Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

QUENCHING / INDUCTION HEATING

QUENCHING: A LONG AND VARIED HISTORY

COMPANY PROFILE ///

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JULY 2022
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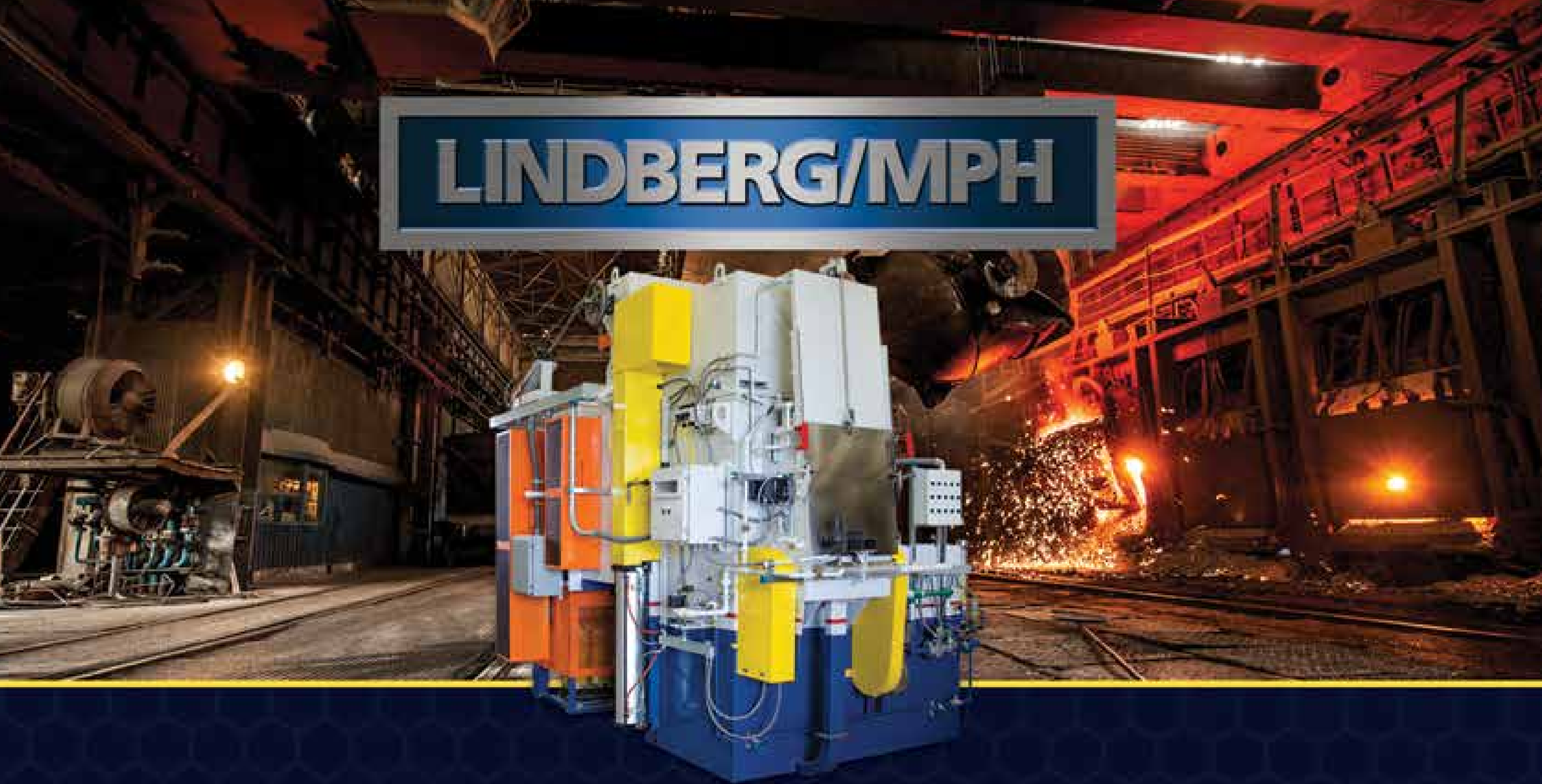
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JULY 2022 VOLUME 11 / NUMBER 7

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New Products, Trends, Services & Developments

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JOHN LUDEMAN

DIRECTOR ///
ADVANCED HEAT TREAT CORP.

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Industrial Heating Equipment Association (IHEA)

METAL URGENCY ///

HOT SEAT ///

QUALITY COUNTS ///

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FROM THE EDITOR ///

We take your message farther than anyone

If the global climate has taught us anything, it's shown us that the industry is made up of an amazing network of companies that is changing and adapting in order to keep those furnaces and ovens hot and running.

Was it easy? The answer to that would be an emphatic "no." But it's been a necessary task that has proven the industry's mettle — or should that be metal?

Thermal Processing wants you to know that we are here for you, and in ways that continue to make us your No. 1 source for heat-treating news and information on a variety of platforms.

What do I mean by that?

Thermal Processing is the only heat-treat magazine that presents this information in print as well as online.

What does that mean for you?

It means your information — whether it's an eye-catching advertisement or an intelligently written article presented by an industry expert — is not only visible and available on the internet through our website and social media, but it also enjoys a long shelf life as a physical printed vehicle in offices and homes around the country.

That's good news for your audience in search of the very services and products that you can provide every day.

With that in mind, I hope you find the articles in our July issue of interest.

Our July issue takes interesting looks at induction hardening and quenching.

On the subject of quenching, get ready for a fascinating history lesson as D. Scott MacKenzie takes a deep dive into the history of quenching, especially those methods used by ancient blacksmiths and how that can lend further understanding to the technological and cultural contributions of the first metallurgists.

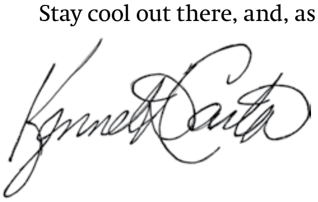
Also, in our Focus section, ALD Vacuum Technologies' Nicki Teumer shares his thoughts on how a new furnace innovation will allow the efficient production of high-purity melts by using vacuum-induction technology on an industrial scale.

In addition to those main articles, this issue also offers up a look at how compact printed circuit heat exchangers (PCHE), produced through a diffusion bonding process, can surpass traditional alternatives in extreme temperature and pressure environments.

That's just a taste of what July's issue has in store for you.

Thermal Processing is here to serve you. With that in mind, if you have any suggestions or would like to contribute, please contact me. I'm always looking for exciting articles to share.

Stay cool out there, and, as always, thanks for reading!



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ceramics expo

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Ceramics Expo brings together engineers, decision makers, end-user OEMs and buyers from across the globe to source new materials, components and technologies, network with like-minded professionals, and discuss the challenges and opportunities in the ceramics industry.

Running concurrent to the exhibition is the free-to-attend Ceramics Expo Conference, where industry leaders will share their technical expertise in ceramics and provide real-world case studies, new technologies and materials, along with information on industry trends.

Discover the exhibition and sponsorship opportunities, the conference program, the full exhibitor list, and how to secure your free visitor pass at:

ceramicsexpousa.com

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www.ceramics.org

NEW FOR 2022

THERMAL TECHNOLOGIES EXPO

HIGH PERFORMANCE PLASTICS EXPO North America

Ceramics Expo has been joined at the Huntington Convention Center of Cleveland by two co-located events: Thermal Technologies Expo and High Performance Plastics Expo. This exciting new partnership gives Ceramics Expo visitors the opportunity to discover the very latest thermal management technologies and innovations, plus the latest high performance plastics and polymers solutions. Your free Ceramics Expo 2022 pass gives you access to both Thermal Technologies Expo 2022 and High Performance Plastics Expo 2022.

