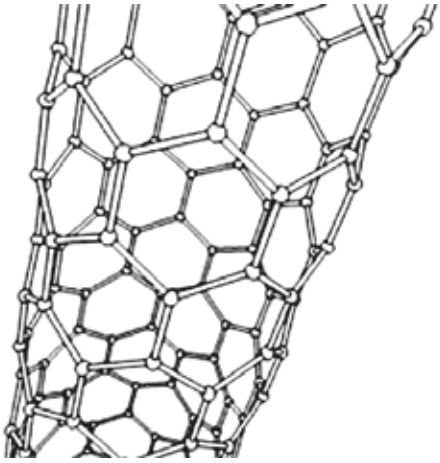


Figure 1: Carbon nanotubes

Figure 2: Damascus steel

THE SCIENCE

Scientific principles link the processing parameters to structure and properties and are increasingly necessary for proper application of the equipment and instrumentation.

An example of scientific efforts that directly support the advancement of heat-treat technology includes the characterization of mechanisms of phase transformation which produce desired structures and properties of heat-treated steel.

Before studying the heat treatment of steel, it is helpful to explain what steel is. Fundamentally, all steels are alloys of iron, carbon, manganese, silicon, sulfur, and phosphorus. Carbon content in commercial steels usually ranges from 0.05 wt% to 1.0 wt%. The broad possibilities with regards to steel and its use are attributed to two main characteristics:

› Iron is an allotropic element. (Allotropy is the phenomenon of an element having different crystal lattices depending on the particular temperature and pressure.)

› The carbon atom is much smaller than the iron atom.

The alloying mechanism for iron and carbon is different from most other alloy systems in that the alloying of iron and carbon occurs in a two-step process. In the initial step, iron combines with 6.67 percent carbon, forming iron carbide, which is called cementite. At room temperature,

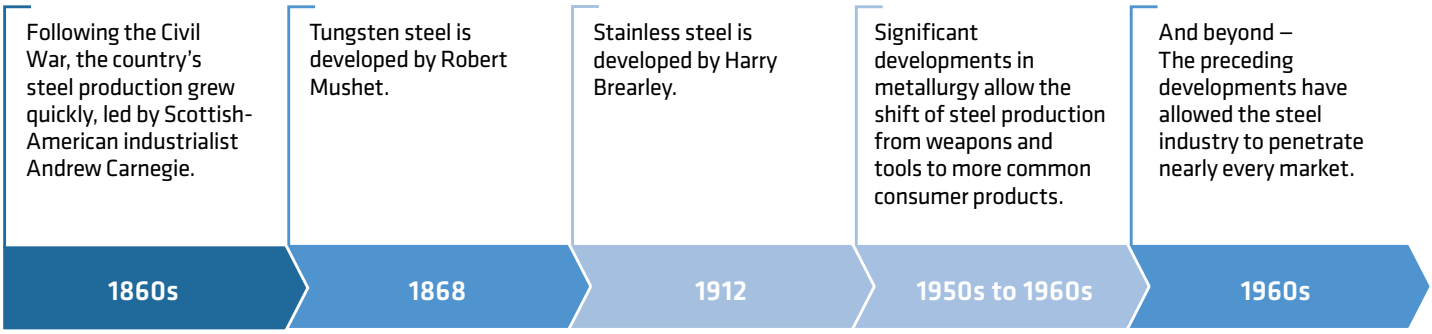


Figure 3: A recent history of steel production

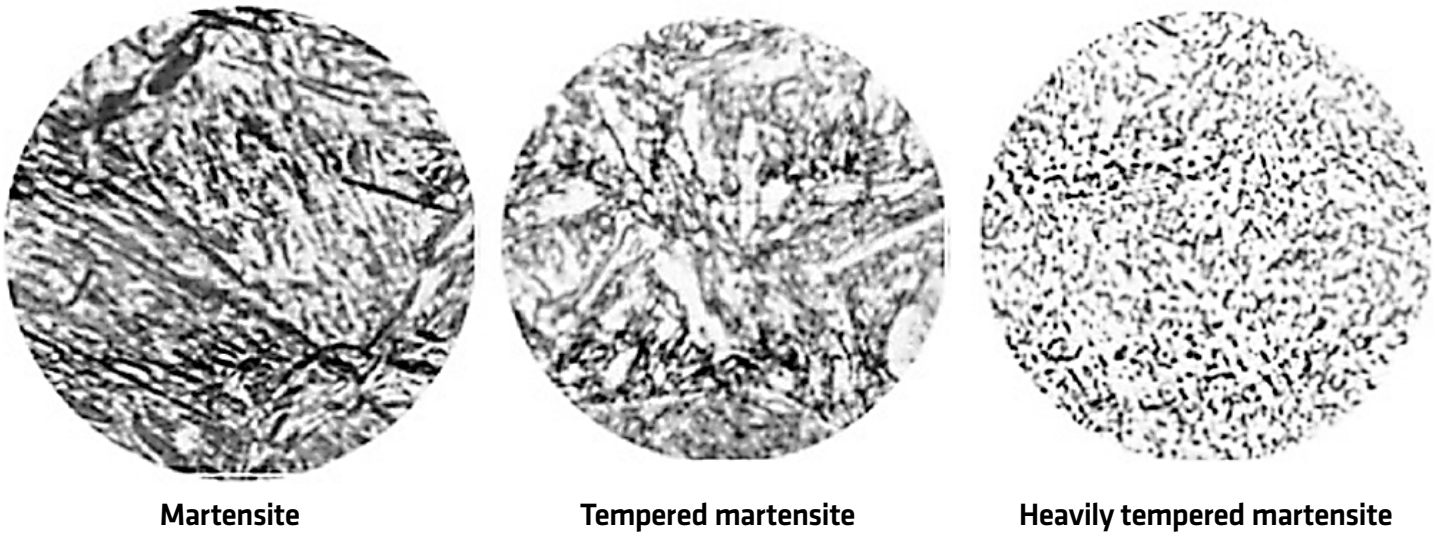


Figure 4: Martensite

conventional steels consist of a mixture of cementite and ferrite. Each of these is known as a phase (defined as a physically homogeneous and distinct portion of a material system). When a steel is heated above 1,340°F, cementite is dissolved into a new matrix phase called austenite. Austenite is designated as a solid solution of one or more elements in face-centered cubic iron (gamma -iron). Unless otherwise designated (such as nickel austenite), the solute is generally assumed to be carbon. The next phase of transformation, martensitic transformation, takes place when the steel is cooled rapidly. When alloys are cooled rapidly, the carbon atoms cannot make an orderly escape from the iron lattice. This results in distortion of the lattice which manifests itself in the form of hardness and/or strength. If cooling is fast enough, a new phase known as martensite forms. Eventually, the martensite decomposes into a mixture of ferrite and cementite if heated below the A1, and this structure is referred to as tempered martensite (Figure 4).

After this comes the crystal structure and phases (bcc to -Fe) of which are not as pertinent to this article and would take quite a bit of extra time to go into.

HEAT TREAT KEY-PROCESS CHARACTERISTICS

Ensuring the material being heat-treated is of the required composition is critical to successful and repeatable results. When material is received, there should be a verification process in place that ensures a quality representative (or delegate) verifies material composition against the purchase order.

A simple visual comparison using the purchase order and the material certification is enough to ensure the material is conforming.

Furnace pyrometry testing is key to ensuring that:

› The furnace systems are in working condition.

› Consistent conforming results will be obtained on all product processed in the furnace.

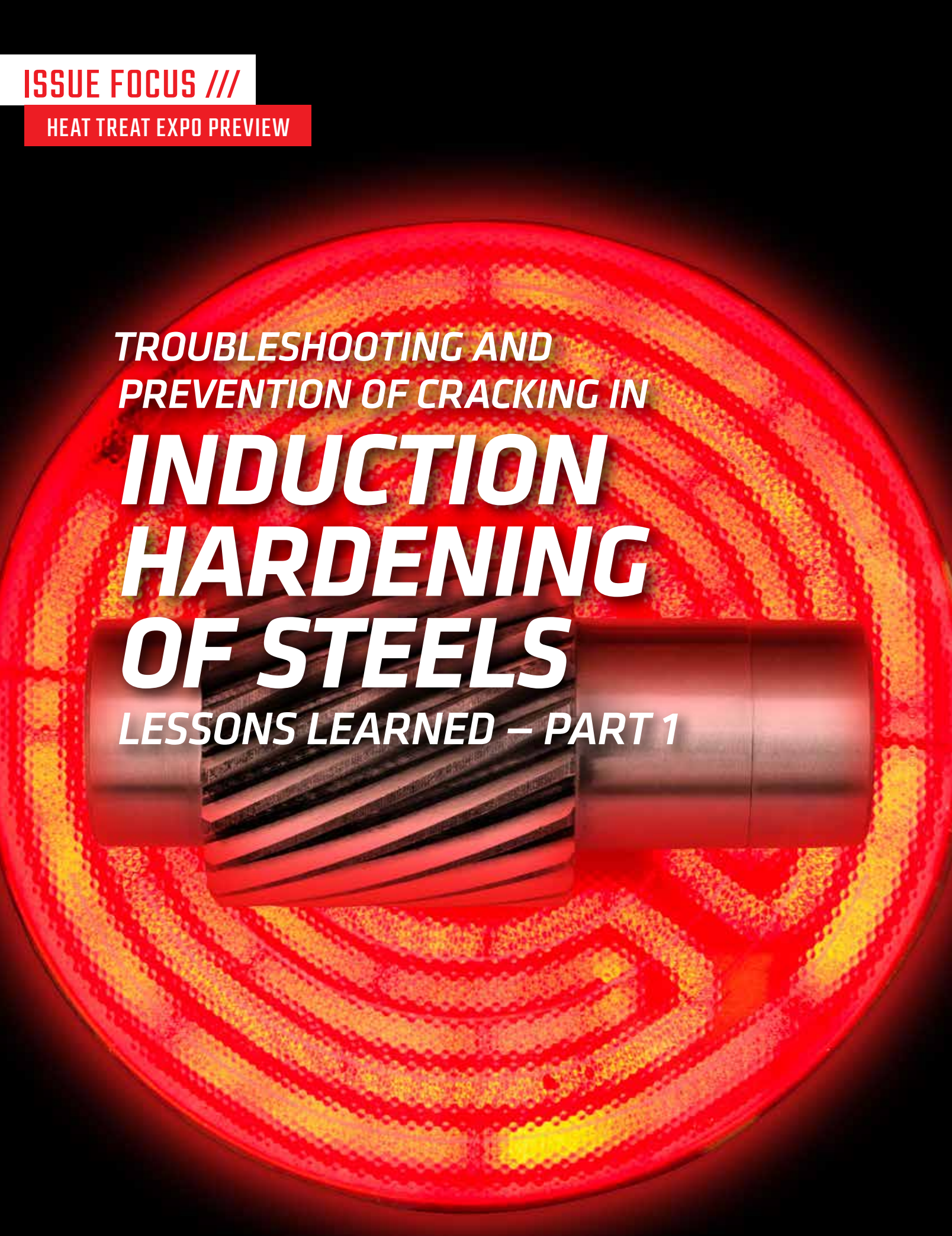
Pyrometry results should be reviewed carefully by quality to ensure conformance. Any deviations should be investigated promptly before processing further production. Subsequent pyrometry testing should be performed at the required frequency per AMS2750 to ensure consistent results.

