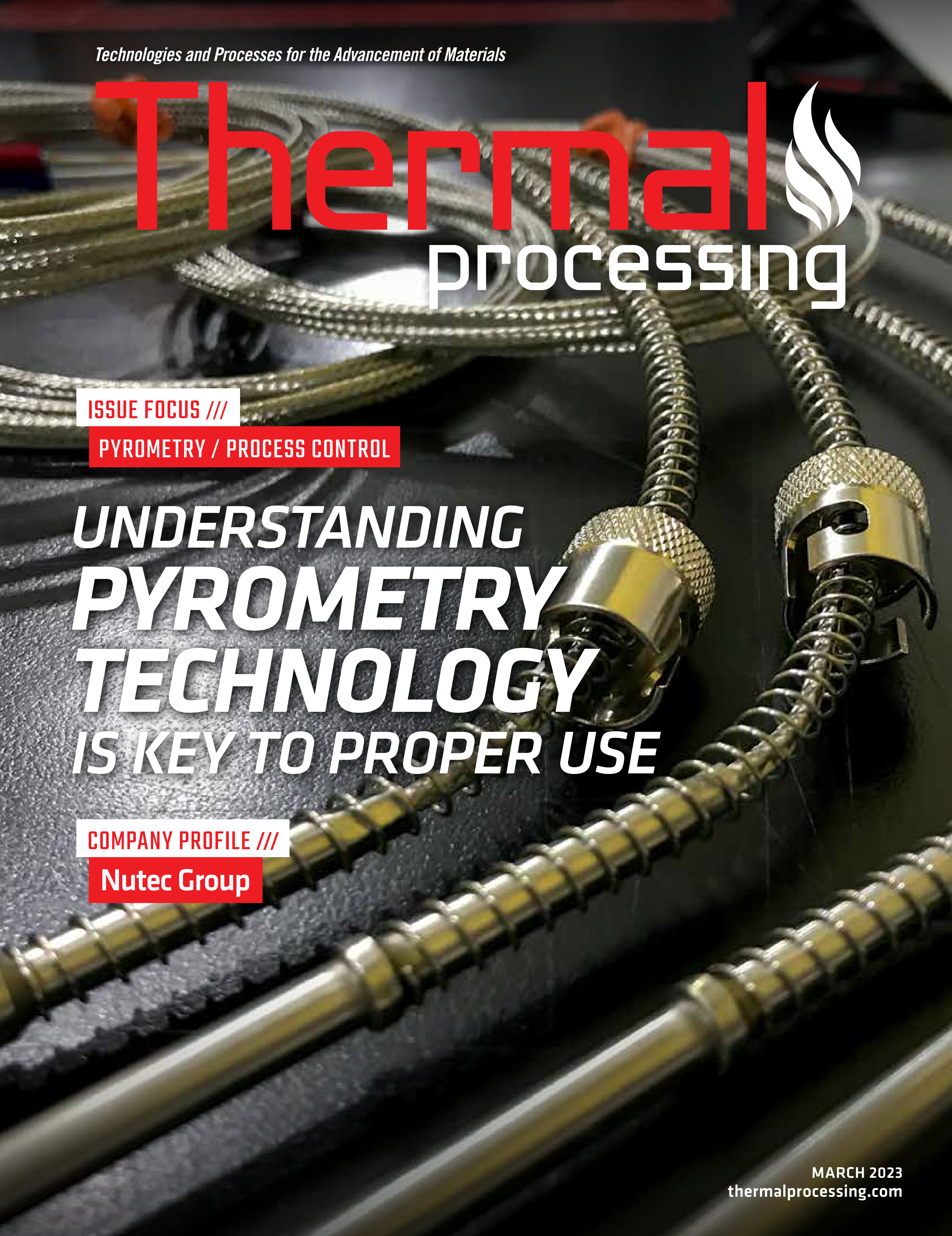

Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

PYROMETRY / PROCESS CONTROL

UNDERSTANDING PYROMETRY TECHNOLOGY IS KEY TO PROPER USE

COMPANY PROFILE ///

Nutec Group

MARCH 2023
thermalprocessing.com


The leader in quality and innovation.

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UNDERSTANDING PYROMETRY TECHNOLOGY IS KEY TO PROPER USE

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SOLUTIONS FOR INDUSTRIAL HEATING AND THERMAL INSULATION

Nutec Group manufactures high temperature insulation, kilns, and furnaces and supplies quality products and superior service while exceeding its clients', employees', and stockholders' expectations.

COVER PHOTO: SHUTTERSTOCK

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FROM THE EDITOR ///

Pyrometry and process control take center stage

The March issue of *Thermal Processing* takes a deep dive into activities vital to the heat-treat industry, namely pyrometry and process control, and you'll find quite a few articles this month that deal comprehensively with those subjects.

On the subject of pyrometry, long-time contributor Jason Schulze shares his understanding on how pyrometry technology is key to proper use and what important factors should be considered when buying and using thermocouples.

An article from Fanjie Wei looks at the design and implementation of PLC-based industrial temperature control systems.

Our final article is part one of a three-part series. Over the next three months, new contributor Gregory Fett will share his insights on carburized steel mechanical properties. He begins part one by looking into how medium- and high-carbon steels heat treated to higher hardness levels are subject to quench embrittlement, which is normal and not an anomaly, and how steps can be taken to get samples to published values.

You'll also find other areas of interest in our March issue as well.

Ipsen is starting its Ipsen U course series again this year. In our Q&A, Ipsen's Matt Clinite lets you know what to expect from the three-day course and when you can sign up. It looks to be an exciting hands-on educational experience for the industry.

In our company profile, I had the pleasure to speak to Nutec Group CEO Daniel Llaguno. In the feature, he gives a detailed look at what Nutec Group offers the heat-treat industry, including the manufacture of high-temperature insulation, kilns, and furnaces.

That's just a taste of what you'll find in this month's issue of *Thermal Processing*.

I also want to take the opportunity to say that if you're looking for a forum to share your expertise, please hit me up with suggestions at the email below so we can continue to make *Thermal Processing* the best heat-treat source it can be.

As always, thanks for reading!

KENNETH CARTER, EDITOR
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(800) 366-2185 x204

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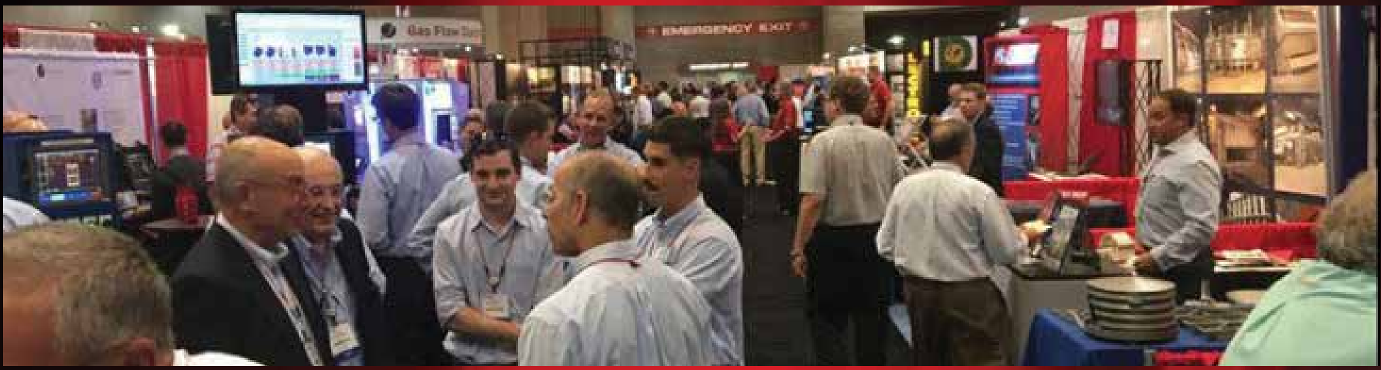
IFHTSE

HEAT TREAT EVENTS 2023



AEROMAT 2023 › March 14–16 | Fort Worth, TX

Heat Treat Mexico 2023 › March 28–30 | Monterrey, Mexico

Ceramics Expo 2023 › May 1–3 | Novi, MI

Rapid + TCT 2023 › May 2–4 | Chicago, IL

AISTech 2023 › May 8–11 | Detroit, MI

Forge Fair 2023 › May 23–25 | Cleveland, OH

PowderMet 2023 / AMPM 2023 › June 18–21 | Las Vegas, NV

IFHTSE World Congress › Sept 30–October 3 | Cleveland, OH

FABTECH 2023 › September 11–14 | Chicago, IL

IMAT 2023 › October 16–19 | Detroit, MI

Heat Treat 2023 › October 17–19 | Detroit, MI

Global Materials Summit › December 5–7 | Naples, Florida

Thermal processing

Look for bonus distribution of *Thermal Processing* at many of these shows. And we look forward to seeing you at select events this year.

The NEO's vacuum chamber is designed to thermally heat parts with the use of work thermocouples, transferring into a vacuum protected vestibule within 20 seconds, and finally immersing a maximum 2,000-pound load into a hot agitated 3,000-gallon oil quench bath. (Courtesy: Solar Atmospheres)

Solar Atmospheres has Boeing OK for vacuum oil quenching

Solar Atmospheres of Western PA announces the approval of a critical Boeing specification for the oil quenching of alloy steels in accordance with Boeing's specification BAC 5617.

"We are honored to earn this accreditation from Boeing," said Michael Johnson, sales director. "The approval for our new vacuum oil quench furnace, the NEO, represents a massive addition to Solar's heat treat capabilities. The NEO's vacuum chamber is designed to thermally heat parts with the use of work thermocouples, transferring into a vacuum protected vestibule within 20 seconds, and finally immersing a maximum 2,000-pound load into a hot agitated 3,000-gallon oil quench bath. All of this processing is done without a single flame or a puff of smoke.

"Additionally, the inert processing and fast reliable transfer times provide our customers with superior metallurgical properties. Maximum through hardness is achieved and the surface contamination of flight critical components is totally eliminated. From landing gear to additive manufactured components, the NEO is unlocking an entirely new world of bright, clean, safe, and environmentally friendly oil quench processing for us. Now Solar can support additional Boeing programs including their extensive domestic supply base."

MORE INFO www.solaratm.com

L&L ships dual-chamber electric box furnace

L&L Special Furnace Co. has shipped a dual-chamber heat-treating and tempering furnace to a leading global manufacturer of shopping carts and display cases located in the southeastern United States. The equipment will play a supportive role in keeping key production equipment on-line along with thermal processing of various projects.

The L&L model QDS124 has two chambers. The top chamber, rated to 2,350°F, is used for heat-treating various steels and other non-ferrous materials. The bottom chamber, rated to 1,250°F, includes a recirculation fan and baffle for tempering, stress relieving, or preheating.

The effective work zone of the top chamber is 10" high by 11" wide by 22" deep, with the tempering chamber work zone being 10" high by 10" wide by 20" deep. The furnace is controlled by Eurotherm controls with overtemperature protection. The top and bottom chambers are sealed for use with inert atmosphere and include a manual flowmeter/regulator system for both chambers. Solid-state relays drive the heating circuits and are housed in a side-mounted NEMA1 panel. The furnace was painted with custom colors to match the customer's existing equipment.

Shipped with the furnace was an accompanying QTO1224 oil quench tank. The quench tank has a working size of 12" high by 12" wide by 24" deep and holds 65 gallons of oil. Included is a hinged safety lid, immersion-style heater with thermostat, and an agitator with explosion-proof motor for deployment with oil. Provisions are offered for additional oil to the air cooler if needed. The quench tank and furnace are NFPA86-compliant for safety.

All L&L Special furnaces can be configured with various options and be specifically tailored to meet customers' thermal needs. The company also provides furnaces equipped with pyrometry packages to meet ASM2750.

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

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

The QDS124 dual chamber heat-treat furnace's top and bottom chambers are sealed for use with inert atmosphere and include a manual flowmeter/regulator system for both chambers. (Courtesy: L&L Special Furnace Co.)

Canada. International startup and training service is available by factory quote.

MORE INFO www.llfurnace.com

APMI International names Christopher Schade 2023 Fellow

APMI International's most prestigious award recognizes APMI members for their significant contributions to the goals, purpose, and mission of the organization as well as for a high level of expertise in the technology, practice, or business of the industry. The 2023 Fellow Award recipient will receive elevation to Fellow status at PowderMet2023, during the opening General Session on June 19, in Las Vegas, Nevada. The 2023 recipient is Christopher T. Schade, vice president of Advanced Materials, Hoeganaes Corporation.

Christopher Schade

Chris Schade is an accomplished member of the PM community. His experience is a combination of manufacturing, research, and education. He manages an additive and specialty powder manufacturing facility and performs research into alloy and lubricant development in addition to being an instructor at Drexel University, teaching both metallurgy and PM classes. Schade's innovations in alloy and lubricant development have expanded the catalog of materials now manufactured and available in the PM and AM industries. Some of these activities resulted in having several patents issued. His research extends into the use of the powder in an application, where he collaborates with part makers to create a process for successful part manufacture. Schade received the Outstanding Adjunct Faculty Award in 2021. He continues to be a mentor for students and new engineers. He is a long-time contributor to the technical programs in the PM and now the AM conferences and was co-chairman of the fledgling AMPM2017 Conference. He has received the Howard I. Sanderow Outstanding Technical Paper Award three times, the Metal Additive Manufacturing Outstanding Technical Paper twice, and has been a member of the winning APMI Metallography Competition team four times. Schade received the MPIF Distinguished Service to Powder Metallurgy Award in 2019.

Established in 1998, the Fellow Award recognizes APMI members for their significant contributions to the society and high level of expertise in the technology of powder metallurgy, practice, or business of the PM industry. Fellows are elected through their professional, technical, and scientific achievements; continuing professional growth and development; mentoring/outreach; and contributions to APMI International committees.

MORE INFO www.mpif.org
apmiinternational.org

Delta H provides two SCAHT tempering furnaces

Delta H® recently supplied twin SCAHT®-HD (heavy-duty) Series convection furnace systems to Winston Heat Treating. The furnaces replaced older tempering systems that were extremely difficult to qualify to even Class 5 (±25°F). Pyrometry expert Andrew Bassett of Aerospace Testing and Pyrometry (ATP) recommended to Winston Heat Treating management the acquisition of Delta H furnaces as "the easiest furnace brand to qualify and maintain for aerospace pyrometry compli-

Twin SCAHT®-HD tempering furnaces certified for aerospace parts production. (Courtesy: Delta H)

ance, for this specific application." The furnaces had to be heavy-duty for rugged daily use in a commercial heat-treating facility. Another challenging aspect was the ability to heat rapidly but also to cool just as fast, without damage to interior metal as a load heat treated at 1,000°F could be quickly followed by the next at 300°F. The result is that the new Delta H furnaces can heat and cool in a fraction of the time of the previous systems.

ATP independently demonstrated both systems as capable of passing Class 1 uniformity (±5°F), throughout the operating temperature range, but qualified them as Class 2 (±10°F) from 300°F to 1,200°F. Both are set up with instrumentation Type B and feature two load thermocouples.