Can-Eng Furnaces announced a contract to deliver a second mesh belt heat treatment furnace to a commercial heat treater. (Courtesy: Can-Eng Furnaces)

Can-Eng to deliver second mesh belt furnace line

Can-Eng Furnaces International, Ltd. has recently been awarded a contract to deliver a second high-capacity mesh belt heat treatment furnace line to a commercial heat treater in the Midwest United States. Can-Eng completed commissioning of a 4,000 lb/hr mesh belt furnace system for this customer in 2020. With some run time on the new equipment, it was quickly realized that improvements in the Can-Eng designs — which include soft part handing, precision temperature + atmosphere control, energy efficiency, and reduction in oil drag out — not only were producing a higher quality part but doing so at a reduced operational costing.

This duplicate 4,000 lb/hr high-capacity mesh belt furnace line is to be installed alongside the previous furnace line in the recently expanded plant.

These custom-engineered continuous atmosphere heat-treating systems feature an increase in usable hearth area to provide high-volume processing when running products requiring carbon diffusion and lighter belt loading, as they will be used primarily for demanding processing including carbonitriding and carburizing. The furnaces are capable of a maximum throughput capacity of up to 4,000 lb/hr neutral hardening each.

Both furnace lines feature a computerized controlled automated bin dumping and vibratory part feeder system, dunk and spray pre-washer, protective atmosphere-controlled mesh belt hardening system, oil quench, dunk and spray post wash system, forced recirculation temper furnace, in-line post cooling system, and Can-Eng's PETTM Level 2 SCADA system. By integrating Can-Eng's Level 2 Automation, the end user has access to vital tracking of products' status, detailed process data for continuous process improvements, comprehensive equipment diagnostics, cost analysis, and inventory management, which is required by many demanding customers.

This new line marks the fifth Can-Eng mesh belt furnace line to be in operation at the facility.

Can-Eng Furnaces International is a global provider and leader of state-of-the-art thermal processing systems. Headquartered in Niagara Falls, Ontario, Canada, Can-Eng is an ISO 9001:2015 certified company.

MORE INFO www.can-eng.com

Ceramics Expo enhances gathering with co-located event

The seventh edition of Ceramics Expo will be August 30-31 in Cleveland, Ohio. To enhance its offering for 2022 and in response to developments in the use of advanced ceramic materials across high-tech industries, the event welcomes the launch edition of Thermal Management Expo.

"The introduction of Thermal Management Expo is great news for the industry and even more so for the markets that already attend Ceramics Expo each year," said exhibition manager Raymond Pietersen. "We are confident the synergy between the two events will provide an engaging experience for our visitors but also increase the opportunity for our exhibitors to do business."

The exhibition is set to welcome more than 350 global market-leading exhibitors across the entire advanced ceramics and glass manufacturing supply chain, including GeoCorp Inc, Saint-Gobain Ceramics, Osterwalder Inc, Corning, and Bosch Advanced Ceramics.

Alongside the exhibition will be a free-to-attend conference, addressing the most pressing challenges facing stakeholders from across the advanced ceramics supply chain. Sessions will be delivered by technical

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 2021 Ceramics Expo successfully brought together exhibitors, decision makers, and buyers. (Courtesy: Ceramics Expo)

experts from Morgan Advanced Materials, IMERYS Performance Minerals Americas, Air Force Research Laboratory and more, delivering thought leadership on topics including material advancements, key applications, and manufacturing developments.

"Ceramics Expo, now in its seventh year, provides an unrivaled opportunity to see firsthand and up close the innovations in materials, processes and products that are driving today's ceramic manufacturing industry," said Mark Mecklenborg, executive director at The American Ceramic Society (ACerS). "ACerS is proud to be a founding partner of this event. If you are an engineer, researcher, business leader, decision maker or buyer in the ceramics and glass manufacturing industry, this is a must-attend event. More than 350 global suppliers and manufacturers will be front and center on the show floor, ready to show you their latest products and demonstrate their cutting-edge technology."

Ceramics Expo is the leading event for the advanced ceramics and glass supply chain, bringing together engineers, decision makers, and buyers from the advanced ceramics and glass supply chain and end user OEMs. The event began in 2014 and is set to attract 3,500-plus visitors, more than 350 exhibitors and 60-plus speakers to its specialist conference stages at Cleveland's The Huntington Convention Center. The event is a platform for the industry to share technical expertise in ceramics with real-world case studies, cutting-edge new technologies and materials, along with the very latest industry trends.

Attendees have an all-access pass to not only Ceramics Expo but also to Thermal Management Expo. Thermal Management Expo is dedicated to bringing together end-users with suppliers of thermal technologies, systems, and materials.

MORE INFO www.ceramicsexpousa.com

The XLC Series box furnace for ceramic matrix composites. (Courtesy: L&L Special Furnace Co.)

L&L receives order for two retort box furnaces for CMC use

L&L Special Furnace Co., Inc. has received an order for two atmosphere-controlled retort box furnaces used for de-bindering ceramic composite matrix parts (CMC), along with powder metals processing (PM), and hot isostatic processing (HIP).

Initially, CMC and other ceramic matrix components and additive manufactured parts were developed for bullet resistive armor and cloth. These materials were found to be lighter and stronger than some alloy and ceramic substitutes. Additive manufacturing and CMC materials are now becoming more routine and are finding their way into more and more widespread industries.

Aerospace and military have always been the key areas that CMC and additive technologies are applied. The CMC development is a key part of the subsonic ordnance project along with multitudes of other military applications. This technology allows for lighter and more durable aircraft, munitions, and body armor. Automotive has also always had a strong presence in the additive manufacturing industry as well.

It is new application areas where CMC technology is starting to shine. CMC technology is beginning to establish a presence in agricultural applications such as water desalinization, power, and battery technology in providing lighter fuel cells. This technology will be applied to battery operated transportation vehicles, not only improving transportation capabilities but also lowering greenhouse emissions.

The main function of the furnace is to remove all organics and other materials used in the product prior to placing in a high fire vacuum chamber. This de-bindering process is extremely important and allows for a finished product which is a very strong lightweight part.

The model XLC3648 furnace has a work zone of 23" wide by 23" high by 36" deep. The furnace has a single zone of control with a temperature gradient of ±20°F at 1,100°F using four zones of temperature control with biasing to balance any temperature gradients.

The furnace is constructed of low mass insulating firebrick which allows for quicker cool down times. The furnace has a Venturi cooling blower which also aids in cooling. The furnace is controlled by a Eurotherm program control with overtemperature protection. There is also a programmable flow panel to control the nitrogen flow throughout the process.

The parts are heated to 1,220°F in a retort chamber that is pressurized with nitrogen. The by-products of the outgassing part are directed by pressure and flow out the rear of the furnace. The parts are then heated in a vacuum furnace to temperatures in excess of 2,300°F. The result is a super strong component which is stronger and lighter than titanium.

All L&L Special Furnace Co., Inc.'s furnace can be configured with various options and be specifically tailored to meet your thermal needs. L&L also offers 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 included with each system within the continental US and Canada. International startup and training service is available by factory quote.

MORE INFO www.llfurnace.com

Advanced Heat Treat hires Chris Williams as new sales manager

Advanced Heat Treat Corp. (AHT), a recognized leader in heat treat services and metallurgical solutions, announced Chris Williams has joined the company as its new regional sales manager. Williams will be responsible for driving sales and providing customer service for its location in Cullman, Alabama.

Chris Williams

Williams joins the AHT team with more than 20 years of experience in heat treatment, quality, and operations, serving most recently as a plant manager for another heat treater in Alabama.

"With Chris's background, he will hit the ground running. He has a great personality and will connect immediately with our customers and employees. We are excited about the growth and new opportunities he'll help us achieve," said AHT President Mikel Woods.