SUMMARY

For those of us involved in quality as it applies to heat treat, it is essential to have a good understanding of the process. This knowledge will help the quality team in the disposition and process approval.

ABOUT THE AUTHOR

Jason Schulze is the director of technical services at Conrad Kacsik Instrument Systems, Inc. As a metallurgical engineer with 20-plus years in aerospace, he assists potential and existing Nadcap suppliers in conformance as well as metallurgical consulting. He is contracted by eQualearn to teach multiple PRI courses, including pyrometry, RCCA, and Checklists Review for heat treat. Contact him at jschulze@kacsik.com.



TROUBLESHOOTING AND PREVENTION OF CRACKING IN

INDUCTION HARDENING OF STEELS

LESSONS LEARNED – PART 1

For real-world needs, producers of IH equipment should have the experience and analysis necessary to help heat-treat practitioners with specific problems.

By GARY DOYON, DR. VALERY RUDNEV, RANDALL MINNICK, and TIM BOUSSIE

Newly employed heat-treat engineers, designers and practitioners may need an appreciable amount of time to gain the required knowledge and experience in understanding the subtleties of induction hardening. Underestimating specific geometrical features of parts and hardness patterns by novices, as well as negligence in understanding an impact of different process factors on the outcome of heat treatment may produce faulty results. Finding that your completed parts have cracked after heat treating is frustrating, wasteful, and expensive. The goal of this two-part article is to minimize the impact of a workplace generation gap by helping new induction heat-treat professionals better understand the factors related to steel cracking and the actions to be taken to avoid it.

It is important to learn that crack initiation within the heat-treated components, its growth, and propagation is affected by a number of factors. This includes specifics of the component's geometry, its chemical composition and microstructure, processing temperatures, quenching subtleties, hardness pattern, inductor design, magnitude and distribution of initial, transient and residual stresses, design of tooling/fixtures, etc. Cracking can be caused by a single factor or by an undesirable combination of several factors.

There is virtually an endless variety of components that are routinely induction hardened (IH). Certain geometries may be associated with a tendency toward crack initiation requiring careful selection of process recipes and an equipment design. As an example, Figure 1 shows a few examples of typical cracks caused by improper process recipes or inductor designs or that have been caused by underestimation by heat-treat practitioners on specific geometrical features of heat-treated components.

Cracking and fractures can be classified in different ways, including ductile and brittle fractures, environmentally affected crack initiation, fatigue fractures, delayed crack initiation, and others. It would be appropriate to review a case study at this point.

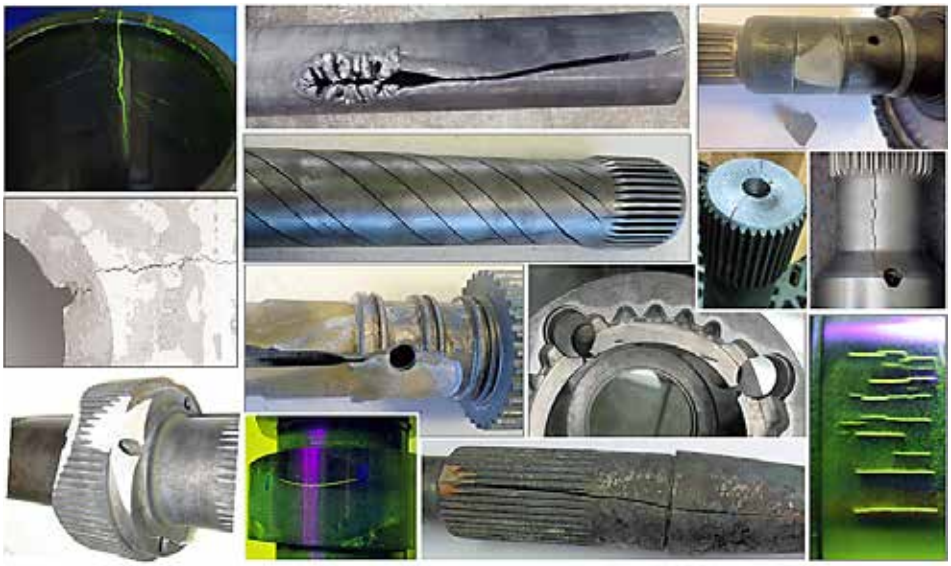


Figure 1: Examples of typical cracks caused by improper process recipes or inductor designs.

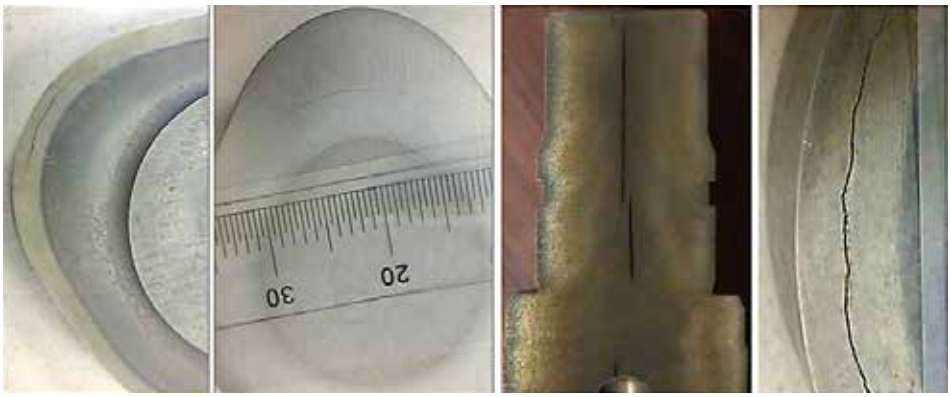


Figure 2: Examples of typical subsurface cracks, which often are not visible to the naked eye.

CASE STUDY

A heat treater had a run-off of an induction hardening machine on a Friday evening. All components that had been induction hardened were checked, and no problem had been found. NDT eddy current testing, as well as magnetic particle inspection (MPI), did not reveal any presence of cracks. However, after the weekend, it was found that a certain percentage of heat-treated parts developed cracks just sitting on a pallet. This is a typical example of delayed crack initiation, and measures should be taken to prevent such failures. Other examples of delay cracking may be associated with fractures that occur during assembly of heat-treated parts.

Some practitioners may also distinguish transverse, longitudinal, or circumferential fractures, as well as surface cracks vs. subsurface or internal cracks. As an example, Figure 2 illustrates subsurface cracking, which often are not visible to the naked eye, and only appropriate NDT inspection (e.g., ultrasound/acoustic inspection)

or destructive examination may reveal their presence in order to prevent a premature failure of the component during its service life.

In recent years, light-weighting initiatives have become common in automotive, off-road, and agricultural vehicle designs, as well as aerospace and other industries. To minimize weight and cost of steel components, designers might choose to drill holes, reduce cross sections, make grooves, cutouts, and re-entrant corners, as well as to use custom shapes and alloys to accomplish these goals [1]. In some cases, in an attempt to reduce costs, designers create a component's geometries that might be prone to cracking during heat treating.

Failure analysts are also dealing with parts that failed prematurely in service. Why? Perhaps something had not been done properly during heat treating or perhaps inadequate equipment and/or a process recipe were used for a particular component without appropriately addressing its geometrical features or hardness pattern requirements resulting in a compromised outcome of the heat treatment that might not be easy to detect.

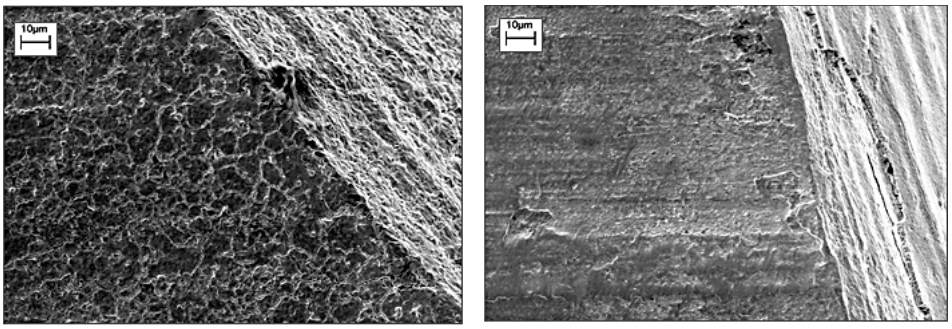


Figure 3: Side-by-side comparison of two SEM images of as-quenched structures. The left image illustrates moderately liquated grain boundaries steel, while the right image shows a so-called "clean" structure [2].

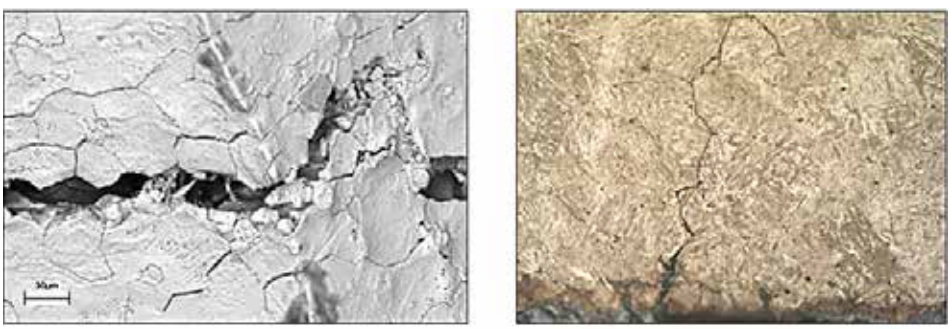


Figure 4: Severe grain boundary liquation must be avoided because it is associated with extreme brittleness and notch sensitivity leading to intergranular cracking.