The furnaces feature a guaranteed certified TUS volume of 2 feet wide, 1.5 feet high, and 2 feet deep with a maximum continuous operating temperature of 1,200°F. Both are designed to receive baskets of parts from many nearby heat-treating operations for secondary heat treatments. Temperature control and data acquisition are provided by Super Systems and feature the SSi 9130 controller/programmer. Both furnace systems were quickly integrated into their Super Data facility monitoring system with zero learning curve.

The SCAHT®-HD Series is available in a variety of sizes with current models featuring a guaranteed TUS volume up 2' x 2' x 4'. All models feature the high-performance characteristics and attention to detail that have distinguished Delta H for compliance to strict aerospace and Nadcap standards.

MORE INFO www.winstonht.com
www.delta-h.com

Solar Atmospheres hardens massive H13 extrusion dies

Solar Atmospheres of Western PA successfully vacuum heat treated two massive H13 extrusion dies at its Hermitage, Pennsylvania, facility.

The company's newest high-performing Solar Manufacturing 10-Bar 600 horsepower high-pressure gas-quench vacuum furnace was able to fully harden two huge H13 extrusion dies in successive cycles. The dies, received from two different customers located in Ohio, resulted in an as-quenched hardness of HRC 50-52 using nitrogen as the quench gas. The hollow die was 30" OD x 15" ID x 103" long and weighed 16,000 pounds. The solid die, belonging to a different customer, was 34" OD x 64" long and weighed 14,000 pounds. Post-quench, each component was triple air tempered resulting in a final hardness of HRC 46-48.

"This 10-bar 600 HP high-pressure vacuum furnace allows Solar to attain cooling rates that are inconceivable," Mike Johnson, director of sales. "Solar is always willing to accept the challenge of vacuum heat treating and brazing any job, no matter the size."

MORE INFO www.solaratm.com

Industrial chain manufacturer saves with Endoflex S

Nordic Traction Finland, a manufacturer of traction chains and tracks for forestry and agricultural machinery, recently upgraded their heat-treatment operations by installing a new EndoFlex™ S endothermic gas generator system. Nordic Traction relies on endogas to carburize its traction chains.

The EndoFlex S replaced an outdated generator that could not effectively control volume or atmosphere quality and was incapable of scaling up when the demand increased. The new system is also less expensive to operate and mixes to more precise ratios, which helps to maintain a constant furnace atmosphere and consistent gas quality at all times — improving process reliability and the quality of the finished product.

Additional benefits include increased heating efficiency and lower operating and maintenance costs. Because its multi-retort design operates at a lower temperature, the catalyst and retorts last longer, requiring less preventative maintenance. The capabilities of the EndoFlex S were further enhanced by the addition of an AtmoSense™ analyzer, which continuously controls and monitors methane (CH_4) to consistently produce the ideal gas mixture for high-quality endothermic gas.

"Nordic Traction was looking for the most sustainable and cost-effective, onsite source of endothermic gas production for their facility in Loimaa," said Daniel Panny, head of sales at UPC-Marathon, a Nitrex company, in Europe. "Since the EndoFlex S produces only the amount of gas required by the carburizing furnace, there is zero waste in endogas production. This also allows Nordic Traction to save big by maximizing energy usage and gas consumption. I visited the plant six months after the EndoFlex S was commissioned to see how it was working and discovered that Nordic Traction is saving up to 20 percent per month in energy and resource costs."

MORE INFO www.nitrex.com

Aluminum Dynamics contracts Tenova for roll grinders and PDT

Aluminum Dynamics LLC, a Steel Dynamics Inc. joint venture, awarded Tenova a new contract for its aluminum flat rolling mill located in Columbus, Mississippi.

The contract is for the design and supply of technologies offered by Pomini Tenova, a well-known brand of Tenova and a worldwide leader in the production of roll grinders and a leading developer and provider of sustainable solutions for the green transition of the metals industry.

The scope of works includes two foundationless combination roll grinders, two foundationless work and intermediate roll grinders, and one Pomini Digital Texturing™ machine (PDT™) equipped with four laser heads for texturing of cold mill work rolls. Tenova will also provide a roll shop management system for the management of the roll shop production data, which is interfaced with the Pomini roll grinders and Aluminum Dynamics' level two and business management software.

The roll grinders are equipped with an advanced set of automated devices, including the new Pomini Digital Surface Analysis (PDSA), the automatic roll demagnetizer, the on-line automatic roughness measurement, as well as a full range of Non-Destructive Testing (NDT) devices for roll inspection.

Moreover, the use of the PDSA in conjunction with Pomini Inspektor3, in its complete configuration, guarantees the surface quality of the roll and its internal structural integrity.

In addition, the adoption of foundationless technology for roll grinders will allow for a simplified construction process and efficient installation in the roll shop.

"We are excited to work with Tenova on this project," said Glenn Pushis, president of Aluminium Dynamics LCC. "Partnering with a leader in this space, their focus on decarbonization, and high-quality equipment drove this crucial decision."

"The selection of PDT to address the higher requirements of product quality for automotive and appliances production is perfectly aligned with the client's focus on decarbonization," said Petar Rokic, sales area manager at Pomini Tenova. "This equipment — an advanced fiber-laser based technology — substantially reduces the energy utilization when comparing it with the previous processes based on electro-discharge. Furthermore, the choice of PDT, the first EPD-certified technology, will allow

Aluminum Dynamics LLC to establish in-house a clean, lean, and safe ownership and control of their roll texturing technology and expertise development."

MORE INFO www.tenova.com

PowderMet2023, AMPM2023 slated for June 18-21

The North American conference on powder metallurgy (PM) and particulate materials has launched its 2023 conference program for PowderMet2023, co-located with AMPM2023.

The conference features more than 200 technical presentations from worldwide industry experts presenting on PM, particulate materials, and metal additive manufacturing (AM) at the Caesars Palace, Las Vegas, Nevada, June 18–21, 2023.

PowderMet2023 is an information exchange site for professionals from every part of the industry, including buyers and specifiers of metal powders, tooling and compacting presses, sintering furnaces, furnace belts, powder handling and blending equipment, quality-control and automation equipment, particle-size and powder-characterization equipment, consulting and research services, and more.

Focusing on metal additive manufacturing, AMPM2023 will feature worldwide industry experts presenting the latest technology developments in this fast-growing field.

In addition to PowderMet's high-level technical programming, the conference features the PM industry's largest tradeshow devoted exclusively to powder metallurgy, metal injection molding, and metal additive manufacturing. With more than 100 booths, this international marketplace will present leading companies featuring the latest PM and metal AM equipment, powders, products, and services. Industry networking events such as the popular PM Evening Alehouse provide the best opportunity to meet industry suppliers all together in one place.

Review the program and register now at PowderMet2023.org and AMPM2023.org.

PowderMet2023 and AMPM2023 are sponsored by the Metal Powder Industries Federation and APMI International.

MORE INFO www.mpif.org

Ipsen announces 2023 dates for Ipsen U curriculum

Ipsen's comprehensive training course in vacuum equipment, Ipsen U, is returning in 2023 with some upgrades. Expanded course offerings will dig deeper into metallurgy, thermal processes, troubleshooting, and furnace mechanics. The curriculum will also be tailored for each class based on attendees' industries, job functions, and types of furnaces used.

The three-day course, taught by Ipsen subject matter experts, teaches heat-treatment fundamentals and industry best practices and incorporates hands-on training. The course is appropriate for anyone who manages, maintains, or operates vacuum furnace equipment.

"Ipsen U is presented in a format that is informative and engaging to individuals from entry-level through seasoned veteran and encourages collaborative discussion amongst the participants," said a past attendee in the aerospace industry.

Classes for 2023 are scheduled to take place April 11-13, June 6-8, August 8-10, and October 3-5. All classes are located at Ipsen's Vacuum Technology Excellence Center, 984 Ipsen Road in Cherry Valley, Illinois. Seating is limited. Reserve a spot by visiting ipsenglobal.com/event/ipsenu.

MORE INFO www.ipsenusa.com

L&L provides MRO distributor bench-top furnace

L&L Special Furnace has delivered a highly uniform box furnace to a distributor of equipment to maintenance repair and overhaul (MRO) facilities located throughout the world.

The L&L Model XLB124 has working dimensions of 11" wide by 10" high by 22" deep. The furnace is capable of heat-treating a wide variety of tool steels — from D-2 to high-speed M-2 tool steel — along with low-temperature tempering. It is equipped with a sealed case for inert atmosphere capability, as well as a fully functional atmosphere control panel with pressure regulator, flowmeter, and manual shut-off valve.

Elements are very evenly spaced around the chamber. There is a manually operated, spring-assisted vertical door. Included is a NEMA 1 control cabinet with a Eurotherm program controller, high-limit backup system, thermocouples, fusing, and all interconnection wiring. Power control is accomplished with quiet two-zone, long-lasting solid-state contactors. The furnace hearth is a rugged cordierite plate with ceramic support.

The Model XLB124 is insulated with 2-1/2-inch lightweight firebrick and backed up with two inches of insulating board. The bottom is reinforced with a high-density calcium silicate that provides extra support for the load weight.

The L&L XLB series comes in several sizes, with custom configurations available upon request. There are also many options available for the XLB series, from atmosphere-sealed casing for use with inert atmosphere to an array of control and recorder varieties, along with recirculation fans and controlled cooling.

MORE INFO www.llfurnace.com

5th International Conference and more coming in 2023

The 28th IFHTSE Congress, sponsored by the Japanese Society for Heat Treatment, will be November 13-16, in Yokohama, Japan. (Courtesy: Shutterstock)

The 5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies (HTSE-TD), sponsored by the Chinese Heat Treating Association, will be April 24-27, 2023, in Hangzhou, China. This conference will finally resume the HTSE-TD series. At the present time, it is being planned as a face-to-face conference. Please remember that a visa for entry to China is required. Correspondence should be sent to Lihui Liu, chta@chta.org.cn.

›› **More info:** htse-td.allconfs.org/meeting/index_en.asp?id=6861

ECHT 2023 CONFERENCE

AIM is proud to announce the ECHT 2023 Conference in Genova, Italy, at Magazzini del Cotone. The conference will meet May 29-31, 2023. ECHT 2023 will cover all relevant topics for the heat-treatment and surface-engineering community. The conference will include a special focus on sustainability. Full paper submission deadline is March 31, 2023.

›› **More info:** www.aimnet.it/echt2023.htm

HEAT TREAT 2023

Heat Treat 2023 will be co-located with IMAT 2023 in Detroit, Michigan, October 17-19, 2023. It will cover many topics of interest. Abstracts were due February 17, 2023. If an abstract was accepted into the Heat Treat 2023 technical program, the author should submit a full manuscript (6-8 pages) by the deadline date. Complimentary full conference registration will be offered to authors (presenting author only) who submit a full manuscript for the proceedings.

Important dates:

›› **Accept/Reject Notification:** April 17, 2023.

›› **First Draft Manuscript Due:** May 31, 2023.

›› **Final PDF Manuscript Due:** July 17, 2023.

›› **More info:** www.asminternational.org/web/heat-treat/event-info

28TH IFHTSE CONGRESS

The 28th IFHTSE Congress, sponsored by the Japanese Society for Heat Treatment, will be November 13-16, 2023, in Yokohama, Japan.

The ECHT 2023 Conference will be in Genova, Italy, May 29-31.

This wide-ranging conference offers participants the opportunity to network and hear papers on a wide ranging series of topics, including the thermal processing of steel, surface hardening additive manufacturing, and modeling and simulation of industrial processes.

Important dates:

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

A special issue of JSHT is scheduled to be published in March 2024. Applicants can submit a full paper to the special issue. Only the presenters of the 28th IFHTSE Congress can submit full papers for this special issue.

SPOTLIGHT ON MEMBERS

PD2i is a Paris-based company that specializes in turn-key solutions in PVD and PeCVD coatings and machines. Since its inception in 2003, it is deeply involved with plasma nitriding and provides much needed components for the process, including magnetrons, arc sources, ion guns, and more. It also provides consulting services on thin film coatings and plasma nitriding for molds and forming tools.

- **More info:** pd2i.com

UPCOMING IFHTSE EVENTS

APRIL 24–27, 2023

5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies

Liangzhu Dream Town, Hangzhou, China

MAY 29–31, 2023

ECHT23

Genova, Italy | www.aimnet.it/echt2023.htm

OCTOBER 17–19, 2023

Heat Treat 2023

Detroit, Michigan | www.asminternational.org/web/heat-treat

NOVEMBER 13-16, 2023

28th IFHTSE Congress

Yokohama, Japan

For details on IFHTSE events, go to www.ifhtse.org/events

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

IHEA MEMBER SPOTLIGHT

Dry Coolers specializes in cooling systems

Dry Coolers offers reliable, energy efficient cooling solutions that meet the specific needs of its customers. (Courtesy: Dry Coolers Inc.)

Dry Coolers Inc. specializes in engineered fluid cooling systems primarily servicing an industrial market. Since 1985, it has designed and manufactured a range of industrial fluid cooling systems from small, standard point-of-service cooling solutions to complex, plant-wide systems. Dry Coolers provides right-sized, reliable, and energy-efficient cooling solutions for the specific needs of its customers around the world. Dry Coolers was founded by Brian and Margy Russell in 1985. The first industry that Dry Coolers served was the heat-treating industry, and it still remains its primary focus.

However, in addition to heat treating, Dry Coolers also serves the aerospace, automotive, power generation, additive manufacturing,

fuel cell, data center cooling, tube mills, telecommunications, and coatings industries.

Dry Coolers offers reliable, energy efficient cooling solutions that meet the specific needs of its customers.

Dry Coolers' AVI series Air Cooled Heat Exchangers offer closed-loop cooling solutions for processes where the fluid temperature is close to ambient. These offer significant energy and water savings as compared to a refrigerant chiller or evaporative cooling system.

Dry Coolers' day-to-day business is designing and building engineered cooling systems to suit each customer's individual needs. Because the company does this daily, it makes what could be an expensive custom solution affordable and competitively priced.

Dry Coolers offers a variety of cooling solutions for each temperature requirement of its customers. The experts at Dry Coolers always steer customers into the most robust and cost-effective system that will operate into the future.

With 60 employees, the company's secret ingredient is its people. It boasts a high retention rate of employees who are experts in industrial cooling systems. When customers have a question, a team of engineers and technical service specialists is ready to help them answer and solve it. Dry Coolers prides itself on taking care of customers with the utmost care and quick response times.

Over the years, Dry Coolers continues to find new industries and markets to serve, and it will continue to develop new products to meet customers' needs. The Exo-Shed is a unique product that is versatile to suit various industries. It is essentially an outdoor mechanical room that lets customers save valuable shop floor space for other needs. The Exo-Shed allows the entire water-cooling system to be installed outdoors. The new LSX Series Spot Cooler combines the AVI series dry coolers with variable speed fan motors on a common skid with pump, tank, and motor controls. It's another space saver solution that has been well received.