Williams will be based in Cullman. The AHT facility in Cullman offers ion (plasma) and gas nitriding, ferritic nitrocarburizing, UltraOx®, stress relieve, and more. This summer it will also be announcing an additional heat-treat service.

"I am excited to work for Advanced Heat Treat Corp., a company that is family-oriented and promotes a positive work-life balance," Williams said. "The technical expertise at AHT is unmatched in the thermal-processing industry and I am pleased to be part of the team."

MORE INFO www.ahtcorp.com

Turkish company buys second Nitrex furnace

Yazici Transfer Makina company will add a second Nitrex turnkey nitrocarburizing system to its Istanbul facility as a way to increase the manufacturing capacity of tooling and machinery components for the company's precision CNC machines. It started production with the new system in the fall of 2021, and is used for Nitreg®-C nitrocarburizing and ONC® in-process oxidation treatments.

This second Nitrex furnace is the same type as the first installation, a compact size NXK series furnace that became operational in 2019, simply bigger.

"In addition to improving tooling quality and performance, the NXK-812 is very economical to operate, if you take into account the low gas consumption and optimized energy efficiency. A solution that improves the company's bottom line and reaffirms its commitment to sustainable manufacturing," said Marcin Stokłosa, project manager at Nitrex Poland.

Yazici Transfer Makina chose Nitreg®-C nitrocarburizing and ONC® in-process oxidation for their combined ability to improve the wear and corrosion properties of alloy and carbon steel parts.

"In the beginning, Yazici Transfer Makina was relying on a very well-known commercial heat treater from the Turkish market to nitrocarburize the parts it needed," said Utku Inan, Nitrex representative in Turkey. "But now, the company has moved heat-treating operations in-house, purchasing its own systems to nitrocarburize metal parts, which saves the company on lead time and transportation costs."

Yazici Transfer Makina is in Turkey, with its main office in Istanbul. The company operates in the fastener, button, needle, and pin manufacturing sector. This family-owned company was established in 2003 and oversees two plants.

Nitrex was founded as a private Canadian company in 1984. The company started as a pioneer in computer control-based nitriding and nitrocarburizing with its proprietary technology NITREG®. Over the next two decades, the company has grown in the United States and Poland, thriving thanks to its sustained efforts in research and development and bringing new technologies to the heat-treating market such as the ONC® technology that further enhances the corrosion and wear resistance properties of NITREG® treated steels and of NITREG®-C nitrocarburizing, an environmentally friendly alternative to salt bath nitrocarburizing.

MORE INFO www.nitrex.com

Vastex offers EconoRed III high-capacity oven

An EconoRed ER-III-30 high-capacity oven with a 30 in. (76 cm) wide conveyor belt cures composites, thermoset plastics, adhesives, epoxies and related materials at high rates. (Courtesy: Vastex Industrial, Inc.)

A new EconoRed ER-III-30 high-capacity oven from Vastex Industrial is said to cure composites, thermoset plastics, adhesives, and epoxies at high rates, in a smaller footprint and at lower cost than comparable ovens.

Warrantied for 15 years, the unit's three 24-inch (61 cm) wide, 3,600-watt infrared heaters (total 10,800 watts) feature closely spaced coils that provide high-density, medium-wavelength infrared heat for maximum cure speed without cold spots or under-curing.

To compensate for varying shapes and thicknesses of items being cured, the unit's Infrared Focusing System allows heater-to-conveyor height adjustments from two to seven inches (5 to 17 cm) as standard, with greater clearances available as an option.

The expandable design allows the addition of modular heating chambers and conveyor belt extensions as production needs increase.

A top-mounted exhaust system draws in filtered air and cools the outer skin of the oven while a 388 CFM (11 m^3/min) exhaust system evacuates moisture and fumes from the heating chamber.

The oven is supplied as standard with a digital PID temperature controller accurate to ±1°F (±0.5°C), and a control box that can be positioned on the right (standard) or left side of the enclosure to suit plant layouts.

The 30 in. x 105 in. (76 x 267 cm) Teflon®-coated fiberglass belt is equipped with a low friction belt aligner and belt speed controls to precisely set dwell times from 35 seconds up to four minutes.

Optional stainless-steel mesh belts satisfy high-heat and/or sanitary applications.

Vastex Industrial also manufactures the EconoRed ER-III-54 with a 54-inch (137 cm) wide conveyor belt and 13 other models of tunnel and cabinet ovens for pilot testing up to high-capacity production.

MORE INFO www.vastexindustrial.com

Thermal engineering sector has new event for industries

Thermal Management Expo, the only free-to-attend exhibition and conference dedicated to the thermal management sector, will be August 30-31 in Cleveland, Ohio.

Co-located with Ceramics Expo, (now in its seventh year, and bringing together engineering professionals from across the supply chain) Thermal Management Expo will showcase the latest systems, materials, and technologies addressing thermal management challenges within the automotive, aerospace & defense, energy storage, power electronics, telecoms, and medical sectors.

Some of the brands showcasing their solutions include ThermAvant, Morgan Advanced Materials, Colder Products Company, CAVU Group, and MG Chemicals.

Alongside the exhibition will run a free-to-attend conference, with sessions delivered by technical experts from Collins Aerospace, Meta (Facebook), Lord Parker, ThermAvant Technologies, 3M, and many more leading voices from the sector. Sessions will offer insights into thermal management systems and design, covering topics including thermal interface materials, innovations in battery cooling, and electronic thermal management.

Driven by advancements across new and emerging technologies — such as the increased demand for EV battery cooling and the miniaturization of electronics within 5G and telecoms — the global thermal management market is projected to grow by a CAGR of 8.2 percent to be worth USD 12.8 billion by 2025.

Exhibition manager Ipek Saltik said, "Thermal management plays a critical role in any application that generates energy, from jet turbines, engines, motors, actuators, inverters, batteries, and fuel cells. Our aim is to provide a unique platform for the manufacturers, suppliers, and end-users to interact about the materials, solutions and technologies for their thermal management challenges in various industries – all under one roof."

"Like the proverbial elephant in the room, so often while the engineering community is cognizant of the critical importance of thermal management in system performance and efficiency we treat it as a secondary issue to be addressed after other design considerations have been finalized," said Richard Clark, global lead, energy storage at Morgan Advanced Materials. "Here at last is a focused forum where the latest technologies and strategies for tackling thermal management will be demonstrated, presented and discussed."

"We believe this event will help us to achieve our stated goal of helping to establish Ohio and the region as North America's hub for fuel cell technologies, and that's why we're delighted to have signed up as official event partners," said Ohio Fuel Cell Coalition executive director Pat Valente. "A dedicated forum to network and share ideas and development was badly needed, and we look forward to participating in the inaugural edition of Thermal Management Expo in August 2022 and meeting thousands of peers and industry professionals."

MORE INFO www.thermalmanagementexpo.com

Ipsen USA provides Turbo²Treater for Italian heat treater

Temprasud's new Ipsen furnace will help them continue to grow business in the automotive market, with anticipated expansion into aerospace. (Courtesy: Ipsen USA)

Ipsen recently installed the second Turbo²Treater vacuum furnace at Temprasud, a commercial heat treater in Fresagrandinaria, Italy.

"With the addition of this vacuum-hardening and low-pressure carburizing furnace, we can offer our customers greater flexibility and production capacity," said Temprasud CEO Michelangelo Del Vecchio.

Their first Turbo²Treater was purchased in 2017 and allowed Temprasud to expand services, improve part quality, and reduce cycle times. The new furnace will help them continue to grow business in the automotive market, with anticipated expansion into aerospace. They also have a large customer base in the construction equipment, wind energy, and agricultural machinery industries.