FACTOR OF COMPONENT'S GEOMETRY

Induction scan-hardening is one of the most popular techniques to strengthen steel components. An increased popularity of scan-hardening is associated with several distinguished advantages of this technology, including but not limited to a lower capital cost compared with alternative processes. Scan hardening exhibits impressive process flexibility with respect to the workpiece length and, to some extent, variations in a part's diameter. In scan hardening, the inductor or workpiece (or both) can move linearly relative to each other during the hardening cycle [2]. Depending on workflow, the system can be built vertically, horizontally, and at an angle, though vertical-scan hardening is the most popular design for a number of reasons, including a reduced equipment footprint and natural quench flow due to gravity.

The advantage of scan hardening is that only a small portion of a component's needed hardened length is heated at a given time, enabling the hardening of elongated parts using relatively small (and generally less expensive) power supplies. Conventional scanning systems offer the ability to vary scanning speed and power during the process, which controls the amount of heat applied to different areas of the workpiece. Induction scanners incorporate a number of different elements with inductor design, quenching conditions, and power supply having the most significant impact on hardening results.

Geometrical irregularities and discontinuities (that are very typical for a great majority of modern components) can distort the electro-magnetic field generated by an inductor, potentially causing several undesirable phenomena associated with reaching excessive temperatures and thermal gradients.

Overheating is one of the most common causes of cracking. Extreme temperatures result in grain boundary liquation (incipient melting) associated with liquation of low-melting phases and steel's impurities concentrated at grain boundaries, leading to a degradation of those boundaries. Weakened grain structure significantly increases the steel's brittleness, sensitivity to developing intergranular cracking, and negatively affects the overall metallurgical outcome of IH [2].

The phenomenon of grain boundary liquation can be amplified by the segregation of manganese, sulfur, copper, and some other elements to the austenitic grain boundaries. Both phosphorus and sulfur markedly affect the steel overheating temperatures, increasing steel's tendency for a crack initiation.

As an example, Figure 3 (left) illustrates steel microstructures exhibiting grain boundary liquation. A network (chains) of liquated areas located at the grain boundaries is easily visible. As a comparison, the image in Figure 3 (right) shows a so-called "clean" structure.

Different magnitudes of overheating cause various degrees of grain boundary liquation and are commonly designated as slight, moderate, or severe. This designation is relatively subjective and might be different for different corporate standards.

Certain geometrical features could make a component become prone to localized heat surpluses during austenitization, which could cause a crack initiation during subsequent spray quenching. Longitudinal or transverse holes, keyways, flanges, undercuts, splines, sharp edges, shoulders, and corners are typical examples of such geometrical irregularities and discontinuities.

Nevertheless, such features are not unique as they are commonly found on many transmission and engine components [1,2]. Therefore, it might be unavoidable to have a certain degree of incipient melting at grain boundaries when induction hardening complex geometries. In cases like this, some corporate standards might allow a slight amount of grain-boundary liquation. The presence of compressive residual stresses of appreciable magnitude that is quite typical in induction surface hardening applications is often sufficient in preventing "opening" slightly liquated grain boundaries. Severe grain boundary liquation must be avoided, because it is associated with extreme brittleness, notch sensitivity, and poor fracture toughness, leading to failure caused by intergranular cracking (Figure 4).

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FACTOR OF INADEQUATE SELECTION OF EQUIPMENT AND/OR PROCESS PARAMETERS

Another example of an impact of very common geometrical irregularities on results of heat treatment would be a scan hardening of stepped shafts consisting of multiple diameter changes, sharp shoulders, as well as a combination of solid and hollow sections and wall thickness changes. The user may also specify appreciably different hardness case depths along the length of a workpiece for multifunctional, complex geometry components.

All these geometrical features are quite typical and can produce unwanted deviations in hardness patterns, metallurgical structures, magnitude, and distribution of stresses, which could unfortunately develop favorable conditions for a grain boundary liquation and a crack development. Therefore, a capability to control not only heating intensity but also the depth of heat generation during scan hardening is imperative for a great majority of modern IH applications.

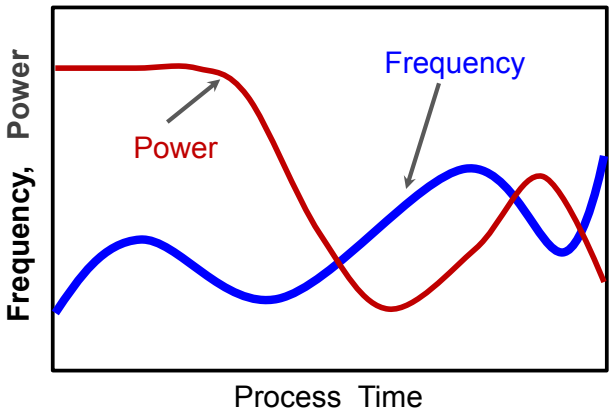

Figure 5: New generations of inverters (Statipower-IFP) developed by Inductoheat enable instant, independent adjustment of power and frequency (5-60 kHz) in a preprogrammed manner during the heating cycle, optimizing electromagnetic, thermal, and metallurgical conditions and greatly expanding induction equipment capabilities.

Temperature distribution across the radius/thickness of a workpiece is primarily a function of the applied frequency, power density, and the heat time/scan rate. Frequency is a single most critical factor that affects the depth of heat generation in induction heating, because frequency determines depth of eddy current penetration. In addition, the frequency exhibits a potent impact on a reduction of heat surpluses when dealing with the most geometrical irregularities and discontinuities.

In a majority of cases, an optimal frequency that would appropriately address all geometrical features and hardness depth requirements of modern components simply does not exist. This is why conventional scan hardening equipment applying a fixed frequency must always compromise between achieving the desired metallurgical quality, process capability, production rate, distribution, and magnitude of transient and residual stresses as well as developing structures free of cracking and excessive distortion.

Besides that, global competitiveness demands that heat treaters be extremely flexible. Long-term customers may move their production at a minute's notice, and heat treaters must be flexible to a market demand [1]. For example, today, you might need to surface harden 12 mm (~0.5 in.) diameter pins with an effective hardness case depth of 1.6 mm (0.0625 in.). This would normally require a frequency in the 50-60 kHz range. Tomorrow, the product might change, and you need to run a 30 mm (1.2 in.) diameter shaft with a nominal 5 mm (0.2 in.) hardness case depth requiring a frequency of 5 to 7 kHz range to ensure more in-depth heat generation. However, the day after that, you might need to through-harden both: 8 mm and 25 mm diameter pins.

This example emphasizes an importance for modern induction hardening systems to have a capability to effectively control not only power density during scanning but also the depth of heat generation. Unfortunately, the majority of commercially available medium- and high-frequency power sources are designed to deliver a certain frequency, which cannot be instantly (practically speaking) and deliberately changed to an appreciable degree during scan hardening [1].

New generations of inverters (Statipower® IFP™) developed by Inductoheat eliminates this drawback and simplifies achieving the required hardness pattern without compromising metallurgical quality [1-3]. This innovative technology enables instant, independent adjustment of power and frequency (5-60 kHz) in a preprogrammed manner during the heating cycle optimizing electromagnetic, thermal, and metallurgical conditions of your products and offering numerous considerable benefits (Figure 5).

IFP technology (Independent Frequency and Power control) effectively addresses industry needs for cost-effectiveness and superior process flexibility, greatly expanding induction equipment capabilities, simplifying process development, and enhancing metallurgical quality.

Therefore, if one automotive company comes to a processing company and then, a day after tomorrow, another one with a totally different requirement needs processing; a component supplier would be able to process those parts using the same equipment available at their shops.

In induction heat treating, the coil is commonly dedicated to a particular component's geometry, but its cost is relatively small compared to the cost of the entire system and, in particular, an inverter. Thus, if the power supply will provide greater flexibility, then it will be a big cost-saving deal in our highly competitive world. The extent of projects that can be undertaken with Inductoheat's patented technology is widening as the company works to introduce new models that expand coverage of different ranges of frequencies and maximum powers.

STRESSES, THEIR APPEARANCE, AND IMPACT ON CRACK INITIATION AND PROPAGATION

Stresses are prime causes of cracking. It is imperative to have a clear understanding regarding nature and causes of stresses while discussing a subject of cracking in heat treating.

Stresses can be classified in several different ways. Depending on the distance over which they extend, stresses can be "macroscopic" or "microscopic." Macroscopic stresses typically appear at a distance that exceeds several grains. In contrast, microscopic stresses take place within a grain and include stresses that appear on the atomic level. Studies of residual stresses in steel heat treating typically focus on the distribution and magnitude of macroscopic stresses [1,4].

On the basis of their cause in IH, several types of stresses are encountered, including thermal stresses, phase transformation stresses, and applied stresses. Thermal stresses are caused by differ-

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ent magnitudes of temperature and thermal gradients, as well as unequal metal expansion/contraction.

Phase transformation stresses primarily occur because of volumetric changes accompanying the formation of different phases such as austenite, bainite, martensite, and others.

Applied stresses during IH are associated with the specifics of tooling/fixture of heat-treated components during heating and quenching. For example, cylinder workpieces (such as shaft surface hardening) experience compressive and torsion stresses during their rotation in single-shot or scan-hardened systems.

In applications requiring through hardening, a workpiece firmly held between two holders, centers, or nests, will "try" to expand during the heating cycle, potentially causing disproportionate applied stresses and developing favorable conditions for an excessive distortion (due to buckling) and potential cracking. Allowing for a part growth by using a low-pressure spring on one of support/tooling end could help reduce those stresses and solve this problem.