One of Dry Coolers' primary goals over the next five to 10 years is to train newer employees to fill the shoes of the more senior employees. The company is continuing to innovate with its dry cooler solutions to make them more streamlined to manufacture and service and be more cost effective.

Dry Coolers continues to lead the industry in heat-treat cooling solutions while giving back to the industry with support and participation with industrial trade groups such as IHEA.

»**More info:** drycoolers.com

Dry Coolers' day-to-day business is designing and building engineered cooling systems to suit each customer's individual needs. With 60 employees, the company's secret ingredient is its people. (Courtesy: Dry Coolers Inc.)

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DR. WILLIAM MARK MCVEA, P.E.
PRESIDENT AND PRINCIPAL ENGINEER /// KBE+

Determining the applicability, effectiveness, and best choice for heat treating, depending on the final properties of the gear we need to produce.

An overview of heat treatment techniques

Editor's note ›› This is the first in a five-part series.

I recently had the wondrous experience of being invited to tour a very modern state-of-the-art heat-treatment system fabrication facility. I want to say thanks to my friends at SECO/ Warwick and SECO / Vacuum for the tour, the technical discussions regarding their technology, and finally the opportunity to present in their e-Seminar 4.2.

This article is the first in a five-part series wherein I will cover all the most common, major heat-treating techniques and equipment as well as taking a look ahead to the future of heat-treating metals. This will be an extension of a series of articles and technical summaries of industry today.

There are four main categories of heat-treatment techniques and equipment. The order in which I have presented does not mean to imply a chronology or precedence in terms of the end result.

Carburizing is a case hardening process in which a metal part or component of low carbon content is heated in a carbon-rich gas atmosphere. The process of heating the metal component in a high carbon environment allows for diffusion of carbon atoms directly into the surface of the part that needs to be case hardened. The enhanced performance of case carburized parts, especially gears, is that the process induces tensile stress in the surface of the material.

Carburizing is a thermochemical process in which carbon is diffused into the surface of low carbon steels to increase the carbon content to sufficient levels so that the surface will respond to heat treatment and produce a hard, wear-resistant layer. There are three traditional types of carburizing commonly used:

- Gas carburizing.
- Liquid carburizing (or cyaniding).
- Solid (pack) carburizing.

All three processes rely on the transformation of austenite into martensite during quenching. The increase in carbon content at the surface must be high enough to give a martensitic layer with sufficient hardness, typically 58 to 62 HR_C to provide a wear-resistant surface. The required carbon content at the surface after diffusion is usually 0.6 percent to 1.00 percent carbon. These processes can be carried out on a wide range of plain carbon steels, alloy steels, and cast irons where the bulk carbon content is a maximum of 0.40 percent and usually less than 0.25 percent carbon. Incorrect heat treatment can lead to oxidation or de-carburization. Although a relatively slow process, carburizing can be used as a continuous process and is suitable for high-volume surface hardening.

An overview of the four major techniques:

Gas Carburizing: In gas carburizing, the component is held in a furnace containing an atmosphere of methane or propane with a neutral carrier gas, usually a mixture of N_2, CO, CO_2, H_2 and CH_4. At the carburizing temperature, methane (or propane) decomposes at the component surface to atomic carbon and hydrogen, with the carbon diffusing into the surface. In most cases, the carburizing atmosphere is created from methane or propane and is produced in a special device (the endothermic generator) by gases partially oxidated with air. The reaction for methane is: $2CH_4 + O_2 (+N_2) \Rightarrow 2CO + 4H_2 (+N_2)$ and similar for propane. The atmosphere consists mainly of CO, H_2, and N_2, while the main C carrier is CO (reaction $2CO \Rightarrow C + CO_2$), while CO_2, H_2O, O_2, and CH_4 are residual gases. The carburizing atmosphere is delivered to a furnace from the endothermic generator (not directly), and methane or propane is injected directly into the furnace in small amounts to compensate for the carbon absorbed by steel. Methanol is the only agent that can create the carburizing atmosphere directly in a furnace and decomposes accordingly: $CH_3OH \Rightarrow CO + 2H_2$. The temperature is typically 925°C and carburizing times range from five to six hours for a 1 (mm) depth case to as many as of around 90 hours for a 4 (mm) case. The quenching medium is usually oil, but can be water, brine, caustic soda, or polymer, and neutral gas under high pressure.

Liquid Carburizing (or Cyaniding): Liquid or cyanide carburizing is carried out by placing the component in a salt bath at a temperature of 845°C to 955°C. The salt is usually a cyanide-chloride-carbonate mixture and is highly toxic. The cyanide salts introduce a small amount of nitrogen into the surface, which further improves its hardness. Although it's the fastest carburizing process, it is suitable only for small batch sizes.

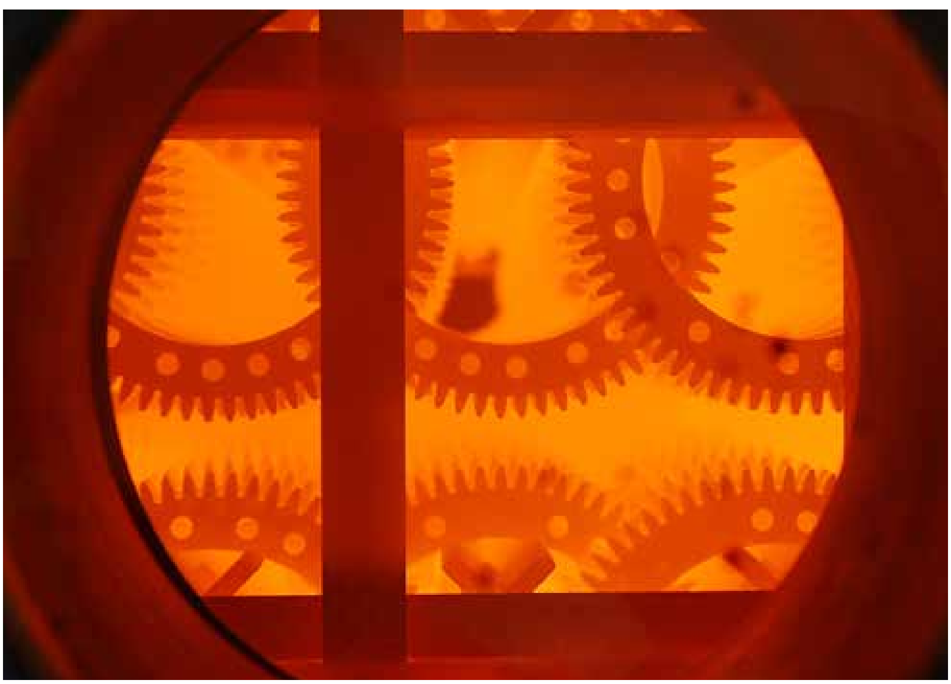
Solid (Pack) Carburizing: In solid or pack carburizing, the components are surrounded by a carburizing medium and placed in a sealed box. The medium is usually coke or charcoal mixed with barium carbonate. The process is really one of gas carburization since the CO produced dissociates into CO_2 and carbon, which diffuses into the components' surface. Temperatures are usually 790°C to 845°C for times of two to 36 hours. Pack carburizing is the least sophisticated carburizing process and as a result remains a very limited use method, as such I will not cover this process or method in any detail.

Carbonitriding (Carbo-Nitriding): Carbonitriding is undertaken on a similar range of steels although the bulk carbon content can be as high as 0.4 to 0.5 percent carbon. The process is particularly suited for hardening the surface of components that need a through-hardened core, such as gears and shafts. Carbonitriding is a modification of gas carburization where ammonia is added and is the source of nitrogen. By carbonitriding the metal, technicians increase the strength of the material. It is stronger and more resistant to wear and tear. The carbon and nitrogen diffused on the surface creates increased strength on the surface while maintaining a lesser hardness at the core.

What are carburized gears? Carburizing is a widely used, effective technique to increase surface hardness of steel used in gears and achieve compressive residual stresses. There are several methods of carburizing, which is the addition of carbon to the surface of low carbon steels. In gears, and specifically thinking about high cycle fatigue, the load on the surface of the tooth is applied directly on the face of the tooth. This induces a compressive stress within the contact zone or patch (as it is commonly called). In the unloaded condition, the non-heat-treated face of the gear tooth is at zero compressive stress. When a contact load is applied to one gear tooth, from contact with its gear mate, the center of the contact patch deflects to provide enough area in the contact patch that the surface stress is near the yield stress of the material.

In previous articles I have discussed the additional effect of the induced shear stress due to the sliding component of tooth-to-tooth interaction and will not repeat it here. Suffice it to say that any induced shear stress on the surface of the tooth face will theoretically push the state of stress over the yield material limit. We heat treat gear materials, especially case carburizing, to induce a component of tensile stress as a means to offset or prestress the surface of our gear. However, a highly hardened material becomes functionally brittle. To mitigate this adverse effect, we only case carburize the surface over a ductile core. The ductile core supports the hard (brittle) surface that provides a means to deal with the applied compressive stress.

So, let's review some of the common and very effective heat-treatment methods and equipment.



LPC: LOW PRESSURE CARBURIZING

Low Pressure Carburizing (LPC), also known as Vacuum Carburizing, is similar to other case hardening processes and is a carburizing process, a part of case hardening process similar to other carburizing or carbonitriding, followed by quenching. The goal of LPC or vacuum carburizing is to obtain a part with a solid, tough core and a hard, wear-resistant surface. LPC has been established as one of the most popular case-hardening processes. Low-pressure vacuum carburizing is a state-of-the-art thermal process where carburizing is put into the furnace under very low pressures (7-13 mbar). Parts are first heated in vacuum to above the transformation temperature of the alloy and then exposed to carbon-carrying gas, or gas mixtures, under partial pressure. There are three types of carburizing commonly used: gas carburizing, liquid carburizing (or cyaniding), and solid (pack) carburizing. Similar to other case hardening processes, the goal of Vacuum Carburizing is to obtain a part with a solid, tough core and a hard, wear-resistant surface. LPC has been established as one of the most popular case hardening processes. It is applied to increase the fatigue limit of dynamically loaded components. Case hardening essentially consists of three steps: Parts are first austenitized, then carburized, and once the required carbon profile is reached, they are quenched, which is followed by a tempering step.

The LPC process takes place in a temperature range between 870 to 1,050°C with a pressure range between 5 and 15 (mbar). In most cases, the vacuum carburizing temperature is between 920 and 980°C. During the complete process, the treated components are not exposed to any traces of oxygen.

Oxygen-free hydrocarbons such as acetylene C2H2 (ethyne) are used as the carbon source. The hydrocarbons are injected into the furnace chamber, creating a pressure of a few millibars. The use of acetylene is recommended since it provides a homogenous carburizing even for complex shapes, such as bores and even blind holes. Once the targeted carbon profile is obtained, the parts are quenched. In most cases, oil quenching is applied, but High Pressure Gas Quenching (HPGQ) becomes more and more popular after LPC with pressures up to 25 bar of nitrogen or helium.

This is a case-hardening process, carried out in a vacuum furnace using hydrocarbon gases at very low pressure and elevated temperatures to obtain a hardened surface layer of tempered martensite and a tough core. The equipment used to do this is sometimes referred to as an LPC Boiler. The treatment is used to increase the wear resistance and fatigue life of components, and we are likely aware of case carburizing steels such as 8620H, which is used often in high-performance gears. LPC produces parts with high hardness below the surface, which compares with more conventionally carburized parts with faster cycle times. Parts can be carburized between 930°C and 1,000 °C / 1,700°F and 1,830°F. Penetration of carbon in deep blind holes results in uniform hardness on the entire profile.

The benefits of carburizing over conventional hardening heat treatment are that carburizing increases resistance to wear by creating a strong shell while maintaining a softer interior. It is often performed after the parts are rough or green machined and before finish machining or grinding. The benefits are the gears remain durable, the process enhances wear resistance and durability, increases corrosion resistance, improves the effect of the ductile core, and enhances the reliability of the surface hardness. There are other benefits as well:

» Excellent carburizing homogeneity even for components with complex shapes.

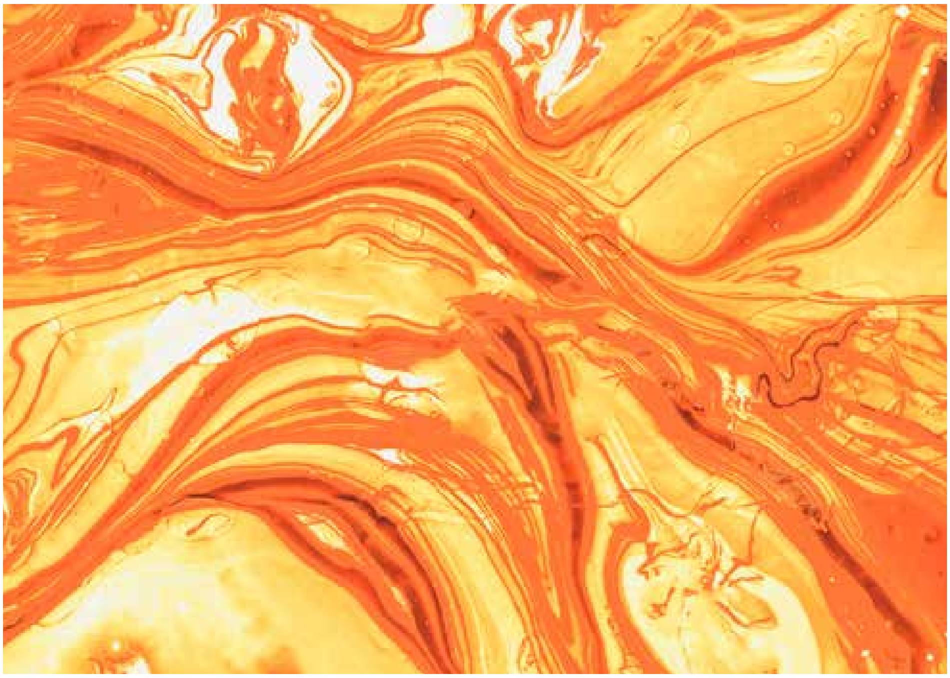
» Avoiding Inter-Granular Oxidation (IGO) and surface oxidation.

» Clean surfaces of parts after heat treatment; no washing of parts necessary.

» Environmentally friendly process (small consumption of resources; no disposal of oil, salt bath residues, or detergent residues).

» Potential to reduce heat treat distortion (unwanted changes of the part-geometry during heat treatment in form and size).

Common or standardized case hardening steels such as 4120, 4320, 5120, 5130, 52100, 8625, 9310, 18CrNi8, 20MnCr5, 27MnCr5, 18CrNiMo7-6, 8620 (for small parts), 16MnCr5 (for small parts), can be treated with LPC and HPGQ. The core hardness after treatment will, of course, depend on the geometry of the treated components and on the hardenability of the chosen steel grade. If necessary, the components can be partially mechanically shielded from carburizing during the LPC process. As an example, if threads need to be kept soft by masking that area of the part, it will avoid subsequent expensive hard machining operations.



