Thermal processing

POWDER METALLURGY

COMPANY PROFILE:
Ipsen

Technologies and Processes for the Advancement of Materials

MAY/JUNE 2017
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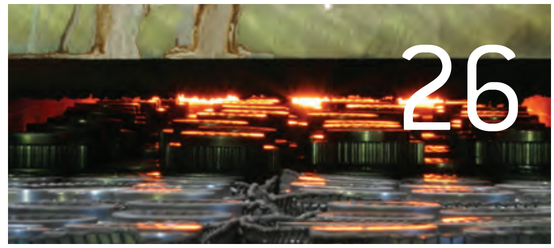
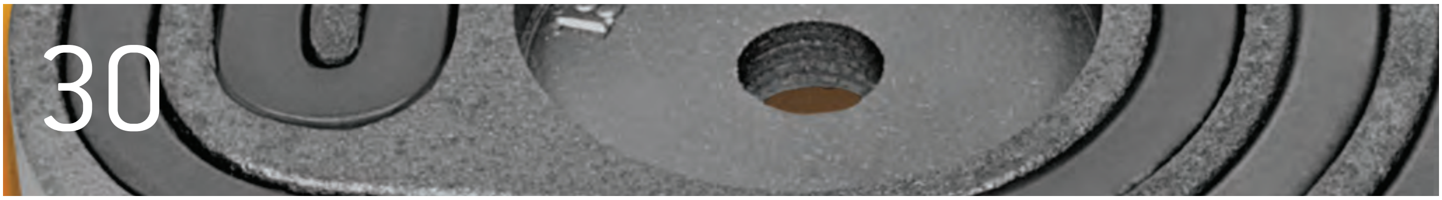
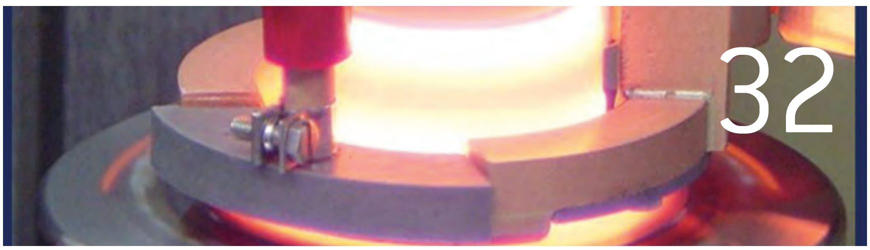
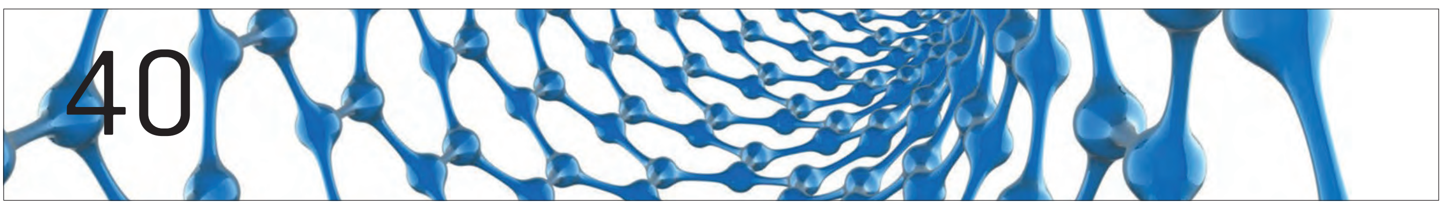
FEATURES MAY/JUNE 2017









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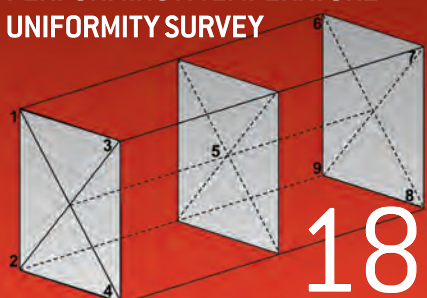
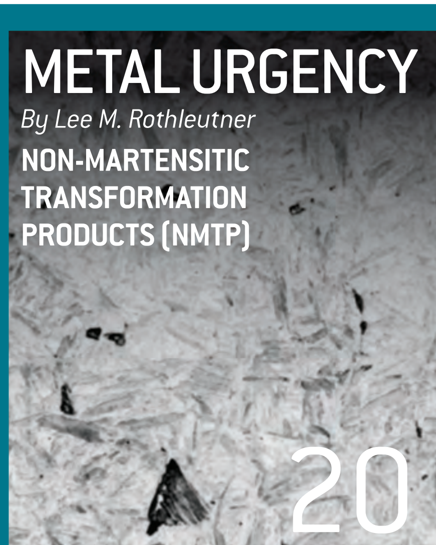
Volume 6 / Number 3





RESOURCES

Cover photo: J.L. Becker/Gasbarre Furnace Group

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LETTER FROM THE EDITOR

Welcome to the May/June issue of *Thermal Processing* magazine!

In this industry, it seems like there are learning opportunities everywhere you turn. One notable event that's just around the corner is PowderMet 2017, sponsored by the Metal Powder Industries Federation (MPIF). It's interesting that MPIF began near the end of World War II, as the powder metallurgy process was being used to make parts for the war, particularly self-lubricating bearings. However, once the war was over, the association was formed to help promote the technology's growth, develop standard and testing methods, and create statistical data. And MPIF has continued to grow alongside the rapidly evolving technology.

MPIF's PowderMet event is held in conjunction with the fourth annual Additive Manufacturing with Powder Metallurgy (AMPM) conference. It will feature worldwide industry experts presenting the latest developments in this field through an in-depth technical program, special events, and the trade exhibition with over 100 booths of leading companies in PM equipment, powders, products, and services.

Probably the main advantage of powder metallurgy is the flexibility of the process that enables products to be made from materials tailored to specific needs and enables refinements to be engineered into the mechanical properties of the part. According to MPIF, powder metallurgy is recognized as a "green" technology because of its net-shape capability, as well as having no waste in the shaping of parts.

If you're attending PowderMet June 13-15 in Las Vegas, we've included a couple of articles in this issue to get you prepared. First, Richard Slattery of Capstan Atlantic provides basic hardening definitions and methods used with powder metallurgy for those who may be unfamiliar with the process. We've also included a paper from authors with Verder Scientific who present an elemental analysis of metal powders and metal parts produced by additive manufacturing and show how non-metallic elements influence the physical properties of metallic materials.

Next, we turn our focus on induction heat treating with an article from Sandra J. Midea of Induction Tooling who discusses testing and validation at the inductor level to produce a fully characterized and proven inductor, complete with production process settings and a metallurgical report from its ISO 17025 accredited commercial test laboratory.

You'll also find an article on ensuring effective furnace lining efficiency as well as an article on vacuum diffusion pumps.

This issue's company profile covers the story of Ipsen, starting with its humble beginning in 1948 when founder Harold Ipsen designed and built a kiln for his wife, to today, a global leader in the heat-treating industry. We hope you enjoy getting to know the company better through the profile.

In this issue's Q&A, *Thermal Processing* associate editor Kenneth Carter had the chance to talk with Aziz Jamaluddin, president and CEO of Epcon Industrial Systems, a leader in custom designing and manufacturing thermal oxidizers.

Last but certainly not least, our regular *Thermal Processing* columnists Jack Titus, Jim Oakes, Lee Rothleutner, and Jim Grann discuss topics on automotive efficiency standards, process control technology, non-martensitic transformation products, and temperature uniformity survey, respectively.

I want to thank all of the contributing writers for taking the time to share their expertise. And if there is a topic you would like to see covered in *Thermal Processing*, feel free to reach out to me by phone or email. I would love to hear from you.

As always, thanks for reading!

Molly J. Rogers

Molly J. Rogers
Editor
Thermal Processing magazine
editor@thermalprocessing.com
(800) 366-2185 x205

Thermal processing for Gear Solutions

David C. Cooper
PUBLISHER

Chad Morrison
ASSOCIATE PUBLISHER

EDITORIAL
Molly J. Rogers
EDITOR

Kenneth Carter
ASSOCIATE EDITOR

SALES
Chad Morrison
ASSOCIATE PUBLISHER

Dave Gomez
REGIONAL SALES MANAGER

CIRCULATION
Teresa Cooper
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Jamie Willett
ASSISTANT

Cole Morrison
ASSISTANT

ART
Shane Bell
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Michele Hall
GRAPHIC DESIGNER

CONTRIBUTING WRITERS
STEVE CHERNACK
JIM GRANN
MIKE LUCKA
NICO MASCIANTONIO
SANDRA J. MIDEA
JIM OAKES
LEE M. ROTHLEUTNER
RICHARD SLATTERY
JACK TITUS
E.W. WHITNEY III

Media solutions

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David C. Cooper
PRESIDENT

Chad Morrison
VICE PRESIDENT

Teresa Cooper
OPERATIONS

J.L. Becker IQ Furnace Line Commissioned at East Carolina Metal Treating

J.L. Becker, a Gasbarre Furnace Group Company, recently manufactured, shipped, and commissioned a complete IQ furnace line at the East Carolina Metal Treating (ECMT) facility in Raleigh, North Carolina. The system is configured to process 36-inch-wide by 48-inch-long by 36-inch-high workloads that weigh up to 4,000 pounds and includes an integral quench furnace, two temper furnaces, a spray-and-dunk washer, a powered load transfer cart, a scissors lift table, and two stationary load tables.

The IQ furnace features a high-energy-efficient recuperative radiant tube heating system, nitrogen/methanol panel, and a double-deck elevator, which enables multi-load processing. To ease maintenance, the circulating fan assembly is bung-mounted, and a catwalk provides access to components on the top of the heating chamber. The temper furnaces are electrically heated and are lined with ceramic fiber insulation. A high convection, bung-mounted squirrel cage achieves temperature uniformity throughout the workload area in the temper furnaces. The spray-and-dunk washer is electrically heated. Dunking, oscillating, and spraying sequences are employed to remove quench oil, machine lubricants, and other contaminants from workloads in the washer. An oil separation system removes contaminants from the wash solution. A powered double-ended cart transfers workloads throughout the system. To meet AMS 2750 requirements, the equipment is configured to tie into ECMT's existing SCADA system for data logging.

According to Jamie Ramm, president of ECMT, the new line reflects the company's long tradition of continually improving its ability to provide excellent service to its customers.

FOR MORE INFORMATION: www.jlbecker.com • www.gasbarrefurnacegroup.com • www.ecmtinc.com

Retsch GmbH Offers Sieving and Pulverization of Metal Powders

Reusing raw materials is an important factor in powder metallurgical processes. Retsch offers a range of instruments that are suitable for sieving powders and pulverizing metal parts, both of which are reintroduced into the production process. The following examples describe the suitability of Retsch instruments for these applications:

Separation of size fractions by sieving to recover metal powder residues after 3D printing using laser technology:

Retsch sieve shakers, such as the Vibratory Sieve Shaker AS 200 basic, are well-suited to sieve agglomerated metal powder before it is used for 3D printing or to separate the unused metal powder after the printing process into fractions with the objective to recover the fine particles for reuse. Concept Laser, a manufacturer of machines for 3D printing of metal components, uses the AS 200 basic for this purpose. It is the economical model of the AS 200 series with Retsch quality and reliability. One to 17 fractions may be obtained after short sieving times.

The shaker features digital setting and display of performance and time, ensuring comfortable sieving of ferrous and non-ferrous metals such as gold, tungsten carbide, or precious metals. The most common test sieves used for this application are Retsch test sieves with 200 or 203 mm diameter and a height of 25 mm or 50 mm according to ISO 3310-1 or ASTM E11. Aperture sizes of 32 µm to 150 µm are best suited to separate the non-agglomerated metal powder after the printing process for recovery. The most commonly used aperture sizes are: 32 µm, 40 µm, 50 µm, 63 µm, 100 µm, and 150 µm.

The Retsch sieves consist of a high-stability stainless steel frame to ensure reliable sieving results. Paying close attention to mesh-specific requirements, the sieve fabric is precisely joined into the frame and tautened. The individual laser engraving of each Retsch test sieve provides a clear and accurate labeling with full traceability.

Recycling of green bodies or hard metal parts produced by metal injection molding:

Metal injection molding (MIM) is used to produce metal parts of complex geometrical shapes. Metal powders and binders are mixed to a feedstock and injected into a mold using plastic injection molding machines to form so-called green parts in the first step, followed by partial removal of the binder to form fragile brown parts, and finally the sintering process to produce stable new metal parts of a defined complex shape. At each stage, intermediate parts with undesired properties may be produced. These are crushed and pulverized to recover the raw material for reuse.

Jaw Crushers such as Retsch's BB 500 XL, pulverize defective green parts, brown parts, or hard metal parts within minutes.

Application example: 10 kg of green parts < 100 mm were crushed in two batches with closed gap (i.e., direct contact between fixed and moving crushing arm) in the Jaw Crusher BB 500 XL. Each batch was pulverized to a final fineness of 85 percent < 250 µm after only one minute.

FOR MORE INFORMATION: www.retsch.com

Conrad Kacsik Completes Control System Upgrade for Modern Industries

The engineering division of Conrad Kacsik Instrument Systems recently completed a plant-wide control system upgrade for Modern Industries, one of the largest commercial heat-treating companies in Pennsylvania.

The project consisted of the replacement of the legacy controls on over 30 furnaces and pieces of equipment within the facility. This included vacuum furnaces, integral quench lines, tempers, nitriders, cast belts, and generators.

All of the upgraded equipment is now encompassed within a plant-wide supervisory control and data acquisition system.

The system is comprised of Honeywell HC 900 controllers and control station operator interfaces for logic and process control, and Specview HMI (human machine interface) software for centralized furnace supervision and data collection.

This platform provides flexibility. The individual control stations are capable of storing over 200 days worth of data, and Specview allows all of this information to be archived to a server on the plant-wide network.

Conrad Kacsik's engineering team worked closely with the facility's personnel to develop customized programs that would enhance operational productivity. For example, Specview was programmed to mirror all of the individual control station screens and to provide furnace operators with recipe-management capability. Customized screens were also developed to enable customer names, part numbers, part quantities, and additional information to be combined with individual furnace data.

The combination control station/Specview HMI package delivers a redundant control and data acquisition system that eliminates the possibility of data loss.

Remote seat licenses were also incorporated into the system. Facility personnel now have the capability of logging in to a network PC to control the furnaces, develop new programs, or review production charts.

The system also enables remote access for Conrad Kacsik's engineering team to provide assistance with control scheme changes, problem diagnostics, and general system maintenance and support.

According to Dennis Sweny, co-president of Modern Industries, Modern had never embarked on such a large-scale, plant-wide upgrade. Maintaining production capacity during the installation was imperative. Conrad Kacsik's engineering team worked with Modern's staff to ensure this was accomplished. Sweny also stated that, upon completion of the project, he was pleased with the timeliness and ease of transition from the legacy controls to the new system, as well as the minimal number of problems encountered compared to what he had anticipated for a project of this magnitude. Modern has worked with Conrad Kacsik to expand upon the original scope of the project to further customize the system to meet the specific needs of Modern Industries.

FOR MORE INFORMATION: www.kacsik.com

Premier Furnace Specialists/ BeaverMatic Supplies Mesh Belt Brazing Furnace to Tool Supplier

Premier Furnace Specialists/BeaverMatic recently supplied and installed a complete 20-inch mesh belt brazing furnace system to a major tooling supplier in the Midwest. Along with the brazing furnace, a 6000 CFH exothermic gas generator, 6000 CFH gas dryer, a water recirculation system, Marley evaporative cooler/tower, and turnkey installation/startup was included. The furnace is capable of brazing, annealing, and operational temperatures up to 2050°F.

FOR MORE INFORMATION: www.premierfurnace.com

Wisconsin Oven Closes on Property Purchase from Plymouth Tube

Wisconsin Oven recently announced it has closed on a property purchase from Plymouth Tube. The property is on Young Street in East Troy, Wisconsin, between two other Wisconsin Oven factories. This facility offers over 130,000 square feet of manufacturing space. Wisconsin Oven's total investment in the community will exceed $2.5 million after purchase and renovation.

"We are very excited to secure this facility," said Wisconsin Oven President and CEO Dave Strand. "Over the next year, we will be doing some extensive renovation and plan on hiring 80 to 90 employees between 2017 and 2019."

FOR MORE INFORMATION: www.wisoven.com

Aerospace Supplier Orders Titanium Rotary Hearth Forging Furnace

Can-Eng Furnaces International Limited was contracted to commission a turnkey 36-foot-diameter "pancake"-style rotary hearth furnace for a leading North American-based aerospace supplier. The open hearth configuration allows for flexible loading and uniform heating. The furnace will be used in the production of large fixed wing aircraft titanium and nickel-based alloy closed-die structure forgings.

The furnace system features an advanced low NOx combustion system designed to meet the most stringent environmental and temperature uniformity requirements. A special dual-door design provides the customer with significant flexibility for forging to press manipulation within their existing plant layout. The system is capable of processing up to 250,000-pound load capacity in a 24/7 production environment. The furnace system complies with thermal performance requirements laid out in AMS 2750E and integrates a low shrinkage ceramic fiber lining, unique rotating hearth drive, and sealing system. The system is scheduled to be commissioned to the United States in the third quarter of 2017.

FOR MORE INFORMATION: www.can-eng.com

Global Automotive Supplier Invests in New AFC-Holcroft Heat-Treating Equipment

A leading global automotive supplier of systems and components has purchased a new roller hearth annealing furnace from AFC-Holcroft. The new equipment will be installed in the southeast region of the United States, where the same plant has been running production using two Holcroft-brand roller hearth annealers since the late 1990s.

The new roller hearth furnace will be similar to the existing installation in design but updated with modern controls systems and features.

The roller hearth design offers the customer more flexibility than other types of thermal processing technology such as induction. A roller hearth furnace can produce a larger volume of parts, change recipes easily, provide long cycle times, and offer the flexibility of batch-style processing in a continuous type design.

"The customer's team recognized and acknowledged the strength and flexibility of the original roller hearth design for their application," said Ron Graham, sales engineer at AFC-Holcroft. "They provided vital feedback to us on areas of potential improvement, which allowed us to provide the optimal solution by combining the known functionality of the existing design with identified areas of improvement based upon decades of in-plant experience."

FOR MORE INFORMATION: www.afc-holcroft.com

ALD Receives Contract for Third SyncroTherm System Slated for the North American Aerospace Industry

ALD Vacuum Systems Inc. in Wixom, Michigan, has received a purchase order from a North American-based aerospace manufacturer for a SyncroTherm® brand, fully-integrated vacuum heat-treating system. This system will primarily perform low pressure carburizing (LPC) and is the direct replacement for two vintage batch IQ atmosphere carburizing furnaces. In addition to LPC, the unit will also perform austenitizing, vacuum brazing, gas quenching, cryogenic treating, and tempering. This fully integrated, compact heat-treating cell will be among the first known captive LPC operations west of the Mississippi.

ALD continues to expand the SyncroTherm presence in the heat-treating world with applications for the automotive drivetrain, consumer tool, textile, bearing, commercial heat treating, hydraulics, aerospace, and fuel systems markets. This will be the third SyncroTherm to support the needs of NADCAP (National Aerospace and Defense Contractors Accreditation Program), and it will be comprised of five independently controlled hot zones, each rated for load sizes of 24-inch by 20-inch by 9-inch high and up to 110 pounds. SyncroTherm systems operate using recipe-selectable high-pressure gas quench and incorporate support processes such as cryogenic and temper sequences in a fully automated, lights-out fashion. Individual part tracking and complete process history retention are key functions within the system along with a consistent process cadence.

FOR MORE INFORMATION: www.aldvac.com

Lucifer Furnaces Equips R. Hueter with Benchtop Oven for Heat Treating with Nitrogen

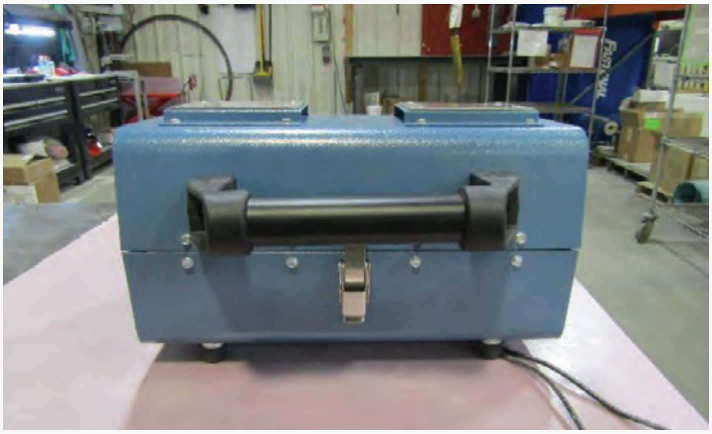
R. Hueter Co. in Beverly, Massachusetts, a northeast CNC machine shop specializing in male and female RF connector contact production, has added a Lucifer Furnaces heat-treating oven to meet its growing heat-treating needs.

Model 42GT-H12 was customized as a benchtop unit. With a chamber size of 9-inch by 12-inch by 12-inch, the oven is insulated with 5 inches of both insulating firebrick and mineral wool backup, and 4 kilowatts of power allows fast heat-up to 1200°F. GT ovens, built for operation using inert atmosphere, are crafted with a continuously welded outer steel shell and gasketed roof plate. A strong seal on the double pivot door is achieved with a square gasket around the door perimeter to form a tight seal to the oven faceplace. Swing bolts with T-handles make clamping easy. The stainless-steel liner baffles the work chamber from the sidewall heating elements and directs the airflow horizontally through the chamber for uniform heating. Hueter chose a Honeywell DC2500 temperature controller with a soak timer to shut off heating elements at the end of a programmed cycle, in addition to a flowmeter mounted and piped to the oven for easy connection to the atmosphere supply.

Hueter plans to use the furnace primarily around 600°F for two-hour cycles to achieve a specific Rockwell hardness with small lots of BeCu pins under a nitrogen atmosphere to reduce surface oxidation in order to achieve a scale-free, bright finish.