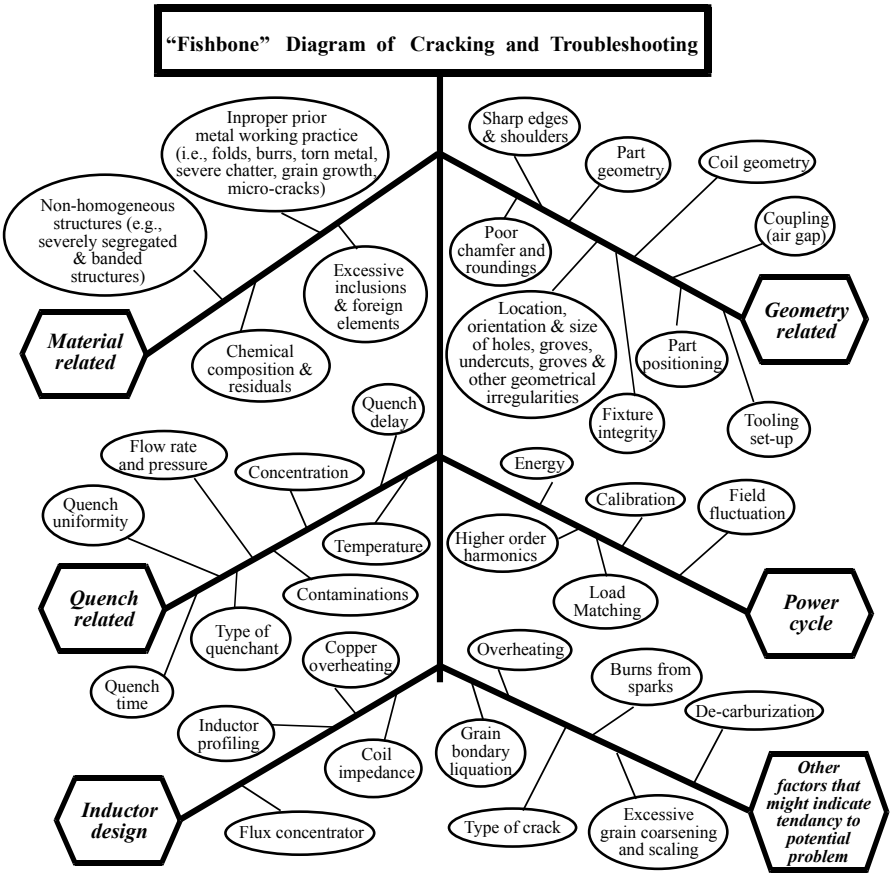

Figure 6: "Fishbone" diagram of cracking and prevention in induction hardening revealing the complexity of this subject and its interrelated nature [2,5].

Although stresses are three dimensional (3D) in nature, having axial, circumferential (hoop), and radial components, a discussion is often simplified by considering them as one-dimensional stresses (highest magnitude stress).

On the basis of the timing of their appearance, stresses can be divided into three groups: initial, transient, and residual stresses.

Initial stresses. Initial stresses are "hidden" within the "green" part. Their distribution and magnitude depend on the manufacturing steps preceding IH (casting, forging, welding, rolling, upsetting, drawing, etc.). For example, the maximum of tensile stresses is commonly located in the core of hot-forged components. During heating, initial stresses of appreciable magnitude may combine with transient stresses and develop crack initiation resulting in subsurface cracking. Thus, if in doubt, stress relieving of a workpiece before IH should be done.

Transient stresses. In addition to initial stresses, there are transient stresses, which occur during IH due to volumetric expansions and contractions associated with temperatures, thermal gradients, and the phase transformations. Our experience shows that in IH, the transient stresses are responsible for the great majority of cracking.

Residual stresses. These stresses remain within the workpiece after the IH process is completed. Thus, residual stresses are the product of initial and transient stresses, and they exist in an absence of external force or temperature gradients. In many cases, these stresses can be very beneficial, complementing desirable microstructural changes in providing needed engineering characteristics. In other cases, magnitudes and the distribution of residual stresses may be harmful, increasing crack sensitivity, facilitating crack initiation and propagation, causing delay cracking, and shortening the component's service life.

These stresses can elevate or reduce the mean stress occurred during the component's service life. Surface-compressive residual stresses are considered desirable in most applications. Among other factors, these stresses are important for improving the fatigue properties of the workpiece, delaying the crack initiation and the propagation of micro-cracks, and providing desirable protection against geometrical stress risers (e.g., scratches, notches) as well as microstructural heterogeneities. Compressive residual stresses are particularly beneficial to parts that experience bending, impact, and/or torsion in service. They enhance the fatigue resistance because the applied stresses in service are often tensile, and the presence of the compressive residual surface stresses helps minimize the magnitude of the sum of both decreasing the mean stress.

It is important to remember that the residual stress system is self-equilibrating; that is, there is always a balance of stresses within the workpiece owing to static equilibrium. If certain regions have compressive residual stresses, then somewhere else there must be offsetting tensile stresses. If the stresses were not balanced, "movement" would then result; this is bad.

Tensile residual stresses of a certain magnitude and location can be dangerous, making a negative impact on fatigue resistance, and they may also cause stress-corrosion cracking in the presence of a corrosive environment. These stresses are combined with the load stresses in service, amplifying the magnitude of the total stress, which may exceed the strength of material resulting in a crack development.

In applications where only surface hardening is required, the maximum of the tensile residual stress is commonly located just beneath the hardened case within the transition zone, and it is often responsible for subsurface crack initiation.

The greater magnitude of residual tensile stresses of the surface hardened component is usually associated with increased brittleness and notch sensitivity, reduced toughness, and fatigue strength. This is one of the reasons for specifying a stress relief/tempering after IH, which helps reduce the peak of the tensile residual stress

and shift it farther from regions of applied stress, while retaining the useful surface compressive stresses.

In contrast, in through-hardening applications, the surface residual stresses are frequently tensile, but under certain quenching conditions, they can be reversed into compression.

Mathematical modeling is an essential tool that helps assess the complexity of transient and residual stress distributions, taking into consideration the intricacy of the kinetics of displacive and reconstructive transformations based on thermodynamic and phenomenological approaches and has been discussed in many publications. Some of the most intensive computer-modeling studies of stresses in induction heat treatment are those conducted by scientists from companies such as DANTE Solutions, Inc.

FISHBONE DIAGRAM OF CRACKING IN INDUCTION HARDENING

Virtually an endless variety of components routinely induction hardened call for a corresponding, almost endless, variety of process recipes and inductor designs. Each of these components has its own "personality" that affects the outcome of heat treatment, including a propensity to cracking. Figure 6 shows the "fishbone" diagram of cracking and prevention related to IH, revealing the complexity of this very broad subject [2,5].

We hope readers of this article would never experience a cracking problem. but if such an event occurs, then this fishbone diagram might be helpful since one or several factors of this diagram might be causing a crack initiation.

As can be concluded from the fishbone diagram, the potential causes of cracking can be categorized into seven main groups:

- Material related.
- Geometry of the workpiece.
- Power/energy cycle (heating stage) and unspecified heating conditions.
- Improper quenching conditions (including quench severity and uniformity).
- Inadequate inductor design.
- Improper accessories, tooling, fixtures.
- Other factors.

Even a cursory look at Figure 6 unveils the intricacy and challenges in determining the root cause and the consequential factors associated with cracking. If cracking occurs, there may be a number of interrelated factors responsible for its appearance. Understanding a broad spectrum of factors associated with various failure modes is an important step in developing crack-free processes. At a minimum, an analyst must have knowledge in failure analysis, electromagnetics, metallurgy, materials science, mechanics, heat transfer, chemistry, spectroscopy, and other disciplines. It is difficult to overestimate an importance to have a sufficient degree of familiarity with the hardening equipment and process specifics of a particular machine under investigation.

Cracks that occur very infrequently are usually the most difficult to fix because some of those occurrences may take place so rarely they may be considered as a statistical event, and their root cause(s) is often associated with previous stages of a manufacturing chain. Each preceding stage of manufacturing exhibits a potential for certain problem(s) for which the IH is sometimes blamed.

It is much easier to determine the root cause of cracking if crack initiation can be turned "on" and "off" by modifying process parameters.

If, for some reason, steel does not respond to heat treatment in an expected way, developing cracking, then one of the first steps in determining the root cause for such unexpected behavior is to make sure the steel has the proper chemical composition, homogeneity, and initial prior microstructure, as well as appropriate thermal history. In some cases, what is supposed to be the same grade of steel purchased from two different suppliers may have appreciable variations of composition and properties.

In real-world needs, producers of IH equipment should have the experience and analysis necessary to help heat-treat practitioners with specific problems.

An interested reader can find numerous publications and words of wisdom shared by industry experts to avoid a part's cracking. Some of the recommendations and simple remedies to eliminate or minimize the probability of cracking will be outlined and explained in Part 2 of this article.

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ABOUT THE AUTHOR

Gary Doyon, Dr. Valery Rudnev, Randall Minnick, and Tim Boussie are with Inductoheat Inc., an Inductotherm Group company.

INTELLIGENT GAS CARBURIZING WITH SUPER IQ™

An innovative new furnace design means safer processing with simple, yet advanced automation, all with the proven performance of low pressure processed parts.

By MARK K. HEMSATH

Atmosphere furnace or vacuum furnace, which to use? In carburizing, for instance, the workhorse furnace is the atmosphere gas carburizing furnace with integral oil quench. However, inroads in this hardening market have been made by so-called "low pressure carburizing" (LPC) furnaces. LPC uses a carbon gas, but it is introduced at pressures below atmospheric pressure (i.e. vacuum). Vacuum carburizing (LPC) has been around for decades, but high costs and affordability have been issues when combined with an integral oil quench to allow for effective hardening of lower alloy steels.

So, the question was asked, "If one were to newly design and build a furnace today that is both a well-performing furnace, but still affordable, what would that furnace look like?" One can imagine the typical customer saying they want all the best features, but also for a low cost. Well, the answer today is that intelligent and affordable carburizing and hardening only needs a Super IQ™ furnace.

Fortunately, such a furnace is now available. The Super IQ™ furnace means safer processing with simple, yet advanced automation, all with the proven performance of low pressure processed parts. Low pressure processing means no use of endothermic gas and its inherent environmental issues or safety concerns. Such a furnace combines the benefits of low-pressure carburizing technology with a simple atmosphere oil quench.