VOQ: VACUUM OIL QUENCH

In vacuum heat treatment, air (specifically oxygen) is removed from the furnace to create a vacuum. The part may be heated in the vacuum with or without an inert gas (typically nitrogen and argon) to achieve the desired properties while protecting the part's surface. As in traditional heat treatment, the metal is quickly cooled. Quenching is the cooling part of the heat-treatment process that comes after other heat treatment has been performed on a part. By submerging hot metal into a quench media, it can be rapidly cooled and therefore retain the beneficial properties it gained through the heating process.

Quench oils have two primary functions. First, they harden the component by controlling heat transfer during quenching. Second, they enhance the wetting of the component in order to minimize undesirable conditions that may cause distortions and even cracking. Quench oils can range from a very generic motor oil (which is a common quenching oil used in both blacksmithing and blade-smithing applications) to new and used motor oils, which are both widely available. New motor oil is typically cheaper to use than commercial quenching oils.

Parts made of low-carbon steel and low-hardenability alloys quench better in fast oils. Hot oils are kept at much higher temperatures and are used to ensure that the core temperature and surface temperature of the part do not vary too greatly during a quench. This controls distortion and reduces the risk of cracking.

The process of heating and then quickly cooling parts is a way to achieve added hardness in the part. The heating causes changes in the crystalline structure in the surface layer(s) of the metal. The rapid cooling "freezes" those changes in the crystalline matrix and makes the surface harder. The first stage in a quench is known as the vapor stage. The submerged part is so much hotter than the quenchant, a vapor blanket forms around the part. Cooling of the part occurs during this stage, but it is impeded by the vapor, which acts as an insulator.

The second stage is the boiling stage, which is characterized by the violent boiling of the quenchant. Parts cool fastest in this stage because the temperature of the part has decreased enough during the previous stage for the vapor blanket to dissipate. With the quenchant able to contact the part unimpeded, it can carry away the most heat through boiling.

The third stage is the convective stage, during which convection and conduction further carry heat away from a part. Convection refers to the movement of a liquid due to the tendency of hotter, less dense liquids to rise while cooler, more dense liquids sink. Conduction refers to the tendency of heat to dissipate throughout a substance when there are temperature differences in the liquid. Oils are aggressively agitated, typically by mechanical means (rotating impeller, etc.), during the quench. The intent of this dynamic fluid (oil quenchant) is to force it to flow upward through a workload; natural convection becomes insignificant in the overall thermal reduction of the part.

HPGQ: HIGH PRESSURE GAS QUENCH

The most common definition for High Pressure Gas Quenching is accelerating the rate (speed) of quenching by densification and cooling of gas. One of the reasons for the intense interest in this quenching technique is related to improved part distortion with full hardness. Gas quenching is an important step in the treatment of steel parts. The process consists of cooling the parts down from their critical temperature quickly in order to strengthen and harden the metal. This process

is best suited to ferrous metals and those with high alloy content.

One benefit of the high-pressure gas quenching technique is it provides a means to reduce part distortion while still achieving the full hardness potential of the material. A critical concern is to avoid sacrifice of metallurgical, mechanical, or physical properties, while retaining the ability to transform a material to a microstructure that is similar, identical, or superior to that of a known quenching medium (e.g. oil or salt). Common quench gases include nitrogen, argon, and helium. Hydrogen, although excellent with respect to heat transfer, is seldom used as a quench gas due to safety considerations and hydrogen embrittlement concerns.

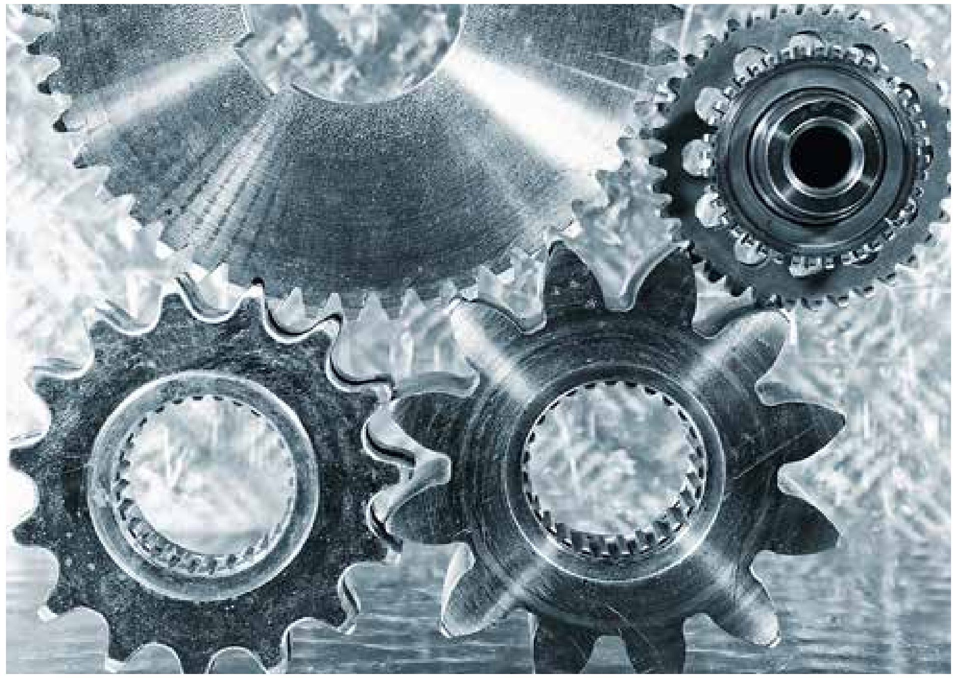
HPGQ offers a number of attractive benefits including unprecedented part cleanliness and less overall dimensional change. Fixed or variable cooling rates are applied as required to control hardness and distortion with the ability to vary quench pressure depending on load size, material type, and part section thickness. Product consistency and repeatability are excellent using high pressure gas quenching.

The goal of the gas quenching process is to improve hardness. Upon completion of austenitization, the parts are subjected to HPGQ in order to change the microstructure from austenite into martensite, thus obtaining the desired increase in hardness. One advantage to using high-pressure gas is that it treats material in a much more uniform way. While all forms of heat treatment will cause some level of distortion, there is typically 50–75 percent less distortion with gas than with oil quenching. There is also a difference in ductility between gas and oil methods. When comparing identical AISI 4140 parts that have been heat treated using the different methods, there is a higher yield strength and greater elongation in the sample treated with high-pressure gas over the oil-quenched part.

4DQ: 4D QUENCH

The 4D Quench is a modern alternative to a quench press. 4D quenching is a vacuum heat-treatment solution for single piece quenching with distortion control and reduction. The process replaces oil quenching with a clean, and environmentally friendly, cost-effective nitrogen quenching technology. It also provides a distortion-free alternative to oil and quench presses and the problems associated with their operation. The benefits are single piece flow vacuum heating (through hardening only). The process also provides a means to heat treat parts without generating an oxide layer due to the vacuum environment of the process. Since it does not use the press methodology, there are no press maintenance issues, which also means that the process can be a continuous, or through-flow, process. This allows for parts to be conventionally carburized, slow cooled, then processed through the 4D Quench system.

The 4D Quench system is a unique single-piece flow vacuum furnace designed to heat or re-heat products such as gears on a single conveyor deck. Each part is then individually transferred out of the vacuum furnace and into a quench chamber that uses a proprietary arrangement of cooling nozzles to surround the part (3D cooling). The part is then rotated (the 4th dimension) during the quench. This additional step to the typical process provides a uniform flow of cooling gas from all sides; top, bottom, and surround to ensure high-speed cooling. The pattern of cooling nozzles can be adjusted to fit the particular parts size and shape to provide optimum cooling rate and uniformity during the cooling process. The entire system provides uniform quenching, which results in very repeatable finished part geometry with significant reduction of distortion.



LOOKING AHEAD

So, what's next in this series? In the next four articles I intend to go into depth on each of the major heat-treating processes I have outlined:

- Gas carburizing.
- Liquid carburizing (or cyaniding).
- Solid (pack) carburizing.
- Carbonitriding (carbo-nitriding).

For each article I am planning to discuss these aspects for each of the processes:

- The technical details of the process.
- What the process does to the material.
- What is the benefit of this / these processes and the effects they create within the material.
- Why one would choose this process over the others in the list.
- The applicability and common areas of use for the particular process.

What I want to help all of us understand is determining the applicability, effectiveness, and best choice for heat treating, depending on the final properties of the gear we need to produce.

ABOUT THE AUTHOR

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

To avoid this problem with aluminum, be sure parts are clean and dry before heat treating and use a dry furnace atmosphere. If flaws persist, there are slightly more complex options.

Blistering of aluminum during heat treatment

In this column, we will discuss the blistering of aluminum during heat treatment, and methods to prevent its occurrence.

INTRODUCTION

High-temperature oxidation, or blistering, often occurs in heat treated aluminum alloys. High-temperature oxidation is a misnamed condition of hydrogen diffusion that affects surface layers during elevated-temperature treatment. This condition can result from moisture contamination in the furnace atmosphere and is sometimes aggravated by sulfur (as in heat-treatment furnaces also used for magnesium alloy castings) or other furnace refractory contamination. The visual appearance of blistering is shown in Figure 1.

CAUSE OF BLISTERING

Moisture in contact with aluminum at high temperatures serves as a source of hydrogen, which diffuses into the metal. Foreign materials, such as sulfur compounds, function as decomposers of the natural oxide surface film, eliminating it as a barrier either between the moisture and the aluminum or between the nascent hydrogen and the aluminum. The most common manifestation of high-temperature oxidation is surface blistering, but occasionally internal voids are formed.

The symptoms of high-temperature oxidation are identical to those of high gas content in the original ingot. Blisters resulting from ingot defects, improper extrusion, or improper rolling may be lined up in the direction of working. However, it usually is impossible to distinguish among defect sources, and therefore the possibility that a contaminated atmosphere is the cause of the defects must be checked.

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

The worst contaminants in attacking aluminum are sulfur compounds. Forming or machining lubricants, or a sulfur dioxide protective atmosphere (used in prior heat treatment of magnesium), are potential sources of sulfur contamination. In one plant, surface contamination resulted from sulfur-containing materials in tote boxes used to transport parts. In another, an epidemic of blistering was cured by rectifying a “sour” degreaser. In a third instance, it was found that a vapor-degreasing operation was not completely removing a thin, hard waxy residue, and an alkaline cleaning and rinsing operation was added.

CORRECTIVE ACTION

Moisture can be minimized by thoroughly drying parts and racks before they are charged. Drain holes often are needed in racks of tubular construction to avoid entrapment of water. Another common requirement is adjustment of the position of the quench tank with respect to furnace doors and air intake. Because it is unlikely that all moisture can be eliminated from the atmosphere in a production heat-treating furnace, it is extremely important to eliminate all traces of other contaminants from both the parts and the furnace atmosphere.

The source of contamination is often obscure and difficult to

Figure 1: Appearance of blistering on 7075 forging.

detect, and the problem must be combated in another way. The most common of the alternative methods is the use of a protective fluoroborate compound in the furnace. Such a compound usually is effective in minimizing the harmful effects of moisture and other undesirable contaminants because it reacts with the moisture on the aluminum surface. The additive is not a universal solution; in some applications, high-temperature oxidation has occurred even though a fluoroborate compound was employed. Also, the use of such compounds, particularly ammonium fluoroborate, may present a hazard to personnel if used in poorly sealed furnaces or in furnaces that discharge their atmospheres into enclosed areas. The decomposition products may increase corrosion of the rack and interior of the furnace.

During initial handling of the white crystalline material, proper personal protective equipment should be worn. This includes protective eyeglasses or chemical safety goggles. Gloves and other protective clothing should also be worn to protect skin exposure. Depending on exposure, a respirator may be required.

Protective fluoroborate compounds accentuate staining or darkening of the parts being treated. Although this minor nuisance might be considered a small price to pay for the solution of a problem of high-temperature oxidation, the residual compound in the furnace dissipates slowly. Therefore, subsequent loads of alloys and product forms whose end uses require bright surfaces, and that are not susceptible to high-temperature oxidation, may be detrimentally affected.

Successful use of fluoroborate protective compounds appears to depend on specifying the right amount for each furnace. This must be established on a trial-and-error basis. One aircraft manufacturer adds 4 g/m3 (0.004 oz/ft3) of furnace chamber to each load. Another adds 0.45 kg (1 lb) per shift to a metal container hung on the furnace chamber wall, thus avoiding loss of the compound during quenching.

A second method of combating high-temperature oxidation is to anodize the work before it is heat treated. The resultant aluminum oxide film prevents attack by contaminants in the furnace atmosphere. The only deterrents to the use of anodizing are its cost (in money and time) and the slight surface frostiness which results from the subsequent stripping operation.

The usual objection to the blistered surface produced by high-temperature oxidation is its unsightly appearance. This often can be improved (for salvage purposes) by applying local pressure to flatten each blister and then finishing by a mechanical process such as polishing, buffing, sanding, or abrasive blasting. In general, the effect of HTO on static properties and fatigue strength is slight. However, if a void resulting from HTO is located close to another stress concentration, such as a hole, much greater degradation of fatigue strength is likely. In critical aluminum alloy forgings, any blistering must be evaluated carefully for its effect on the integrity of the part. Any "cosmetic" salvage should be performed only after it has been established that the blisters are superficial and will not remain in the finished product.

CONCLUSION

In this short article we discussed the cause of aluminum blistering during heat treatment, and methods to mitigate blistering. The best method is to ensure that the parts are clean and dry prior to entering the furnace. Use of a dry atmosphere also helps. If all these things fail, then it is necessary to apply either ammonium fluoroborate during the solution heat treatment or anodize the parts prior to heat treatment.

Should you have any questions or comments regarding this article or have suggestions for any new columns, please contact the editor or the writer.