Temprasud cites Ipsen's technical expertise and customer service as motivators in their decision to continue ordering Ipsen equipment. In reference to the Turbo²Treater, they say it produces parts with optimal hardness, bright surfaces, and minimum distortion.

"Ipsen provides innovative treatment systems and technologies that guarantee the best results in terms of quality," said Del Vecchio.

Temprasud also has two Ipsen VDR furnaces for nitriding and nitrocarburizing in their plant. Their Ipsen furnaces have helped to reduce the environmental impact of production with better temperature uniformity and faster processing speeds. This helped Temprasud receive ISO 14001 certification, which is the international standard for environmental management systems.

MORE INFO www.ipsenusa.com

Seco/Warwick India celebrates five-year anniversary

The Indian subsidiary of the Seco/Warwick® Group marked its fifth anniversary recently.

During that time, the company received several dozen orders for metal heat-treatment equipment, placed by the leading companies on the Asian market. Regular customers of the company include the TATA Group — the largest and the oldest (154 years old) Indian company, generating approximately USD 314 billion in revenue.

Seco/Warwick in India celebrated its fifth anniversary, although it has been operating in that market since 2007. During the first ten years of their presence in the region, they completed dozens of orders.

"Our first steps in India were a challenge, but with perfect products and positive opinions among the customers, we were quickly able to become the first-choice supplier for the Indian companies looking for aluminum heat treatment solutions, CAB or vacuum furnaces," said Piotr Skarbiński, vice-president business segment aluminum process and CAB, Seco/Warwick Group.

The activity there became a starting point for the establishment of the company dedicated to the market. In 2017, Seco/Warwick Systems & Services (INDIA) Pvt. Ltd. was established to be focused on the sales and servicing of the equipment for heat treatment under

Seco/Warwick in India celebrated its fifth anniversary in May, although they have been operating in that market since 2007. (Courtesy: Seco/Warwick)

vacuum, vacuum and aluminum metallurgy in India, ensuring the best service and support for the Indian customers.

Over the years of business activity in the Indian market, Seco/Warwick has built its position as a trustworthy partner with great competence when it comes to metal heat-treatment equipment. The TATA Group (both automotive and steel companies) has partnered with Seco/Warwick several times with great success.

"In India, we are the first-choice supplier of metal heat-treatment equipment, which is often underlined by our customers themselves. It is great that we have created a company that is a partner for the largest producers in the region. The vast majority of our customers come back and place orders for successive technological solutions. This proves that establishing a dedicated company was the right step to make," said Manoranjan Patra, managing director, Seco/Warwick India.

Harsha Engineers was one of the first customers for Seco/Warwick India. The company delivered equipment to this partner in 2018 and 2019. Winning the first order from a global automotive manufacturer for the CaseMaster Evolution-T furnace with oil quenching and LPC technology was a big success.

Customers of Seco/Warwick India also include Bharat Forge and Kalyani.

"Over these few years, there have been many milestones. We should certainly mention the fact that large equipment (for the aluminum segment) is in part produced on site in India, which clearly affects our competitiveness. We assembled the largest Vortex® furnace in the history of the entire Seco/Warwick Group or the largest VertiQuench® for the TATA Group. We have won with the competition that, during the early years of our operations, had an advantage, with both experience and knowledge of the market. However, good products, a perfect team providing a quick response as well as the local service department increased our advantages and today we can optimistically look into the future years of our market presence," Patra said.

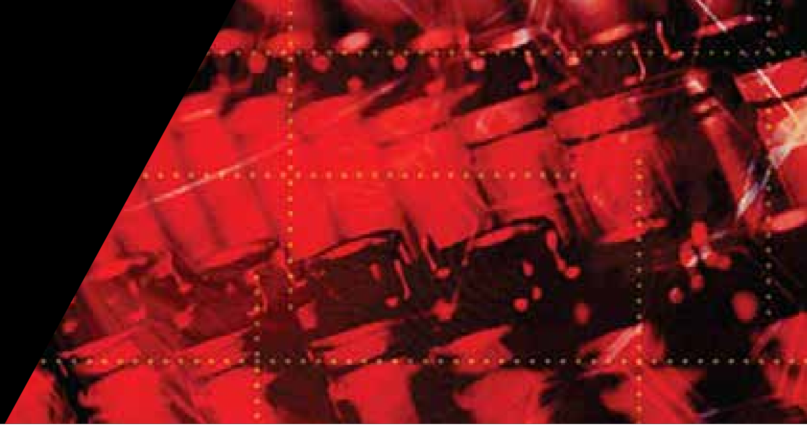
The innovative ZeroFlow® technology also has a great future ahead in India. More and more customers opt for it due to a shorter process compared with traditional gas nitriding and nitrocarburizing, while ensuring a safe working environment and lower gas emissions. Seco/Warwick delivered a retort furnace for ferritic nitrocarburizing to Harsha Engineers Limited, a leading Indian manufacturer of bearing cages.

A world-class Indian leader of automotive components uses a CMe vacuum furnace featuring LPC technology. The device was used to solve the problem of intercrystalline oxidation occurring in conventional atmosphere furnaces. The Seco/Warwick vacuum furnace is used for the heat treatment of components of small and large-toothed gears, pinions, and other car gears.

Recently, India's corporation manufacturing feed machinery and the contractor for "turnkey" agricultural engineering projects has also placed an order for a Vector vacuum furnace with vertical insertion of loads. The device will be used in the production of ring dies and rollers for palletizing equipment. These are the parts used in many common large-dimensions agricultural machines.

This year's customers of Seco/Warwick India include a fastener manufacturer, Sundram Fasteners Limited. The company will receive a VECTOR® vacuum furnace from Seco/Warwick. It will be used for manufacturing the highest-quality aviation bolts.

MORE INFO www.secowarwick.com



Make sure you have these conferences on the calendar

Advances in Materials and Processing Technologies Conference aims to bring together leading academic scientists, researchers and research scholars to exchange and share their experiences and research results on all aspects of Advances in Materials and Processing Technologies

EUROPEAN CONFERENCE ON HEAT TREATMENT/ IFHTSE 27TH CONGRESS

Wyndham Grand Salzburg Conference Center
Salzburg, Austria | September 5-8, 2022

Sponsored by ASMET, the Austrian Society for Metallurgy and Materials.

»www.ifhtse-echt2022.org

ADVANCES IN MATERIALS AND PROCESSING TECHNOLOGIES

Portorož, Slovenia | October 10-14, 2022

The Advances in Materials and Processing Technologies (AMPT) conference series provides a forum for academics, researchers, and practicing engineers to meet and exchange innovative ideas and information on all aspects of material-processing technologies. It was founded in 1990 at the Dublin City University, Dublin, Ireland, and has since been held in different countries around the globe. After being canceled in 2020 due to the COVID pandemic, the 2022 AMPT conference will be at the coast of Slovenia in Portorož.