FOR MORE INFORMATION: www.luciferfurnaces.com

Lindberg/MPH Ships Tube Furnace to Prominent Laboratory Equipment Distributor



Lindberg/MPH announced the shipment of a 1200°C tube furnace for a laboratory application.

The “Mini-Mite” furnace has a wide temperature range of 500°C to 1200°C. The chamber dimensions are 1-inch-wide by 12-inch-long. The furnace includes a mild-steel hinged-shell design to allow for ease of use. Vacuum-formed ceramic fiber insulation with embedded heating elements is used for quick heat-up and low heat storage. This unit is available in either 120V or 240V rated at 960 watts. The small footprint makes this unit ideal for benchtop use. It can also be mounted horizontally or vertically. Single-zone helically coiled FeCrAl alloy heating elements are retained by refractory shapes. The furnace does not include an integral control system.

This tube furnace was completely factory assembled, pre-wired, piped, and tested prior to shipment.

FOR MORE INFORMATION: www.lindbergmph.com

Distinguished Service to Powder Metallurgy Awards Announced

The Metal Powder Industries Federation's (MPIF) Awards Committee announced the recipients of the 2017 MPIF Distinguished Service to Powder Metallurgy (PM) Award that recognizes individuals who have actively served the North American PM industry for at least 25 years.

Receiving special recognition by their peers, the 2017 award recipients include the following:

- Eric Iver Anderson, FAPMI, Ames Laboratory
- Diran Apelian, FAPMI, Worcester Polytechnic Institute
- Sherri R. Bingert (Los Alamos National Laboratory)
- Matthew Bulger, NetShape Technologies, Inc.
- Dean Howard, PMT, North American Höganäs, Inc.
- Mark D. Kesterholt (Rio Tinto Metal Powders)
- Sydney H. Luk, Royal Metal Powders Inc.
- Glen Moore (Burgess-Norton Mfg. Co.)
- Thomas J. Pontzer, (Gasbarre Products, Inc.)
- JoAnne Ryan, Alpha Sintered Metals, Inc.
- Rohith Shivanath, Stackpole International (Canada)
- John Sweet, FMS Corporation

(Note: Company names in parentheses indicate employer at time of retirement.)

The awards ceremony will be at the industry luncheon on June 14, 2017, during the PowderMet conference in Las Vegas.

FOR MORE INFORMATION: www.powdermet2017.org

Heat Treaters Can Benefit from Current Technology and Advancements on the Horizon.

By Jim Oakes

IT IS HARD TO FIND A MARKET SEGMENT THAT has not benefited from technology advancements. Heat-treating process control is no different. While there are variations between heat-treating processes, the goal is the same: altering the metallurgical properties of a part using time, temperature, and, in some cases, the atmosphere it is exposed to.

Control- and process-related documentation and technology are riddled with industry buzzwords that can be heard or read in any technical publication or interview. Optimization, IoT (Internet of Things), KPI (key performance indicators), smart technology, and predictive planning are just a few, and the list goes on. With that said, these are all relevant when considering where process control is today and where it will be tomorrow. Technology weaves its path into platforms used in the most sophisticated, as well as the simplest, of operations. Today's heat treater benefits from technology to help reduce errors on the shop floor, make better decisions, and provide a quality product.

This discussion will cover what heat treaters are doing today and what they are looking at in the future — by identifying existing technology being used with current equipment and looking at some of the new equipment and capabilities being provided.

Process control starts with a sensor connected to a control instrument. This instrument reacts to the reading by altering the state. In the simplest form, this is a thermocouple used to measure temperature, connected to a microprocessor-based controller that uses an algorithm to alter the heating/cooling output to achieve the desired set point. In today's heat-treat environments, you see a wide variation of equipment to address process controls. Some are current technologies, and some are older than one might think.

The state of process controls today is, in many cases, driven by the functionality of the equipment in use, for example, the furnace/oven. The latest furnace equipment is set up with all the bells and whistles that provide feedback on the current operating variables, the health of the equipment, and enhanced system methods using more sensors and controls. Because of the capital expenditure on the actual furnace equipment, many existing furnaces are updated with more current control and sensor technology, providing a "current" operating environment on the older equipment. These retrofits are usually feature-rich and only limited to the investment the end user wants to make on controls and sensors.

In many cases, industry standards such as CQI-9 and AMS provide guidelines for process control, sensors, and accuracy. CQI-9, the automotive industry's heat-treat self-assessment, calls out specific tolerances required for control instrument calibration sensitivity and calibration frequencies for control and monitoring equipment. CQI-9 also provides guidelines for heat-treatment process monitoring to address parameters needed for real-time control and monitoring. Examples include the control monitoring of temperature and atmosphere for carburizing applications, daily verification of atmosphere using alternate testing methods, and microstructure verification for each batch.

The ASM standards provide guidelines for heat-treat providers to run parts as well. The ASM standards cross-reference these specific processes. For example, the ASM 2759/7 specification addresses nitriding applications but also references ASM 2750 for pyrometry. The specifications will call out necessary steps for the control, monitoring, and verification of the process being performed.

Technology today is being used to address tighter tolerances for high-quality work. The ultimate goal is providing a high-quality part to meet the performance standards set forth by the design engineer. Sensors and controls today provide redundancy and a level of smartness to ensure that the disruption to a heat-treatment process is limited.

One of the most significant cost factors in heat treatment is scrap and rework. Today's smart controllers provide the highest level of user friendliness to eliminate operator error and reduce mis-heat-treated parts. Automation of process control from the start provides the foundation for achieving a properly heat-treated part. Trends in automation are not necessarily removing workers from jobs but rather repurposing those individuals. Likewise in heat treating, operators can spend less time in areas of entering, monitoring, checking, and reviewing to allow for exception management, giving them opportunities to optimize, consolidate, prepare, and anticipate.

Multifunction process controllers allow for smart algorithms that go beyond the traditional PID (proportional, integral, and derivative) control. Any process controller in use today uses this algorithm to meet a desired set point using the process output. Expanding on this are even more options to provide greater functionality around controls that allow for limiting output, trimming specific control zones, auto-selecting by set point, overshoot suppression, and fuzzy logic. The reality is there are endless options for setting up controls when engineering a system. But even with everything that can be engineered, there is a limitation to implementation time and invest-

ment. The good news is that out-of-the-box functionality addressing heat treatment process control is rich in features and cost-effective.

Smart controllers provide immediate reference to key parameters that enable a true preventative maintenance system. The days of reactive maintenance are slowly being phased out with the use of smart controls, data acquisition, and redundant sensors.

Controls today are represented by discrete microprocessor controllers, multi-loop process controllers, programmable logic controllers (PLC), computer-based controls, and a combination of all these variations. PLCs and hybrid controllers represent a flexible control scheme that allows specific logic to be developed and programmed to meet the desired design requirements of the equipment. Expanded logic can include additional features, in many cases, only limited by the programmer's available bandwidth. Caution should be taken when implementing a control system. Availability of replacement parts, support of functionality, and even over-engineering is a common pitfall. What is right for the end user isn't always the most sophisticated system and may not be the least expensive. Business drivers for control solutions should be defined that allow for the controls integrator or equipment supplier to provide you with the right solution to meet your business requirements.

ABOUT THE AUTHOR: Jim Oakes is vice president of business development for Super Systems Inc., where he oversees marketing and growth in multiple business channels and helps develop product innovation strategies in conjunction with customer feedback. He has extensive experience working in the heat treating and software/IT industries. For more information, email joakes@supersystems.com or go to www.supersystems.com.

Material and Process Options for Vehicle Weight Reduction Are Available to Automobile Designers and Heat Treaters.

By Jack Titus

FOR AUTOMOBILES WHERE COMPETING HARDening processes and materials are involved, automotive designers and heat treaters have choices when deciding how to meet efficiency standards.

There are only two methodologies for reducing the weight of an automobile: Reduce the overall size of the unit, or adopt less dense (lighter) materials for construction. Auto manufacturers in Europe and the U.S. each face their own challenges because consumers, for many reasons, desire different car models that affect the size and utility of the product offerings. The bottom-line criteria are not just to manufacture vehicles that meet the government standards but also produce vehicles that consumers will actually purchase.

The VW Golf has been and continues to be the leading vehicle sold in the EU in 2016. In the U.S., SUVs and crossovers have been the segment leader — 6,480,325 cars of all sizes were sold in 2016 in the U.S. compared to sales volumes of 9,379,597 light trucks (which includes all sizes of SUVs). Considering that SUVs and light trucks on average weigh more than passenger cars, they will require a higher proportion of weight reduction on average to meet their respective efficiency criteria.

Best-selling cars in Europe in 2016:
- VW Golf: 491,681 (most models sold)
- Renault (Clio): 310,944 (most models sold)
- VW Polo: 307,462 (most models sold)
- Ford Fiesta: 298,999 (most models sold)

Best-selling vehicles in the U.S. in 2016:
- Ford F-Series: 820,799 (½ ton pickup truck)
- Chevrolet Silverado: 574,876 (½ ton pickup truck)
- RAM Trucks: 489,418 (½ ton pickup truck)
- Toyota Camry: 388,616
- Honda Civic: 366,927
- Toyota Corolla: 360,483
- Honda CR-V: 357,335 (SUV crossover)
- Toyota RAV4: 352,139 (SUV crossover)

Meeting the 2025 CAFE standards in the U.S. certainly will be a challenge due to the weight of the vehicles; Americans love their trucks. With just eight years until 2025, improving the mileage by weight reduction alone seems undoable; therefore, a new generation of engines, transmissions, and hybrid technology likely will have to play a major role. However, EV and hybrid vehicles have yet to impress the American consumer.

Attempts at reducing fuel consumption have been adopted over the decades including decreasing the number of cylinders to reduce engine block mass. Probably the most significant and successful solution to date — and probably the most cost-effective one — has been the integration of turbochargers to four- and six-cylinder gasoline and diesel engines combined with six-, seven-, eight-, or even nine- and 10-speed transmissions. That approach also has limits, especially as the economy standards are applied to larger passenger vehicles and half-ton pickup trucks.

Where light trucks are concerned, one OEM has substituted aluminum for steel body panels, and a weight savings of 500 to 700 pounds (227 to 318 kilograms) has been reported. However, body panels are just one component subject to potential weight reduction. There are many other items that would be candidates for weight reduction such as suspension parts, transmission and transfer cases, structural, and space-frame components. Some will be fabrications; others will be castings and still others, forgings. In every case, the tradeoff between mass and strength will have to be considered as well as their potential for reducing post-heat-treat processing.

There are six materials with suitable strength-to-weight ratios used in automotive construction today:
- Magnesium
- Carbon composites
- Cast (gray iron)
- Aluminum
- Steel
- Austempered ductile iron (ADI)

Each of these materials is used for a specific performance characteristic. The advantages of these include the following:

Magnesium has slowly gained acceptance in automotive applications. Its low density and machinability makes it an ideal candidate for transmission, differential, and transfer cases. However, it lacks aluminum's overall strength, making it unsuitable for engine blocks and similarly stressed applications. It also requires a protective coating to reduce corrosion, whereas aluminum has good oxidation resistance. Probably the biggest advantage of magnesium is its availability, although it is expensive to refine. It is not found in a pure state, but it can be refined from several materials such as dolomite, magnesite ore, and sea water and salt brines, which contain about 10 percent magnesium chloride. Ocean water alone contains about 0.13 percent magnesium [1].

Carbon fiber reinforced polymer (CFRP) has one of the most advantageous strength-to-weight ratios of any engineered material; however, it is not as easily recycled as aluminum and wrought and cast ferrous alloys. Much effort is being expended to make recycling more cost-effective. Most of the virgin woven poly fiber is produced in Japan and is used for aerospace applications as well as expensive automobiles. The aerospace industry produces about 35 percent CFRP scrap used in many under-hood automotive applications. The chopped recycled fiber material does not have the structural strength offered by virgin long fiber polymers for chassis or body panel applications [2]. Although heat is used to manufacture the raw carbon fiber, it does not play a significant role in making the final product.

One of the major obstacles facing CFRP is the end-of-life products stated in ELV Directive 2000/53/EC. This directive issued a 2015 target applicable to Europe and Japan that 95 percent of an automobile ready for the scrapyard must be recoverable and recyclable. Today, it is accepted that approximately 75 percent of an automobile is made from ferrous and non-ferrous metals, and the remaining 25 percent is toxic materials.

Gray cast iron has been the material for automobile engine blocks for decades, primarily because of its low cost and adequate strength for gasoline, but not for diesel, engines. Due to its lack of as-cast strength and the fact it is not normally hardened by heat treatment, it has limited application for stressed components. As for heat treatment, gray iron is rarely heat-treated to increase hardness, but it does receive treatment such as annealing or normalizing to enhance machinability. Stress relieving after welding is also common.

Examples of cast gray iron automotive components include:

- Engine blocks
- Brake rotors
- Constant velocity joint housings
- Exhaust manifolds
- Transmission cases
- Cylinder heads

Aluminum is more expensive to manufacture than steel, but it has an attractive strength-to-weight ratio and therefore has continued to see more application in automobiles and trucks. Much of it is recycled, and it requires different forming and coating techniques. Series 2000, 6000, and 7000 grades are hardenable by solution treating, rapid water quench, and either natural or artificial (heat) aging. As such, Series 6000 is finding application in structural and body panels of vehicles. A less tangible effect of material selection is sound conduction — a material may possess the ideal properties but transmit undesirable sound and vibration to the passenger cabin.

Steel and its alloys enjoy the highest percentage of application in cars and trucks, simply because of their wide range of strength-to-weight relationship through diverse heat-treating options. HSLA (high-strength low-alloy) grades have been used for years in substructures of cars and trucks in the U.S. The more recent use of higher hardenability alloy steel has been directed to drivetrain components such as transmission and differential gears where the goal is to reduce gear mass resulting in the growth seen with HPGQ (high-pressure gas-quench) and improved distortion control. HPGQ has seen its primary growth due to increased distortion control required for the more precise and less massive gearing for multi-speed transmissions. In addition, OEMs have realized that improving the hardenability, even at increased cost, may reduce or eliminate post-heat-treat machining/grinding/straightening in the end. One of the original drivers of the growth of HPGQ was the use and recovery of helium. However, as the capital cost and maintenance of compressors have increased, nitrogen is being used again. Nitrogen forces the user to improve the hardenability of steels since the horsepower for the fan motors to equal the quench capacity of helium would have to be increased to impractical levels.

DI (ductile iron) — specifically ADI (austempered ductile iron) — has been around for decades, but it has never seemed to gain mainstream acceptance compared to steel or aluminum. In my view, one of the reasons for this has been the negative perception of heat treating in salt. However, the salts used today are much more U.S. EPA-friendly than those used in the past for carburizing and cyaniding. Austempering salts comprise a 50/50 mixture of sodium nitrite and potassium nitrate compounds. A significant quantity is recycled by recovering salts from post-wash solutions. Similar to steel, alloying elements play a significant role in ADI to produce properties that will either increase hot strength or improve tensile strength and hardness. The major advantages of ADI is its lower density, strength-to-weight ratio, and toughness with wear resistance, plus it predictably has half the distortion of martensite.

Examples of cast ADI automotive components include:

- Turbo charger housings
- Suspension and steering components
- Constant velocity joint housings
- Exhaust manifolds
- Ring and pinions

CONCLUSION

There are several weight-reduction options regarding material and processes available to designers and heat treaters for automotive applications. However, the challenges are two-fold:

- Can the weight reduction choice be cost-effective in vehicle pricing?
- Can the selected process be integrated cost effectively into the predictive process automation (PPA) methodology of the manufacturer?

From a heat-treating viewpoint, controlling distortion in drivetrain components is a primary goal in reducing manufacturing cost. Since steel and ductile iron have the greatest potential for choosing an appropriate strength and wear-resistance parameter, austempering with its predictable and uniform growth seems poised to satisfy a number of weight-related obstacles. The one remaining issue facing austempering, the "Holy Grail of bainite," is hardness. Additional research in micro-alloying ADI and steel would solve that major hurdle.

REFERENCES

1. "How Is Magnesium Metal Produced?" Commodities: by Terence Bell, Updated August 14, 2016.
2. Composites World, Recycled carbon fiber update: Closing the CFRP lifecycle loop, Ginger Gardiner, article: 11/30/14.

ABOUT THE AUTHOR: Jack Titus can be reached at (248) 668-4040 or jtitus@afc-holcroft.com. Go to www.afc-holcroft.com.

These Seven Simple Steps Can Help You Prepare a Successful Temperature Uniformity Survey.

By Jim Grann

PERFORMING A TEMPERATURE UNIFORMITY survey (TUS) can be somewhat of a daunting process. After all, a TUS carries the weight of not only being necessary for validating your equipment but also being required for those that adhere to AMS 2750E.

Typically speaking, a TUS should be performed prior to the first use of the furnace; the frequency it is performed thereafter depends on what furnace classification/instrumentation group you are subscribing to and the overall performance of your furnace. This is regardless of whether you adhere to ancillary specifications for aerospace applications. For those who do adhere to stricter specifications, such as AMS 2750E, you should always refer to them for your specific TUS requirements.

Half the battle of performing a TUS, though, is preparation. To aid in the preparation process, here are seven steps that are instrumental in streamlining your TUS efforts.

1. Determine the desired temperature uniformity range.

The first step in preparing for a TUS is making sure your furnace is capable of meeting the temperature uniformity range needed for your specific parts and processes. If this is your first time performing a TUS, we recommend referring to your OEM specifications to verify that your furnace is performing according to its design classification and the specific class at which it was sold.

If you are performing a TUS in adherence with AMS 2750E, you should determine what the design capabilities of your furnace are and what furnace classification level you are going to test. Vacuum furnace systems are classified into six categories: Class 1 through Class 6. Class 1 has the most stringent temperature requirements with the smallest allowable deviation in temperature uniformity, while Class 6 applies the least restrictive temperature requirements and the widest allowable deviation in temperature uniformity. The range of temperature uniformity varies from ±5°F (±3°C) to ±50°F (±28°C).

It is also important to note that while many manufacturers claim to be AMS 2750E compliant, there are actually several different versions that constitute compliance in regard to vacuum heat-treating systems. As such, it is imperative that you know the process for which you seek compliance, so you can ensure the furnace classification you are purchasing meets your specification requirements.

2. Select number of sensors.

The size of the furnace, as well as the temperature uniformity you are trying to obtain for your specific process, can affect the number of required TUS sensors. Ipsen recommends that wherever you decide to place the thermocouples (TCs), you should make it part of the preparation process and ensure employees who perform the TUS are also trained on the preparation process. This will help reduce any variability that may occur when tuning the equipment for later surveys.

If you are performing a TUS in accordance with AMS 2750E, the number of required TUS sensors is mandated in Table 11 of AMS 2750E. This number is dependent on the specified workspace volume. While the AMS 2750E specification mandates the number and basic geographical location of the sensors, where you place the TC numbers (e.g., TC 1, TC 2, TC 3) is up to you.

Figure 1 shows some examples of how the sensors could be positioned, depending on the furnace size, instrumentation class, and total number of sensors required.

3. Understand furnace temperature ranges.

A single furnace can be qualified to operate within ±10°F at one temperature range, as well as within ±25°F at another temperature range. If the TUS shows the furnace meets the more stringent temperature variation (e.g., ±10°F at 1500°F), then it also automatically meets the less stringent temperature variation (e.g., ±25°F at 1500°F).

This is also true for a TUS performed according to AMS 2750E specifications. As stated in section 3.5.2 of AMS 2750E: "A furnace may have multiple qualified operating temperature ranges. For example, a furnace may be qualified to operate within ±10°F from 600° to 1,000°F and ±25°F from 1000° to 1800°F."

4. Replicate furnace parameters.

It is also important that the testing parameters utilized during the TUS replicate — to the best of your ability — the normal operation of the equipment when it's in production. This means, if fans and/or partial pressure are utilized during production, they should also normally be utilized during the TUS.

If you adhere to AMS 2750E, refer to section 3.5.8 for further details, as well as a few noted exceptions.

5. Decide on load condition.

While the furnace parameters should duplicate the normal operation of the equipment during production, the load condition is one of the

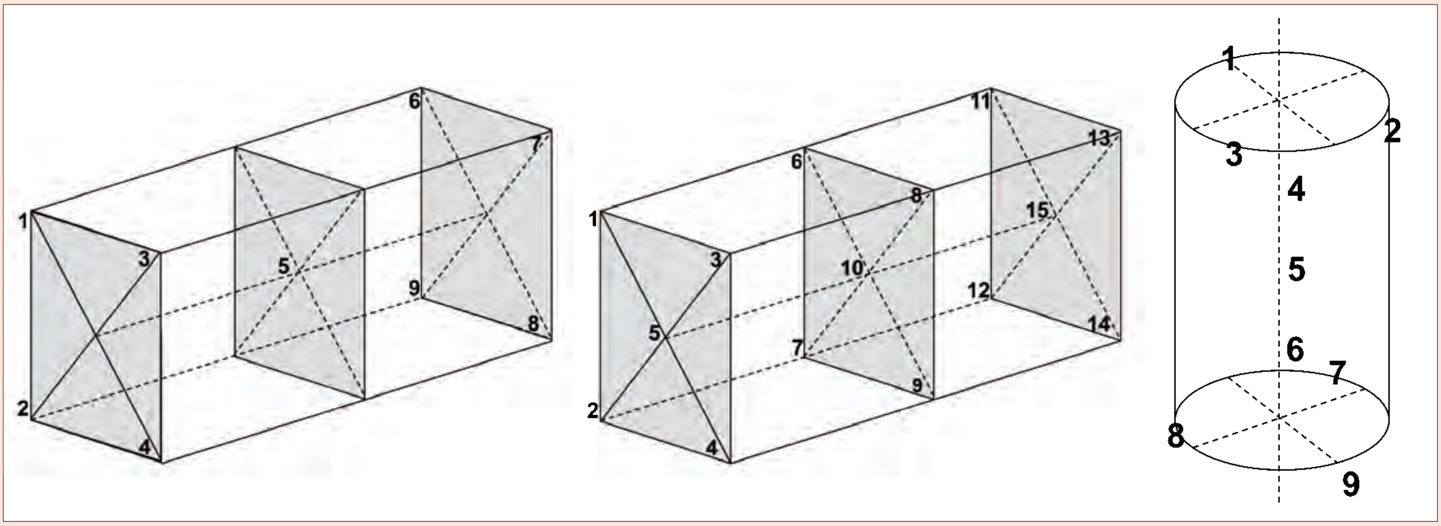


Figure 1

exceptions to that rule. The TUS can be performed with an actual production load, a TUS fixture, an empty furnace, etc.