Great technology without affordability means it will not be readily accepted by industry nor widely adopted, so affordability was a must. Hence, the design needs to be as simple and affordable as it is practical. The intelligent design of this new furnace style accomplishes these goals.

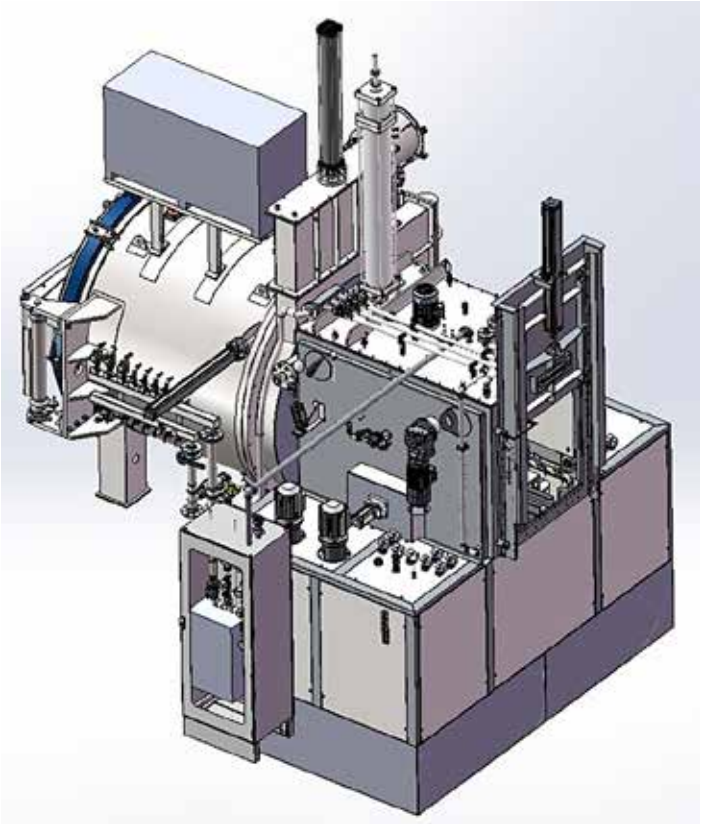

Figure 1: 3D model of the final designed Super IQ™.

WHAT IT LOOKS LIKE

Figure 1 shows a 3D model of this new technology, which combines an atmosphere integral oil quench and low-pressure carburizing technology in the heating chamber. The obvious question is: What is unique here? Well, until now, the equipment performing both LPC and vacuum hardening was always coupled with either a vacuum oil quench or a very high pressure (20 bar absolute) gas quench. These types of quenches are expensive, even though they have been built for decades. However, the simplicity of an integral oil quench coupled to a gas atmosphere hardening furnace is a low cost, long-proven technology. Hence, the need is to combine these technologies to reduce the ownership cost of this equipment.

This new furnace looks like a typical gas carburizing furnace. Figure 2 shows the as-built new Super IQ™ furnace installed at a high-production heat-treat facility. This design is not revolutionary, but rather, it is evolutionary. It is not a hybrid design, but a re-imagining of the existing, old-style atmosphere integral quench furnace (shown in the next Figure 3). This new furnace design results in:

› Elimination of the need for endothermic gas.

› Elimination of flames from the flame curtain and billowing hydrogen and CO gases.

› The heating chamber can easily be used at temperatures over 2,000°F (Tool steels, etc.).

› Elimination of dangerous carbon monoxide gases.

› Quiet operation.

› Clean operation – no smoke and/or soot.

WHAT IS DIFFERENT?

Atmosphere Designs

Atmosphere integral (sealed) quench furnaces, either in a batch in-out or continuous straight-through configuration, were introduced to industry more than 70 years ago. They have seen some design modifications/improvements over this time but with few real significant technological changes. Almost every heat treater knows this furnace style or owns one. A typical, old-style atmosphere integral quench furnace (as shown in Figure 3) has four main components:

› A heating chamber with either gas-fired radiant tubes or electrical heating elements and an atmosphere recirculating fan.

› An oil quench with oil-agitation system and oil-cooling system.

› Instrumentation and controls, often including only a limited form of HMI (Human Machine Interface).

› Gas sensors — often in the form of oxygen (carbon) probes and gas analyzers — and ports to add shim-steel stock to determine quality of the atmosphere to make manual and/or automatic adjustment of hydrocarbon (natural gas or propane), air, and/or ammonia additions.

Various manufacturers have added additional features or variations to these basic furnace styles.

Vacuum Designs

Low-pressure vacuum-carburizing furnaces, either in a batch in-out or continuous straight-through configuration, were mostly commercialized in the mid-1990s based on designs conceptualized even earlier. The driving force behind this technology was the aerospace industry, and the initial uses were mostly vacuum hardening with vacuum oil quenching. The perfection of low-pressure carburizing expanded the use of these furnaces. A high-volume production design of such a vacuum hardening furnace (straight through with pre-heat) by SECO/WARWICK is shown in Figure 4. Such a typical vacuum integral quench furnace also has four main components:

› A vacuum heating chamber with electric heating elements and a cold-wall design. Typical vacuum level being on the order of 10^{-3} Torr.

› Either an oil quench or separate high-pressure gas quench chamber.

› Instrumentation and controls, including comprehensive vacuum programmable controller and extended HMI (Human Machine Interface).

› Process simulation and development software primarily to allow the repeatability of the carburized case based on many factors such as case depth, carbon profile, part geometry, and surface area.

In the batch in-out configuration, an entry vestibule (above the oil) is provided, in the case of the straight through design, a pre-heat chamber shortens the heating/carburizing cycle (Figure 4).

Figure 2: The new atmosphere integral quench furnace (batch in-out style), known as Super IQ™.

Figure 3: Typical atmosphere integral quench furnace (batch in-out style) with radiant tube fired heating.

PERFORMANCE OF THE NEW FURNACE DESIGN

Low-Pressure Carburizing

Little discussion needs to be spent on the low-pressure carburizing features and benefits (often referred to as vacuum carburizing), as this is well-proven technology employed in dozens of furnaces (see the references at the end of this article for deeper details). Being that the heating chamber is a high temperature vacuum chamber, this furnace style is also well-proven technology for decarb-free hardening of a wide variety of performance alloys, without the need for shim stock experimentation to prove the atmosphere efficacy. The desired vacuum level, readable with a standard vacuum gage, easily verifies the atmosphere (vacuum) purity.

Operation of this new furnace requires nitrogen purging after putting the load into the loading vestibule over the oil. The loading door is closed, and nitrogen is further introduced to reduce oxygen levels even more. Shortly after purging, the hot door to the heating chamber (which also contains nitrogen and is at an elevated "pre-heat" temperature) opens. After transfer to the heating chamber, a convection assist fan helps pre-heat the load before a vacuum is pulled on the heating chamber. Once the entire part load has reached temperature and is uniformly at temperature, a hydrocarbon gas source is added per the recipe from the software-assisted simulation. Typical gas mixtures are 100-percent acetylene.

Process Confirmation Testing

There were tests performed to establish the operation steps needed for this new furnace design and to prove the quality with the absence of both vacuum in the transfer to quench or endothermic gas in the transfer to oil quench. Three steel grades were selected for process comparison with known atmosphere and vacuum car-

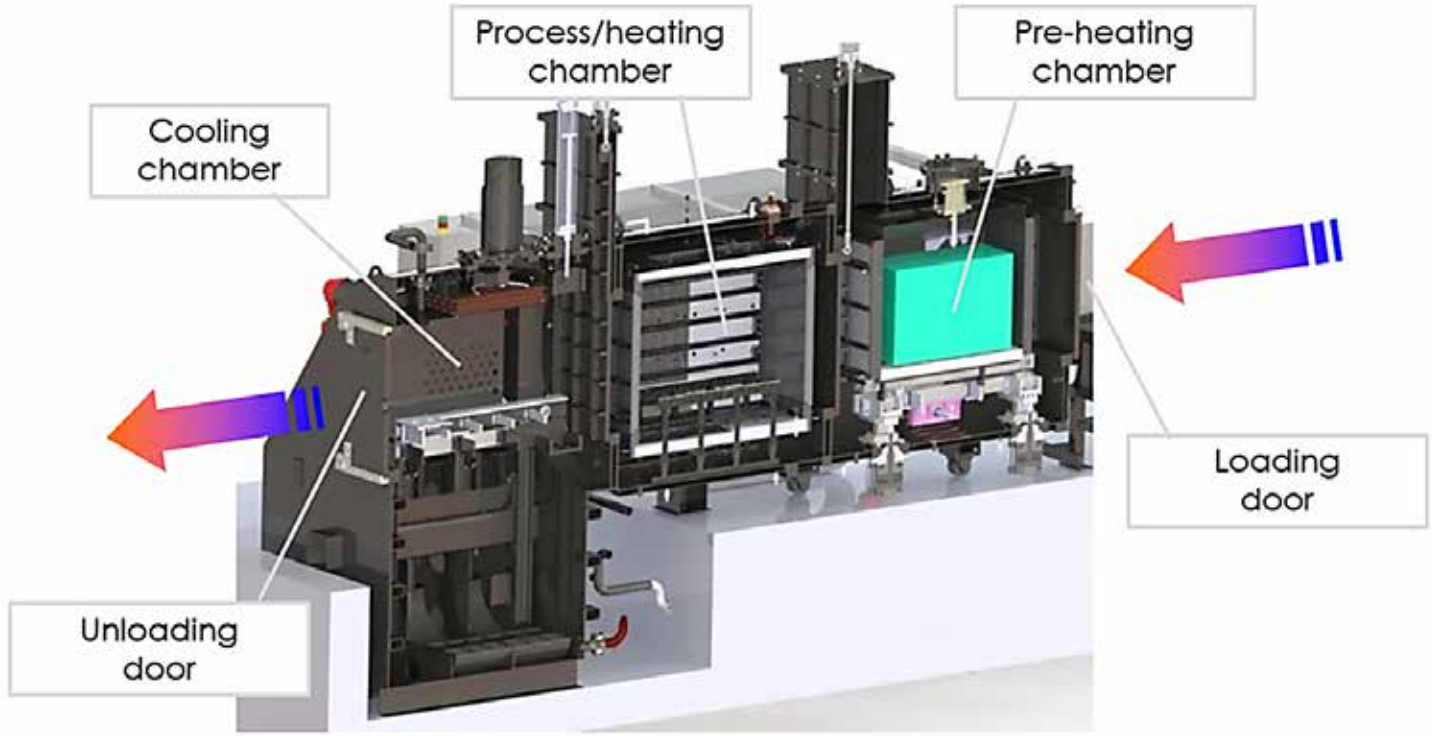

Figure 4: Typical vacuum integral quench furnace, continuous, straight-through style.