»www.AMPT2022.org

HTS – 14TH INTERNATIONAL EXHIBITION AND CONFERENCE ON HEAT TREATMENT

Mumbai | November 2-4, 2022

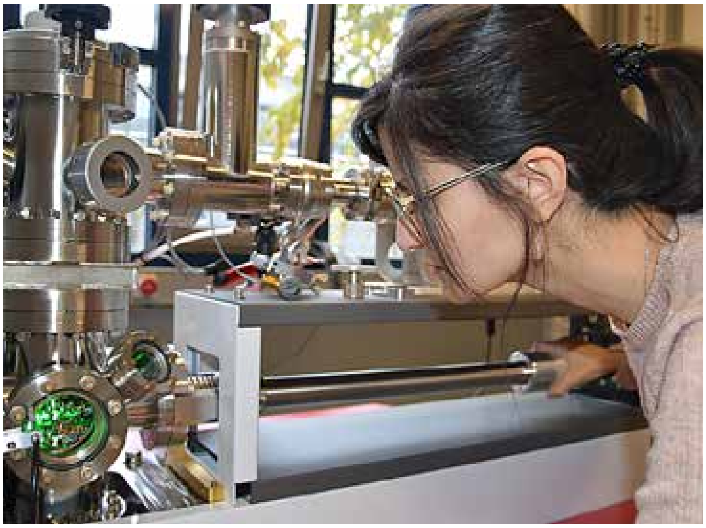
This event is now scheduled for November 2-4, 2022, at the Bombay Exhibition Centre in Mumbai. The three-day, international concurrent conference on "Advances in Heat Treatment" will have sessions on equipment, process improvement, emerging technologies, and innovations and case studies. The HTS conference will focus on advances in heat treatment with specific topics such as NADCAP certification, Industry 4.0, process modeling, optimization and control, and case studies with specific reference to different industry sectors — transport, power, defense, etc.

»htsindiaexpo.com/international-conference

PAST CONFERENCES AND PROCEEDINGS

Over the past 50 years, there have been numerous IFHTSE conferences throughout the world. The proceedings from these conferences have been printed on paper (until recently). Archives of these past papers are important for the work and for future reference. We are trying to capture these conference proceedings and digitize them for posterity and retrieval. Should you have any of the older conferences, please let the editors know so these can be digitized.

SPOTLIGHT ON MEMBERS



At Leibniz-IWT, material engineering, process engineering and production engineering competences are combined into one institute.

Leibniz-IWT

Since 1950, research has been conducted at Leibniz-IWT in Bremen on highly stressed metallic structural materials. On July 13, 1950, the Institute for Hardening Technology (IHT) was founded in Bremen-Lesum as the forerunner of today's Leibniz IWT under the provisional management of the chief engineer of the C. Borgward company, Hubert M. Meingast.

At Leibniz-IWT, material engineering, process engineering and production engineering competences are combined into one institute. This interdisciplinary cooperation enables the scientists to map and research overarching issues of high practical relevance of highly stressed components along the entire process chain.

At Leibniz-IWT, they have a very complete heat-treating shop, including induction-hardening equipment, integral quench furnaces, vacuum low pressure carburizers, and pressure and oil quench, as well as numerous pieces of analytical equipment.

IFHTSE UPCOMING EVENTS

SEPTEMBER 5–8, 2022
27th IFHTSE Congress / European Conference on Heat Treatment
Salzburg, Austria I www.ifhtseecht2022.org

OCTOBER 10–14, 2022
Advances in Materials and Processing Technologies
Portorož, Slovenia I www.ampt2022.org

NOVEMBER 2–4, 2022
HTS – 14th International Exhibition and Conference on Heat Treatment
Mumbai, India I www.htsindiaexpo.com

APRIL 21–24, 2023
5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies
Liangzhu Dream Town, Hangzhou, China

OCTOBER 17–19, 2023
Heat Treat 2023
Detroit, Michigan I 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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IHEA education coming this fall – Learn from the best

Infrared curing demonstrations enhance the knowledge gained of the technology.

This fall, the Industrial Heating Equipment Association (IHEA) will offer its Combustion Seminar and Safety Standards and Codes Seminar in Indianapolis, Indiana, October 3-4, 2022.

"The IHEA seminars provide fantastic educational opportunities both in the combustion field and industry safety standards and codes," said IHEA's education committee chairman, Brian Kelly of Honeywell Thermal Solutions. "IHEA's Combustion Seminar offers essential education on basic, as well as advanced, combustion subjects and the IHEA Safety Standards and Codes Seminar provides the latest updates on the NFPA 86 Standard and other safety related topics that are unique in the industrial heating market."

The concurrent technical seminars will be Monday and Tuesday, October 3-4, at the Indiana Convention Center in conjunction with the Metal Treating Institute's (MTI) Furnaces North America (FNA). The schedule provides attendees the benefit of expanding their technical knowledge and allows time to visit with FNA exhibitors, including IHEA members and companies represented by IHEA seminar speakers.

For over half a century, the Combustion Division of IHEA has delivered quality education for those in the thermal heat processing industry. IHEA's Combustion Seminar will provide attendees with updated and relevant information from experts in combus-

Interactive sessions give attendees hands-on experience to increase learning at IHEA seminars.

tion technologies. The seminar is designed for those responsible for the operation, design, selection, and/or maintenance of fuel-fired industrial process furnaces and ovens. Seminar speakers are industry leaders in combustion and members of IHEA. Attendees will receive 15 Professional Development Hours upon completion of the two-day event. Registration is open now, go to www.ihea.org/event/Combustion22.

IHEA's popular Safety Standards and Codes Seminar will provide a comprehensive overview of the NFPA 86 Standard for Ovens and Furnaces. This is the first opportunity for attendees to learn about the most recent updates to the standard. Speakers have a first-hand knowledge in the development of NFPA 86 and serve on the technical committees that develop the changes. They will explain the updates in the 2023 NFPA 86 edition that will be released this summer. Attendees will also receive a copy of the newly released NFPA 86 Standard for Ovens and Furnaces with their registration. For more details and registration information, go to www.ihea.org/event/Safety22.

HEAT UP YOUR SKILLS

The Infrared Equipment Division of IHEA (IRED) partners with the Chemical Coaters Association International to present a one-and-a-half-day training. The Powder Coating and Curing Processes Seminar will be September 20-21 in Henderson, Nevada. Attendees learn everything from pretreatment and powder materials to curing processes and testing equipment for powder coating. There will be live demonstrations and time in a custom coater facility for attendees to see the processes up close and try their skills at spraying powder and curing a part. Instructors from all subject matters are on hand throughout the seminar to guide attendees and answer questions. For details, go to www.ihea.org/event/PCCSept22.

LEARN ONLINE

In addition to the in-person training, IHEA also offers an extensive six-week online course. The Fundamentals of Industrial Process Heating will run from October 24 through December 11. IHEA's online course has been a successful source of high-level education for those who prefer a virtual learning experience. A basic understanding of process heating and some engineering background are recommended to take this course. The curriculum includes the combustion fundamentals and fuels, combustion equipment for gaseous and liquid fuels, advanced heat transfer principles, elements of heat transmission, heat balance and efficiency calculations, and fundamentals of electrical heating. Weekly coursework, quizzes, and a final exam project are administered to guide students on their progress and evaluate their knowledge of the material. Instructor interaction is available during the weekly forum discussions and via email for questions and to review the coursework. Students receive an electronic copy of IHEA's Fundamentals of Process Heating Handbook with registration. For a complete listing of the topics covered and to register, go to www.ihea.org/event/OnlineFall22.

JOIN IHEA

IHEA members take advantage of discounts on all events or may use member vouchers to attend. To learn about all the benefits of IHEA membership, go to www.ihea.org/benefits.

JUSTIN SIMS
MECHANICAL ENGINEER /// DANTE SOLUTIONS

Simulation used to compare the stress evolution of carburized and thru-hardened components.

Stress evolution during quench hardening of steel

Quench hardening of steel components involves complex, nonintuitive phenomena, particularly as it relates to the dimensional changes and stresses induced. Figure 1 shows a dilatometry curve for AISI 9310 steel alloy, with a 10°C/sec heating rate and a 20°C/sec cooling rate. Quench hardening of a steel component begins with the component at room temperature, with some initial microstructure; the structure is assumed to be pearlite in Figure 1 and room temperature is defined as 20°C. As thermal energy is supplied to the component, the material expands linearly with respect to the temperature change. This expansion continues until enough energy has been supplied that the steel undergoes a solid-state phase change, transforming from a ferritic, body-centered cubic structure (BCC structure) to an austenitic, face-centered cubic structure (FCC structure). This atomic rearrangement increases the density and reduces the overall dimension of the component; this can be seen at the "Austenite Transformation" in Figure 1. After completing the austenite transformation, the component continues to expand until thermal equilibrium is achieved.