This is also true for AMS 2750E as stated in section 3.5.10: "A TUS may be performed with an actual production load, simulated production load, a rack, or empty." However, dependent on the load condition used and where the TUS sensors are attached, there are required thicknesses for the heat sink and/or load material. Refer to sections 3.5.10.1 and 3.5.10.2 in AMS 2750E for additional details.

6. Choose furnace atmosphere.

Whatever atmosphere you utilize during production should be used during the TUS. However, you can use an atmosphere of air or inert gas (furnace-design specific) if:

- The process uses a required atmosphere that might contaminate the test sensors.
- The atmosphere might pose a safety hazard.

In short, whatever the production environment is, you should emulate it to the best of your ability (unless it's one of the specified exceptions) when performing a TUS.

7. Perform TUS data collection.

When you perform the TUS, it is important to follow the necessary data collection procedures. If adhering to AMS 2750E, specific requirements are laid out in sections 3.5.13.3–3.5.13.3.4.

Overall, some key points to remember include:

- Start data collection before the control TC and TUS sensor reach the lower tolerance limit of each test temperature.
- Do not let any sensors exceed the upper temperature uniformity tolerance.
- Continue data collection for at least an additional 30 minutes after stabilization.

As you finish preparing for the TUS, you should also make sure your test load (e.g., box, basket, or fixture) is properly placed. To start, center your test load from left to right so that the distance between the heating elements and test TCs are equally spaced from the surface of the heating element to the test TC.

Also, check the test load to make sure it is symmetrical with regard to the front and rear positions of the work zone. You can do this by ensuring the front and rear TCs' view of the heating element is equal. For example, if the front TC is centered between the heating elements, then the rear TC should also be centered. Or, if the front TC starts at the center of a heating element, so should the rear element.

Finally, once you have finished establishing the test load's front-to-rear position, mark the hearth rails with a Dremel tool, hacksaw, etc. These marks will help you accurately place the workload for subsequent temperature surveys and remove variability from the testing.

It is also important to always take into consideration the age and condition of the jack panel. If it is older than two years or showing visual signs of degradation, it should be replaced before performing the survey. An older or damaged/discolored jack panel will cause errors in the temperature readings during the TUS.

In the end, properly validating your equipment helps ensure uniformity, reliability, and, most importantly, repeatability. Learn more about adhering to AMS 2750E and other specifications at www.IpsenUSA.com/Articles.

ABOUT THE AUTHOR: Jim Grann, Ipsen's senior technical manager, started with Ipsen in 1978, and since then, he has held roles in quality control, technical support, and Ipsen U instruction, among others. He is a technical expert who works with support services, furnace orders, inspections, and special processes. His 38 years of experience and interactions with customers around the world allow Grann to provide excellent solutions and support when troubleshooting furnace- and process-related issues.

Process Evaluations Can Help Narrow Down the Causes of NMTP Formations that Can Reduce Component Performance.

By Lee M. Rothleutner

WHETHER FORMED DURING A CONVENTIONAL quench and tempering process, carburizing, or induction hardening, non-martensitic transformation products (NMTP) are widely considered undesirable microstructural features. However, both the cause of NMTP formation and the extent to which NMTP impairs component performance are points for deliberation.

IDENTIFICATION

By definition, NMTP comprises all microstructural features other than martensite that transform from austenite upon cooling when a fully martensitic microstructure is intended. The fact that NMTP forms during transformation from austenite upon cooling is an important distinction, particularly in highly dynamic processes such as induction hardening. If an induction-hardened process is not optimized, it can result in both retained and transformed non-martensitic constituents, with only the latter truly being considered NMTP. Retained constituents such as ferrite result from insufficient temperature and/or time at temperature to fully transform the microstructure to austenite before cooling. Identifying retained versus transformed constituents is critical in effectively improving the specific heat-treating process.

Figure 1 shows an optical micrograph of a 1045 steel in a region of an induction-hardened case that was intended to be fully martensitic. The dark etching features are readily identifiable as non-martensitic constituents; however, not all are easily identified as NMTP. Understanding the processing used to generate the microstructure and/or higher magnification imaging are usually required to distinguish between retained and transformed non-martensitic constituents. Figure 2 shows a higher magnification secondary electron image of a region adjacent to the micrograph shown in Figure 1. Arrows indicate the microstructural features in question. Based on the sharp ferrite morphology and carbide precipitation behavior, the constituents appear to have formed upon cooling, confirming their designation as NMTP.

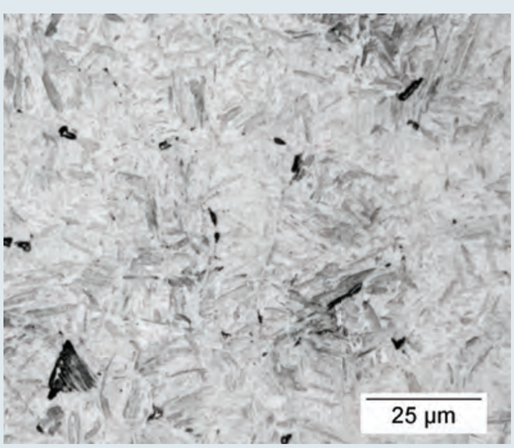


Figure 1: Optical micrograph of a region within the induction-hardened case of a 1045 shaft showing NMTP as dark etching features [1]

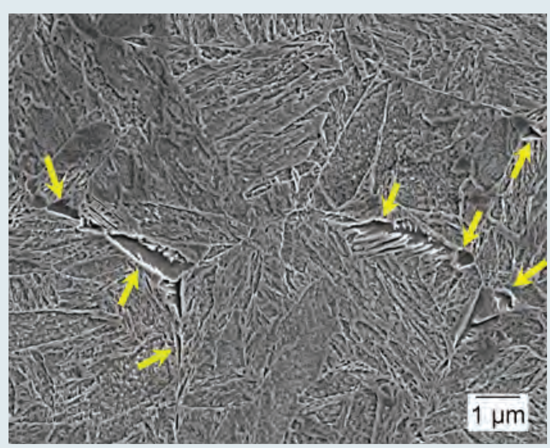


Figure 2: Scanning electron microscope secondary electron image of NMTP identified by arrows [1]

POTENTIAL CAUSES

In most cases, NMTP formation is caused by an unexpected change in process. A "change in process" can be narrowed to anything that alters the austenitizing cycle (e.g., temperature and/or time at temperature) or the cooling characteristics (e.g., cooling rate and quench severity) of the component. Potential causes include, but are not limited to, the following:

Change in Performance of Fixed Assets and Tooling

In both furnace and induction heat treating, preventive maintenance is critical. Ensuring the equipment and tooling are performing as intended is key to a stable and capable process.

Change in Part Stacking or Spacing of Batch-Processed Parts

Operator-controlled factors such as part stacking consistency and spacing during batch heat treatment can result in significant process variations, especially with regard to cooling characteristics. In addition, each part geometry usually requires a slightly different configuration to achieve the desired results. Having well-established procedures, clearly documented work instructions, and adequate operator training minimizes inconsistencies.

Change in Heat-Treating Atmosphere

During austenitizing, it is critically important to have precise control of surface oxidation. Changes in alloy chemistry localized at the surface, such as decarburization and alloy depletion, can result from oxygen exposure during heat treatment. One well-known example of this phenomenon is intergranular oxidation (IGO), which can occur during gas carburizing. IGO has been observed to reduce the hardenability of the matrix adjacent to the oxides by depleting the region of alloying elements such as manganese (Mn), resulting in NMTP [2].

Change in Quenchant Characteristics

The reduction of cooling rate and quench severity can be specific causes of NMTP formation. Following quenchant supplier-recommended maintenance procedures helps ensure acceptable results.

Although many of the scenarios that can result in NMTP are listed here, a conceptual understanding of the factors controlling NMTP formation is often more useful when actively troubleshooting a process. Figure 3 shows continuous cooling transformation (CCT) diagrams for three plain carbon steels: 1008, 1045, and 1080. For the sake of simplicity, only the 1-percent transformed locus for each phase or constituent is shown. This figure clearly shows the relationship between carbon composition and transformation behavior for a given cooling rate. As carbon content increases, transformation temperatures decrease, as does the cooling rate required to achieve a specific microstructure.

For example, one hypothesized scenario in which this figure is useful is under-heated 1045 steel ("under-heated" meaning insufficient temperature or too little time at temperature during austenitization). In this case, it is unlikely that all the carbon will go into solid solution, resulting in regions that may exhibit transformation behavior analogous to steels of lower carbon composition and shift the CCT to slightly higher temperatures and shorter times (more toward a 1008 steel). Consequently, a higher cooling rate is required to achieve a fully martensitic microstructure.

Figure 3 also shows the importance of cooling rate control. For both the 1045 and 1080 steels, the bainite "nose" has a nearly vertical region where the cooling rates are close to the critical cooling rate (i.e., the minimum cooling rate required to create a fully martensitic microstructure). This behavior indicates that these steels can exhibit significant amounts of NMTP with only minimal reduction in cooling rate.

INFLUENCE ON PERFORMANCE

Qualitatively, there is no doubt that NMTP decreases performance in components that are intended to be fully martensitic [2]. However, there is little literature quantifying the deterioration of properties such as strength, ductility, and fatigue performance as a result of NMTP. Nevertheless, the concept of fatigue performance reduction due to the presence of NMTP is relatively straightforward. In general, the fatigue limit of steels scales with tensile strength [4]. Therefore, a component containing microstructural features with lower strengths than martensite, such as NMTP, would likely accumulate fatigue damage at an accelerated rate and would ultimately nucleate a fatigue crack at lower cycles than a fully martensitic component.

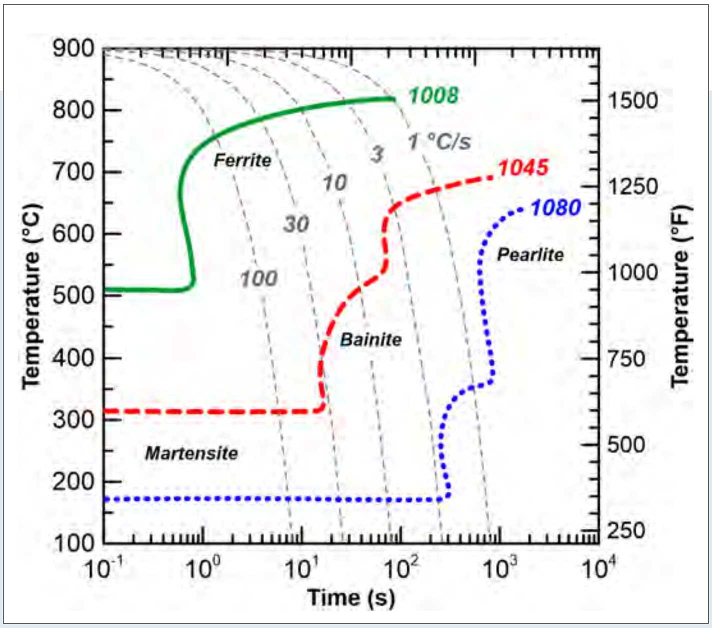


Figure 3: Continuous cooling transformation diagrams for 1008, 1045, and 1080 plain carbon steels, indicating the initiation of austenite decomposition into different phases and constituents (in this case, 1-percent transformed). A range of cooling rates is shown for reference. Developed using data from EWI [3]

CONCLUSION

NMTP can be an indication of a variety of issues. Identifying the root cause often requires a systematic evaluation of the process, but having a good understanding of the fundamentals of NMTP formation can help narrow the focus more quickly.

REFERENCES

1. L.M. Rothleutner, "Assessment of the microstructure and torsional fatigue performance of an induction hardened vanadium microalloyed medium-carbon steel." Ph.D. diss., Colorado School of Mines. Arthur Lakes Library, 2016.
2. G. Krauss, Steels — Processing, Structure, and Performance, 2nd Edition, ASM International, Materials Park, OH, 2015.
3. Edison Welding Institute, "TTT and CCT Prediction," accessed March 10, 2017. http://calculations.ewi.org/vjp/secure/TTTCCTPlots.asp.
4. G. Dieter, Mechanical Metallurgy, Vol. 3. New York: McGraw-Hill, 1986.

ABOUT THE AUTHOR: Lee Rothleutner is a principal development engineer with The Timken Company. He received his Ph.D. in Metallurgical and Materials Engineering from the Colorado School of Mines. His research experience includes microstructural evolution during induction hardening, torsional fatigue, and vanadium microalloying. Rothleutner serves on the Heat Treating Society Membership Committee and is a veteran of the U.S. Coast Guard. He can be reached at lee.rothleutner@timken.com.

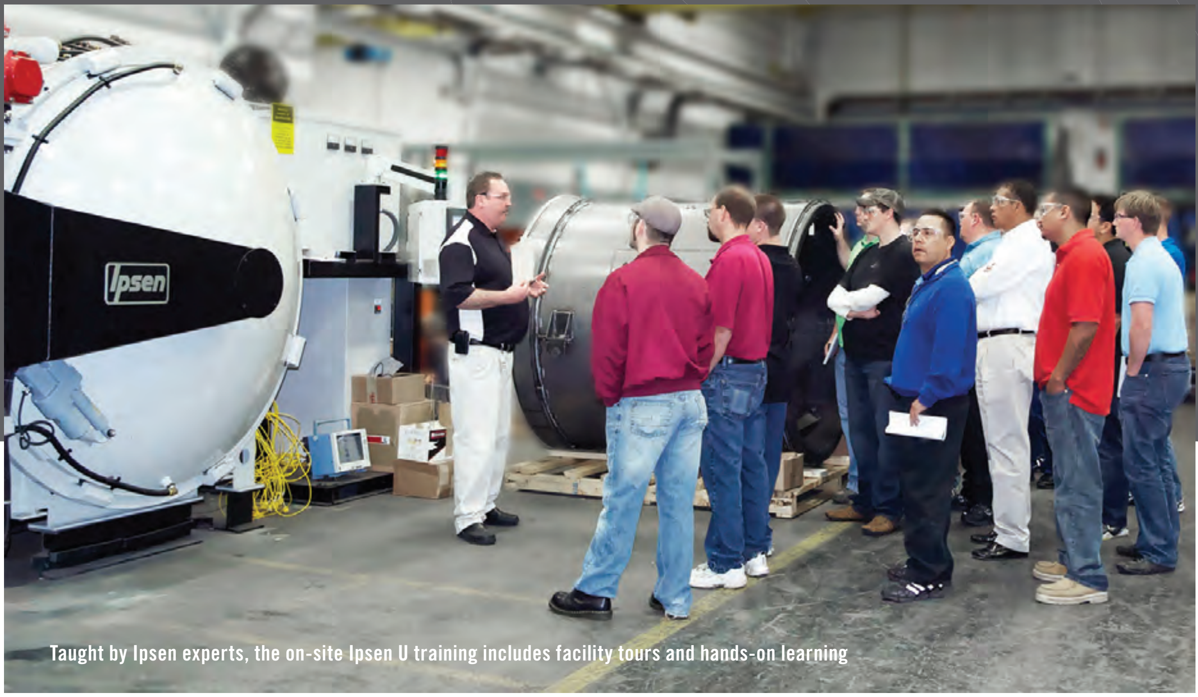
COMPANY PROFILE

Ipsen

A broken-down pottery kiln, an engineering degree from Brown University, and an entrepreneurial spirit helped to successfully launch Ipsen as a global leader in the heat treatment industry.

By Kenneth Carter

Ipsen's predictive maintenance software platform, PdMetrics®



Taught by Ipsen experts, the on-site Ipsen U training includes facility tours and hands-on learning

SINCE ITS HUMBLE BEGINNINGS IN 1948, IPSEN HAS become much more than just an equipment manufacturer. With an operation that spans across countries and oceans, Ipsen is a global supplier of integrated heat treatment solutions.

This heat treatment company was founded on the principle of making a stronger, safer world through innovation and hard work, and it continues to deliver proven technology for a range of applications that enables customers to transform space exploration, improve titanium medical implants, and develop more efficient cars and jet engines.

Operating in all the major markets around the world, Ipsen supports a wide range of industries that include aerospace, automotive, commercial heat treating, energy, industrial machinery, medical, and tool and die — to name a few.

Ipsen doesn't stop at providing technologies used in many mission-critical applications, though. The company continues to emphasize the importance of the customer experience, delivering full-scale solutions aligned with each customer's desired outcome.

WIDE RANGE OF SOLUTIONS

Ipsen not only designs, manufactures, and services vacuum and atmosphere technologies around the world, but the company also has its own supervisory controls systems and predictive maintenance software platforms. With more than 10,000 systems installed worldwide, Ipsen leads the industry with the experience necessary to provide optimum technology. That experience lets customers achieve maximum flexibility and meet strict industry demands.

From the time Ipsen starts a project to the very end, the company provides comprehensive service and support for any brand of vacuum or atmosphere furnace. This assistance includes process development, material-handling systems, factory layout planning, and integration with current production processes and factory operating systems.

"With aftermarket services representing more than 45 percent of our global business, providing comprehensive, immediate service and support to our customers is a top priority," said Geoffrey Somary, CEO of Ipsen USA.

Ipsen also knows obtaining precise process and metallurgical results are essential. This is why the company focuses on process research and development, as well as on providing advanced customer support, training, and process testing to ensure customers obtain the desired results.

PDMETRICS® SOFTWARE PLATFORM FOR PREDICTIVE MAINTENANCE

As part of this focus on innovative solutions, one of Ipsen's recent achievements was the development of the first predictive maintenance platform for the thermal processing industry.

"Since we introduced the PdMetrics platform for predictive maintenance in 2015, it has dramatically transformed how companies approach maintenance," Somary said. "This software platform securely connects to a network of integrated sensors on your furnace to gather data, run algorithms, and provide you with real-time diagnostics that actually matter."

Building upon existing maintenance programs, PdMetrics also provides automatic maintenance reminders based on furnace performance and component usage. With the ability to minimize unplanned downtime, reduce costs, and place a team's attention where it's most important, the PdMetrics platform helps companies save valuable resources in terms of time, energy, and focus.

IPSEN CUSTOMER SERVICE

The Ipsen Customer Service (ICS) Team helps keep equipment running at peak performance and minimizes costly downtime through upgrades, retrofits, parts, maintenance, service, and training. No matter where customers are in the world, the ICS Team is available to provide timely support and the necessary solutions so that production can be kept on schedule.

For example, when one customer had unique requirements for its parts that necessitated a specific cooling pattern and design, the ICS Team was able to provide a custom solution. Once they reached a better understanding of what the customer wanted, the necessary Ipsen team members were brought in to provide valuable input and devise an initial proposal.

"When this customer came to us with their special requirement, we started the collaborative process by discussing their end goal, timeline, and budget," Somary said. "Throughout all of this, we kept in mind the customer's process and the effects any modifications to the equipment could have on the process. We do this for all the projects we work on — whether it's optimizing the cooling or heating rate, upsizing the equipment, doing a complete rebuild, or providing a material handling system."

Once a solution was reached, Ipsen reviewed every detail with the customer to make sure it would meet their needs. Once Ipsen and the customer had decided on the full scope of the project, Ipsen provided a fully engineered solution that met all process, specification, budget, and timeline requirements.

COMPREHENSIVE SUPPORT

Over the past few years, Ipsen has focused on retooling the ICS Team so they can be increasingly supportive of customers' needs and expectations.

This emphasis on offering immediate customer support has included expanding Ipsen's designated Regional Service Centers. In addition to these centers, which are located across the United States to support customer needs locally, Ipsen also has a network of 120-plus service technicians that provides global support.

"During a recent vacuum furnace hot zone installation, one of our field service engineers discovered that the power-feed connections, while currently serviceable, could potentially fail in the future," Somary said, relating an instance of the extensive support provided. "He took the time to make sure the customer was aware of the potential issue and suggested a repair in the near future. It is this type of attention to detail and positive customer relationship that we pride ourselves upon and expect from all of our team members."

In addition to comprehensive customer service, Ipsen also is committed to hiring the best people, as well as providing current employees with the tools needed to ensure continued success.

"As we continue to grow globally and advance so our customers can continue to innovate, one of the challenges is how to find new ways to attract, train, inspire, and retain skilled, qualified workers," Somary said. "We have developed some unique ways to tackle this challenge that have proven very effective."

With this focus on fostering a workplace culture that encourages innovation and new ideas, Ipsen worked on changing the recruitment strategy and training new hires quickly and effectively.

Ipsen Corporate Academy was born from these goals. The Academy features a full-time trainer who teaches a structured six months books-to-business program to new hires. Ipsen also took an in-depth look at its onboarding process, customizing it to convey the values the company stands for — innovation, industry-leading heat treatment solutions, and high-quality services — as well as give new employees the tools they need to succeed.

The Titan® vacuum furnace is one of Ipsen's global modular platforms

EDUCATING THE INDUSTRY

However, Ipsen's education and training programs aren't just for Ipsen employees. Having provided training to the heat treatment industry for 30-plus years, Ipsen goes to great lengths to share its industry knowledge with the companies it serves.

That's where Ipsen U comes in. Ipsen U's three-day courses have a long-standing tradition of teaching best practices and helping improve equipment's performance and life span. The classes provide attendees with a broad overview of furnace equipment, processes, and maintenance, as well as a hands-on approach to learning while receiving qualified tips directly from the experts.

Ipsen experts also travel around the world to train and share their knowledge with thousands in the industry. In addition to providing training at customers' facilities, Ipsen also takes part in annual industry trade shows and holds one-day seminars such as Meet the Heat and HeatTec in Europe, maintenance seminars in the U.S., and customer days in China.