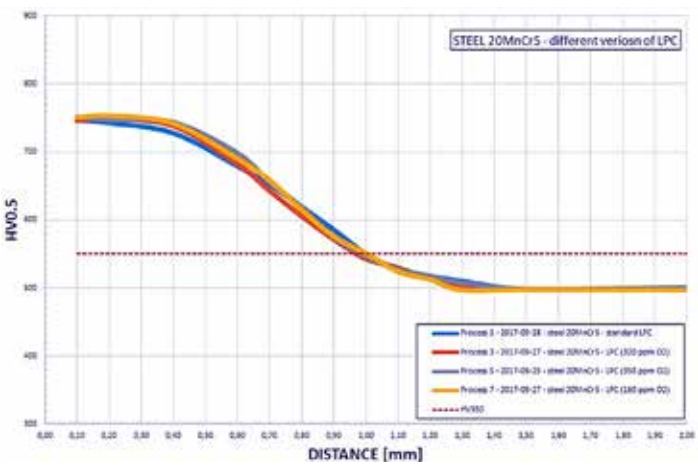

Figure 5: Verification of process under varying levels of oxygen contamination (3 to 350 ppm O2). SAE 5120 or 20MnCr5 steel grade. Surface hardness was greater than 62 HRC on all samples.

One of the design requirements set was to create a furnace that not only competes with the quality of gas carburizing by beating it, but the furnace also needed to be a realistically priced option to those buying a standard atmosphere integral quench furnace.

burizing results:

› **SAE 5120 (20MnCr5):** A popular carburizing grade used in the automotive and transportation industry.

› **X4317H (18CrNiMo7-6):** A carburizing grade used in the energy segment.

› **SAE 9310 (14NiCrMo13-4):** A carburizing grade by the aerospace, industrial, and automotive industries.

Various process variables were fixed and common to all testing including:

› Loads were charged into the vacuum heating chamber at ambient temperature.

› Pump down heating chamber to the 10-3 Torr range.

- Heat in vacuum.
- Carburize with acetylene at 980°C (1,800°F) to a case depth of 0.80-1.00 mm (0.032 – 0.040") effective case depth measured at 550HV (52.5 HRC).
- Drop temperature from the carburizing temperature to the hardening temperature.

› Immediately before quenching, backfill the heating chamber with nitrogen to atmospheric pressure (while measuring the oxygen content).

- Transfer the load onto the quench elevator.
- Quench into 60°C (140°F) agitated oil.

› Quench for 30 minutes in the oil, raise the elevator and allow the load to drain prior to unloading.

› Wash and temper all samples (at appropriate tempering temperatures).

TEST RESULTS – ABSENCE OF PART CONTAMINATION DURING LOAD TRANSFER

Intergranular oxidation (IGO) was still prevented with this new furnace design. The nitrogen atmosphere was even purposefully contaminated to simulate oxygen contamination during transfer from the heating chamber to quench, but results were still acceptable. Cryogenic nitrogen from a bulk tank was used for the tests. The

end result — after extensive metallurgical examination using optical and scanning electron microscopy and hardness verification — was that no contamination affected the materials.

TEST RESULTS – HARDNESS AND CASE DEPTH CONFIRMATION

Typical results for hardness tests are shown in Figure 5.

LOADING THE FURNACE AND INTEGRATION WITH EXISTING LOADERS

The design team decided that loading should not only be similar to existing methods, but that integration with popular loaders from other makers of gas-carburizing-style furnaces was a feature worth designing in. In Figure 6, one can see the old-fashioned gas carburizer with its inherent flames during unloading. Directly across from it is the new, clean Super IQ, which uses the same loader.

As in any furnace design, the engineers must make compromises between features, size, and cost factors. One of the design requirements set was to create a furnace that not only competes with the quality of gas carburizing by beating it, but the furnace also needed to be a realistically priced option to those buying a standard atmosphere integral quench furnace. Until now, vacuum carburizing required almost twice the investment of similar old-fashioned gas equipment. Since no endothermic generators are needed, the new Super IQ is even simpler, and the costs are not far apart from the much older technology. There is no longer an excuse to avoid going with clean, productive, and state-of-the-art furnace equipment.

Figure 6: Shared loader with decades-old existing gas carburizing integral quench furnace and modern Super IQ™.

To keep things even simpler, only one size is offered. The design team decided to offer only the popular 36" x 36" x 48" deep size. Those using smaller sizes can turn their trays around and double the production. Those using the most popular size are ready to go. Washing and tempering equipment can be shared, or basic tempers and washers can be added.

One final factor for the design team was to create a furnace design that exhibited high-production capability, much like the atmosphere units. This means fast transfer into a pre-heated chamber, the ability to carburize at higher temperatures (without furnace degradations), and a unit that can perform other processes such as fast through hardening, annealing, normalizing, etc. Intelligent furnace design needs a Super IQ.

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ABOUT THE AUTHOR

Mark Hemsath is director of Nitriding and Super IQ product manager for SECO/VACUUM Technologies LLC. www.secovacusa.com, a SECO/WARWICK Group company.

OFFERING TURNKEY INDUCTION HEAT TREAT AND FORGING EQUIPMENT

Cyprium Induction performs a number of induction services, including induction heat treat coil and induction forge coil repair, and induction coil and tooling design. (Courtesy: Cyprium Induction)

With a broad range of services from coil design, coil repairs, associated tooling builds and repairs, and transformer repairs, Cyprium Induction is dedicated to do all it can to ensure its customers get the highest quality returns.

By KENNETH CARTER, Thermal Processing editor

Cyprium Induction may be a new name to the induction industry, but the company more than makes up for it when it comes to what it can offer its customers.

As a matter of fact, Cyprium often ends up taking — and completing — jobs that other, more established induction companies sometimes turn down.

"I've made a good name for myself, and as a company, we have made tremendous strides in the short five years that I've been in business. We have customers that prefer to not go anywhere else because our team has achieved difficult patterns on parts that were extremely problematic for them both currently or in the past," said James Link, president and founder of Cyprium Induction. "Manufacturing companies currently using other induction suppliers and who have not achieved acceptable pattern have reached out to Cyprium Induction, and we've stepped in and achieved success, many times on our first attempt."

INDUCTION SERVICES

Cyprium Induction performs a number of induction services, including induction heat treat coil and induction forge coil repair, and induction coil and tooling design. The company supplies all new tooling as well as repair of Buss Bars, Quench heads, Quick Disconnects, and all associated tooling. Cyprium also repairs power supply isolation transformers, offers industrial electrical coatings, in-plant consultation, and much more.

"I would say to anyone in the industry using induction, that we can offer expert tooling advice," Link said. "We almost always get pattern on the first shot with our coil designs. Very rarely do we have to modify it, but we don't charge for modifications to our design, because we are extremely confident in applying our knowledge to designs. We also offer spare parts; we're an OEM supplier of Jackson Transformer and Hunterdon styles as well, so we can supply brand new transformers when customers request such."

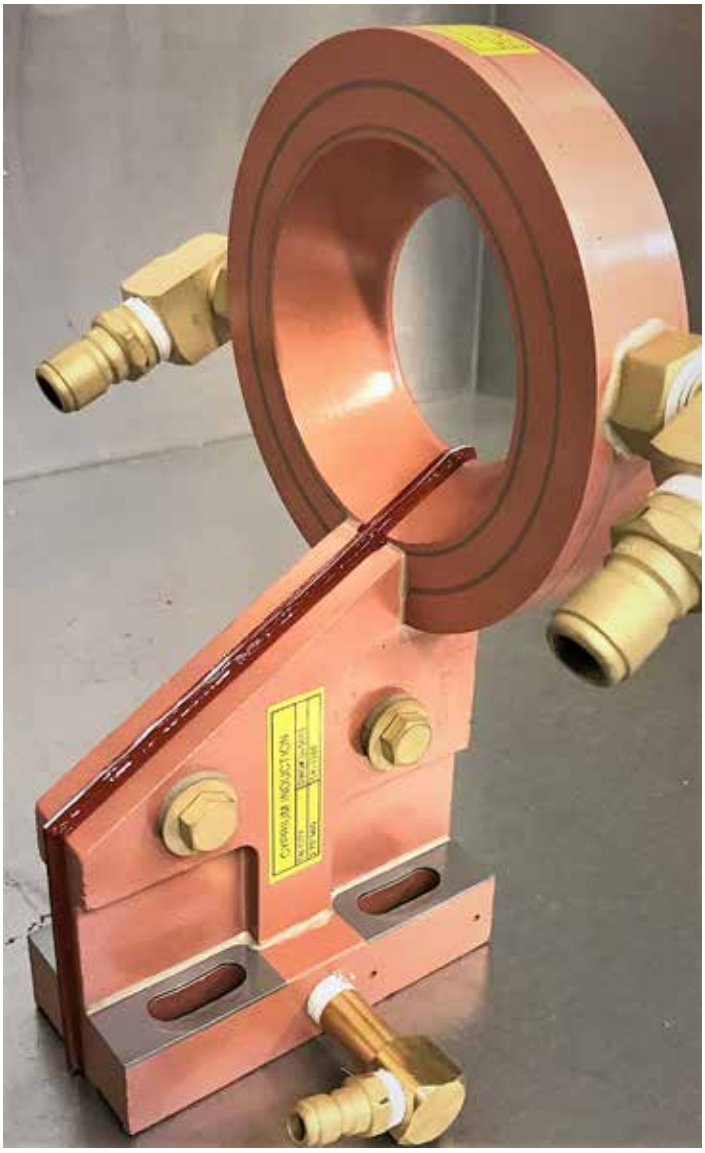
Link also stresses that Cyprium is a full-service shop. It can supply new equipment as well as refurbish any type of old induction equipment in-house.