Quenching is the rapid removal of thermal energy from the part by some fluid. As the component is cooled, its overall dimension is reduced, though at a different rate compared to the initial structure, as seen in Figure 1. This is due to the difference in the coefficient of thermal expansion between an FCC and BCC structure. All transformation products at room temperature will be a ferritic structure (BCC structure) with varying carbide forms. The exception is as-quenched martensite, which is a BCC structure super-saturated with carbon. The trapped carbon contorts the BCC structure into a body-centered tetragonal structure (BCT structure). However, upon tempering, the crystal lattice is relaxed back to a BCC structure with fine, spherical carbides.

Although there are several phases which can be realized during quenching, all will increase the dimension of the component compared to the austenite phase, though to varying degrees since they occur at different temperatures. The change in density is the cause of distortion, which can be classified as size change and shape change. Size change is inevitable with the volumetric change of the phase transformation, but significant shape change distortion can occur if the phase transformations occur at different times locally within the component. For the example shown in Figure 1, the only phase obtained during quenching is martensite. The dimensional change as the material transforms to martensite is significant and is the cause of most stresses generated during quenching and then those remaining at room temperature as residual stress. This large change in strain can be seen at the "Martensite Transformation" in Figure 1.

To see how this dimensional change correlates to the in-process and residual stress, the heat-treatment simulation software DANTE was used to model a 50.8 mm sphere, made of AISI 9310, and subjected to a quench hardening process. A sphere was chosen for this study to negate any geometry related effects on stress and strain. Additionally, two different scenarios are evaluated: carburized to an effective case depth (ECD) of 0.8 mm and thru-hardened. Figure 2 shows the hoop stress in the sphere as a function of total processing time for the entire hardening cycle for both cases; tempering was not modeled, though it can be and is expected to reduce the residual stress slightly. Stress histories are compared at the surface and at depths of 0.8, 1.6, 12.7, and 25.4 mm from the surface of the sphere for both cases. Depths of 0.8 and 1.6 mm represent the ECD and total carbon case in the carburized part, respectively. The mid-radius and core points are represented by the depths of 12.7 and 25.4

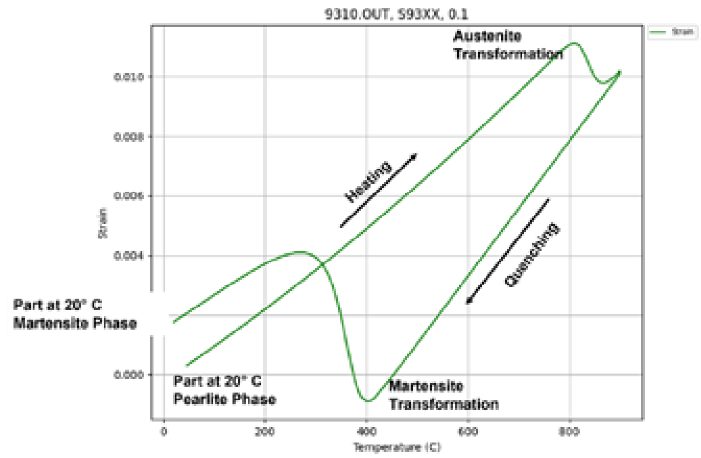


Figure 1: Dilatometry curve for AISI 9310.

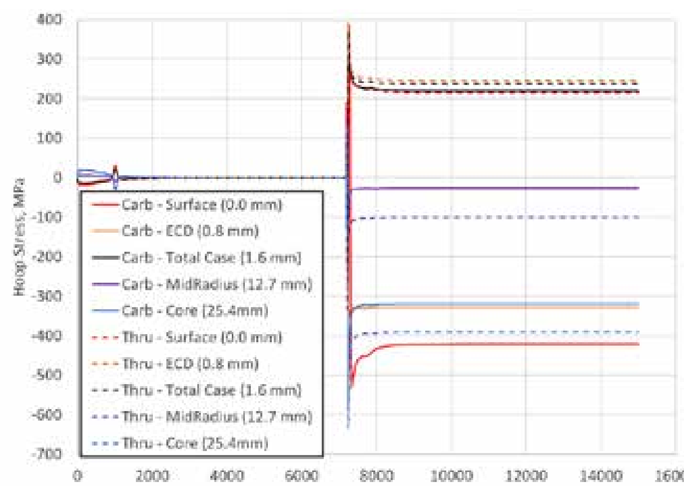


Figure 2: Hoop stress as a function of total processing time for the carburized and thru-hardened cases at various depths from the surface for the heating and quenching.

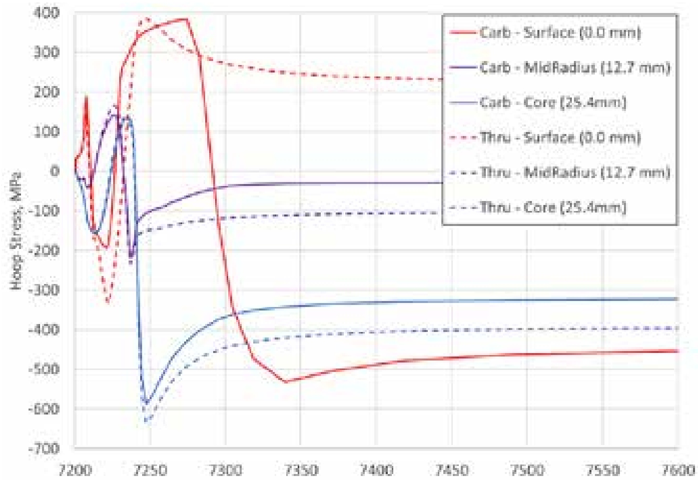


Figure 3: Hoop stress as a function of total processing time for the carburized and thru-hardened cases for the surface, mid-radius, and core points for the quenching step only.

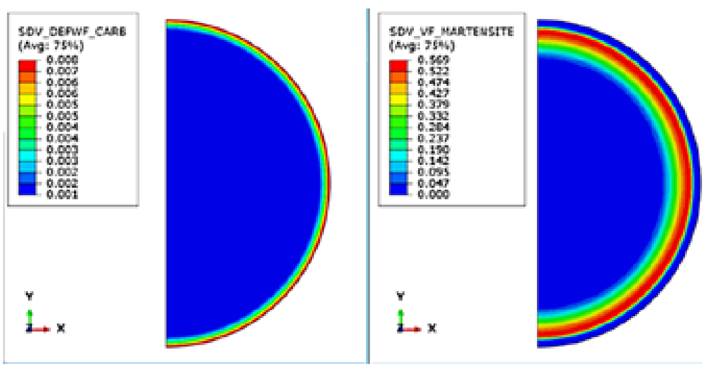


Figure 4: Carbon profile of the carburized sphere (left) and the progression of the martensite transformation during the quenching process.

mm, respectively. The stresses generated during heating, and the subsequent austenite transformation are insignificant compared to the stresses generated during quenching. However, a component's geometry can influence its dimensional response, so it should never be assumed that there will be no distortion or stress-related issues during heating.

To gain a better understanding of the stress evolution during quenching, Figure 3 plots the first 400 seconds of the quenching process for the surface, mid-radius, and core points. Interestingly, the core and mid-radius positions behave very similarly in the carburized and thru-hardened spheres. Quench hardening, with respect to in-process stresses, is a cyclic process. For the mid-radius location, a slight compression is first induced, followed by a spike in the tensile stress. As the process progresses, the mid-radius is again driven into compression, where it remains as a residual stress. The core position behaves in a similar fashion as the mid-radius, but with slightly larger magnitude of compression. The compression in the core of both cases is due to the fact that the core is the last area, far removed from the surface, to transform from austenite. Although the mid-radius and core positions are effectively the same, with respect to the stress evolution, the surface behavior differs between the two cases.