EVOLVING WITH THE INDUSTRY

Ipsen's constant vigilance in training and emphasis on innovation will be essential as the heat-treating industry continues to evolve to a point where thermal processing systems and applications will seamlessly intersect with the latest digital technologies.

"As more companies begin to realize the possibilities of the Internet of Things (IoT), I believe we will continue to see it emerge in ways that positively impact the productivity, efficiency, and operations of industries around the world — including the heat-treating industry," Somary said.

After all, integrating complex physical machinery with networked sensors and software for data trending and analysis contributes to product development and enhanced maintenance strategies. It also opens the door to new opportunities for growth. Over time, physical devices and the manufacturing process will become one entity as the IoT and integrated machines become more prevalent. In other words, the process itself will eventually become part of the physical, integrated system.

"Of course, PdMetrics is only a first step toward this goal," Somary said. "Imagine a future where downtime is always avoidable … a future where the best functioning furnace teaches another, lower-performing furnace how to improve. This is the future we are building and innovating toward."

BEGINNING WITH A KILN

With a solid foot in the future — and around the world — it might be hard to believe that Ipsen began as a project for Lorraine Ipsen, the wife of company founder Harold Ipsen.

Lorraine made small ceramic figurines and dishes for friends and family. When her kiln broke down, Harold Ipsen — equipped with an engineering degree from Brown University — decided to design and build a replacement instead of buying a new one.

The new kiln produced wonderful results: no more cracking. As friends and acquaintances heard about the kiln, many began asking him to build one for them as well. It soon occurred to Harold Ipsen that he could take some of the elements of his invention and apply them to the business of heat-treating steel. With that decision, Ipsen Industries was born in Rockford, Illinois.

The company grew rapidly during the 1950s, including the addition of a manufacturing location in Kleve, Germany. Ipsen ended the decade by moving into a larger facility near Rockford in Cherry Valley, Illinois. On April 19, 1965, Harold Ipsen died in a plane crash at the Greater Rockford Airport. His family sold the company soon after.

The company continued its growth into the mid-1980s when Ipsen — a market leader in atmosphere furnaces — merged with Abar Corporation, a market leader in vacuum furnaces. Together, they became AbarIpsen Industries. In the 1990s, AbarIpsen expanded into China and India, becoming the first true global supplier of heat-treating systems at a time when customers were building factories all over the world and demanding the same AbarIpsen quality everywhere. During this decade, the company also changed its name back to Ipsen.

The Atlas integral quench batch atmosphere furnace offers ease of integration

In 2000, Ipsen purchased VFS (Vacuum Furnace Systems) Corporation in Souderton, Pennsylvania, which added another brand and specialty skillset to the Ipsen portfolio. Ipsen later expanded into Osaka, Japan, in the same decade, establishing wholly owned manufacturing facilities in the United States, Germany, China, India, and Japan.

Today, Ipsen continues to provide expert-driven solutions that strengthen heat treatment throughout the world with an extensive network of global locations and partnerships in America, Europe, and Asia, along with representation in 34 countries.

STRONG FOCUS ON THE FUTURE

As Ipsen continues to position itself as an industry leader with a focus on providing expert-driven solutions, the company plans on emphasizing some key areas over the next few years:

Services: Ipsen wants to double its global service network over the next five years. While it supports customers for any brand of vacuum or atmosphere heat-treating system, the company also will focus on expanding its product portfolio to include a broader range of custom equipment solutions.

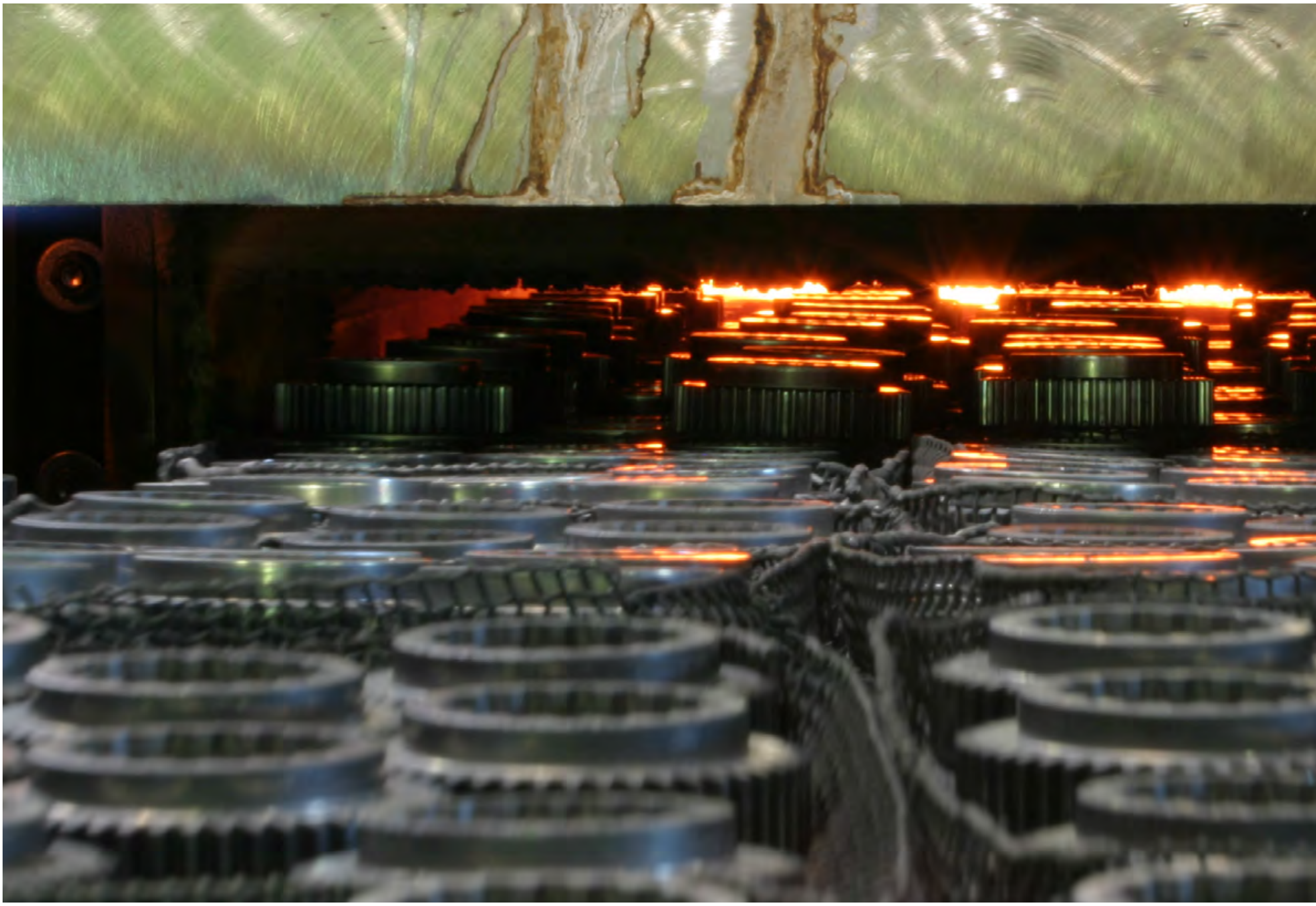
Innovation: Ipsen spends millions of dollars annually on innovation, and the company looks to double down on those investments to further differentiate its products.

Expand variety of solutions: Ipsen prides itself on fully supporting the customers' complete value chain. This means the company doesn't just provide the furnaces and controls, but rather delivers full-scale solutions that play an essential role in making mission-critical parts.

Winning culture: Ipsen is not only focused on hiring employees who believe in innovation and pushing the boundaries of what's possible, but also on maintaining a culture characterized by trust, cooperative leadership, open communication, and teamwork.

With Ipsen's myriad of industry contributions and decades of experience, it's easy to see how Harold Ipsen's legacy of innovation still lives on in all the company creates. Whether it is the company's versatile heat treatment systems, advanced process technology, or extensive customer service, Ipsen aspires to provide cutting-edge solutions that continuously improve and refine its customers' operations.

FOR MORE INFORMATION, go to www.IpsenUSA.com.



Hardening of Powder Metallurgy Parts 101

Definitions and hardening methods used with powder metallurgy are described to provide a basic understanding of the nuances associated with the process.

By Richard H. Slattery

Powder metallurgy (PM) is unique in that one has the ability to create a process system (alloy, process steps, and secondary operations) specific to the requirements of a given application. The following is a brief overview of the key terminology associated with the hardening of PM parts.

DEFINITIONS

Particle Hardness Versus Apparent Hardness

Any hardened PM part will have both an apparent and particle hardness.

The apparent or macrohardness is a composite value with the key influences being part density and particle hardness. This is best described as a measure of yield strength.

The particle or microhardness is the measure of hardness, at a micro level, in the hard phase (martensitic region) of the microstructure. This is best described as a measure of wear resistance. Note: Particle hardness is unaffected by density.

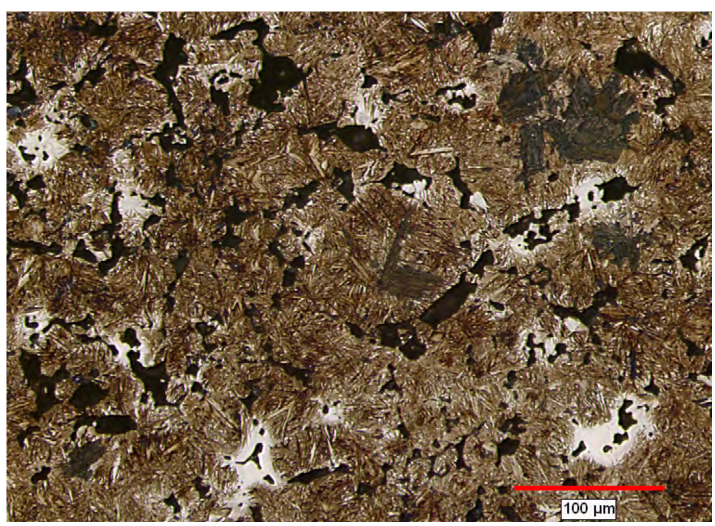
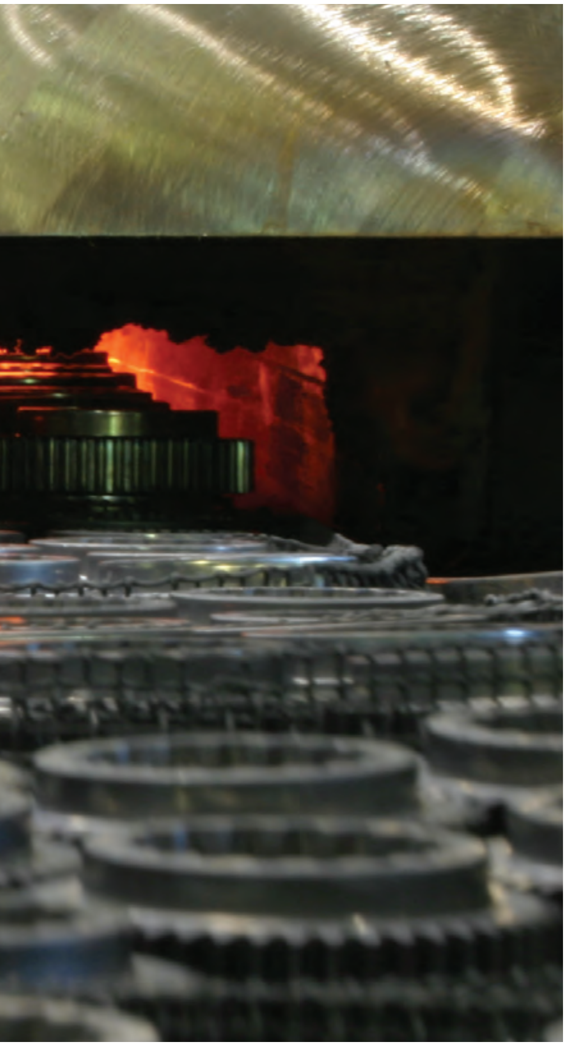


Figure 1: MPIF FLNC 4408, sinter hard microstructure, 75 to 80 percent martensitic

Case Versus Core Hardness

Often with case-hardened parts, there will be separate hardness specifications for both the case and the core of the component. These are typically particle hardness specifications, but this should always be confirmed with the customer. The case region is the outer "skin" of



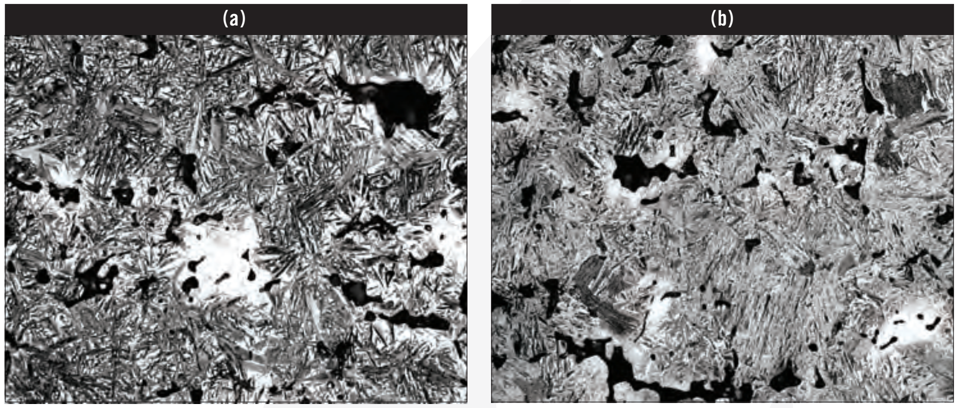


Figure 2: (a) Case, sharp acicular martensite needles; (b) Outer core, lath martensite

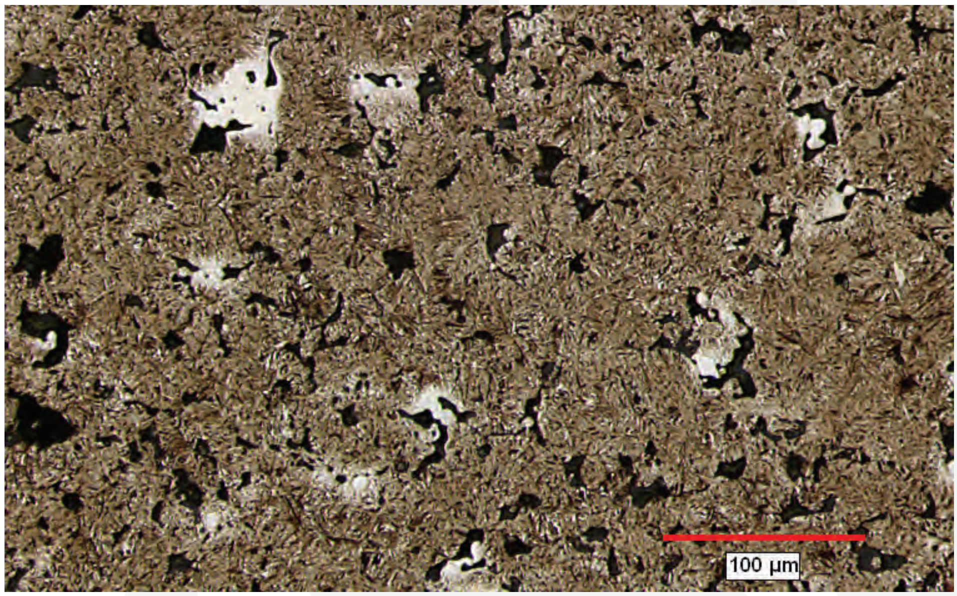


Figure 3: MPIF FLN2 4405, carburized microstructure, through-hardened, fully martensitic with nickel-rich regions

the part and is typically about 0.010-0.015 inch (0.25-0.38 millimeter) deep, into the part. Oftentimes, the customer will define a minimum case depth. The case depth is the result of the austenitizing time in heat treat and the part density (i.e., a lower dense part achieves case depth more quickly). The core region of a part begins at the end of the case (in this example, 0.015 inch deep), and the hardness diminishes as one gets further from the case, for example, from HRC 50 to HRC 40, micro, assuming a minimum case hardness of HRC 55. Case-hardened parts typically have a core carbon content of <0.5 percent.

HARDENING METHODS

Sinter Hard

A sinter-hardened part is one that is hardened in a sinter furnace by using accelerated cooling coupled with a sinter-hardenable alloy system. This is an atmosphere quench, as opposed to an oil quench typically used at heat-treat facilities, and carries with it the advantage of reduced distortion for dimensional stability. Sinter-hardened parts are through-hardened, meaning that the case and core have the same hardness. The reason for this is that they have a higher core carbon (typically 0.7 to 0.9 percent) than a case-hardened part. Sinter-hardened parts at a 6.8 g/cm^3 density typically have an apparent hardness of HRC 25 and a particle hardness of HRC 55.

Case Harden

Case-hardened parts typically have a low core carbon (ductile core) and a hardened surface for wear resistance. Case hardening is typically performed in an integral quench furnace and is commonly referred to as a quench-and-temper process. Parts are gas carburized at about 1550°F in an atmosphere with a furnace carbon potential higher than the carbon content of the component being heat-treated. Then the parts are oil-quenched, washed, and tempered. This is also referred to as case carburizing.

Through Harden

A through-hardened part typically has a core carbon of >0.5 percent. Through-hardened parts will usually have greater yield strength than case-hardened parts, as both the surface and core are hard. Through hardening is also achieved via the quench-and-temper method. In the through-hardening process, the furnace carbon potential is typically the same as, or slightly higher, than the carbon content of the component being heat-treated.

Carbonitriding

Carbonitriding is performed for applications that require extreme surface wear resistance. This process is performed using the quench-and-temper method with one exception: In carbonitriding, the components are carburized to achieve carbon consistency between the furnace atmosphere and the parts, and then NH3 is added to the atmosphere, while maintaining carbon potential, to apply a nitride "skin" to the surface of the parts. Then the parts are oil-quenched, washed, and tempered.

Induction Harden

Induction hardening is used to harden only a specific region of a part, e.g., a critical wear surface, and have the rest of the part remain soft. This operation is often performed on parts that have a critical wear zone yet also need to be machined. An example of this is a gear that would need to have hard teeth for wear resistance as well as a tight-tolerance machined feature in a softer region of the part. If a part is to be induction hardened, it needs to have a relatively high core carbon (0.8 percent), as this is not a carburizing method. In the hardened region, a typical apparent hardness of RC 35 and a typical particle hardness of RC 58 can be expected.

MATERIALS

The hardening method is only one step in a processing system of a PM component that is engineered for a specific application. The selection of the proper material is also critical and dependent upon the application requirements. Characteristics such as density, yield and tensile strength, ductility, and wear resistance should all be considered.

PROCESS

The process design is also critical to the success of the component in its application. Press, sinter, machining, and secondary hardening operations all define the characteristics of the finished part.

REFERENCES

1. Metal Powder Industry Federation (MPIF).

ABOUT THE AUTHOR: Richard H. Slattery is vice president of engineering at Capstan Atlantic in Wrentham, Massachusetts. Prior to this, he served as Capstan's director of quality and technology. Slattery has been in the powder metallurgy industry for over 20 years, working in both powder and parts production. His research and technical focus has been in the development of high-performance precision helical pinions and has researched and developed the densification and crowning of planetary PM pinions for aggressive applications. Additionally, he has authored numerous technical articles and has been published in several trade industry publications. Affiliations include APMI, SAE, SME, AMA, and AGMA.

Figure 4: MPIF FL 4405, carbonitrided, microstructure; white halos surrounding pores are nitride layer

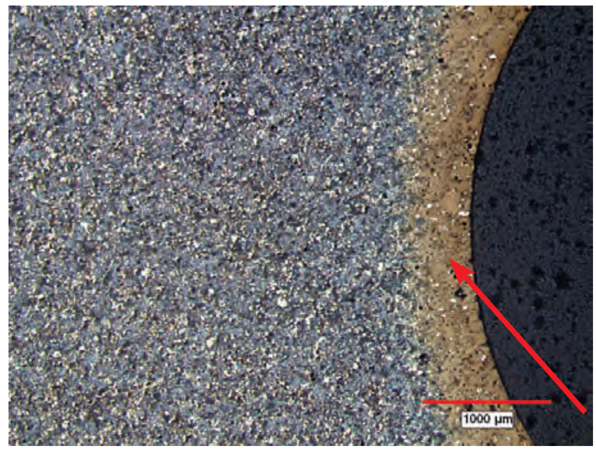


Figure 5: FL material, induction-hardened region

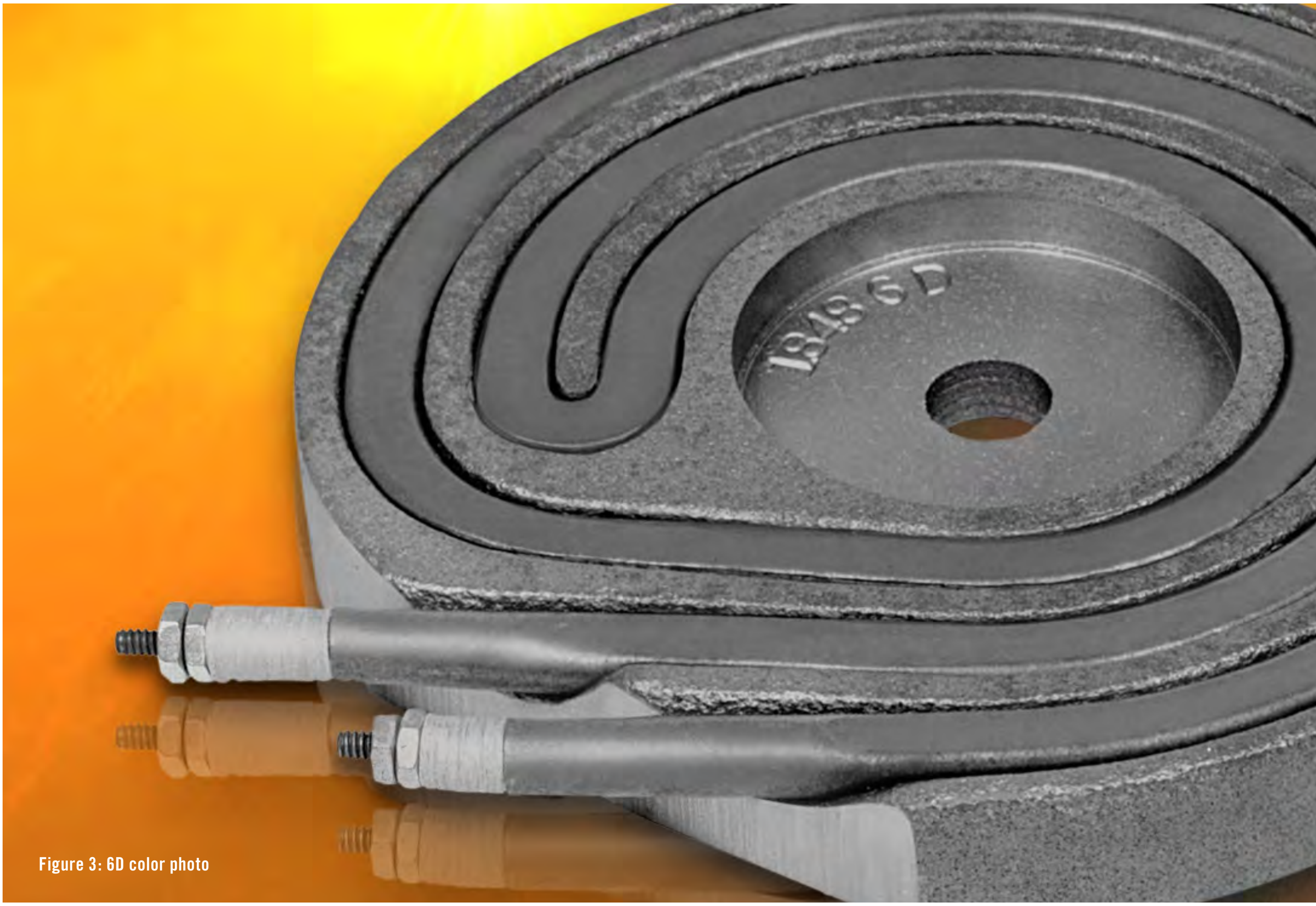


Figure 3: 6D color photo

Vacuum Diffusion Pumps

With no moving parts, diffusion pumps become a durable and reliable tool for many industrial applications.