"Where we stand out from a lot of people is that we actually do transformer repair in-house," Link said. "We can turn around a transformer in a week, and that just prevents a tremendous amount of downtime for our customers. We also use a proprietary coating on our transformers that extends the life and is able to take thermal shock and standard wear much better than the traditional nylon."

SUCCESSFUL PARTNERSHIP

Another key part of Cyprium's success is the company's partnership with Heating Induction Services, according to Link.

"A few years ago, a couple of my customers had asked me if I had a place for power supplies or who I'd recommend," he said. "So, I went with this place called Heating Induction Services. I met the owner, who was George Haddad, and George started talking to me about things and showed me some of the machines that he had built. And I said, 'Hey, do you want to work as a collective unit on selling heat treating and induction-forging systems?' Because I do induction forge and induction heat treat. Once I saw how clean and well-designed his systems were, I instantly had 100-percent confidence in them. And I knew we would be a good team."



An "M.I.Q." coil. (Courtesy: Cyprium Induction)

Haddad agreed, and a collaboration began.

Cyprium Induction and Heating Induction Services also won't cut corners when designing the best equipment for its customers, according to Link.

"We are able to walk in their plant, and they simply give us a square footage of what they have to work with along with other important information (ceiling height, available power, etc.)," he said. "We can quote, design, and build a machine all the way from part loading, heating, and then unloading. So, it's not like we're just selling an induction box. We're selling a full service, turnkey induction machine. That goes for induction hardening or tempering and also forging and melting as well. George Haddad and I are a great team, due to the fact that if we go into a meeting together for a new system, you can get your questions answered thoroughly, accurately, and on the spot."

The two companies have been designing and building systems together as such, according to Link. Heating Induction Services designs and builds all the mechanical and all the power aspects of it and the material handling, and Cyprium does all the inductors, inductor design, and induction tooling associated with the machines.

"And then, we collectively offer a complete package," he said. "When we do machine quotes, both of our names are at the very top of the paper. He's a separate company; I'm a separate company, but we work in connection together to give the customer the best service and advice."

Induction is growing rapidly, but as it grows, so does the technology, according to Link.

"For example, the systems we offer are technologically advanced for this industry," he said. "We are also working on prototype data-collection software for the machines far ahead of its time. I think this can be intimidating to some of the heat-treating shops out there, which use no or very little induction. To them I would say: Take my lead; stick your neck out there, and switch to induction. We will be there with you every step of the way. We can recommend the power and frequency of a machine for your part, design induction tooling to get pattern, build the machine, and even test it and program the machine for you at Heating Induction Services' building. This might sound cliché, but when choosing to get into induction or stepping up to try more challenging work, you should ultimately choose us."

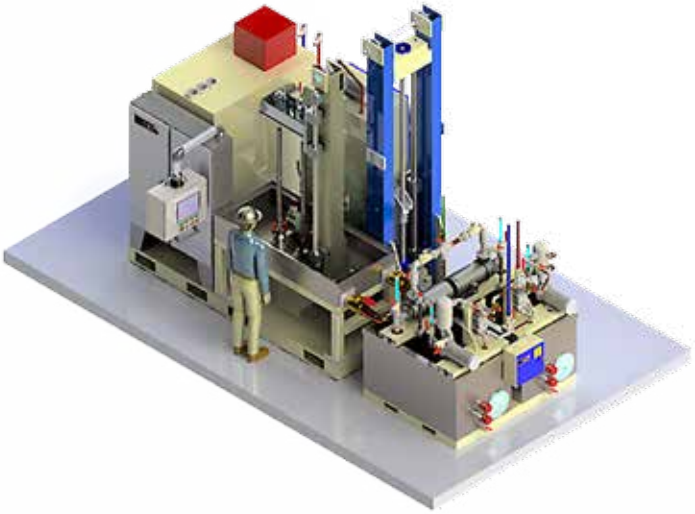
MEETING CHALLENGES HEAD ON

The collaboration between Cyprium Induction and Heating Induction Services has allowed Link to focus on what he finds the most challenging: taking on the most difficult projects.

"We take pride in taking challenging projects on, to the point where I have taken on coils such as large crankshaft coils, extremely stringent pattern profiles on types of yokes, which many of my competitors have 'no-quoted,'" he said. "They were difficult projects, but I firmly believe that to consistently advance, you must tirelessly challenge yourself, your company, and the 'norm.'"

With Cyprium's and Heating Induction Services' combined expertise, Link stressed that no challenge is too big or difficult, adding that his sales staff also have strong engineering backgrounds. They can collectively handle everything to the most demanding induction forge lines, melting lines, or any type of induction heat treating or tempering projects. They can also routinely design and build loading and unloading systems to offer a turnkey machine, and all on Solid Works for real-time rendering.

"The technical sales team that we have, we can go into a place, and if you're having issues, we aren't going to kind of look around, look at the floor and say, 'Hey, we'll beat the price. We'll give you faster turnaround,'" he said. "I've always said, 'Show me what your issue is.



This rendering of a dual spindle scanner is currently being built for a customer. The rendering, as well as progress photos of the build, will be available at Cyprium Induction's booth at Heat Treat 2019. (Courtesy: Cyprium Induction)

A transformer repair. (Courtesy: Cyprium Induction)

I am here to win your business, of course, but while I'm here, show me what you would like to see improvement in.' Whether or not you use us, you might as well take the time to ask me some questions because if I can spot your problem firsthand, I am going to tell you on the spot. One customer brought a project to me where he was getting one part every 28 seconds. He needed to speed up production, and with a total coil redesign, he was able to achieve his desired pattern in only seven seconds."

Any job that involves induction is fair game to Cyprium, according to Link.

"Before we take it on, we will tell you if it's probable or even if it is impossible, and I've had to tell people that bad news before, based on their machine parameters in relation to the part and desired pattern," he said. "We're pretty forthcoming, but pretty much I tell people, 'I guarantee you that if we take the project on, we will work

with you to get your desired pattern.'"

BIG STRIDES IN A SHORT TIME

Cyprium has accomplished quite a few things in its short lifetime, but one of the things Link finds he's most proud of is the inroads the company has made in five years.

"I have come to the forefront of induction in just five years," he said. "To gain a reputation in high quality in a very short amount of time is our proudest achievement."

That constant search for the highest quality in every job it takes on is what helped Cyprium at the beginning and what continues to push the company's success, according to Link.

"When I started this company, I just had a couple customers that were willing to give Cyprium Induction a chance and start giving me some work," he said. "And those first customers that I have, we've held onto them, and there are some customers that choose us over all else because we're really good at induction coil design and service. We don't rest until we get pattern for our customers, meaning that I've taken coils back that didn't get pattern and completely redesigned it on my dime, and then got pattern. We also have the best customers you could ever ask for. We have discussions with our customer regularly, and they all offer great opinions and ideas."

WHAT'S WITH THE NAME?

Tenacity may be at the heart of Cyprium Induction, but it's not what it means.

Cyprium has an ancient connection, being the word Romans used for copper alloys such as bronze. The copper was mined from Cyprus, which is where the word is derived. The word eventually evolved into the modern "copper."

Since copper is involved in the induction process, it made sense to Link to use the ancient word for the metal in the company name, making way for Cyprium Induction.

And just like that resilient and highly sought-after metal, Link predicts Cyprium's expertise will continue to be a welcome commodity as the company moves into the future.

"I think in the next 10 to 20 years, Cyprium Induction is going to be one of the front runners in the induction industry," he said. "I would even say my goal is worldwide. I would say down the road in the next 10 years that we're going to be an international, recognized name in the induction industry, and that's kind of my goal to supply all induction machines with expert design and the highest quality repairs."

HEAT TREAT 2019

But here in the present, Link expects Cyprium to make a splash at this year's Heat Treat Expo, where Cyprium and Heating Induction Services will have adjoining booths.

"Attendees should expect to have some pretty knowledgeable discussions, and they should expect to get answers right there on the spot," he said. "If they have a question with a part or current project they are battling with, let us look at it. I would just ask people, if they are going to come with a particular project, they should bring documentation of what their machine's power and frequency is. Have that ready, and we can offer expert advice based on the information and have some very detailed discussions."

MORE INFO www.cypriuminduction.com

HEAT TREAT 2019

"This show allows us to meet with many of our existing customers as well as introduce our products and capabilities to new attendees."

HEAT TREAT 2019, is scheduled to hit Detroit, Michigan, October 15–17. The show will bring thousands of industry experts and insiders to the motor city, where they will be on hand with knowledge to take heat-treating into 2020 and beyond. *Thermal Processing* reached out to several exhibitors and asked them to share their plans for HEAT TREAT 2019. If you're going to be at the show, be sure and stop by their booths for more information.

(Courtesy: ASM International)

ADVANCED ENERGY INDUSTRIES

Booth #1008

Scott Burkemper, Regional Sales Manager

Heat Treat Expo is important to Advanced Energy because it allows us to showcase our newest technology and solutions to current and prospective OEM and end-user customers. This year, in booth #1008, we will exhibit our SCR power controllers, pyrometers, and thermal-imaging technologies for the industrial markets. We especially look forward to demonstrating how our SCR products provide superior control in a wide range of applications, and how our advanced communications protocols provide easy integration into a connected enterprise for data collection and analytics.

AFC-HOLCROFT

Booth #1809

Mike Coburn, Technical Sales

As any manufacturer using heat treatment for parts processing knows, finding people knowledgeable on that topic can prove difficult. Isn't that why you visit events like ASM Heat Treat? AFC-Holcroft will have product experts on hand, ready to discuss your specific thermal-processing needs. Come in, have a seat, and let one of our experienced, knowledgeable staff discuss your unique situation in a face-to-face setting. Tell us about your production and process requirements, and let us offer suggestions. We're sure you will find your visit to be productive and informative.

DEKALB BLOWER

Booth #310

Eric Johansen, President

DeKalb Blower is exhibiting in the Heat Treat Expo so customers or potential customers may see our offerings, and the patented and patent-pending features we offer on our products due to the severity that most of these fan impellers and components are subject to in the demanding heat-treating industry. These heavy-duty products typically add durability and service life to the equipment. We are also available to answer any questions that are fan-related and offer insights on any of the issues you may be encountering that are fan- or blower-related at your facility. We will also have a lot of great giveaways to all visitors at our booth.