As shown in Figure 3, the surface of the thru-hardened case remains in tension, but the surface of the carburized case is driven into compression. This is a result of the transformation beginning at the case-core interface and progressing toward the core and the surface, simultaneously, as shown in Figure 4. The red band of martensite transformed first, and is spreading toward the core and the

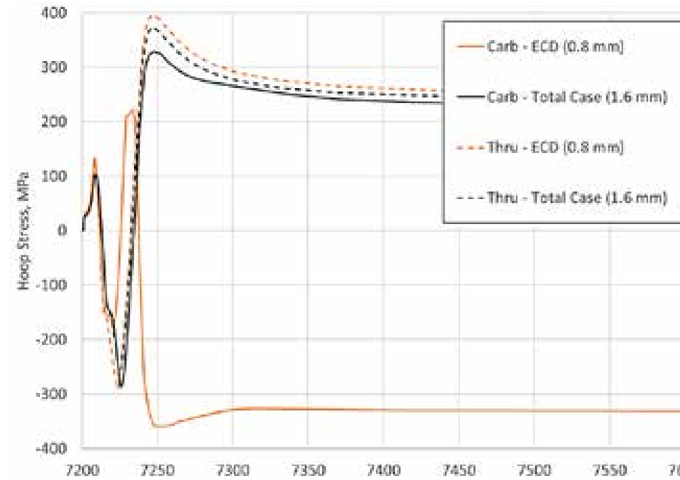


Figure 5: Hoop stress as a function of total processing time for the carburized and thru-hardened cases at the ECD and total case points for the quenching step only.

surface, though at different rates, as revealed by the thickness of the green band. The rate at which the transformation front progresses in either direction will depend on the alloy's hardenability, the carbon gradient, and the cooling rate. However, unless influenced by geometric effects, the stress morphology for carburized components proceeds as shown in Figure 3.

Figure 3 showed that the stress evolution between a carburized and thru-hardened component are effectively the same, though great differences exist at the surface. Figure 5 explores the stress morphology between the two cases at the distances from the surface defining the ECD and total carbon case depth (i.e., the case-core interface). The behavior at the total case depth, 1.6 mm in this example, is effectively the same between the two cases. However, the behavior at the ECD is significantly different. The carburized case has a high level of compression at this location, whereas the thru-hardened case is in tension. It should be noted that the material's hardenability, the component's geometry, the depth of carbon enrichment relative to the total cross-sectional thickness, and the cooling rates can all have a significant effect on the stress morphology. However, in the most general sense, compression will be realized at the surface, and through the carbon case, for a carburized part and residual tensile stress will generally be present at the surface of thru-hardened parts.

In conclusion, the quench hardening process of steel components can be a counter-intuitive process, as the thermal and phase transformation influence on dimensional change counteract one another. The heat-treatment simulation software can be used to explore this phenomenon and show that the volumetric change brought about by the solid-state phase transformation induces a tremendous amount of stress in the component, leading to residual stresses. It was also shown that carburized and thru-hardened components have significantly different stress histories at the surface and near surface locations, but effectively progress the same away from the carbon gradient.

ABOUT THE AUTHOR

Justin Sims is a mechanical engineer with Dante Solutions, where he is an analyst of steel heat-treat processes and an expert modeler of quench hardening processes using Dante software. Project work includes development and execution of carburization and quench hardening simulations of steel components and analysis of heat-treat racks and fixtures. He has a mechanical engineering degree from Cleveland State University.

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

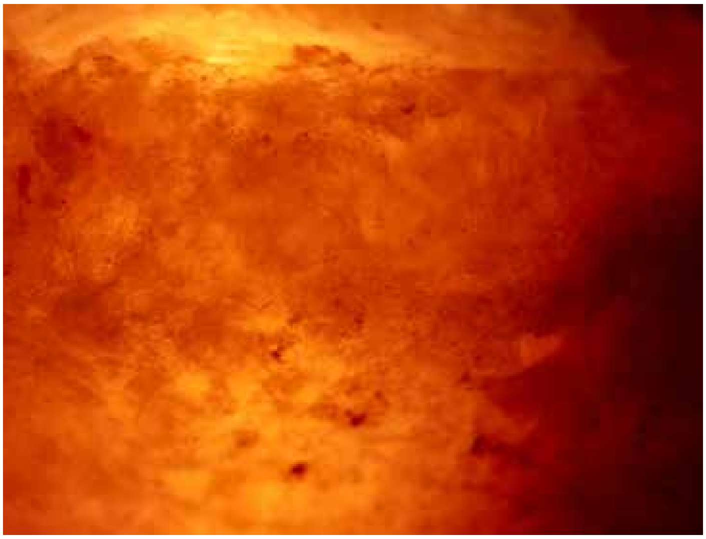
Heat treating can be hazardous if the necessary precautions are not implemented and followed, including ensuring engineering controls and properly trained personnel.

Safety considerations when quenching with oil or salt

In this column, we will consider safety aspects of quenching with oil or molten salt.

Heat treating is a manufacturing process where the goal is to change the microstructural characteristics of the metal being treated. At its simplest, for steel parts, this is usually accomplished by heating to above the austenite temperature, quenching in a suitable quenchant to harden the part into martensite, followed by tempering to reduce residual stresses, and turn the hard and brittle martensite to more ductile, tempered martensite.

To heat the part to the austenite region, there are four general methods of accomplishing this. The most common method is to heat the parts using either gas or electric in a gas atmosphere. Parts can be heated under a vacuum to reduce surface oxidation. Parts can also be heated in a molten salt bath, but this is becoming less common due to health, safety, and environmental concerns. Finally, parts can be heated completely, or at the surface using induction or flame. There are also many other ways to locally heat a part, but that is beyond the scope of this article.



For quenching, and converting the austenite to martensite, there are really two methods. The first is by either immersing, spraying, or flooding the part with liquid quenchant. The second method is by rapid-cooling the part using gas (air, nitrogen, helium, argon, or mixtures, etc.). Again, the goal of quenching is to convert the austenite to hard martensite using a controlled cooling process.

Not every heating process is compatible with the different quenchants. For instance, the workhorse sealed integral quench furnace, is not suitable for polymer or water-based quenchants. This is because the water vapor from the quench tank can infiltrate the hot zone and contaminate the atmosphere. Expensive modifications are required to allow water or polymer quenchants in integral quench furnaces. Oil (most common), molten salt, and high-pressure gas have been used as quenchants for sealed quench type furnaces.

Heating Process or Furnace Type	Quenching Process and Medium					
	Type of Quenchant Tank	Oil	Polymer	Salt	Water	Gas
Gas atmosphere or Integral Quench	Closed	X		X		X
Gas Atmosphere Box Furnace	Open	X	X	X	X	
Vacuum Furnace	Closed	X				X
Salt Bath	Open	X	X	X	X	
Induction or Flame	Open	Rare	X		X	

Table 1: Typical combinations of heating processes and quenchant types.

Induction or flame hardening using oil as the quenchant is rare, but it is done commercially. This heating process is usually followed by a water or polymer quench, the idea being to reduce or eliminate fire hazards.

A simple table showing the various combinations of heating process and furnace types, with their associated compatible quenchants, is shown in Table 1.