By E.W. Whitney III

Vacuum diffusion pumps come in a variety of sizes and are capable of producing high vacuum in a range from 10^{-2} to 10^{-10} torr. It's a simple operational principle that makes it desirable for many industrial applications including electron-beam microscopy, vacuum deposition, coatings, and vacuum furnaces.

The durability and reliability of a diffusion pump is based on the absence of moving parts. The operation of the pump depends on the presence of two elements: diffusion pump oil and a heater. The heater heats the boilerplate, which brings the oil to a boiling temperature. The rising oil vapor is compressed in a vertically tapered stack with jet openings along its height. The jets are angled so as to create an umbrella of vapor that captures air.

Cool condensing coils on the pump's exterior continue the downward motion of the oil, and the air is released at the base of the pump. The top of the pump is connected to a vacuum chamber, and the differential pressure between the top and bottom of the pump will draw down high vacuum in the chamber.

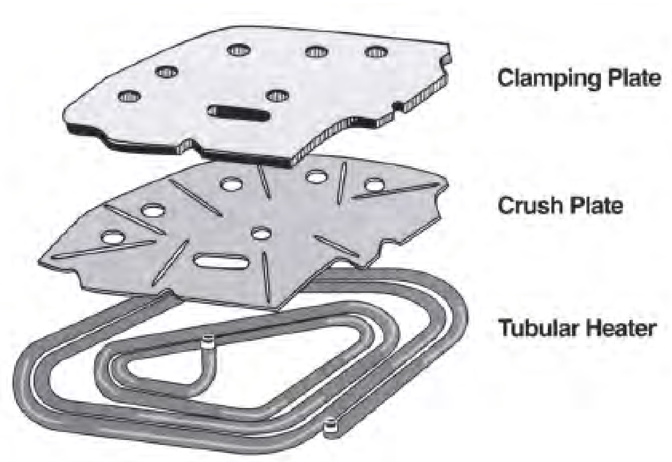


Figure 1: Conventional crush plate assembly

Maintenance for a diffusion pump is simply a matter of ensuring the appropriate level of oil and an operational heater or collection of heaters. A traditional design for heating employed a tubular element, a crush plate, and a clamping plate. (See Figure 1.) The tubular is held against the boilerplate by the crush plate, and that assembly is aligned by the clamping plate with one or more threaded studs on

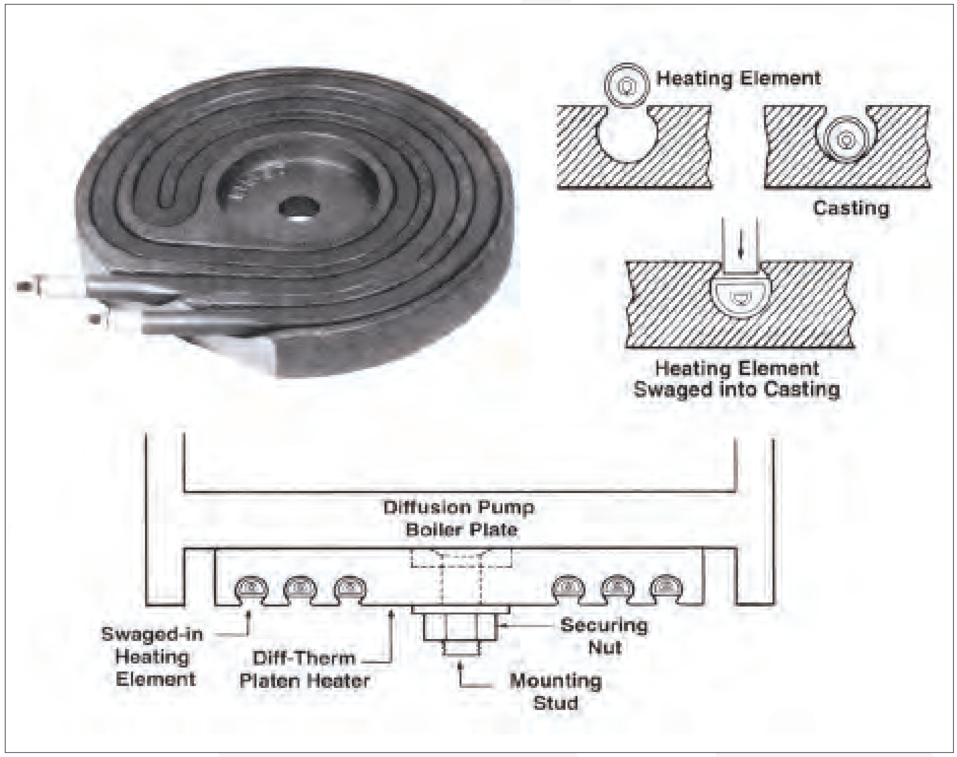


Figure 2: One-piece construction

the pump. Proper alignment is critical and can be difficult if space is limited.

The one-piece platen heater solves the problems of the conventional heater design. A tubular element is swaged directly into undercut grooves in a gray cast iron platen, increasing the density and uniformity of the insulation. This process locks the heating element into contact with the casting, creating uniform heat conduction along the length of the groove.

This platen has a flat ground surface, which is bolted to the boilerplate, eliminating a complicated alignment process. (See Figure 2.) "Full-power" heaters are also available, carrying up to 20 percent more wattage than standard alternatives for maximum pump throughput and higher processing rates for the vacuum system.

Compared with the limited contact area (one slightly flattened side to the tubular element) of conventional designs, the flat contact area of the platen provides greater contact area for more effective heat transfer to the boilerplate. Better heat transfer means longer heater life.

Platen heaters come in a variety of sizes and shapes as direct retrofits for diffusion pumps by Varian/NRC/Agilent, CVC Products, Edwards High Vacuum, Cooke Vacuum, Torr Vacuum, Veeco, Hitachi, Balzers/Pfeiffer, Ulvac, and others.

Larger CVC pumps employ ring heaters that are fashioned onto circular flanges on the base of the pump. Each ring is designed with three tubular elements, swaged into the circular profile of the ring. Clamping them onto the flanges requires a procedure of applying and curing a thermal cement to promote effective conduction heat transfer.

This conductive cement may be used in cases where the boilerplate, requiring a flat platen, has become warped. A thin layer of this cement may be applied to accommodate the uneven surface differences between boiler plate and platen.

Oerlikon/Leybold approaches oil heating a bit differently in its DIP series of pumps. Instead of a boilerplate, it has designed finned stainless tubes in the base of its pump. Cartridge heaters are inserted in the tubes, numbering 2 to 24, depending on the size of its pump.

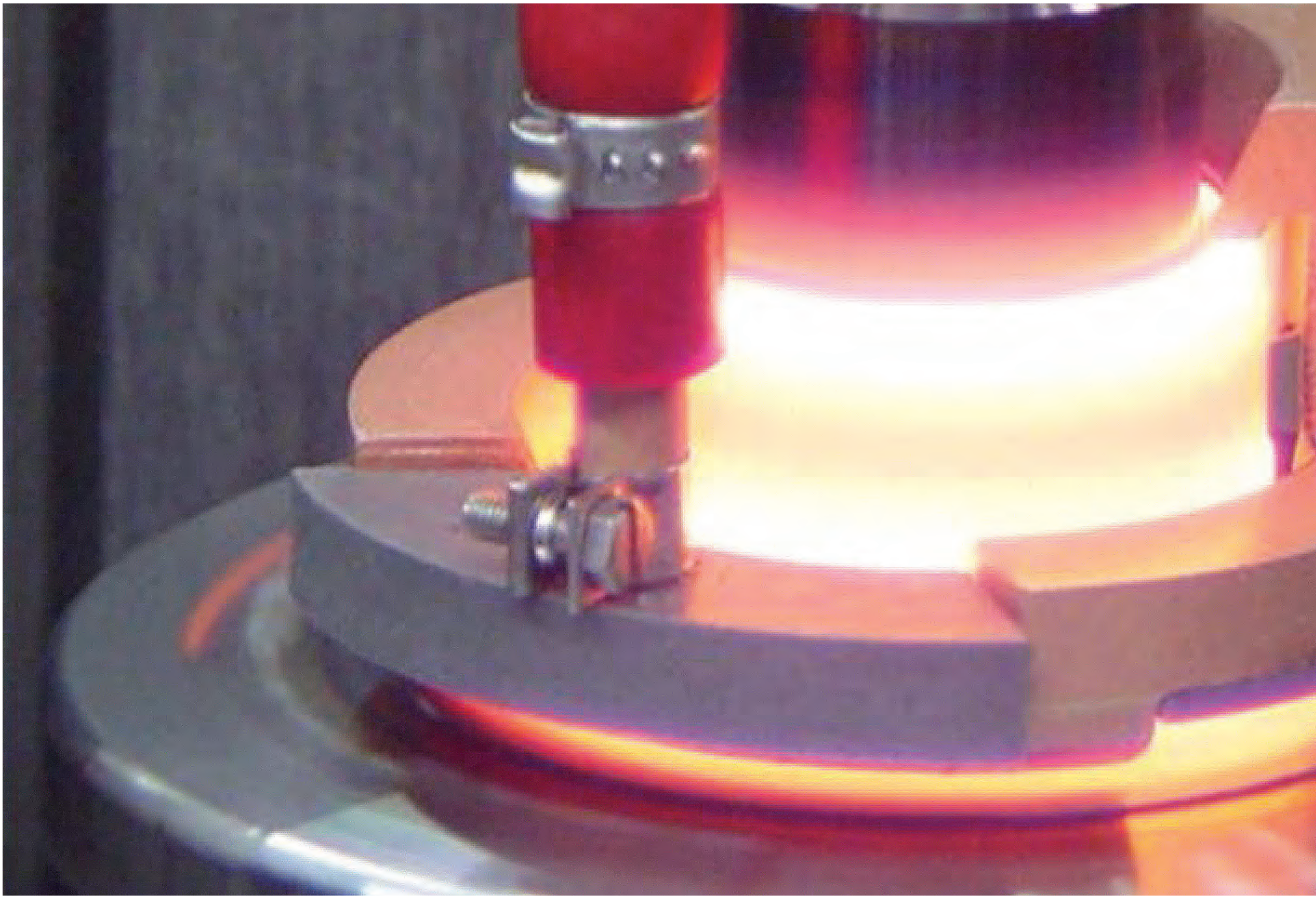
The optimum oil level is in the middle of the heater tube, so the oil under the heater is brought to a boiling temperature by the fins, and the evaporating oil vapor above the oil level is accelerated by the heat off the upper fins. This is an effective design for heating the oil, but the tube has a closed end in the pump. If the installed cartridge heater seizes in the bore — a somewhat common experience — it is most difficult to remove.

If the heater must be drilled out, damage to the stainless heater sheath is difficult to avoid. The best way to approach this problem is to use a split-sheath cartridge heater. This heater, with two semicircular halves, is designed to expand in the bore to affect optimum heat transfer.

And when the heater is de-energized, it contracts for ease of removal. Replacement heaters are rated between 800 and 1,250 watts and are fitted with a mounting flange to match the OEM offering.

In summary, the right heater choice will provide better performance, extending operational life, reducing pump downtime, and easing maintenance requirements.

ABOUT THE AUTHOR: E.W. Whitney III is the president of Dalton Electric Heating Co. in Ipswich, Massachusetts. He has a B.S. from the University of New Hampshire and an MBA from Pepperdine University, and he began with Dalton as a sales representative 31 years ago. He can be reached at eli@daltonelectric.com.

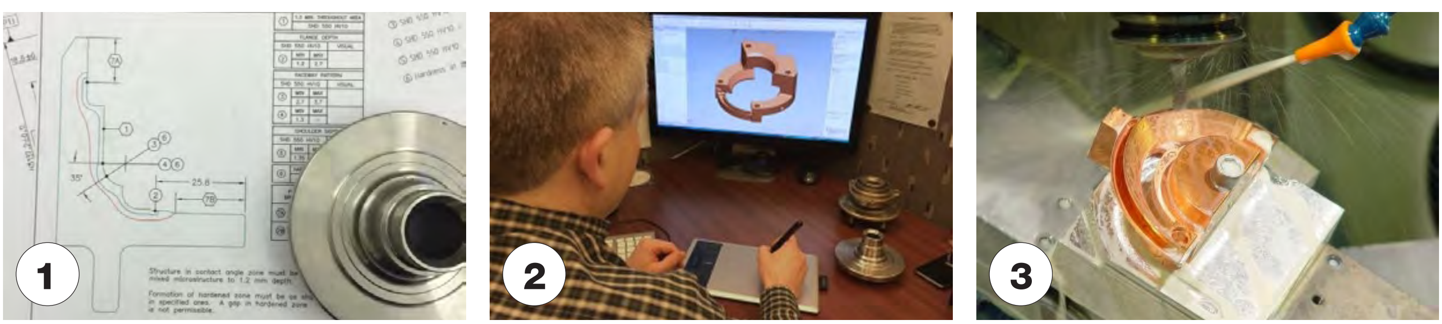


Induction Heat Treating: How to Shorten the Time to Production

Laboratory testing and validation at the inductor-manufacturer level can result in a fully characterized and proven inductor with process parameters and a metallurgical report.

By Sandra J. Midea

In an increasingly competitive world, it is good to pause and ask: How can we do our work faster, better, and use fewer resources? Induction Tooling Inc. has disrupted the traditional approach to validating selective hardening inductors, getting them into production faster than ever before and with improved production results. The vision allows testing and validation to occur at the inductor manufacturer



Discussion — Design — Fabrication and assembly

Figure 1: Process cycle of a heat-treating inductor from design to production

before it ever reaches the heat treater. The final product is a fully characterized and proven inductor, complete with production process settings and a metallurgical report from an ISO 17025 accredited commercial test laboratory specializing in induction heat treating. This high-quality report is suitable to forward to an end customer. Sample parts for show-and-tell or small lots for further testing are also commonly requested. Best of all, this occurs without breaking into production or tying up company personnel.

Mirroring the heat treaters' production parameters, the inductor, commonly called a coil, can be characterized to produce a hardening pattern that meets the nominal case depth requirements. Meeting nominal requirements, rather than the minimum or maximum, gives the induction operation the greatest flexibility in manufacturing. Induction heat treating often encounters problem areas including sharp corners, fillets, holes, difficult runouts, deep case requirements, or thin walls. Addressing these issues before production actually solves problems before they can become issues.

ABOUT INDUCTORS

The technology that goes into the design and manufacture of robust production-ready induction heat treating inductors incorporates both calculations and experience. The number of variables influencing the induction-hardening pattern produced by a specific power supply, inductor, and part geometry are extensive. In the time between receipt of an engineering drawing and hardening of production parts, the following steps must occur (see Figure 1):

1. Discussion regarding the induction-hardening requirements (engineering requirements, alloy, and part geometry), induction heating equipment (system capabilities and constraints), and material handling (throughput, part loading, etc.).
2. Design of inductor including integrating clearances, equipment centerlines, part loading, and contacts. Expertise is required to design an inductor to produce the desired pattern. Generally, coils are designed slightly oversized so material can be removed rather than added to produce the required pattern if changes are required.
3. Fabrication and assembly of fixtured tubular or machined copper for the inductor includes machining, brazing of joints, pressure and flow testing, and finalizing for production environments.
4. Laboratory testing and characterizing. The induction-heating operator can control part position, air gap, power, and cycle time or scan rate to influence the induction-heating pattern created. A coil must be tested and the results confirmed before it can be used in production. If changes to the coil geometry are required (a process called characterizing the inductor), it is done during this stage.
5. Metallurgical evaluation and reporting. Validation includes looking at the induction-hardened pattern using etching techniques to reveal the case depth and Rockwell hardness to verify hardness. If these are found acceptable, the microstructure, grain size, and microhardness profiles are checked to validate good microstructure transformation, checking for overheating and good case/core transition. If issues are noted, coil development must return to step 4.
6. Capable and proven inductor. At the end of the cycle, the inductor should be capable of producing the required pattern in a documented and repeatable manner. Results would be validated and then approved by the final customer.

The sequence of testing, characterizing, and validating offers a great opportunity to reduce the time into production. Currently, this cycle may require the following process: For example, the inductor is sent to the induction heat-treating facility. This may involve breaking into production to set up and run the prototype part. Once the part is run, it must be checked to validate the settings. If it needs to be characterized, it must be returned to the inductor manufacturer for modifications and then returned to the induction heat-treating facility. If additional characterizing is necessary, it is returned to the induction house and then returned to the induction heat-treating facility. In a complex part geometry, changes in one area of the inductor will influence the pattern in another. This cycle may continue, using up resources and requiring interruptions to production schedules.

Laboratory development

Metallurgical evaluation and reporting

Proven and capable inductor

Instead of interrupting production at the heat-treating facility, the process can be developed at the inductor manufacturer. The production settings of power and frequency, quenchant, cycle time, and material handling can be matched to those used at the heat treater. If inductor modifications (characterization) are needed, they can be performed and revalidated at the inductor facility and then reverified on-site. With the addition of a commercial testing laboratory, a full metallurgical evaluation can be performed and results submitted in a format that can be forwarded directly from the heat treater to the end customer.

Multiple changes and validations are performed quickly by a staff dedicated to that purpose. Having all of these resources under one roof — design, fabrication, induction development, and metallurgical validation — is a disruptive method to improve production efficiency and significantly shorten the time to PPAP or production. The result is a fully characterized inductor, process parameters for the operator, prototype lots of processed parts, plus a metallurgical evaluation conducted by an ISO 17025 accredited testing laboratory specializing in induction heat treating.

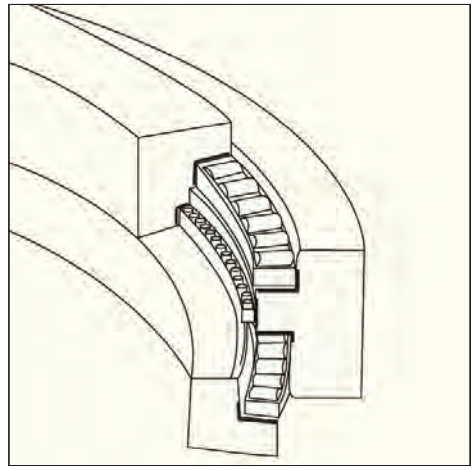


Figure 2: Three-row roller bearing configuration; induction-hardened raceways are shown in bold outline

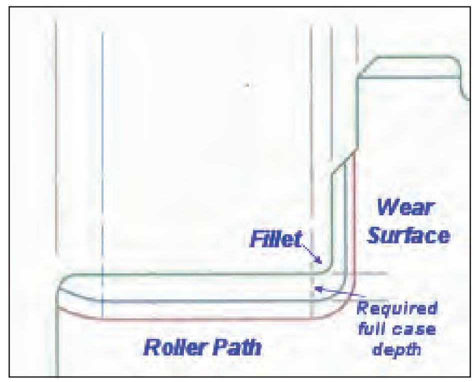


Figure 3: Schematic of roller path induction-hardened zone (blue outline)

The following are four examples of development work performed at Induction Tooling's Induction Development Laboratory:

Roller Path Inductor Characterization

Large forged bearing and gear companies have found this service extremely useful for their products. Large bearing components (100 inches in diameter and up) are often made in lots of one with costs of tens of thousands of dollars when the parts reach the heat-treating operation. In addition, these are often manufactured under expedited conditions. The Induction Development Lab has been used repeatedly to develop processes that are close to production-ready for this purpose.

A three-row bearing (see Figure 2) is composed of three rings containing several bearing surfaces. The bold surfaces are the induction-hardened raceways. This discussion pertains to the lower roller path shown in the figure.