ABOUT THE AUTHOR

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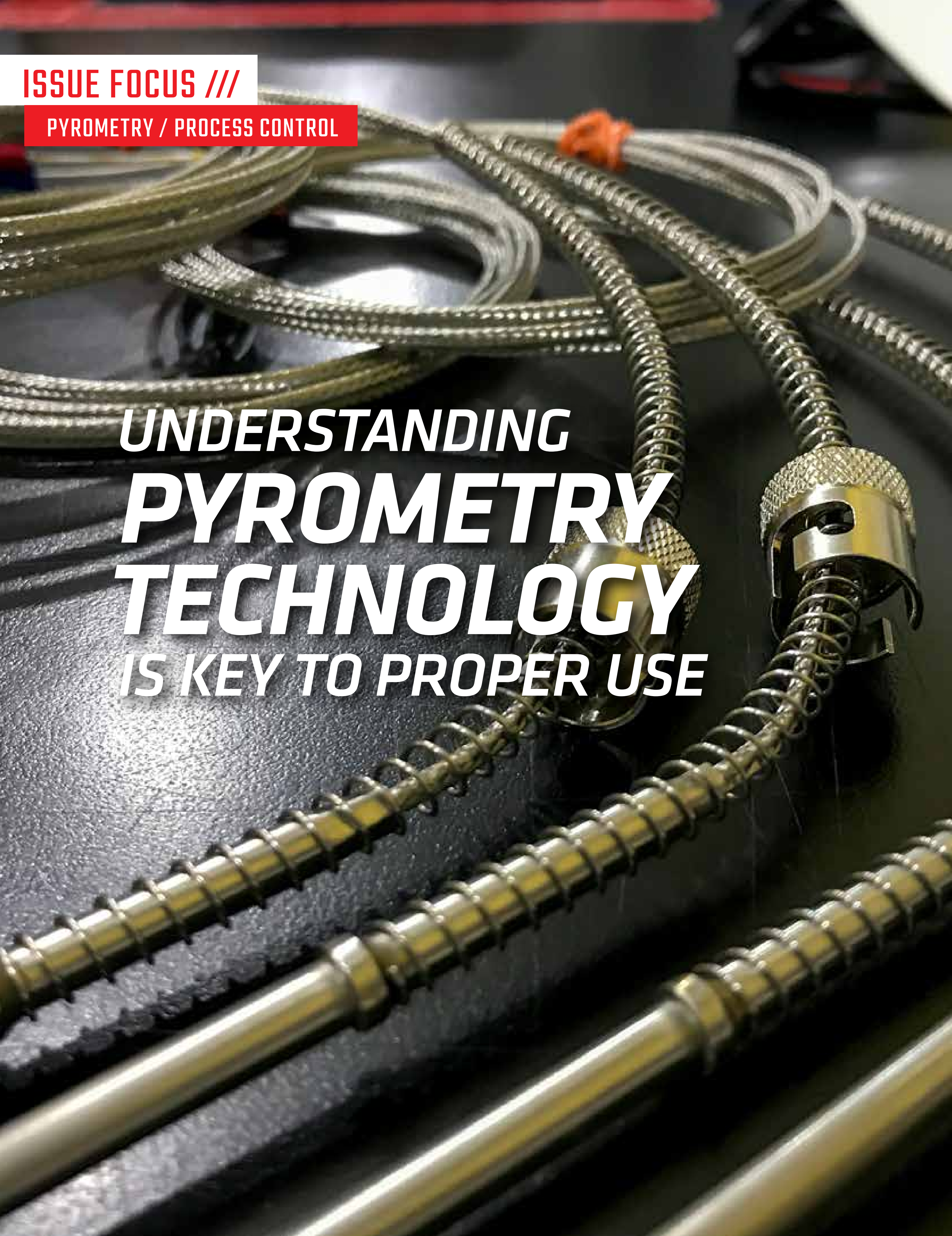
UNDERSTANDING PYROMETRY TECHNOLOGY IS KEY TO PROPER USE



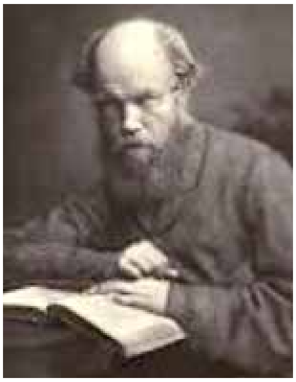
Important factors should be considered when buying and using thermocouples, including environment, temperature, and damage.

By JASON SCHULZE

I teach pyrometry courses throughout the year and, when I do, I include a thermocouple tutorial video from YouTube. In this video the function of thermocouples is discussed, and examples shown. I have always thought that this video gave good examples, although a friend of mine who was attending one of my courses was nice enough to tell me that he felt the video was, well, let's just say "corny" for lack of a better term. He and I then discussed different ways I could present the technical workings of thermocouples. As he said, "thermocouples are simple; dissimilar wire emits an EMF signal, which is then turned to temperature." While he is generally correct, there are details in between that thermocouple users may find valuable or, at the very least, interesting.

Hans Christian Ørsted

Thomas Johann Seebeck



P.G. Tait

Thermocouple type and usage tends to receive quite a bit of attention. In this article, we will examine the history, basic function, and requirements of thermocouples used in thermal processing.

HISTORY

Typical historic accounts of thermocouple technology begin with Thomas Johann Seebeck's accidental discovery of the thermocouple in 1821. There is a back story that helps support Seebeck's involvement and eventual, albeit accidental, discovery.

Seebeck, born in Estonia April 9, 1770, was the son of a wealthy merchant who left home at 17 to study medicine in Berlin. Seebeck was financially independent due to his father's wealth and had an attraction to natural science. Because of this, he eventually changed his focus to private research, where he worked on optics. Arriving in Nuremberg in 1810, he met and was the guest of Hans Christian Ørsted, who was a physicist and is responsible for discovering the connection between electricity and magnetism (Oersted's law). This connection once again changed Seebeck's focus from optics to electromagnetism. It was 1821 when Seebeck announced his discovery of the thermocouple. Once announced, Seebeck's experiments were repeated throughout Europe in several areas of research, cementing thermocouple technology.

While Seebeck is credited with the discovery, thermocouple technology as it exists today owes homage to several other scientists. Professor P.G. Tait of Edinburgh University performed several tests in an attempt to establish thermo-electric diagrams. He concluded thermocouple technology is based on electromotive force (EMF), which is a parabolic function of an absolute temperature. Tait also stated that the slightest impurities in the metals will severely change the accuracy of the readings.

Of course, there were American contributions as well. Dr. Carl Barus was researching high-temperature measurement and attempted his study with multiple alloys of platinum-iridium.

Rhodium-Platinum thermocouple wire.

The first available temperature measurement device shows up in a Cambridge Instrument Company catalogue from 1898, although it was not available until 1902 once a large enough collection of platinum and rhodium-platinum was obtained from Johnson Matthey.

There are several other scientists not mentioned who also had an influence on current thermocouple technology.

THERMOCOUPLE TECHNOLOGY

Let's start with the definition of a thermocouple. According to the

ASM Materials Engineering Dictionary, a thermocouple is “a device for measuring temperatures, consisting of lengths of two dissimilar metals or alloys that are electrically joined at one end and connected to a voltage measuring instrument at the other end. When one junction is hotter than the other, a thermal electromotive force is produced that is roughly proportional to the difference in temperature between the hot and cold junctions.” [1]

While this definition is much more detailed than that of other publications, it underlines the basic principles of a thermocouple.

Each thermocouple has two dissimilar wires that produce a voltage in the microvolt range (Figure 1). Due to being a microvolt, the wire must produce enough voltage to produce an accurate reading. Each one of the wires, being different alloys, has an electric potential gradient in line with the temperature gradient of each wire. The thermoelectric EMF is different in specific alloys for the same temperature, and it is this difference that allows thermocouples to be used to measure metal temperature.

Each wire that makes up the thermocouple is a different metal/alloy. As an example, a type K thermocouple is an alloy called chromel (90% Ni and 10%Cr) on the positive leg and an alloy called alumel (95% Ni, 2%Mn, and 2%Al) on the negative leg. For type K thermocouples, the negative leg is magnetic, making it a bit easier to assemble thermocouples to the appropriate plugs before use. Thermocouples are then separated into base metal and noble metal. Noble metal thermocouples are those containing precious or noble metals, such as Type R and S. It is then that thermocouples can be separated into the expendable or nonexpendable categories (Figure 2). What governs the appropriate category is the type of insulation the thermocouple is purchased with. Put simply, expendable thermocouples can generally be those covered in fabric or plastic-covered wire, and nonexpendable thermocouples are all others. Thermocouple usage limitations are typically defined by expendable and nonexpendable categories, although industry specifications differ, and each user should be aware of the applicable specification limitations.

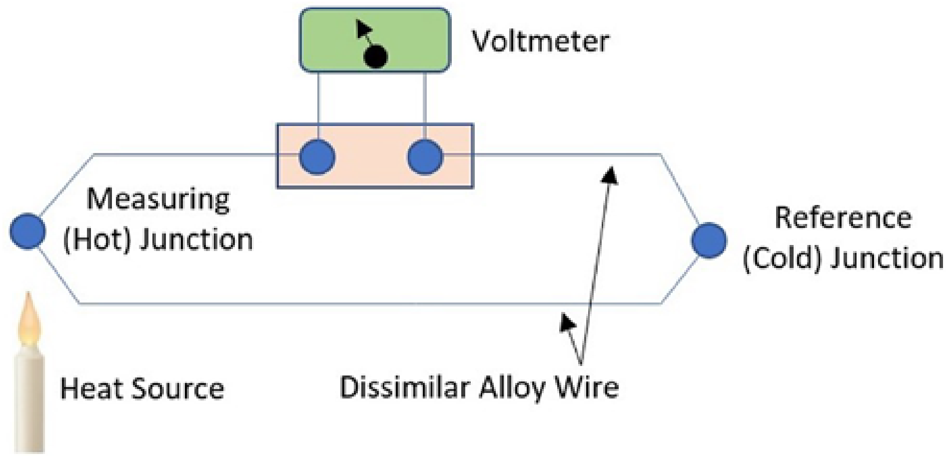


Figure 1: Each thermocouple has two dissimilar wires that produce a voltage in the microvolt range.

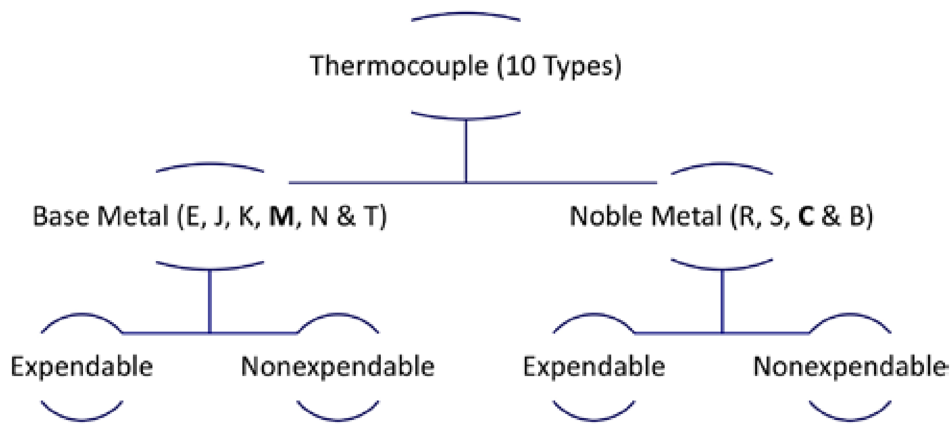


Figure 2: Expendable thermocouples can generally be those covered in fabric or plastic-covered wire, and nonexpendable thermocouples are all others.

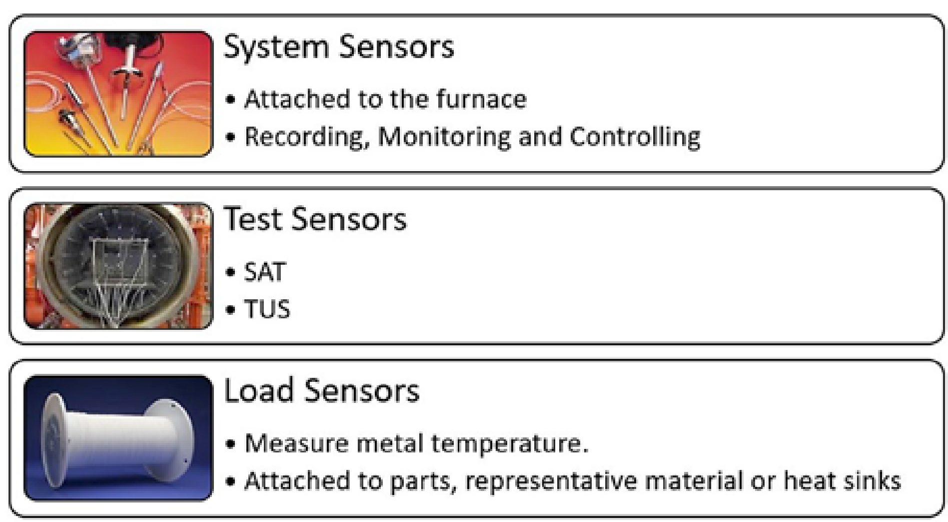


Figure 3: Typical use of thermocouples within thermal processing will align with three categories: system sensors, test sensors, and load sensors.

THERMOCOUPLE LIMITATIONS

Thermocouple temperature limitations are governed by the type (alloy combination) of the thermocouple. In keeping with our example, type K has a range of minus-328°F to 2,282°F, although most users do not use type K thermocouples below ambient, as other thermocouple types (i.e. type T) are better suited for negative/lower temperatures due to their accuracy.

Each thermocouple type has its advantages and disadvantages. Type K is suitable for oxidizing atmospheres in higher temperature ranges, provides a more mechanically and thermally rugged unit than platinum, rhodium-platinum, and longer life than iron. A disadvantage of type K is it is especially vulnerable in reducing atmospheres, requiring substantial protection when used in such atmospheres.

Typical use of thermocouples within thermal processing will

Each thermocouple type has its advantages and disadvantages. (Courtesy: Shutterstock)

align with three categories: system sensors, test sensors, and load sensors (Figure 3). Again, each prime/industry specification may have its own nomenclature for these categories, but in general, these are the three categories of use. Within thermal processing equipment, these categories of thermocouples may be different types depending on the instrumentation type configuration. As an example, a vacuum furnace may have a type S control and overtemperature thermocouple, while the load and test thermocouples are type K.

Thermocouple suppliers can typically help users identify what type of thermocouple will be best to use on their specific process and will be based on temperature and heating environment, as well as heat cycles.

SUMMARY

Understanding thermocouple technology is essential to proper thermocouple use. Consideration of the environment, temperature, and temperature cycling, as well as physical damage, should be considered when using or purchasing thermocouples.