DIABLO FURNACES

Booth #1318

Bill Gornicki, CEO

Diablo Furnaces is a new heat-treating OEM poised for growth. Supporting well-known industrial companies with new equipment, Diablo is exhibiting and conveying "Service" by showing our new Utility Van and how it's an integral part of our company growth. Service is an extension of every aspect in a company from sales, customer relations, installation, and aftermarket, and what better symbol to showcase than our new service vehicle. The ASM HTE is the place where connections happen. If you're a visitor, exhibitor, supplier, or student, one can learn, share, and exchange information under one roof. Diablo is exhibiting and attending to make connections. We are only as strong as our weakest link, so making more connections provides us with better ammunition for solutions.

GASBARRE THERMAL PROCESSING SYSTEMS

Booth #2309

Ben Gasbarre, President, Gasbarre Industrial Furnace Systems

Gasbarre Thermal Processing Systems designs, manufactures, and services thermal-processing equipment for virtually any process. We offer continuous and batch, atmosphere and vacuum equipment, and a full range of aftermarket parts and services. We are excited to be featuring our precision nitriding system for nitriding, FNC, and atmosphere tempering/stress relieving processes. Also, look for our modular vacuum system, designed to give the utmost flexibility as businesses evolve. We provide products and services that combine value and design flexibility through knowledge and understanding of your process. Stop by booth #2309 to find out how Gasbarre can help drive your success.

INDUCTOTHERM GROUP

Booth #1600

Robert J Madeira, President Inductotherm Heating & Welding Mexico and Global Manager of Heat Treating Technologies, Inductoheat Inc.

The Inductotherm Group is much more than skin deep heating. The 2019 exhibit features technologies for heat treating, welding, vacuum-induction brazing, and forging. Please visit booth 1600 to meet a knowledgeable staff from Inductoheat, Inductotherm Heating & Welding Mexico, Thermatool, and PVT Vacuum Thermal Processing Equipment. Come experience the information highway that moves the induction heating industry onward and upward. See it first hand by visiting Inductoheat. Sign up for the ASM organized plant tour of Inductoheat happening Monday, October 14. We are always available at: FSG@inductoheat.com or 248-585-9393 and look forward to meeting you at HTS 2019.

INEX INCORPORATED

Booth #1418

Mike Kasprzyk, President

Share and learn is why INEX exhibits and Heat Treat 19 attendees should visit our booth. For more than 30 years, we have been showing heat treaters from all over the world how composite radiant tubes can improve their furnace performance (throughput) and reduce maintenance costs. Most heat treaters know their alloy tubes all eventually fail due to creep or corrosion. Stop by our booth and learn how to shorten cycles, speed up continuous furnaces, and reduce maintenance/replacement costs for radiant tubes. And if you are already a customer, please stop by and share your success.

INTERNATIONAL THERMAL SYSTEMS

Booth #922

Kurt Willms, Sales Manager

ITS has attended the Heat Treat show for many years, and it is one of our best shows. Heat Treat offers a great combination of networking and educational opportunities. We are able to meet existing customers and have the opportunity to connect with potentially new customers. We also enjoy learning about the new technologies that are being developed in the ever-changing heat-treating industry.

LASERLINE INC.

Booth #2308

Wolfgang Todt, Vice President of U.S. Operations

At Heat Treat 2019, professionals meet and discuss new advancements in heat-treatment and additive manufacturing technologies. That's why Laserline is there. Laserline, Inc. is the largest manufacturer of high-power diode lasers, perfectly suited for these applications. With a power range from 500 W to 60 kW, we pretty much meet any surface heat-treatment challenge. With our newest innovation – the LDMblue – we are able to process highly reflective nonferrous metals such as copper or gold at 450 nm wavelength. See you at booth #2308, and let us help you find the right laser for your needs.

(Courtesy: AGMA)

LINDBERG/MPH

Booth #1819

Kelley Shreve, Applications Engineer

Lindberg/MPH is exhibiting at Heat Treat Expo 2019 to provide attendees with information on our industrial heat treat furnaces, including pit, box, integral quench, and hot-stamp designs for the ferrous and non-ferrous markets. Lindberg/MPH manufactures custom and standard heat-treat furnaces for many different industries, including aerospace, automotive, energy, electronics, foundry, and more. While at Lindberg/MPH's booth (#1819), attendees should look forward to meeting and speaking with our experienced, knowledgeable staff who are able to answer any and all of your heat-treat furnace, industry, and process-related questions.

L&L SPECIAL FURNACE CO., INC.

Booth #1518

Tom Schultz, Sales Manager

L&L Special Furnace Co., Inc., is a leader in high uniformity batch furnaces, ovens, kilns, quench tanks, and heat-treating systems. All manufacturing and engineering is done in-house from one location just south of Philadelphia, Pennsylvania. L&L sells and services worldwide. Visit Booth 1518 to meet company representatives, who can explain how L&L Furnaces can make a difference in your heat-treating applications. You can also visit www.LLFurnace.com and download PDF product bulletins and more.

METAL TREATING INSTITUTE

Booth #1527

Tom Morrison, CEO MTI Management

Being the trade association of the heat-treating industry, we are excited to exhibit at the Heat Treat Show because it helps us connect and get closer to our members on issues such as quality standards, specifications, forecasting, and training. Technology and disruption are causing markets to change faster than ever before for heat treaters, making connecting with them more important than ever before to understand what they need to compete in today's ever-changing environment.

METALLURGICAL HIGH VACUUM

Booth #2307

Dave Milliman, Lead Sales and Engineering Support

As a full-service vacuum system solutions provider, Metallurgical High Vacuum participates in the Heat Treat Expo because it is a valuable platform for talking with people about industry trends and issues. In addition, the Expo is a great forum for explaining how we can supply remanufactured pumps that will perform like new with our unique process "dynamic proof testing." Our on-site preventative maintenance services and vacuum systems optimization are also noteworthy. Come learn how to have confidence in remanufactured vacuum pumps and blowers and how MHV can improve your vacuum system performance at booth #2307.

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ADVERTISER INDEX ///

NEL HYDROGEN

Booth #1215

David Wolff, Region Sales Manager

Reducing gas atmospheres is critical to volume annealing, brazing, and sintering. The need for reducing gas atmospheres is growing to meet the needs of rapidly-expanding additive manufacturing applications. At the same time, the supply of delivered hydrogen is encountering shortages due to liquefaction and transportation limitations. Simultaneously, hydrogen storage and ammonia storage are coming under pressure from code and EH&S officials. On-site hydrogen generation provides hydrogen users a safe, efficient, easy-to-permit, cost-effective hydrogen supply for thermal-processing applications. Nel Hydrogen will assist visitors to determine if on-site hydrogen is a fit with their requirements.

PREMIER/BEAVERMATIC

Booth #1405

Don Selmi, President

As a leading manufacturer of heat-processing equipment, this show allows us to meet with many of our existing customers as well as introduce our products and capabilities to new attendees. Premier/BeaverMatic is a manufacturer of proven-performance atmospheric furnaces as well as other heat-processing systems for captive and commercial heat-treat departments worldwide. We are best known for our performance-proven internal quench furnace, with the latest in furnace controls and data collection. Some of our technical and sales staff will be at the show to answer questions. They are experienced in heat treatments and knowledgeable with various applications and efficiencies used within various markets. We manufacturer standard and custom designs to meet a variety of processes, time lines, and budgets.

SOLAR MANUFACTURING

Booth #2013

Jim Nagy, President

By displaying at Heat Treat Expo, Solar Manufacturing will be introducing our latest innovations developed to improve the quality and operation of our vacuum furnaces, including energy efficient hot-zone designs and advanced features added to our automation systems. Since 2002, Solar Manufacturing's ingenuity has led the heat-treating industry with advances in hot-zone designs, improved energy efficiency, state-of-the-art furnace automation and control systems, and high-performance gas quenching. We will be showcasing our SolarVac® control innovations at ASM Heat Treat 2019 for the benefit of our customers: a new, thermally efficient and extremely strong hot-zone design and a new integrated furnace control system. To see these latest advances in ingenuity on display, visit booth #2013.

SUPER SYSTEMS, INC.

Booth #1407

Steve Duban, Sales Engineer

Super Systems is proud to participate in the Heat Treat Expo and looks forward to greeting existing customers and meeting new companies that are looking to modernize technology-related products and services for their heat-treat operation. Attendees will see SSi's upgraded suite of load entry/load tracking software (LE3) and the latest edition of our plant-wide, data-acquisition software (SuperDATA PRO). We will demonstrate our eFlo2.0 line of flow meters along with a comprehensive line of process controllers and easy-to-use analyzers to meet the demanding specifications of AMS2750 and CQI-9.

TAYLOR-WINFIELD

Booth #1018

Ryan Neiss, Product Manager – Induction Heating Product Group

As a custom machine builder, Taylor-Winfield's niche in induction heating is designing and manufacturing "turn-key" systems customized to our customer's heat-treat and brazing applications. Exhibiting at the HEAT TREAT EXPO is a perfect opportunity to discover attendees' needs, what challenges they face, and how we can build an equipment solution to meet their requirements. Whether it's a single induction power supply or a comprehensive automated system, we have a solution. Stop by our booth #1018 to see what induction-heating solutions we can provide for your part production needs.

WISCONSIN OVEN

Booth #1820

Doug Christiansen, Application Engineer

Wisconsin Oven Corporation is exhibiting in Booth 1820 at the Heat Treat Expo 2019. During the show, we will be showcasing our standard, custom batch, and continuous industrial ovens. Wisconsin Oven manufactures electrically heated and gas fired heat-treat ovens for a multitude of industries, including aerospace, automotive, composites, energy, finishing, and more. We are also inviting attendees to our Solutions Center presentation on Aerospace (AMS 2750/BAC 5621) and Automotive (CQI-9) Pyrometry testing service options, which allow for quicker production start-up and faster revenue generating capabilities with your new equipment purchase. This presentation is scheduled for Tuesday, October 15, at 3 p.m.

VISIT US AT HEAT TREAT 2019

Thermal Processing will be at ASM International's biannual heat-treat show. We hope you'll stop by our booth (2119) to chat with our staff and share your Expo experiences. We look forward to seeing you there.

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