For this application, a field failure required the region of full case depth to be extended as close as possible to the fillet of the roller path for this replacement bearing (see Figure 3). The customer uses a 22 kHz frequency, which is not ideal for a deep case application. With modifications to the inductor, power level, and scan speed in the Induction Development

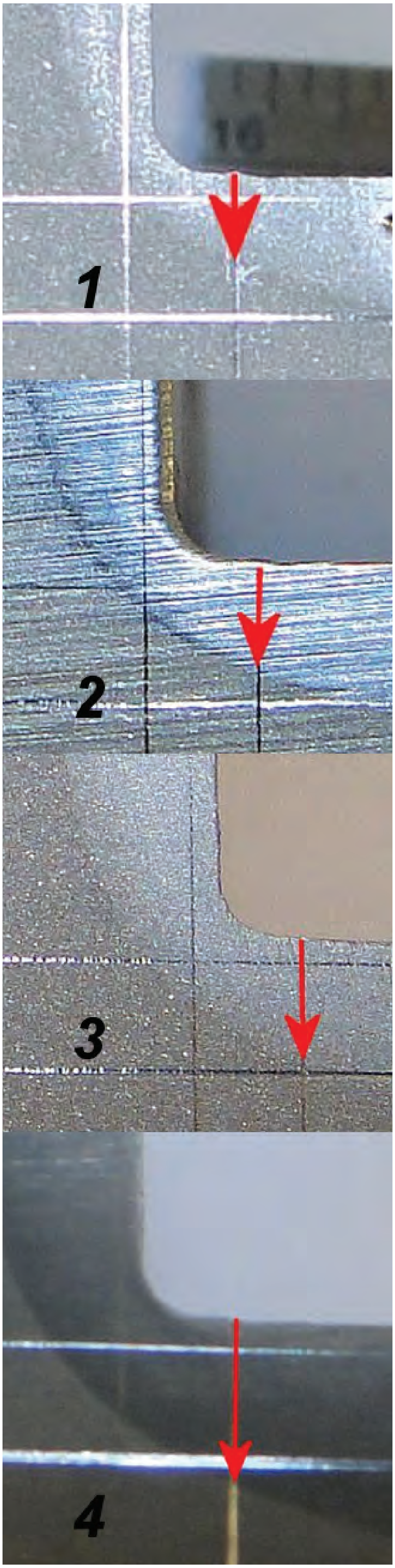


Figure 4: Progression of case depth development for roller path

Lab, full case depth was achieved at the location required by the roller path redesign.

Figure 4 shows a cross-section through the induction-hardened roller path at the fillet. The samples were etched to show the induction-hardened case. The vertical and horizontal lines show the surface hardness and minimum case depth requirement locations. The red arrow is where full case depth is required. The macro-labeled #1 shows that the case is about half the desired case depth. As a result, the inductor geometry into the fillet was modified, and the power was increased by 10 percent to produce the case shown in #2, which is an improvement but still misses the required depth. The power was further increased, and the scan speed was decreased. The resulting pattern #3 meets the requirement; however, laminations needed to be removed from the coil to reduce the pattern depth on the wear surface and outer corner of the roller path. The final result is shown in #4, which meets the desired case depth requirement, exhibits sound metallurgical practice, and operates within the constraints of the customers' production capabilities.

Wheel Bearing Spindle Characterization

Automotive wheel bearings (see Figure 5) are a safety-critical item with complicated geometries. The interior raceway is called the inner ring or spindle. The outer raceway is called the outer race or hub. A typical hardening pattern for the inner ring is shown in Figure 6 [1].

Figure 5: Cutaway view of a wheel bearing

Wheel bearing geometries are often similar as they share many of the same features (see Figure 6). Three characteristics of concern include sharp corners at the raceway ends, convex contact angles, and occasionally problematic runout requirements. Characterizing hubs and spindles can be tricky, because changing the inductor dimension in one area may shift the induction field to a different area. These fields must be balanced across the part.

The following examines these three characteristics: First, overheating at the sharp corners. Corner geometries tend to overheat for two reasons: The electrical field is attracted to sharp geometry, and the heat conducts in from two surfaces. Figure 7 shows acceptable martensitic structure with an ASTM grain size of 7-8. Figure 8 shows an overheated structure with coarse martensite and an ASTM grain size of 4-5. Good inductor design controls the heat at these locations.

The second concern is control of microstructure in the contact angle. The contact angle is required to have optimal microstructure. The heating to austenite followed by effective quenching to form 100-percent martensite without the presence of transformation products is critical during development. Figure 9 shows how ineffective quenching can lead to the formation of bainite, a non-martensitic transformation product.

The third critical concern is the pattern runout. Runouts are where the hardening pattern needs to stop. A runout can be thought of as two competing interests. We want the coil to austenitize and fully transform the structure but also want the pattern to not heat the steel within a short distance. This is controlled with a combination of inductor design, placement, gapping, and quench.

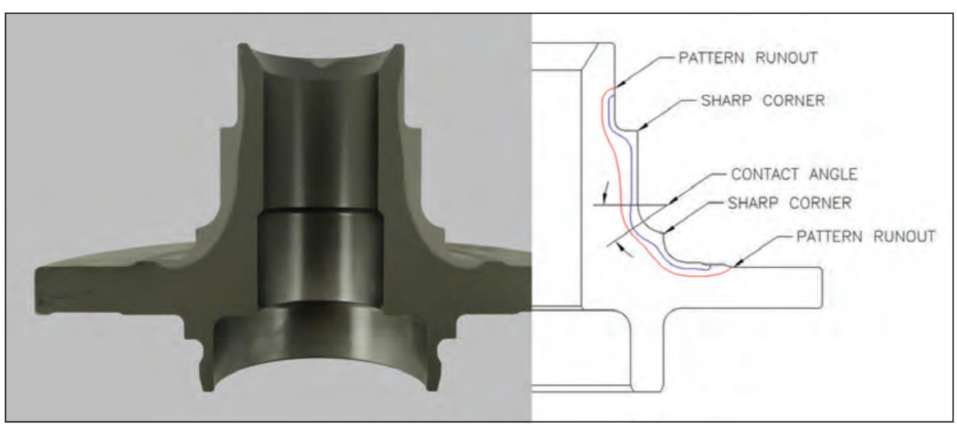


Figure 6: Cross-sectioned spindle with induction-hardened pattern etched in lighter color (left); schematic of spindle illustrating induction-hardened processing issues (right)

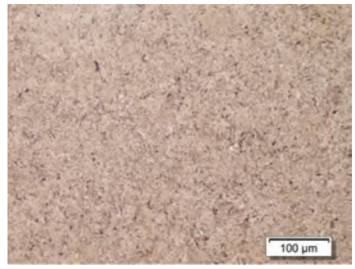


Figure 7: Acceptable martensitic structure; original magnification 100x, 2% nital etch

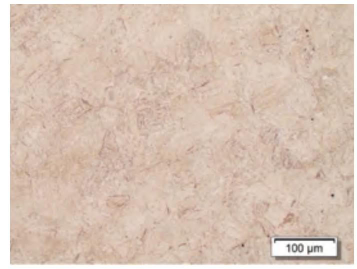


Figure 8: Overheated martensitic structure; original magnification 100x, 2% nital etch

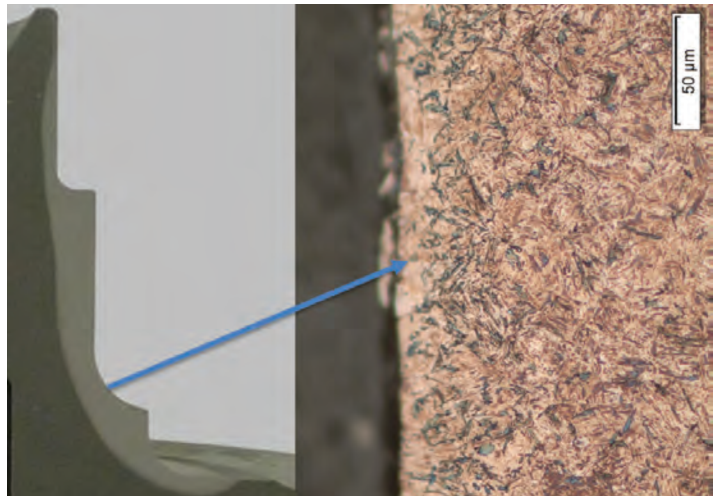


Figure 9: Bainite in martensitic matrix at the contact angle location in an ineffectively quenched wheel bearings spindle; micrograph original magnification is 500x, 2% nital etch

Small Prototype Lots

Once the inductor is characterized and production parameters are identified, small-lot production runoff for parts used for life-cycle testing or similar requirements can be done in the Induction Development Lab. Induction Tooling is not a production heat treater and does not process parts for end use; however, there is a need for the ability to process small lots of parts for evaluation purposes. The parts are made to specification and validated.

Inductor-Life Improvement Projects

Inductors often are subjected to a punishing production environment. Inductor failures result in replacement costs and lost production. Existing coil designs can be modified to increase the inductor life. It is timely to accomplish this objective when changes to the hardened product or equipment changes require a new PAPP effort. Induction Tooling has increased the lives of numerous inductor configurations by removing braze joints, beefing up supports, or improving designs.

REFERENCES

1. "Design and Development of PPAP Ready Wheel Bearing Inductors." S. J. Midea. Industrial Heating Magazine. May 2016.

ABOUT THE AUTHOR: Sandra J. Midea, P.E., is a staff metallurgist and lab manager at Induction Tooling Inc. with more than 25 years of experience in production heat-treating technologies. For more information, go to www.inductiontooling.com.

NOTE: This article is based upon information presented at Furnaces North America 2016 in Nashville, Tennessee.

Ensuring Effective Furnace Lining Efficiency

These five tips can help you maximize energy efficiency and minimize heat loss with effective insulation and furnace lining solutions.

By Steve Chernack

Refractory engineers remain under constant pressure to increase the performance of furnaces, incinerators, and reactors to maximize energy efficiency. Although there are many materials that can enhance the efficiency of furnaces, many still lose heat when in operation through flue gas, excess moisture in fuel, or continued opening of the furnace door. This is preventing many engineers from realizing maximum energy efficiencies, causing businesses to focus their attention on reliable insulation and lining of furnaces — from the floor to the stack — to contain as much heat as possible during operation. Many companies are responding to this challenge with a variety of lightweight, energy-saving solutions with unique refractory designs that significantly minimize heat loss in these units.

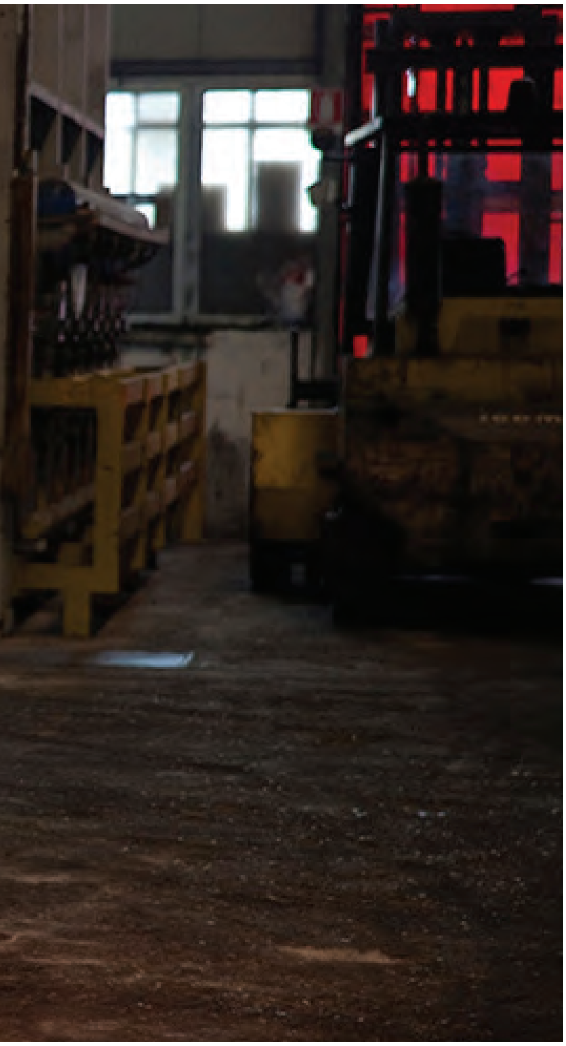
The central processing unit in many refineries and petrochemical plant furnaces consumes more energy than any other piece of equipment, making it essential that all the correct measures are put in place to realize as much energy efficiency as possible. An efficient furnace is key to reducing overall maintenance costs and ensuring that these facilities run smoothly without undue revenue loss caused by downtime.

The right refractory materials deliver a protective and insulating layer of heat resistance attached to the inside of the shell, hearth, and tap holes of a furnace. Not only does this protect furnace parts from extreme heat caused by smelting, but it also prevents excessive heat loss and can lead to greater overall energy efficiency. However, identifying the need for new furnace lining and installing the right material are not easy tasks. To achieve this, here are five tips for maximum furnace lining efficiency:

1. Use infrared (IR) thermography inspection to evaluate existing lining.

Ensuring lining quality is critical to protecting the steel from heat and minimizing instances of heat loss. Furnaces that have developed cracks over time are prone to leakage. Some may also have design issues that are not visible from the outside, which can cause heat-loss issues over time. This is not uncommon with furnaces that have a painted surface.

In order to identify hot spots where the unit is leaking or reducing performance, infrared



thermography scans are essential. This typically involves pointing an infrared camera at several points on the furnace casing to analyze the external temperature and identify any areas where heat loss is occurring. Although these can be conducted from within the furnace, such scans are more effective when performed from the outside, because this enables engineers to keep the furnace in operation. It is advised that specially trained application engineers carry out any infrared imaging, analyze the scans, and provide recommendations on the most appropriate repair options.

2. Make repairs on-line whenever possible to reduce downtime.

In the instance that an infrared thermography inspection reveals a need for repair, it's recommended that this be done on-line wherever possible. This is the most effective method of maintenance and is reliable, fast, and economical, since the unit is still in operation. After all, boilers and process units are constantly generating revenue, so any downtime experienced will likely affect a business quite significantly. Of course, this option does depend on the temperature of the furnace, the difficulty of accessing a particular area, and the size of the hotspot.

For traditional repairs, the furnace must be shut down and cooled until it is safe for maintenance personnel to enter and repair the lining with fiber blankets, pumping solutions, or monolithics.

3. Carefully consider engineering design for efficiency.

In order to realize maximum operating efficiency for the materials specified for furnace relining, it is important to ensure that the engineering design is suitable. Not only must the materials have enough studs to hold them in place, they also require sufficient joints for expansion or shrinkage. If you install a brick lining without adequate expansion joints, the brick can grow so large that it pushes up the entire lining off the furnace wall. This will lead to further inefficiency, requiring the entire process to be repeated.

4. Select the right material for furnace rebuilds.

Some repairs identified by infrared thermology scanning can be too large to address on-line, and instead, the unit must be shut down for a furnace reline or process heater reline. In this scenario, it is important to select the right refractory materials to facilitate a successful furnace rebuild. This will lead to greater efficiency, reliability, and lower maintenance costs.

The best place to start when selecting this material is by using a heat-flow analysis software program, where temperature and use factors are input to obtain information on the best materials to be used. Properties including hardness, density, mechanical resistance, and insulating factor will vary depending upon the furnace application.

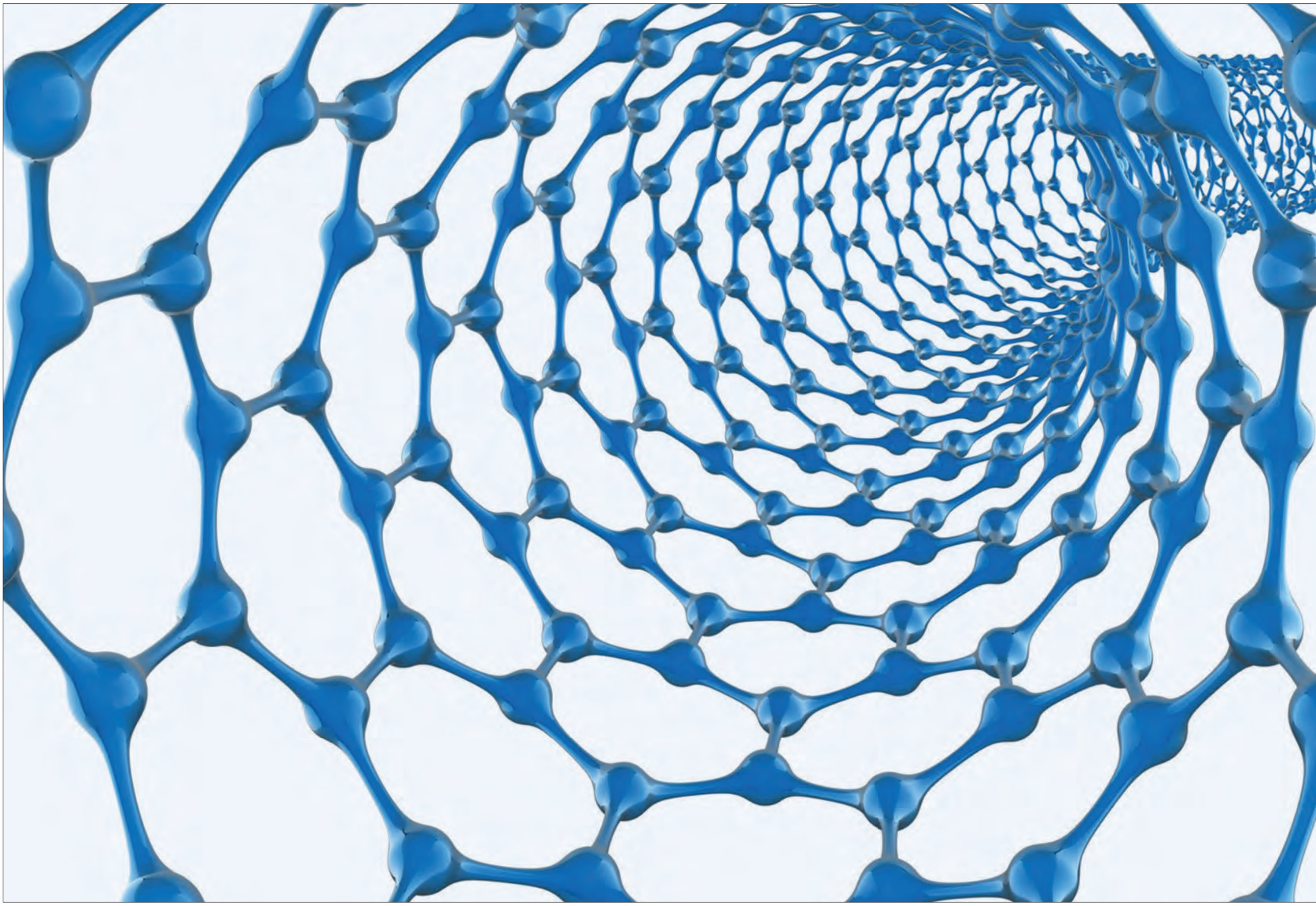
If it's an older-model furnace, it will likely have a different type of insulation to what's commonly specified today, presenting an ideal opportunity to upgrade when relining the furnace.

5. Ensure a successful installation.

The final point to consider when lining a furnace is to ensure that the installation is completed correctly by a skilled professional for the task. There are a number of products available for furnace lining, and all come with their own installation requirements. Getting this wrong will cause inefficient lining as well as waste a lot of money.

Take concrete, for an example of these specific installation requirements: If concrete is not mixed with the right volume of water at the correct temperature, the material will not develop properly, will be difficult to place, and is unlikely to reach expected properties. An ineffective or inaccurate installation is as bad as not having a good design and not making the right material choice. With these points done correctly, you can benefit from an effective and efficient furnace lining for many years to come.

ABOUT THE AUTHOR: Steve Chernack is with the Thermal Ceramics unit of Morgan Advanced Materials, a global materials engineering company that designs and manufactures a wide range of high-specification products with extraordinary properties, across multiple sectors and geographies. For more information, visit www.morganthermalceramics.com.



Elemental Analysis of Metal Powders and Metal Parts Produced by Additive Manufacturing

Because non-metallic elements influence the physical properties of metallic materials, quality control should include analysis of the raw material and the final product to measure element concentrations.

By Mike Lucka and Nico Masciantonio

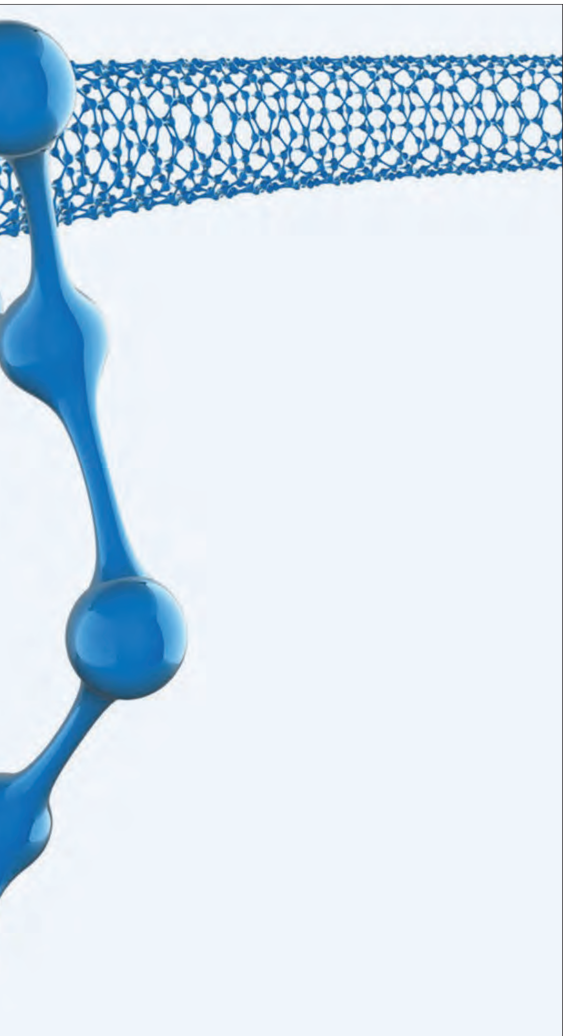
An integral part of industrial product development is the manufacture of prototypes and initial samples, regardless of whether the product is a simple screw or the complex part of an airplane. To fabricate single, and oftentimes small, pieces in a production environment is usually a costly procedure. Based on this cost-benefit calculation, a special application field of powder metallurgy has developed in the past few years: additive manufacturing.