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[2] Dataforth Corporation AN106 – www.dataforth.com

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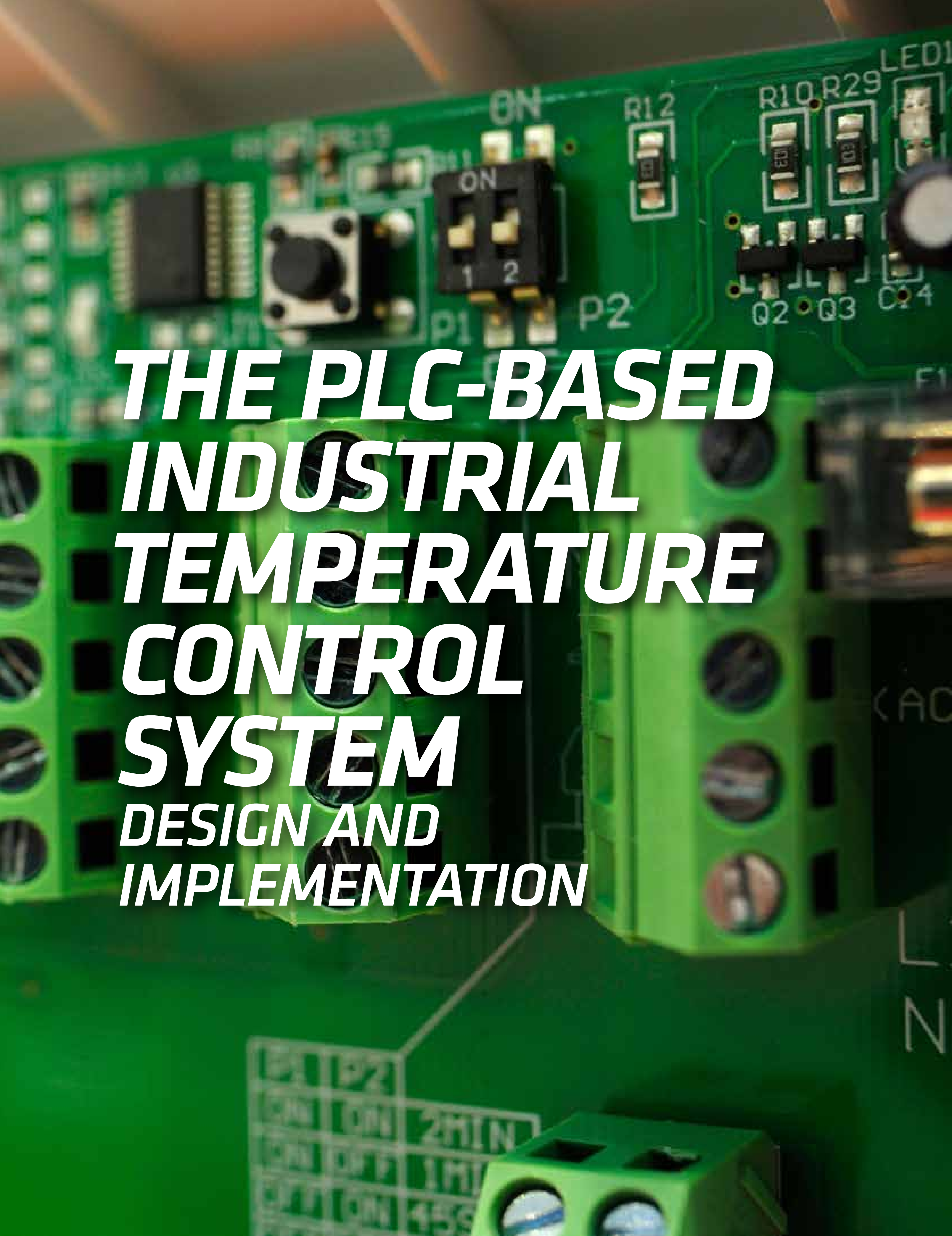

THE PLC-BASED INDUSTRIAL TEMPERATURE CONTROL SYSTEM

DESIGN AND IMPLEMENTATION

By using PLC-based fuzzy PID control technology, the system temperature can be set through the fan and the heating plate to control the box temperature.

By FANJIE WEI

Targeting the problem of slow response and low accuracy of the automatic temperature control system for material processing and boiler heating, a new design method is proposed to work with the PLC-based temperature control system, where the box temperature control may be achieved through the fan and the heating plate. The hardware design and software design of the system are analyzed in detail. In this article, a combination of the traditional PID control and the more popular fuzzy control is taken as the control program to achieve the overall design of the control algorithm. Followed by the simulation in the MATLAB software, the designed system is highlighted by its the characteristics of impressive stability, precision, and robustness.

1 INTRODUCTION

Modern sensing technology and control methods are undergoing continuous innovation, where the real-time temperature control is demanding higher accuracy and faster response more than ever. Temperature control is widely used in production and industrial control processes in all aspects. For example, in the iron and steel smelting process, iron and steel to be baked requires heat treatment in order to achieve their performance indicators; the plastic qualitative process also needs to maintain a certain temperature range. The fact is that the temperature control system is a complex process object involving large inertia and pure delay with multi-variable and time-varying parameters. At present, the PID control methodology is adopted in most cases [1]. In this way, different PID parameters should be selected for different control objects, for which some practical experience is needed. As a language controller, the fuzzy PID control imitates the way of human thinking and experience to achieve its control process so it can more closely reflect the best control behavior of the controller. With strong robustness and control stability, it can be applied to different control objects. The combination of fuzzy control and PLC, which is widely used in industrial control, is one of the hotspots in this research area. Therefore, this work involved the use of the PLC-based fuzzy PID control technology, by which the system temperature was set through the fan and the heating plate to control the box temperature.

2 SYSTEM DESIGN

In this design, the temperature control system consists of hardware and software components.

2.1 System hardware

In the hardware part of the system, the acquisition module uses the temperature sensor to measure the measured object temperature, and the temperature signals are converted into electrical signals [2], which are then transmitted to the temperature transmitter, where the electrical signal is converted into a 4 ~ 20mA current signal, so that the module EM235 in the PLC expansion module can be facilitated as to the analog signal input. EM235 receives data, which will be sent directly to the PLC output control text display (display temperature) and the temperature control device [3] (heating and cooling device). The system block diagram is shown in Figure 1.

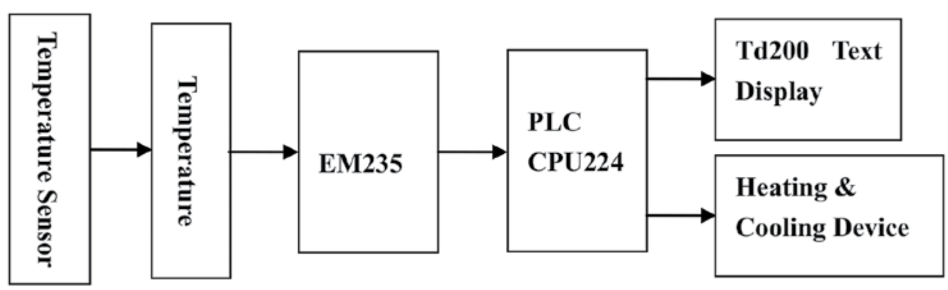

Figure 1: Block diagram of temperature control system.

2.2 System software

The software of this system adopts STEP7 for PLC200, the popular programming software by Siemens, for software compilation [4], and the temperature controller device adopts fuzzy PID algorithm for temperature control, with the simulation to be implemented by MATLAB simulation software.

Figure 1 shows the system consists of four modules: acquisition module, control module, display module, and implementation module. The acquisition module includes a PT100 temperature sensor and temperature transmitter. The PT100 temperature sensor works with a temperature variable that can be converted into a standardized output signal. This instrument is mainly used for industrial process with measurement temperature and control parameters. The temperature transmitter is a signal conversion device, which is responsible for the signals collected by the temperature sensor to be converted to electrical signals of 4 ~ 20mA. This is quite convenient for the PLC200's identification and collection of the temperature signal. For the control module, a Siemens PLC200 is chosen as the core controller, playing the role of the completion of the temperature signal collection, signal processing, and signal transmission. A display module using a TD200 text display can be more compatible with the PLC to complete the data transmission. This display module displays the current temperature and the desired temperature. The implementation module works by through a PLC-controlled cold air fan and heating resistor to complete the instructions for the temperature rise or fall, and finally, the temperature reaches a constant value.

3 FUZZY PID CONTROL TECHNOLOGY

A fuzzy controller is a new controller developed in recent years. The advantage of this device is that it does not require the precise mathematical model of the controlled object. Rather, the control decision table is organized according to the manual control rules, and then the size of the control variable is determined.

3.1 Fuzzy PID control: Principle and rule

The CPU queries the corresponding fuzzy control table according to the system deviation (Deviation = Given Value - Feedback), and deviation change rate (Deviation Rate = Current Cycle Deviation - Upper Cycle Deviation) to get the setting values of Kp, Ki and Kd. Then the PID operation is performed.

The formation of fuzzy control rules comes from operators or experts who use their knowledge and experience to make a number of control decision tables. These rules can be expressed in natural language, only generally to be formalized. The current design of the fuzzy controller is basically used in the fuzzy control process, while the system and the deviation of the set value and its rate of change are taken as a fuzzy input.

This method not only guarantees the stability of the system, but it also reduces the overshoot and oscillation phenomenon.

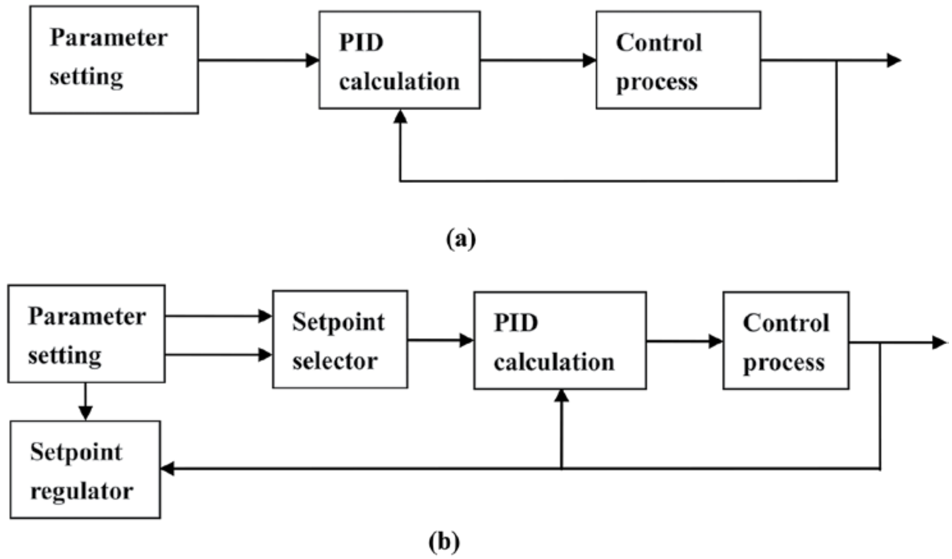

Figure 2: difference between fuzzy control and traditional PID control. (a) Traditional PID control system – block diagram, (b) Fuzzy PID control system - block diagram.

3.2 Fuzzy PID control algorithm

PID control is very effective for the control of linear time-invariant systems, but it is not well controlled for nonlinear, time-varying complex systems and systems with nuclear models. Remarkably, it is quite easy for the fuzzy controller to gain effective control of the complex and the model unclear systems. Note that the fuzzy controller is lacking the integral link, so it is difficult to completely eliminate the static difference in the fuzzy control system. Furthermore, in the case of an insufficient number of variable classifications, a small oscillation is often found near the equilibrium point. If we combine the two control methods, we can form a fuzzy PID controller with the advantages of both.

There are several methods that can be employed to combine fuzzy technology with the PID control algorithm to form a fuzzy PID controller: One is the use of a fuzzy controller that allows the PID controller to get its online self-tuning PID parameters, making a fuzzy self-tuning parameter PID controller; another may be done in a large deviation range, where the proportional control is used, while the fuzzy control is adopted in the small deviation. These two control modes can be switched upon the pre-determined deviation threshold, which constitutes the FUZZY-P dual-mode segment controller. Similarly, a multi-mode segmentation control algorithm may be designed to achieve sub-sections according to different conditions and requirements, with different modes of control.

3.3 Difference between fuzzy control and the traditional PID control

The distinction between the two may be understood as: PID control is time-based, and fuzzy control is process-based. The structural difference between the two is shown in Figure 2.

The intelligence of the fuzzy controller compared to the traditional PID controller is reflected in an extra setpoint regulator and setpoint selector. The setpoint regulator simulates the control procedures and functions of an experienced operator. It focuses on the control process (in the range of PID control), the dynamic characteristics of the system, and the non-linearity (including load changes). The system is operated by inputting the assumed target value to the PID operator. As the fuzzy control significantly reduces the overshoot, it is capable of effectively improving the system response speed and temperature control accuracy, making it easier to achieve computer control. For this reason, fuzzy control technology is used by many control systems. Concerning the control of heat-treatment equipment, fuzzy control technology marks the most significant progress in the last decade, attracting more and more attention by the heat-treatment sector. Fuzzy PID control is present in a series of control applications, including the resistance furnace temperature system, the raw material mixed system, beer fermentation monitoring system, the wind network throttle control system, magnetic levitation system, motor control system, cement cooling process control, air conditioning constant pressure water supply system, radar seeker servo system, and so on. This is sufficient to illustrate the excellence of the fuzzy PID control algorithm.

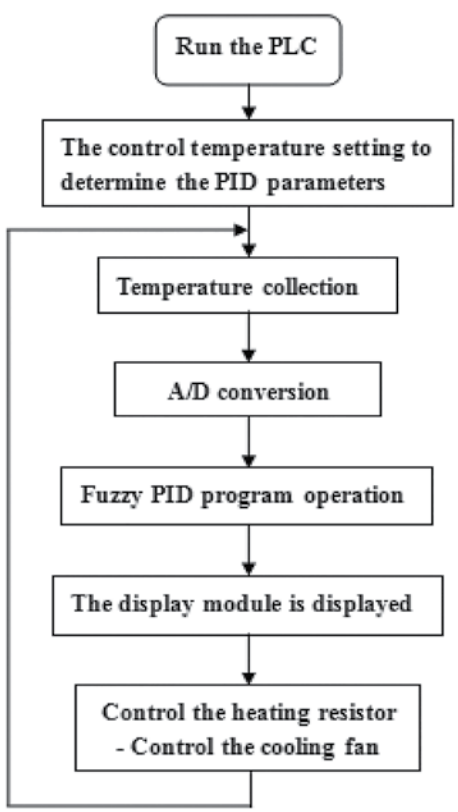

Figure 3: Program flow.

4 SOFTWARE DESIGN

According to the system design requirements, the software program flow is shown in Figure 3.

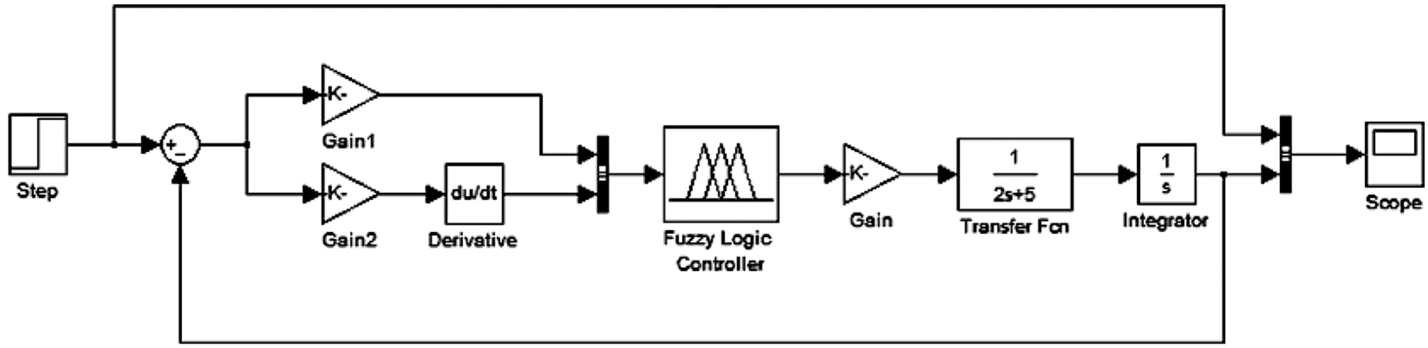

Figure 4: Block diagram of fuzzy control system.

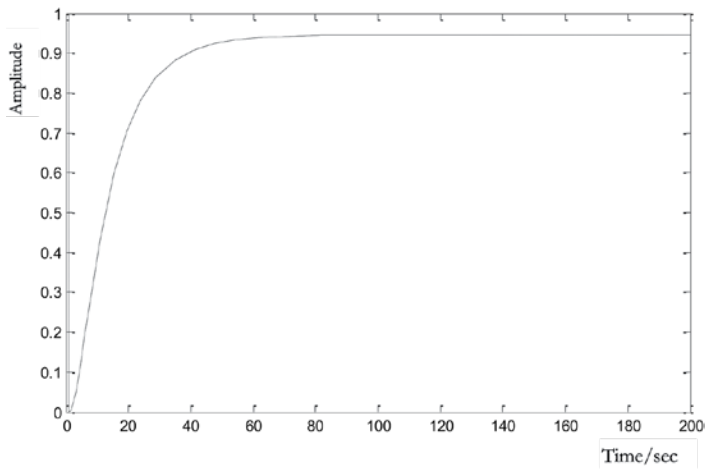

Figure 5: Simulation results of fuzzy control system.

First of all, the parameters of the temperature control system undergo wake-up initialization, mainly to set the control temperature and the PID initial value, including the value settings of PID gain, PID integral time, PID differential time, and PID sampling time. Then, the ambient temperature is collected through the sensor in a range of 6,400 ~ 320,000, as the digital signal. As the fuzzy PID algorithm requires real-format temperature signal input, there is the need for the A/D conversion of the temperature signal prior to the PID algorithm process. The collected digital signal is converted into a double integer signal, which is then transformed into a real figure. The actual temperature is calculated by the temperature calculation formula. The measured temperature is taken as the input signal for PID operation, and the output is ready for the control of the heating resistance and cold air fan.

In the design, the temperature control is based on the PID control algorithm. The PID is the most commonly applied algorithm in industrial production — a control method being able to meet the need for high-precision measurement and control systems. Using the PID algorithm to achieve the temperature control system can be more stable and reliable [5].

5 EXPERIMENT AND SIMULATION

Assume that the system has an open-loop transfer function as G(s) = 1/S (2*S + 5), and a fuzzy control system is established in Matlab, as shown in Figure 4. At this time, the amplifier Gain = -1,000, Gain1 = 0.05, Gain2 = 0.01. Select the controlled object and its reference model, and we can get the simulation curve shown in Figure 5.

6 CONCLUSIONS

In this work, the temperature control system was available for real-time display of the temperature inside the box. By setting the temperature through the fan and the heating plate, the PID control algorithm was introduced to control the temperature of the box to achieve the temperature control needs. With Siemens PLC200 as the controller, system control was quite impressive with high precision, stability, and reliability, and it was not susceptible to outside interference. On-site commissioning revealed that the box temperature could be successfully controlled by the system. This work is expected to bring about a good application prospect.

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CARBURIZED STEEL MECHANICAL PROPERTIES

CASE TENSILE STRENGTH

Medium- and high-carbon steels heat treated to higher hardness levels are subject to quench embrittlement, which is normal and not an anomaly, showing there are ways to cajole the samples to get them to the published values, but this does not represent what is done to actual parts.

Editor's note » This is part one of a three-part series on carburized steel mechanical properties.

By GREGORY FETT

Carburizing is a mature heat-treating process commonly used for gears. The carbon content of the surface is typically increased to about 0.70 to 1.00 percent, and the part is oil quenched. This provides a hard, wear resistant surface or case, and a softer more ductile core. The typical surface hardness after quenching is about 65 HRC and 62 HRC after tempering at 177°C. It is a robust process that is tolerant of many processing variables. It provides good bending and contact strength as well as good bending and contact fatigue life. It is commonly believed the case has a high tensile strength with limited ductility, while the core can range from moderately high to low strength depending on the application. In bending as well as in torsion, the applied stress is maximum at the surface, so placing the highest strength at the surface is ideal.

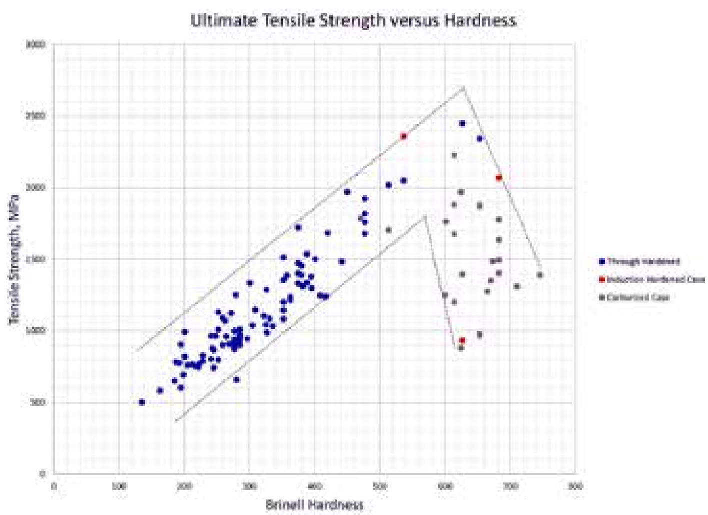

Figure 1

MODELING CARBURIZED GEARS

Carburized gears can be modeled by using axial strain-based static and tension compression data for the case and for the core. Based on SAE J413, the typical carburized case of about 62 HRC should have a tensile strength above 2,269 MPa, while a typical core at 30 HRC would be about 952 MPa. Around 1998, AISI (American Iron and Steel Institute) began a joint steel producer and user program to develop axial strain-based fatigue and static data for carburized, through-hardened, normalized, and induction-hardened steels. The Bar Fatigue Committee was active for about 20 years and, at one point, came under the umbrella of SMDI (Steel Market Development Institute). The data now resides at the University of Waterloo [1].

Steel	Carb Process	Cycle Time Hours	Ultimate Tensile MPa	Elong Percent	Surface Hard HRC	Center Hard HRC	Vis Case 12.7 Grip mm	Avg Max Grain Dia microns
8620	VAC-OIL	12.5	1237	0.38	63	50	1.5	30
8620	ATM-OIL	24	1081	0.27	60	57	1.91	25
8620	VAC-OIL	36	815	0.44	62	62	2.67	28
8620	ATM-OIL	48	923	0.43	61	63	2.13	28

Table 1

Most of the data was generated using 5.08 mm diameter, 10.8 mm gauge length test bars. The through-carburized bars representing the carburized case were typically carburized for 24 to 26 hours at 927°C. This cycle didn't completely through-carburize the sample but provided a core that was just a few points HRC lower than the surface. It was later determined that 36 hours was necessary to completely through-carburize this diameter so the hardness was uniform though the complete cross section. Obviously, these carburizing cycles are much longer than those used for most automotive and truck gears, but they are necessary to through-harden the test bar cross section.

Figure 1 is a chart showing ultimate strength vs. hardness for the data through the first 141 data sets in the database.

This includes quench and tempered through-hardened samples, carburized case and core samples, normalized samples, and induction-hardened samples. There is a good correlation between hardness and strength up to about 575 Brinell or 56 HRC. Above this hardness, the correlation ends, and the strength may continue to increase, or it may significantly decrease. The two through-hardened samples that did increase to 2,343 and 2,450 MPa were 5160 and 9254 spring steel, respectively. Their hardness was 58 to 60 HRC, and the elongation was 0.0 and 3.9 percent respectively. The induction-hardened sample in the same area was 1050M steel induction-hardened and tempered to 54 HRC. The tensile strength was 2,360 MPa, and the elongation was 16.7 percent. The bulk of the high hardness samples are through-carburized case samples, and they vary between 900 to 2,200 MPa, and the elongation ranged from 0.0 to 12.5 percent. The high end of this strength range is close to where they should be per SAE J413 based on hardness, while the low end is equal to the strength of the core at a hardness of 28 HRC. Obviously, this is too much variation to be useful for design purposes.

VARIATION STUDY

Around 2013, a study was initiated to determine why there was so much variation [2]; 8620 test bars from five steel sources were machined and polished to an Ra of 0.2 microns and distributed to three member companies for heat treatment. They were carburized at 927°C on a 12.5-hour cycle at source A, a 24-hour cycle at source B, a 36-hour cycle at source A, and a 48-hour cycle at source C. The data is shown in Table 1.

The 12.5- and 36-hour cycles were done in a vacuum furnace with oil quenching, and the other two cycles were done in atmosphere furnaces with oil quenching. Tempering was done at 177°C. No additional hard finishing or polishing was done after heat treatment. After heat treatment, the Ra surface finish on the atmosphere furnace samples was about 0.28 microns, while the vacuum furnace samples increased to about 0.66 microns. Vacuum carburizing produced an etched appearance on the surface and the individual grains were visible. The average tensile strength was 1,237 MPa for the 12.5-hour cycle, 1,081 MPa for the 24-hour cycle, 815 MPa for the 36-hour cycle, and 923 MPa for the 48-hour cycle. The elongation for all samples was less than 1.0 percent, and there was no measurable yield as the deformation was primarily elastic. Table 1 shows the total visual case depth in the 12.7 mm sample grip area after annealing and furnace cooling. Figure 2 shows there is a good correlation between the visual case depth and the ultimate tensile strength. With less carburizing time and case depth, the strength increased, but it is still only about half of what it is projected to be based on hardness.

CYCLE RESULTS

The deepest case depth was actually produced by the 36-hour cycle, and it was uniform through the entire cross section. The 48-hour cycle was reportedly run with a constant carbon potential rather than a boost diffuse cycle, which may explain the lower-than-expected visual case depth. Table 1 also shows the average maximum grain diameter found at the fracture origin on the SEM images for all samples from each heat-treat group. Maximum grain size was measured rather than the average as this represents the worst case. This can be critical in some cases, and it is much easier to determine. The fracture origins were at the surface and were intergranular, and the grain size was relatively constant among the groups. A finer grain diameter would be expected to result in a higher tensile strength [3]; however, the 12.5-hour cycle had the largest grain diameter and the highest strength. The dominant factor for determining tensile strength was the carburized case depth and less was better. Figure 3 shows the maximum grain diameter vs. tensile strength for all samples.

It appears to show no correlation between grain diameter and tensile strength within the range found. However, if we look at the average maximum grain diameter vs. tensile strength for the five different steel sources in Figure 4, we can see a slightly different story. Here there appears to be some correlation between the maximum grain diameter and tensile strength. The steel source or potentially the heat of steel from the same source can also make a difference in the tensile strength.

Additional work was done with 8620 through-carburized case samples and 52100 quench and tempered samples. The 52100 grade is essentially equivalent to the carburized case on 20MnCr5 steel. The 8620 bars were vacuum carburized and oil quenched on the 36-hour cycle, and the 52100 bars were vacuum oil quenched. The bars were tempered at 177°C, 232°C, and 260°C to investigate the effect of tempering temperature. During the AISI/SMDI program, bars were sometimes tempered above 177°C as the surface hardness aim was 58-60 HRC. All bars were machined prior to heat treatment, and there was no hard finishing or polishing before or after heat treatment. The results are shown in Table 2.

The 8620 sample tempered at 177°C was at 784 MPa, which is the about the same tensile strength as the 8620 samples in the above

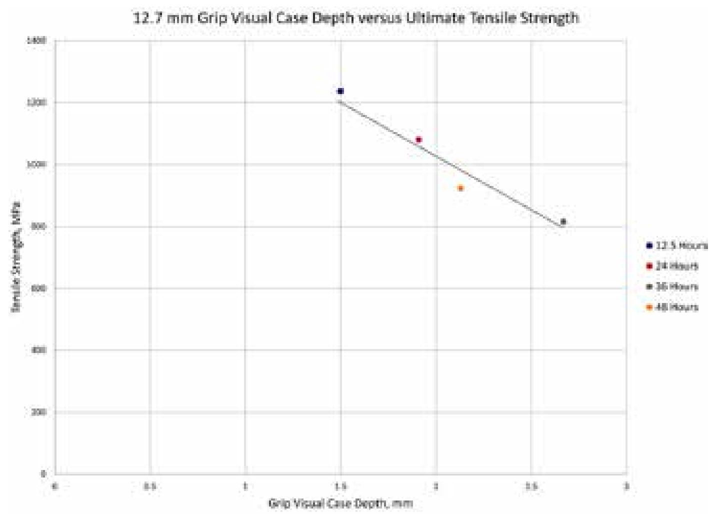

Figure 2

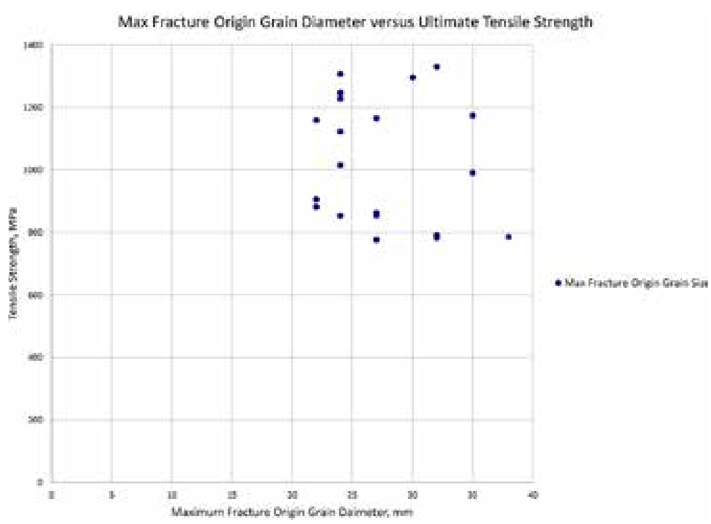

Figure 3

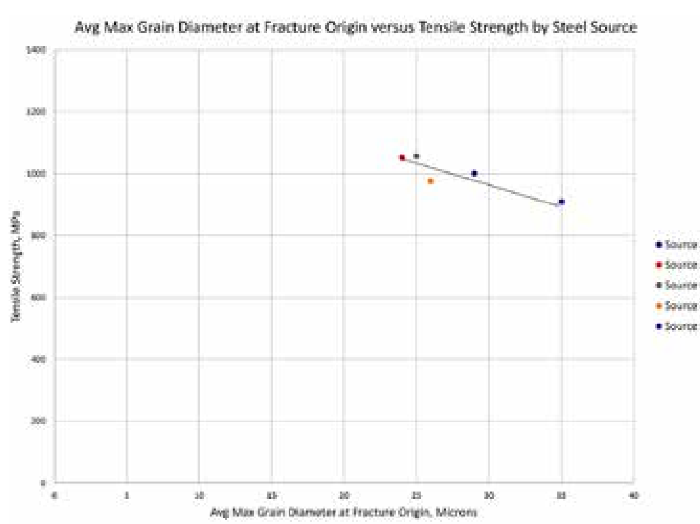

Figure 4

Material	Tempering Temp degrees F	Ultimate Tensile MPa	Elongation Percent	Surface Hardness HRC	Process
8620 thru carb	177	784	0.26	64	Turn before HT
8620 thru carb	232	866	0.46	61	Turn before HT
8620 thru carb	260	934	0.39	59	Turn before HT
52100 Q&T	177	1286	0.32	64	Turn before HT
52100 Q&T	232	1337	0.51	62	Turn before HT
52100 Q&T	260	1421	0.41	61	Turn before HT

Table 2

Material	Tempering Temp degrees F	Ultimate Tensile MPa	Elongation Percent	Surface Hardness HRC	Process
8620 thru carb	177	1178	0.81	63	Turn, polish after HT
8620 thru carb	232	1559	0.89	59	Turn, polish after HT

Table 3

Material	Tempering Temp degrees F	Ultimate Tensile MPa	Elongation Percent	Surface Hardness HRC	Process
52100 Q&T	177	1587	1.00	64	Turn, polish after HT
52100 Q&T	232	1924	0.89	62	Turn, polish after HT

Table 4

study. The lack of polishing prior to heat treatment had no detrimental effect on the strength. The strength gradually increased with the tempering temperature to 934 MPa at 260°C, and the surface hardness was still in specification at 59 HRC. The 52100 sample tempered at 177°C started at 1,286 MPa and gradually increased to 1,420 MPa at 260°C. The major microstructural difference between the 8620 and 52100 samples was the grain size. The maximum grain diameter of the 8620 samples was about 50 microns while the 52100 was about 25 microns. This is a potential contributor to the strength difference between the 8620 and 52100 steels [3].