Additive manufacturing (AM) is the "process of joining materials to make objects from 3D model data" [1]. AM creates objects layer upon layer from different metal powders or metal alloy powders. The specifications of the manufacturing process depend on the requirements and possibilities of the user, as well as the type and size of the object to be produced.

In recent years, different methods have been established in the industry, such as:

- Rapid prototyping
- Rapid manufacturing
- Laser beam melting
- Selective laser melting
- Selective laser sintering
- Direct metal laser sintering
- Electron beam melting
- Powder bed fusion
- Freeform fabrication
- Solid freeform fabrication
- Laser metal deposition
- Laser cladding
- Direct energy deposition
- Direct metal deposition

Most AM methods are based on the same procedure. A laser beam locally melts the upper



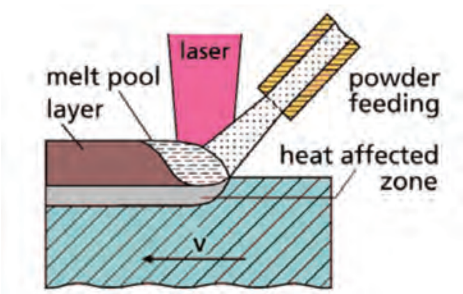


Figure 1: Additive manufacturing by laser metal deposition [1]

powder layer, which solidifies and forms a layer of solid material. This is repeated layer by layer until the final object is created. The quality of the unused powder is determined by particle size analysis (sieving) and, in some cases, also by elemental analysis, before it is returned to the manufacturing process.

QUALITY CONTROL PROCESS

Additive manufacturing is becoming an increasingly established production technology. However, as it is still new, the required process steps have not been uniformly defined yet. There are, for example, no industry-wide standards describing the quality control process. An established parameter is the particle size distribution of the powder used for AM. Particle size, however, should not be the only characteristic used for quality control [2].

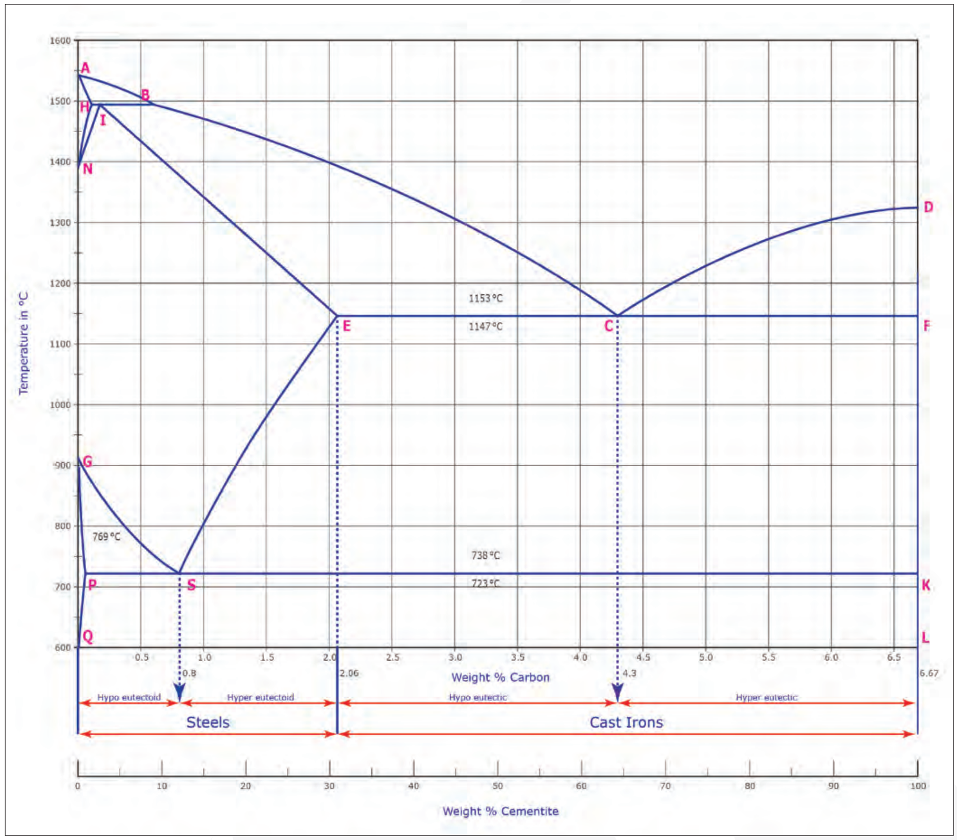


Figure 2: Iron-carbon phase diagram [2]

Among the metal powders used for additive manufacturing are different types of steel and titanium. To check the quality and purity of these raw materials, suitable processes need to be implemented. The content of various "foreign" elements, for example, should be closely monitored to ensure a high-quality end product.

ELEMENTS THAT HAVE AN INFLUENCE ON MATERIAL PROPERTIES

Steel

There are many elements that influence the properties of steel, with carbon at the top of the list. Steel is classified into different quality grades and application fields, depending on the type and concentration of these alloy elements (C, Si, Mn, P, S, Cr, etc.). The following describes the most important nonmetallic elements and their effects.

Carbon [C]: The carbon content affects various physical parameters of steel. This ferrous alloy contains between 0.0002 percent and 2.06 percent of carbon. The higher the carbon content, the lower the melting point. Moreover, brittleness and hardness increase with the carbon content.

Sulfur [S]: If the alloy contains sulfur, this increases the machinability of the steel, i.e., the material's suitability for being treated by methods such as drilling or milling. The higher the sulfur content, the lower the ductility.

Nitrogen [N]: The nitrogen content may be divided into desired and undesired content. There are some special applications that permit a high nitrogen concentration. In these cases, its chemical form has to be taken into account. Nitrogen in its elemental form is localized along the grain boundaries and influences the ductility of steel in a significant way. The nitrogen content that is bound to other elements is usually not considered important.

Oxygen [O]: Oxygen is a so-called steel parasite because it makes the steel brittle and causes aging brittleness.

Hydrogen [H]: Hydrogen in steel causes the mechanical stability to degrade. Hydrogen embrittlement is widely feared because it may cause considerable technical and economic damages. It means that the protons attach themselves to the metal matrix that may lead to cracks in the steel.

Titanium

Hydrogen [H]: Has the same effect on titanium as on steel. Hydrogen may influence the formation of mixed phases in titanium alloys.

Nitrogen [N]: Nitrogen increases the brittleness of titanium.

Oxygen [O]: Even the smallest amounts of oxygen have a considerable effect on the toughness or hardness of titanium. The Specification Book shows that even minor differences in the oxygen content may determine the difference between high-quality (grade 1: 0.18 percent O) and low-quality titanium (grade 3: 0.35 percent). Oxygen changes the mechanical and physical properties of titanium significantly. Titanium with an oxygen concentration of 0.1 percent is approximately three times more stable than with a concentration of 0.3 percent.

Sulfur [S]/Carbon [C]: These elements only have a slight effect on titanium. The determination of the described element concentrations should be carried out before and after the additive manufacturing process to ensure that both the raw materials and the final product possess the required quality.

	M [g/mol]	Density [kg/m³]	Coefficient of thermal conductivity [W/kW][1]
Hydrogen H_2	2.02	0.08987	1.869
Helium He	4.00	0.17839	1.567
Nitrogen N_2	28.01	1.2505	0.260
Argon Ar	39.94	1.7839	0.179

[1] CRC Handbook of Chemistry and Physics, 1995-1996, 76th Edition

Table 1: Different thermal conductivities

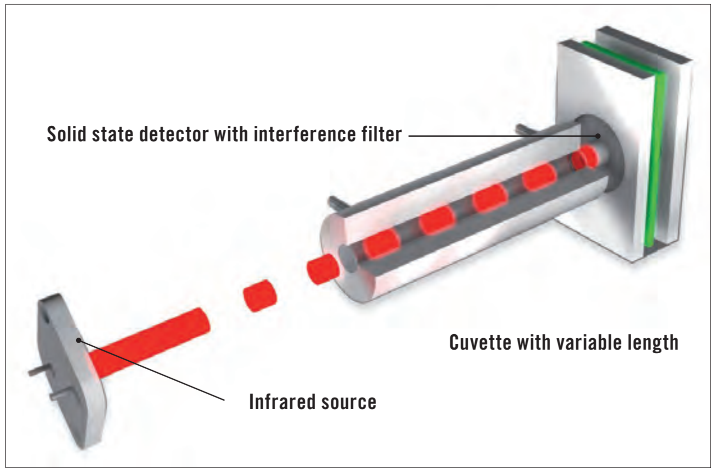


Figure 3: Infrared cell

ANALYSIS METHODS

There are different ways of measuring element concentrations and impurities, most of which require destruction of the sample. This is done to ensure that all relevant components of the analyzed sample are released.

Combustion analysis offers a number of advantages. The samples can be measured in solid form, which means direct measurement without previous treatment. The average particle size required for metal powders used for additive manufacturing processes lies between 5 µm and 150 µm. This is determined by particle size analysis, e.g., by dynamic image analysis. If the powder has the right size distribution, it can be analyzed for elemental concentrations by combustion analysis.

The measurement of H/C/N/O/S cannot be carried out in one single analysis. Oxygen, nitrogen, and hydrogen are analyzed in one step and carbon and sulfur in another.

This is due to different methods being applied:

O/N/H Analysis

The sample is dropped into a graphite crucible and melts due to the high temperature. Consequently, oxygen, nitrogen, and hydrogen are released. Oxygen converts to CO on the surface of the hot crucible. The inert carrier gas removes the gases from the crucible.

A copper oxide catalyst converts CO to CO_2, which is detected in the infrared cells. An infrared ray with a specific wavelength is used to excite the carbon dioxide molecules.

The loss of energy, which was transferred to kinetic energy, is used to determine the exact oxygen concentration of the sample. The nitrogen and hydrogen content are measured in a thermal conductivity cell.

The Elementrac thermal conductivity cell is based on a micromechanical silicon chip, which is coupled to a membrane and works independently of a reference gas flow. If the thermal conductivity of the gas changes — for example, through nitrogen released from the sample — the heating capacity required for heating the membrane changes as well. This is indicated by a measuring signal. The method is robust and sensitive, and it guarantees stable measuring results over a wide concentration range.

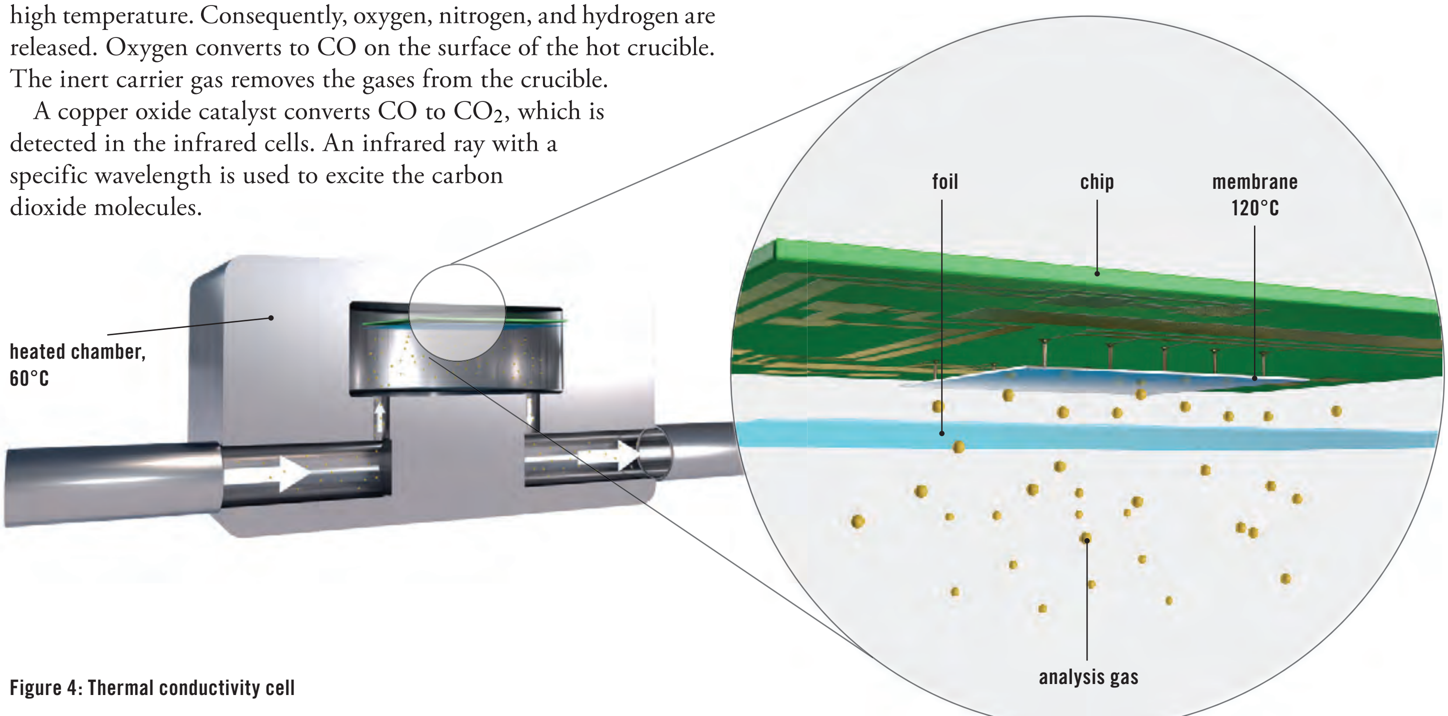


Figure 4: Thermal conductivity cell

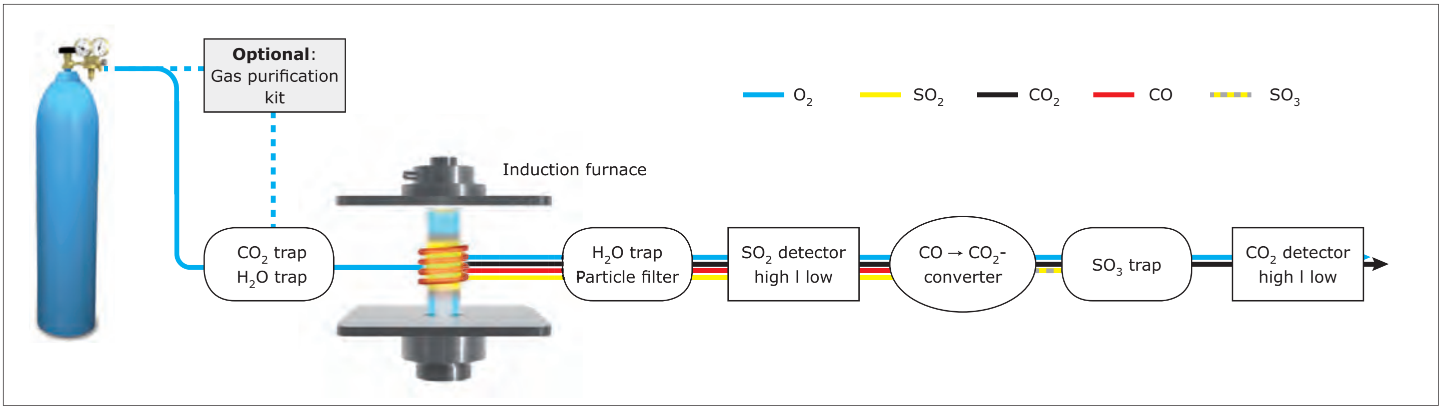


Figure 5: Carbon/sulfur analysis procedure

Weight [mg]	Oxygen [ppm]	Nitrogen [ppm]
994.9	6.1	18.8
999.0	5.1	18.0
1000.2	5.7	17.8
997.6	6.3	18.4
1000.4	6.9	18.6
997.4	5.9	17.8
997.5	7.1	19.4
994.7	5.6	18.4
996.9	5.6	19.4
998.1	5.8	18.4
Mean value	6.0	18.5
Deviation / relative deviation	±0.6 / 10.3%	±0.6% / 3.1%

Table 2: Measurement of Eltra 91100-1001 #714A

Weight [mg]	Carbon [%]	Sulfur [ppm]
1002.8	0.8627	100.11
1001.5	0.8655	100.60
998.9	0.8662	104.47
1000.3	0.8571	101.52
1002.3	0.8676	105.03
1000.8	0.8641	106.54
1005.5	0.8627	107.78
1001.7	0.8716	99.89
1002.0	0.8671	103.09
1001.7	0.8627	104.35
Mean value	0.862	104.35
Deviation / relative deviation	±0.0037 / 0.43%	±02.29 / 2.21%

Table 3: Measurement of AR 875 #51256

Table 2 shows typical results for a simultaneous oxygen and nitrogen analysis of a steel sample. Reproducibility is clearly below 1 ppm, even for low concentrations.

C/S Analysis

In the induction furnace, the sample is melted in a pure oxygen atmosphere, causing sulfur to react to sulfur dioxide (SO_2) and carbon to react to a mixture of carbon monoxide (CO) and carbon dioxide (CO_2).

The combustion gases pass through a dust filter and moisture absorber for purification. In the next step, the sulfur dioxide is detected in infrared cells. In Eltra's CS-800, infrared cells with different sensitivities (high/low) can be adapted according to the user's requirements. Oxidation of both carbon monoxide to carbon dioxide and sulfur dioxide to sulfur trioxide follow the sulfur measurement. The SO_3 gas is removed with cellulose wool; the carbon content is detected by infrared cells that can be individually customized. Eltra analyzers can be equipped with up to four independent infrared cells.

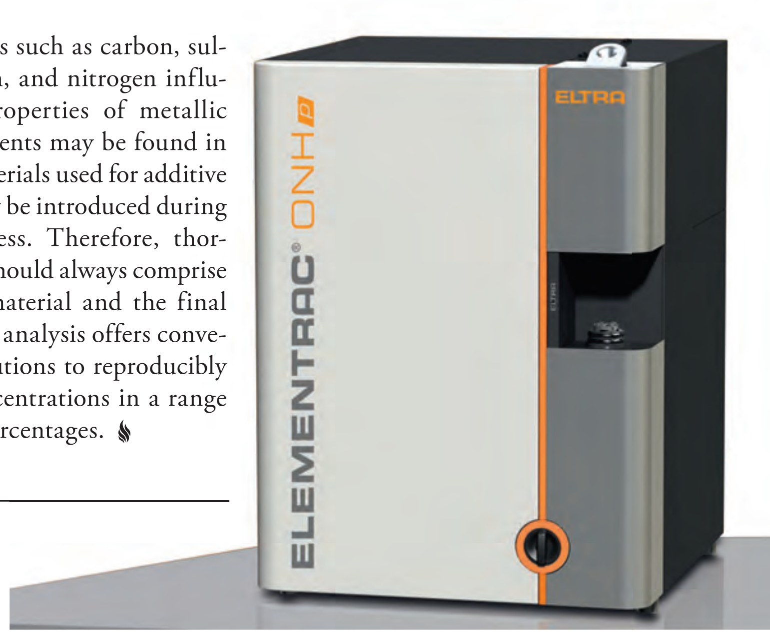
The sample is weighed in a crucible and covered with tungsten for analysis. Table 3 shows a typical result for a steel sample.

CONCLUSION

Non-metallic elements such as carbon, sulfur, hydrogen, oxygen, and nitrogen influence the physical properties of metallic materials. These elements may be found in the powdered raw materials used for additive manufacturing or may be introduced during the production process. Therefore, thorough quality control should always comprise analysis of the raw material and the final product. Combustion analysis offers convenient and reliable solutions to reproducibly measure element concentrations in a range from a few ppm to percentages.

REFERENCES

1. Introduction to additive manufacturing technology, www.epma.com/am.
2. Berumen, S.; Bechmann, F.; et al, Quality Control of laser and powder bed-based Additive Manufacturing (AM) technologies, Physics procedia, 5, 617-622, LANE 2010.



ABOUT THE AUTHORS: Mike Lucka is an application specialist at Eltra GmbH in Haan, Germany. Nico Masciantonio is an Eltra application specialist at Verder Scientific Inc. in Newtown, Pennsylvania.