The next step was to through-carburize oversized 8620 bars and hard turn and polish after heat treatment. The results are shown in Table 3.

AISI/SMDI PROGRAM

During the AISI/SMDI program, bars were sometimes hard finished and/or polished after heat treatment, and this was not always documented. The tensile strength with the 177°C temper was 1,178 MPa, and the strength with the 232°C temper was 1,559 MPa. The hardness for both conditions was still above 58 HRC.

This same exercise was repeated with the 52100 quench and tempered samples. The results are shown in Table 4.

The tensile strength with the 177°C temper was 1,597 MPa, and the strength with the 232°C temper was 1,924 MPa. It is likely tempering at 260°C would come close to the 2,269 MPa target. Hard finishing and polishing after heat treatment coupled with tempering at an elevated temperature is capable of significantly increasing the strength. The key is reducing the surface finish after heat treatment. It would be tempting to blame this on intergranular oxidation (IGO); however, these samples were all vacuum heat treated, and there was no IGO.

NORTHROP AIRCRAFT STUDY

In 1960, a study was done by Northrop Aircraft titled "Heat Treatment of SAE 52100 Steel" [4]. The tensile strength of oil quench and tempered 52100 austenitized at 829°C and double tempered at 204°C ranged from 1,439 to 2,146 MPa. The elongation of all samples was 0 percent, and the hardness was 60 HRC. The tensile strength of oil quench and tempered 52100 austenitized at 982°C and double tempered at 204°C with and intermediate subzero treatment was 905–907 MPa. Again, the elongation was 0 percent, and the hardness was 61-62 HRC. Tempering at an elevated temperatures of 427°C was able to increase the tensile strength to 1,807 MPa and the elongation to 8.0 percent, but the hardness decreased to 52.5 HRC. This data seems to confirm the strength values found in our investigation, and it also shows the austenitizing temperature can be important.

Is the true strength of the carburized case around 900–1,300 MPa or is it 2,300–2,400 MPa as the hardness would predict? If the steel is not hard finished and/or polished after heat treatment and it is not tempered at an elevated temperature, the answer is 900-1,300 MPa. When samples representing the carburized case are heat treated and the strength is roughly half of what it is supposed to be, it is easy to believe something must have gone wrong. However, the data shows the lower strength is correct. Medium- and high-carbon steels heat treated to higher hardness levels are subject to quench embrittlement [5]. This is normal and not an anomaly. There are ways to cajole the samples to get them to the published values, but this does not represent what is done to actual parts.

If the carburized case is weaker than predicted, how is it possible for carburizing to provide adequate bending strength in order to function as a gear? This will be addressed in part 2.

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ABOUT THE AUTHOR

Gregory Fett retired from Dana Corporation in 2016 where he was Chief Materials Engineer for nearly 35 years. He has done considerable research and authored numerous publications in the areas of carburized steels and induction hardened steels. He currently is a materials engineering consultant at Fett Engineering LLC . For more information contact him at fetteng@gmail.com.

SOLUTIONS FOR INDUSTRIAL HEATING AND THERMAL INSULATION

Nutec makes anything that requires combustion systems and combustion equipment and for any applications that require heat. (Courtesy: Nutec)

Nutec Group manufactures high temperature insulation, kilns, and furnaces and supplies quality products and superior service while exceeding its clients,' employees,' and stockholders' expectations.

By KENNETH CARTER, Thermal Processing editor

When it comes to heat-treating solutions involving burners, insulation, and furnaces, the experts behind Nutec Group have been meeting those challenges head on for almost 50 years.

Nutec Group controls several divisions responsible for many products used by the heat-treating industry, according to CEO Daniel Llaguno.

Nutec Bickley makes all types of furnaces and kilns. That includes custom-made, large-capital equipment furnaces used for forging, aluminum heat treating, and more for the aerospace and automotive industries. Llaguno essentially referred to that as the metals business unit.

CERAMICS

"And then we have our ceramics business unit, which makes very high-temperature kilns," he said. "That's actually where the Bickley name comes from. We make high-temperature kilns for advanced ceramics."

Bickley was an acquisition made by Nutec in 2000, and it makes kilns for sanitary work, refractories, technical ceramics, and other applications.

Nutec Group also controls an original business called CCS, Combustion Controls and Systems, according to Llaguno.

"We make anything that requires combustion systems and combustion equipment and for any applications that require heat," he said. "We may build a gas drain or a burner system for an air dryer for the cement industry or for the steel industry. So, within Nutec Bickley, we have those three main product lines — furnaces for metal, kilns for ceramics, and combustion equipment and controls."

INSULATING FIBER PRODUCTS

Another division of Nutec makes ceramic refractory fiber or bio-persistent fiber products, according to Llaguno.

"This is a high-temperature insulation material, which is used in kilns and furnaces and a lot of industries," he said. "Nowadays, it's used in fire protection and a lot of products in construction. But it's mostly used as insulation and fire protection. The insulation reduces energy consumption, of course, but then for fire protection, it helps with protecting boats or large ships from potential fires. It also protects against fire in stadiums, for example, where you have grease ducts and chimneys from concessions and restaurants going outside. Sometimes, the grease condenses in the ducts in the chimneys and they have to burn them, so we actually put that fire protection in. That is all ceramic fiber materials."

For that product, Nutec has plants in Mexico, the U.S., Spain, and Brazil, according to Llaguno. On the furnace side, within Nutec Bickley, the main manufacturing facility is in Monterey, Mexico.

"That facility does turnkey jobs pretty much everywhere in the world," he said. "We have capabilities of installing furnaces and kilns pretty much anywhere."

STRONG CUSTOMER BASE

With all the heat-treating applications offered by Nutec, it wouldn't mean much without a strong customer base, according to Llaguno.

"The customer is at the center of our purpose," he said. "Our reason to exist is to meet and exceed their expectations. We couple that with a very strong culture within the company based on values, ethics, and to protect and enhance."

Nutec has gone from being a small, local, family company to one with more than a thousand employees. (Courtesy: Nutec)

When it comes to building furnaces for its customer, Llaguno referred to Nutec's four pillars: equipment performance, job execution, product quality, and service.

"Those four things are what we pay extremely close attention to, and we want to keep improving on each one of those pillars for the jobs we do for our customers and for the capital equipment we make for them," he said. "Which is, of course, performance of the equipment, execution of the job, quality of the product, and service. That's kind of our philosophical approach to our business."

In order to continue to meet and exceed its customers' expectations, Nutec has worked to make better and more efficient equipment over its decades-long existence. (Courtesy: Nutec)

CONSTANTLY IMPROVING

In order to continue to meet and exceed its customers' expectations, Nutec has worked to make better and more efficient equipment over its decades-long existence, according to Llaguno.

"I think the industry, in general, is looking for tighter controls, for increased quality, and for better efficiencies," he said. "And that takes us to always push us for improving our technology with different fuels — alternative fuels — and tighter controls. But it mostly involves us always trying to be more efficient and produce better quality in our furnaces and equipment as well as in our insulating materials. That's a clear trend, and we need to follow it. One key advantage that we have is that, since we are involved in different industries, the key components of the furnaces and kilns are the same: insulation and combustion equipment controls. We actually take technology from one industry to another, complementing the technology, and we end up getting the best of each industry for the product we make for one industry. I think we've been able to achieve that in a successful way."

SELLING SOLUTIONS

Part of Nutec's unique approach to satisfying its customers is in how it sees what it produces, according to Llaguno.

"We don't sell commodities at all — not even in the fiber business; we sell solutions," he said. "We always try to go beyond. We don't sell out-of-the-box furnaces. We go and try to understand very clearly what the customer's needs are and why he is looking for a new piece of equipment or why he is looking for such insulation. Once we understand the roots of what he needs, then we can actually help him steer the solution and find out a solution that will better fit his needs. Rather than asking for a box with such volume and such temperature, we actually question and try to go beyond that to offer a very specific, custom-fit solution for them that will perform better for their needs."

"We always try to go beyond. We don't sell out-of-the-box furnaces. We go and try to understand very clearly what the customer's needs are and why he is looking for a new piece of equipment or why he is looking for such insulation."

Within Nutec's fiber business, the company has created an applications engineering department, according to Llaguno.

"We have application engineers who actually find what the best solution will be for product needs," he said. "And in the furnace and kiln business in Nutec Bickley, it's always about what the best solution for the customer would be as far as designing a new piece of equipment."

GOING GLOBAL

Being able to serve its customers' needs by taking production and innovation to the next level has been instrumental in Nutec's achievement of transcending borders, according to Llaguno.

"It's gone from being a small, local, family company into a thousand-plus employee company," he said. "But more than anything, we've done it in a sustainable way. We haven't deviated from our values and culture, and that's the way we want to keep it. We want to keep growing. We have opportunities and challenges, of course, but we have made it very clear that we want to keep growing in a sustainable way, which means having strong foundations in talent and culture. Transcending borders and becoming a successful, international company are some of our main achievements. We also take care of the talent of the people of our company. We take care of them, and we develop them. We not only hire them, but we also want them to grow with the company as well."

IN BUSINESS FOR 48 YEARS

Nutec began in 1975, but it's still a private and family-owned company started by Genaro Cueva Sr. as a combustion equipment manufacturer, according to Llaguno.

"In fact, it was a licensee of a North American manufacturing company out of Cleveland, and we still have a very close relationship with them," he said. "Back then, we started making burners and valves for the Mexican market exclusively."

In 1985, Nutec began producing ceramic fiber insulation, according to Llaguno.

"We put in a small manufacturing facility, and we started producing high-temperature insulation, ceramic fiber," he said. "The next logical step was to make furnaces."

Since Nutec was already producing key components of a furnace, what is now Nutec Bickley started designing and manufacturing furnaces and kilns for various industries in 1990.

That growth was rapid and steady, and through various other acquisitions and innovations, Nutec is preparing a solid foundation for itself as it moves into the next decade.

"I'm excited about the future," Llaguno said. "I think, whether we like it or not, the pandemic exposed some weaknesses in the supply chain worldwide. There is this very strong need for nearshoring in different blocks in North America, Europe, and Asia. That movement is here to stay, and it will provide growth for years by building new and more efficient factories closer to end customers. That will provide for growth in our industry in North America. Certainly, it's a big block, which means Mexico, the U.S., and Canada for sure will experience investment. Europe will also have to do that and Asia as well. When those suppliers relocate closer to the end customers in more efficient factories, they will need equipment; they will need installation; they will need the kind of products we make, and we are here to partner with them in their efforts. I actually feel like there is good future for the industry, and Nutec is going to be an important part of that."

MORE INFO www.gruponutec.com

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"This year, Ipsen U will be more interactive, encouraging more Q&A and attendee participation."

Tell us about Ipsen U and what it can do for heat treaters.
The Ipsen U class provides a great learning experience for everyone from entry level to department supervisors or engineers. Classes cover a variety of topics from basic furnace operation and function to furnace troubleshooting and maintenance, to process related discussion on heat treating and brazing. There really is something for everyone to learn in this class.

Ipsen U is a three-day course. How did you decide on that length?
Three days seems to be about the right length for this training based on the broad range of content but also in the amount of time that our customers can be absent from their plant. If the class was any shorter, we wouldn't have sufficient time to cover valuable content. If the class was any longer, we might miss out on some attendees that simply can't leave their critical plant operations longer than three days.

What kinds of upgrades have been added to Ipsen U for this year?
This year, Ipsen U will be more interactive, encouraging more Q&A and attendee participation. We will provide as many live demos in front of an actual furnace as we can. Based on feedback from our 2022 classes, we have also added new classes around furnace processes. Another update we are very excited for is that attendees will receive course materials on an iPad to take with them so they can easily reference anything in the future.

How will the curriculum be tailored to meet attendees' individual needs?
We will take a look at the attendees' industries, job functions, and what type of furnaces they have to determine the best curriculum for each class. This might include breakout sessions on different types of controls, taking a deeper dive into processes such as brazing or increasing the focus on troubleshooting and maintenance. We also plan on sending out a pre-class survey to everyone registered to get direct input from those who will be in attendance. For anyone interested in an even more customized offering, we also conduct on-site Ipsen U trainings directly at customers' facilities.

How often will the course be offered during 2023?
We have four classes scheduled at our Vacuum Technology Excellence Center in Cherry Valley, Illinois. Those dates are April 11-13, June 6-8, August 8-10, and October 3-5. We will also continue to conduct on-site classes, allowing us to work directly with the customer's heat-treating equipment and even further tailoring the training for their specific needs. Last year we did 10 of these on-site classes and expect to do even more this year.

Ipsen U will provide as many live demos in front of an actual furnace as possible. (Courtesy: Ipsen)

If someone is interested but can't make the scheduled times, are there any alternatives available (i.e. online recordings or transcripts)?
Right now, we do not provide the trainings online. We believe it is valuable to experience the class in-person with our hands-on approach. However, we are currently in the process of building a more robust knowledge base for our customers that will include some educational resources. More to come on that later.

Do you have any plans to expand on Ipsen U in the future?
Our goal is to continually improve the class based on customer feedback. After each class, we will evaluate what went well and what can be further improved upon.

MORE INFO ipsenglobal.com/event/ipsenu


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