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8” 18” 8” Lucifer Elec. 1250 F. ... **REF #103**
12” 16” 18” Lindberg Elec. 1200 F. ... **REF #103**
12” 16” 18” Lindberg (3) Elec. 1250 F. ... **REF #103**
30” 48” 22” Dow Elec. 1250 F. ... **REF #103**
34” 19” 33” Poll.Ctrls Burnoff Gas 900 F. ... **REF #103**
36” 36” 35” Despatch Elec. 400 F. ... **REF #103**
36” 36” 120” Steelman Elec. 450 F. ... **REF #103**
36” 48” 36” Grieve Elec. 350 F. ... **REF #103**
36” 60” 36” CEC (2) Elec. 650 F. ... **REF #103**
37” 19” 25” Despatch Elec. 500 F. ... **REF #103**
37” 25” 37” Despatch Elec. 850 F. ... **REF #103**
37” 25” 50” Despatch Elec. 500 F. ... **REF #103**
38” 20” 24” Blue-M Elec. 1200 F. ... **REF #103**
38” 26” 38” Grieve Elec. 1000 F. ... **REF #103**
48” 24” 48” Blue-M Elec. 600 F. ... **REF #103**
48” 30” 42” Despatch Gas 850 F. ... **REF #103**
48” 48” 48” CEC (N2) Elec. 1000 F. ... **REF #103**
48” 48” 60” Gasmac Burnoff (2) Gas 850 F. ... **REF #103**
48” 48” 72” Despatch (2) Elec. 500 F. ... **REF #103**
48” 48” 72” Lydon Elec. 500 F. ... **REF #103**
54” 108” 72” Despatch Elec. 500 F. ... **REF #103**
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J.L. Becker Box Temper Furnace, 1989 ... **REF #101**
Sunbeam Electric Box Furnace, good running condition **REF #101**
Surface 30-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
Atmosphere Furnace Co. 36-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
Atmosphere Furnace Co. 36-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
Atmosphere Furnace Co. 36-48-30 Electric Temper Furnace, good/ very good condition ... **REF #101**
Surface Combustion 30-48-30 Gas Fired Temper Furnace, good/ very good condition ... **REF #101**
Surface 30-48-30 Gas Fired Temper Furnace, good/ very good condition ... **REF #101**
24” wide x 48” long x 18” high, Lindberg batch temper, Gas, 1400 F. ... **REF #102**
30” wide x 48” long x 26” high, BeaverMatic batch temper, Gas, 1400 F. ... **REF #102**
8” 18” 8” Blue-M Elec. 2000 F. ... **REF #103**
12” 24” 8” Lucifer-Up/Down (Retort) Elec. 2150/1400 F. ... **REF #103**
12” 24” 8” C.I. Hayes (Atmos) Elec. 1800 F. ... **REF #103**
12” 24” 12” Hevi-Duty (2) Elec. 1950 F. ... **REF #103**
12” 24” 12” Lucifer-Up/Down Elec. 2400/1400 F. ... **REF #103**
3” 24” 12” Electra-Up/Down Elec. 2000/1200 F. ... **REF #103**
15” 30” 12” Lindberg (Atmos) - Retort Elec. 2000 F. ... **REF #103**
17” 14.5” 12” L & L (New) Elec. 2350 F. ... **REF #103**
22” 36” 17.5” Lindberg (Atmos) Elec. 2050 F. ... **REF #103**
24” 36” 18” Thermnlyne (2) - Unused Elec. 1800 F. ... **REF #103**
36” 48” 24” Sunbeam (N2) Elec. 1950 F. ... **REF #103**
36” 72” 42” Eisenmann Kiln (Car) Gas 3100 F. ... **REF #103**
60” 48” 48” Recco (1998) Gas 2000 F. ... **REF #103**
60” 96” 60” Park Thermal Elec. 1850/2200 F. ... **REF #103**
126” 420” 72” Drever ”Lift Off”-Atmos (2 Avail) Gas 1450 F. ... **REF #103**
13” 14” 12” ELECTRIC 1300ºF ... **REF #104**
10” 10” 18” ELECTRIC 2000ºF ... **REF #104**
22” 36” 22” ELECTRIC 1600ºF ... **REF #104**
12” 6” 8” ELECTRIC 2000ºF ... **REF #104**
12” 8” 18” ELECTRIC 2800ºF ... **REF #104**
20” 13” 36” ELECTRIC 1850ºF ... **REF #104**
12” 18” 18” ELECTRIC 1250ºF ... **REF #104**
4” 10” 4” ELECTRIC 2000ºF ... **REF #104**
22” 10” 8” ELECTRIC - C/W STAND 1250-2000ºF ... **REF #104**
15” 8” 30” ELECTRIC - ATMOSPHERE 1950ºF ... **REF #104**
11” 11” 17” ELECTRIC - CABINET 2000ºF ... **REF #104**
33” 40” 48” ELECTRIC 500ºF ... **REF #104**
18” 18” 30” ELECTRIC - GLO BAR 2900ºF ... **REF #104**
30” 30” 54” ELECTRIC - AGING 500ºF ... **REF #104**
30” 30” 54” R ELECTRIC - AGING 500ºF ... **REF #104**
30” 30” 54” ELECTRIC 500ºF ... **REF #104**
24” 18” 24” NATURAL GAS - BATCH FURNACE ... **REF #104**
24” 18” 24” NATURAL GAS - BATCH FURNACE ... **REF #104**
36” 30” 84” ELECTRIC 1200ºF ... **REF #104**
24” 24” 24” ELECTRIC 2000ºF ... **REF #104**
29” 22” 36” NATURAL GAS 1250ºF ... **REF #104**
12” 11” 24” ELECTRIC - BOX 2000ºF ... **REF #104**
24” 24” 24” ELECTRIC - GAS MAC 850ºF ... **REF #104**
18” 12” 12” ELECTRIC 2100ºF ... **REF #104**
48” 30” 36” ELECTRIC - ATMOSPHERE TEMPERING ... **REF #104**
50” 24” 29” NATURAL GAS 1250ºF ... **REF #104**
36” 18” 24” ELECTRIC 1250ºF ... **REF #104**
17” 17” 36” NATURAL GAS 1250ºF ... **REF #104**
15” 6” 10” ELECTRIC 1850ºF ... **REF #104**
6” DIA 48” ELECTRIC - TUBE FURNACE 1200ºC ... **REF #104**
7” 4” 14” GAS ... **REF #104**
10” DIA 18” GAS - FORGE FURNACE ... **REF #104**
9” 6” 15” GAS - FORGE FURNACE ... **REF #104**
6” 6” 15” GAS - FORGE FURNACE ... **REF #104**
12” 10” 20” ELECTRIC - SPEEDY MELT FURNACE 2000ºF ... **REF #104**
12” 9” 18” ELECTRIC ... **REF #104**
12” 12” 18” NATURAL GAS 1250ºF ... **REF #104**
14” 14” 18” ELECTRIC - GLOBAR 2500ºF ... **REF #104**
17” 17” 17” ELECTRIC - HITEMP KILN 2200ºF ... **REF #104**
35” 24” 60” ELECTRIC 1430ºF ... **REF #104**
10” 9” 14” ELECTRIC - FRONT DOOR LOADING 2000ºF ... **REF #104**
12” 12” 24” ELECTRIC - 13KW 2300ºF ... **REF #104**
12” 12” 24” ELECTRIC - 20KW 2000ºF ... **REF #104**
18” 12” 24” ELECTRIC 2000ºF ... **REF #104**
36” 24” 56” ELECTRIC 800ºF ... **REF #104**
24” 24” 36” ELECTRIC - CYCLONE 1250ºF ... **REF #104**
24” 36” 30” ELECTRIC RE-CIRC. BOX FURNACE 2000ºF ... **REF #104**
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130” 72” 215” GAS FIRED CAR BOTTOM 2400ºF ... **REF #104**
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Surface Combustion 30-48-30 Pro-Electric IQ Furnace **REF #101**
AFC 36-48-30 IQ Furnace with Top Cool ... **REF #101**
AFC 36-48-30 IQ Furnace ... **REF #101**
Surface Combustion 30-48-30 IQ with Top Cool, Excellent Condition, 2000 ... **REF #101**
Surface Combustion 30-48-30 IQ Furnace, Excellent Condition ... **REF #101**

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30” wide x 48” long x 26” high, BeaverMatic batch temper, Gas, 1400 F (NEW) ... **REF #102**
18” 12” 30” ELECTRIC 1250ºF ... **REF #104**
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36” 16” 24” ELECTRIC - BOX DRAW 1250ºF ... **REF #104**
12” 18” 16” ELECTRIC - BOX DRAW 1400ºF ... **REF #104**
30” 20” 48” ELECTRIC - BOX DRAW 1250ºF ... **REF #104**
24” 18” 36” NATURAL GAS ROLLER DRAW 1400ºF ... **REF #104**
30” 30” 48” NATURAL GAS 1200ºF ... **REF #104**
60” 40” 60” NATURAL GAS - DRAW FURNACE 800ºF ... **REF #104**
29” 16” 36” ELECTRIC - DRAW/TEMPER 1400ºF ... **REF #104**
54” 54” 150” ELECTRIC 900ºF ... **REF #104**
24” 18” 10 FEET ELECTRIC 500ºF ... **REF #104**
30” 24” 72” GAS - GRAVITY FEED DRAW 1350ºF ... **REF #104**
12” 14” 12” ELECTRIC - WATER COOLED FAN 1200ºF ... **REF #104**

ENDOTHERMIC GAS GENERATORS

Lindberg 1500 CFH Endothermic Gas Generator, 1992, good condition ...... **REF #101**
Lindberg 1500 CFH Endothermic Gas Generator, 1996, excellent condition ...... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator ...... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator ...... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator ...... **REF #101**
Surface Combustion 5600 CFH Endo. Gas Generator ...... **REF #101**
Rolock Inc. 2000 CFH Endothermic Gas Generator...... **REF #102**

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J.L. Becker 12,000 CFH Exothermic Gas Generator w/ Dryer, w ...... **REF #101**
Thermal Transfer 30,000 CFH Exothermic Gas Generator, 1994, excellent condition ...... **REF #101**
Seco Warwick 2000 CFH Exothermic Gas Generator...... **REF #102**
Sunbeam 2000 CFH Exothermic Gas Generator ...... **REF #102**
Alhern 6000 CFH Exothermic Gas generator ...... **REF #102**
J L Becker 6000 CFH Exothermic Gas Generator...... **REF #102**
JL Becker 6000 CFH Exothermic Gas Generator...... **REF #102**

FLUIDIZING BED FURNACE

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Webber 36-48-36 Chamber Freezer, 1980 ...... **REF #101**
Cincinnati Sub Zero 36-48-36 Chamber Freezer, 1995 . **REF #101**

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23" 4" 10' NATURAL GAS 1250°F ...... **REF #104**
24" 12" 96" ELECTRIC 500°F ...... **REF #104**

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Lindberg Continuous Mesh Belt Brazing Furnace ...... **REF #101**
J.L. Becker 26" Mesh Belt Brazing Annealing Furnace, 2007 ...... **REF #101**
10" J.L. Becker Mesh Belt Furnace with Muffle, 1988 . **REF #101**
24" J.L. Becker Mesh Belt Furnace ...... **REF #101**
Premier Furnace 14" wide mesh belt Aluminum Brazing Furnace 1400 F...... **REF #102**
Alhern 20" wide mesh belt Copper Brazing, Annealing Furnace 2100 F ...... **REF #102**
J L Becker 20" wide mesh belt Copper Brazing, Annealing Furnace 2100 F. ...... **REF #102**
JL Becker 20" wide mesh belt Copper Brazing, Annealing Furnace 2100 F. ...... **REF #102**
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Atmosphere Furnace Co. 36-48 Stationary Holding Stations, 1987, 36"W x 48"L work area ...... **REF #101**
Atmosphere Furnace Co. 36-48 Stationary Holding Stations, 1987, 36"W x 48"L work area ...... **REF #101**
Atmosphere Furnace Co. 36-48 Scissors Lift Holding Stations, 1987, 36"W x 48"L work area ...... **REF #101**
Atmosphere Furnace Co. 36-48 Scissors Lift Holding Stations, 1987, 36"W x 48"L work area ...... **REF #101**
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Surface Combustion 30-96 Stationary Load Tables, 96-inch rail length, 15-inch rail centers ...... **REF #101**
Surface Combustion 30-96 Stationary Load Tables, 96-inch rail length, 15-inch rail centers ...... **REF #101**
Surface Combustion 30-48 Scissors Lift Table, 48-inch rail length ...... **REF #101**
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Airco Flo meter panel# 2 ...... **REF #102**
Smart Skim unit...... **REF #102**
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8xxx 3.000 CFH 12 oz (3) North American 1/2HP ...... **REF #103**
8xxx 5.400 CFH 4 oz North American 1/3HP ...... **REF #103**
8236 12.000 CFH 12oz (3) North American 1/2HP ...... **REF #103**
8712 15.600 CFH 37 oz, North American 5HP ...... **REF #103**
8193 19.500 CFH 32 oz, Spencer 5HP ...... **REF #103**
8245 23.400 CFH 8 oz. North American 1,5HP ...... **REF #103**
8185 24.000 CFH 24 oz. Buffalo Forge 7.5HP ...... **REF #103**
8251 45.600 CFH 16 oz. Spencer 5HP ...... **REF #103**
8252 66.000 CFH 24 oz . Snencer(New) 10HP ...... **REF #103**
8253 66.000 CFH 24 oz. Spencer 10HP ...... **REF #103**
8250 150.000 CFH 16 oz. Hauck 15HP ...... **REF #103**

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22" 11" 14" COILED ELEMENTS ELECTRIC 2200°F ... **REF #104**
12" 7" 30" ELECTRIC - CRESS ...... **REF #104**
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24" 28" ELECTRIC - HOMO CARBURIZING 1400°F ...... **REF #104**
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22" 36" 22" ELECTRIC SQUARE PIT 1600°F ...... **REF #104**
6" 4" 16" ELECTRIC VACUUM PIT 2400°F ...... **REF #104**
24" 24" ELECTRIC 1400°F ...... **REF #104**
12" dia 18" ELECTRIC - HOMO PIT 1200°F ...... **REF #104**
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30" DIA 30" ELECTRIC - PIT CYCLONE 1250°F ...... **REF #104**
12" 20" ELECTRIC - KEYHOLE 1250°F ...... **REF #104**
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22" Dia 26" ELECTRIC - CYCLONE 1250°F ...... **REF #104**
22"Dia 26" ELECTRIC 1250°F ...... **REF #104**
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Abar Ipsen 2-Bar Vacuum Furnace, 1986, good condition ...... **REF #101**
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3600 CFH Endothermic Surface Gas ...... **REF #103**
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24"W 40'D 18"H Despatch Elec. 500°F. ...... **REF #103**
60"W 45'D 12"H Roller Hearth Annealer (Atmos) Gas 1700°F ...... **REF #103**

MARKETPLACE

Manufacturing excellence through quality, integration, materials, maintenance, education, and speed.

AD INDEX

COMPANY NAME PAGE NO.

Q&A | AZIZ JAMALUDDIN
PRESIDENT AND CEO OF EPCON INDUSTRIAL SYSTEMS

WHAT IS EPCON?

Epcon is a full-service organization, starting with front-end business development/marketing, sales and application engineering, through complete in-house engineering, design, and drafting — all highly automated. Manufacturing, fabricating, and assembly is completed at our 250,000-square-foot high-bay facility north of Houston, Texas. We also offer turnkey field installation. Epcon products are highly engineered and fabricated with high-quality materials. Products include thermal oxidizers, industrial ovens, furnaces, washlines, and specialty systems, all pertaining to industrial heat-processing equipment.

HOW DID EPCON BEGIN?

I started Epcon 40 years ago. I am a mechanical engineer with advanced degrees and have worked with industrial thermal processing equipment, specifically coil coating operations. I hold several patents for ovens, oxidizers, and combining the process of the two. Epcon's first project was a 55-gallon drum manufacturing plant in Houston at Mauser Group. I personally designed the entire system consisting of five paint-curing ovens, four dry-off ovens, and two three-stage washlines. There was one large thermal oxidizer to destroy the VOCs (volatile organic compounds) — the hydrocarbons coming out of the paint-curing ovens. Comprehensive heat recover was employed to recover all the heat from the oxidizer, which was put back into the five ovens, generating high-pressure hot water at 273°F for the two washlines. The final exhaust was used to heat the four burnerless dry-off ovens. This leading-edge design led to a patent for the entire system (Patent No. 4,242,084).

Epcon's next project was for Tuboscope, a division of National Oilwell, which consisted of two large car-bottom prebake (burnout) ovens with comprehensive heat recovery. This resulted in two patents (Patent Nos. 4,322,203 and 4,240,787). In addition to the burnout ovens, there were three conveyorized ovens, one final bake oven, and one coupling oven. These two major projects were the foundation for Epcon's success and growth.

WHAT ARE SOME OF EPCON'S PROUDEST ACHIEVEMENTS?

We have done a lot of unique systems in terms of soil remediation. We recently built two unique thermal oxidizers for the government. These bulk oxidizers destroy the nerve gas from WWII stored in underground bunkers in Richmond, Kentucky. We tested those oxidizers here at Epcon. Another engineering project was for nuclear waste disposal.

Another achievement was the thermal deoiler we designed and manufactured for Ford Motor Company about 17 years ago for deoiling aluminum fins in air conditioning condensers. When they are formed, these thin metal pieces have lubricating oils that contain a lot of VOCs, and Ford used tetrachloroethane to remove them. The EPA banned tetrachloroethane because it was a carcinogen. At that time, Ford was making all the automobile air conditioners in one location. So Ford was looking for an alternate means of deoiling the fins before brazing. These are extremely thin fins that go into the condenser, and they are brazed; there's no other way to fuse them. Before brazing, they have to be completely oil- and dirt-free. So we developed this thermal deoiler.

I personally designed this system and built a prototype. And it worked perfectly and resulted in two patents (Patent Nos. 6,135,765 and 6,149,707). Ford was happy, and its operating costs went from $20 million to $108,000.

We designed a new cat cracker unit for Shell Oil Refinery. What they had was over 60 years old when we replaced it. And the stipulation was that it had to last at least another 60 years. We had Shell experts as part of the design team. And it was the largest single project in Epcon's history. And it was done right here in Houston. It is operating very successfully, and it's going to for another 60 years.

WHAT DOES EPCON OFFER?

Epcon not only designs and manufactures ovens and furnaces but also oxidizers and specialty systems. With in-house engineering, manufacturing, fabricating, and assembly, and highly skilled and experienced labor under one roof, Epcon manufactures all types of heat-processing equipment — unlike other manufacturers of heat-processing equipment. That equipment includes industrial ovens, industrial furnaces, and thermal oxidizers of all types. Epcon has many differentiations and holds several patents. We have experienced engineers on staff at our manufacturing and assembly plant complete with modern machinery. Epcon's capabilities include the manufacture, assembly, testing prior to shipping, and installation at our customers' locations.

WHAT GOES INTO CREATING A THERMAL OXIDIZER?

After getting the RFQ, our experienced engineers analyze the application and see what technology would be best suited as a solution. Epcon is a leading manufacturer of regenerative thermal oxidizers, recuperative oxidizers, catalytic oxidizers, and direct fired thermal oxidizers. After analysis and preliminary engineering, we offer the technology to the customer. Just about all our jobs are on a fixed-firm price basis. Everything is integrated fully here. The team interacts with every activity — sales and applications, design, procurement and engineering, and after-sales service. The team coordinates and combines all these activities for a successful project. In 40 years, Epcon has manufactured over 4,000 systems, operating globally in just about all industrialized countries. The majority of the systems are in the U.S.

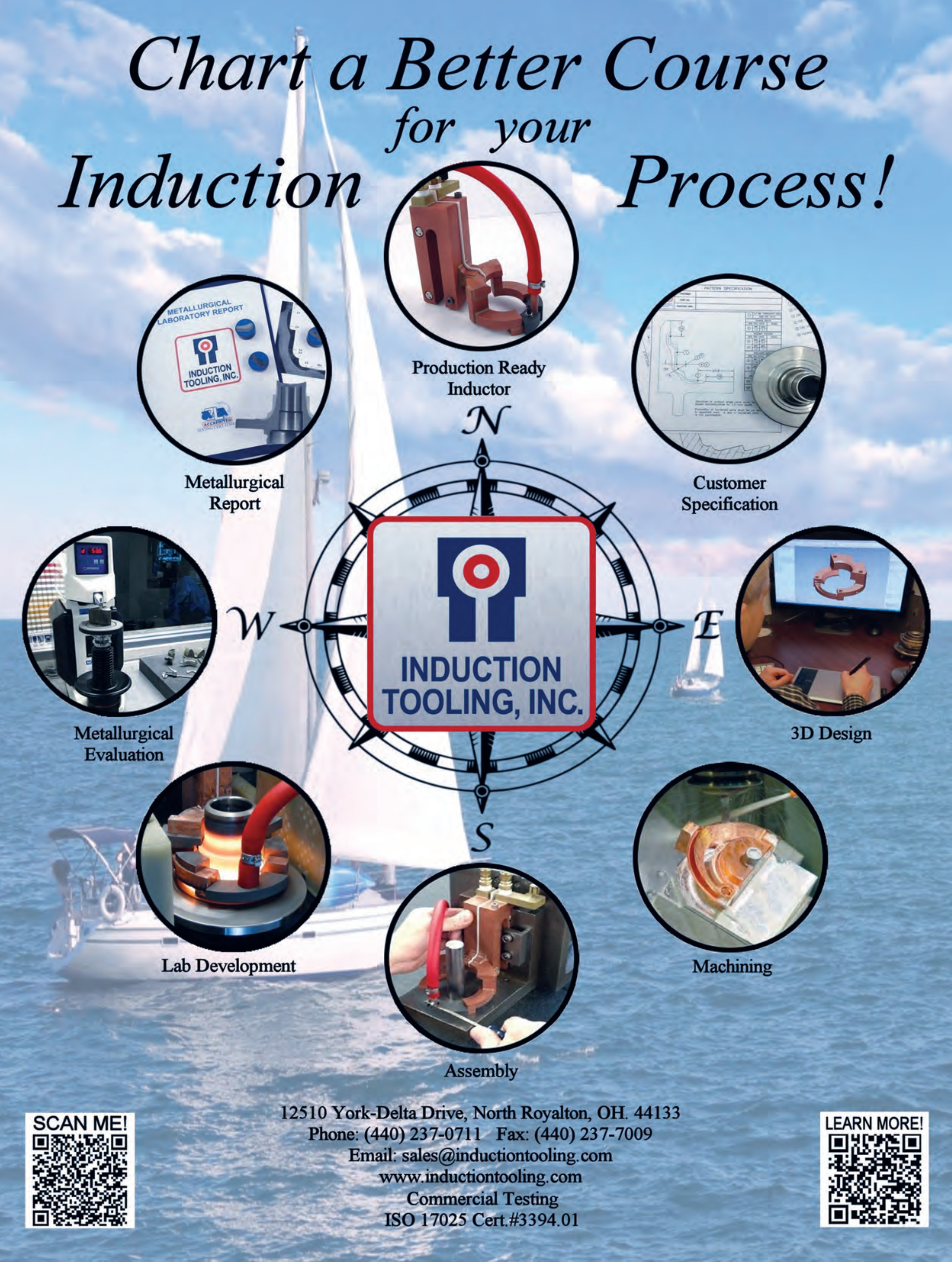
WHAT WORK HAS EPCON DONE WITH NASA AND AEROSPACE?

We manufactured two specialized pieces of heat-processing equipment for NASA. We made an oven for NASA to heat the ceramic tiles that went on the shuttle, one tile at a time. And we did a job for Lockheed Martin, which processed the gold foil that forms the shield around the lunar module on the moon's surface. We made the curing oven.

WHAT SETS EPCON APART?

We don't "sell" anything; we provide a solution of satisfaction. Customers come to us with a problem or something they need to control, so we take charge and fully engineer, design, build, and test before we ship.

FOR MORE INFORMATION, go to www.epconlp.com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