FIRE AND EXPLOSION HAZARDS

Furnace Atmospheres

A typical furnace atmosphere used for heat treating steel parts is composed of roughly 20% CO, 0.5% CO_2, 40% H_2, trace water vapor, and the balance N_2. At temperatures below approximately 750°C, this atmosphere is explosive. These explosive conditions can occur when loading or unloading parts, allowing oxygen to enter the work zone. The flame curtain or heating elements can act as the ignition source. A leaky furnace, or a furnace with an internal negative pressure can also allow air to infiltrate. It is imperative that a suitable flame curtain and process controls be implemented and maintained properly for atmosphere operation. Operators should be properly trained concerning the hazards associated with the heat-treating operation.

Oil Quenching

Fire hazards accompany oil quenching. Hot parts and flammable oil can lead to some pretty spectacular fires if proper controls are not implemented.

Water in the quench tank can contribute to a very hazardous situation during quenching. Water expands up to 1,600 times when turning to steam. This can result in a rather large fire and explosion in a sealed quench furnace, or a froth over in open quench tanks. Keeping any water content of the quench oil below 1,000 ppm will reduce the chance of a water-induced oil fire.

Hung loads, or parts partially submerged in a quench tank, can cause a large fire. The oil at the surface will locally overheat and form combustible vapors that can be ignited by the partially submerged part. Some engineering controls used to combat this are rapid dumps of the quench oil to a reservoir away from the parts, or a rapid release to allow the part to be rapidly submerged in the quench.

Improper oil level (either too high or too low) can result in oil fires. In the case of too low an oil level, the oil inadequately covers the part, resulting in an overheated surface layer, like a hung load. The quantity of oil present could exceed the flash point, and "flash off," resulting in a large oil fire. Excessive oil levels can result in the oil expanding and reaching the hot zone (in an integral quench furnace), or overflow in an open quench tank.

Finally, the ventilation used to exhaust oil quench fumes from the heat-treat shop can become saturated with condensed oil. These types of fires can occur if the flames from the integral quench furnace flame curtain or the exhaust over the burn-off catch the condensed oil on fire. The fire can rapidly spread and be difficult to contain. Maintenance to routinely clean the ductwork should be implemented. The use of higher flashpoint quench oils can reduce the quantity of fumes, which reduces the amount of condensation in the ductwork. Finally, a method of extinguishing ventilation fires, such as flooding with nitrogen or fire extinguishers, should be part of facility design.

Molten Salt Quenching

Quenching in molten salt offers many benefits, including reduced distortion, and the ability to austemper suitable steel parts. However, many of the beneficial characteristics of salt baths can make fires difficult to contain and extinguish.

Salts used for quenching are usually operated at below 350°C and are predominantly mixtures of sodium and potassium nitrates/nitrites. Molten salts used for austenitizing are mixtures of sodium and potassium chlorides. High-temperature carburizing salts can contain cyanide.

Nitrate/nitrite molten salt baths that are operated either intentionally or accidentally above 650°C can result in a large explosion. Nitrate/nitrite molten salt quench tanks (or heating as in the case of aluminum) are prohibited from being operated above 650°C. Operating controls such as high limit controllers and process controllers should be set to shut down the heaters should it detect the thermocouple is open.

For quenching, and converting the austenite to martensite, there are really two methods. The first is by either immersing, spraying, or flooding the part with liquid quenchant. The second method is by rapid-cooling the part using gas (air, nitrogen, helium, argon, or mixtures, etc.).

Quenching from cyanide carburizing baths into nitrate baths will result in a severe exothermic reaction and the release of cyanide gas. Acids should never be stored near drums of cyanide-containing salt.

Organic materials on parts, or baskets and fixtures will burn. Parts and baskets should be thoroughly clean prior to entering the salt bath. This prevents fires and ensures a nice stain-free surface when exiting the bath.

If a molten salt quench tank (or a high heat austenitizing molten salt bath) is allowed to cool, the molten salt will solidify. If allowed to sit, water can sometimes infiltrate the quench tank. Because the solidified tank is opaque, it is difficult to see any water that is at the bottom of the tank or entrained in pockets. It is critical, prior to heating the molten salt, that multiple pathways be created to allow superheated steam in the tank to escape. Otherwise, a large steam explosion can occur. Gradually heating the salt with a torch until the salt is molten enough to be heated by the heating elements or radiant tube is also good practice.

Fighting a salt fire is not straight-forward. Direct streams of water should not be directed at the molten salt. The water can get under the molten salt, and result in a large steam explosion, with the molten salt coming at you. As a young engineer, I had a rather large salt bath fire in my shop. As the firemen came rushing in, I had to stand in front of the hose to prevent the fire first responders from pointing a high-pressure water hose at the flaming salt bath. Had they been successful in pointing the hose at the fire, there would have been multiple injuries and a large explosion.

It is important to relay to the first responders the potential hazards that they might face. This is to ensure that the situation doesn't go from bad to worse.

CONCLUSIONS

Heat treating can be hazardous if the necessary precautions are not implemented and followed. Engineering controls must be in place, and people must be properly trained to operate equipment safely. They should be trained how to respond to upsets in the process. Finally, first responders should be notified of the hazards that they may face when dealing with a fire.

Should there be any questions or comments on this article, or suggestions for further articles, please contact the writer or editor.

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JASON SCHULZE
METALLURGICAL ENGINEER /// CONRAD KACSIK

Successful quality-control personnel need a thorough understanding of technical aspects of any thermal process to better ensure conformance.

Aluminum heat-treating has unique challenges

From a metallurgical and quality perspective, aluminum heat-treating presents unique challenges when compared to carbon-based steels. This article will examine the aspects of aluminum heat-treating that make it unique, and specific ways a quality team can account for the variables to ensure conformance throughout the thermal process. I will not be covering each specific aspect of the process, so excuse me if I leave out fine details.

A BRIEF HISTORY

In 1807, a British chemist, Humphrey Davy (1778-1829) discovered five new metals. One was aluminum. Due to aluminum's strong attraction to oxygen, he was unable to isolate the aluminum using an electric arc. With the introduction of bauxite into the process by Henri Sainte-Clair Deville in the 1860s, Karl Bayer (1847-1904) was able to design a process that could isolate the aluminum. Fast-forward to the modern day — the standard aluminum foundry uses the Hall-Heroult process, which has been modified over decades to produce an efficient process called electrolysis.

The aluminum oxide is melted and electrolyzed (Figure 1). The anode is made of graphite, a form of carbon. Oxygen ions move to the anode where they're converted to oxygen. The anodes are gradually worn away by oxidation. The cathode is also made of graphite. Molten aluminum is produced there. The process requires a lot of electrical energy, which is one reason aluminum is more expensive than steel.

ALUMINUM CLASSIFICATION

In general, aluminum is classified as two types:

- Heat treatable (precipitation-hardenable).
- Non-heat treatable.

Furthermore, aluminum will have a designated temper (i.e. F, O, T3, T4, T6, etc.).

HEAT TREATMENT OF ALUMINUM

Heat-treatable aluminum alloys can be strengthened by a suitable thermal process. The solubility of the alloy elements is directly related to temperature making wt% of each alloy element a critical factor.

Let's use A356.0 Al alloy as an example. This alloy is made up of aluminum (primary) - 6.5-7.5% silicon – 0.25-0.45% magnesium – 0.20% copper – 0.20% iron – 0.20% titanium – 0.10% zinc. The addition of magnesium is key. Magnesium (Mg) – Al-Si- alloys that contain no magnesium are considered non-heat treatable. The addition of Mg provides solid solution strengthening without decreasing ductility. Mg additions offer strength and corrosion resistance.

In general, solution heat-treating takes advantage of the precipitation hardening reaction. The objective is to take into solid solution the maximum practical amount of the soluble hardening elements in the alloy. This process also consists of soaking the alloy at a temperature sufficiently high and for a long enough time to achieve a nearly homogeneous solid solution.

aluminum oxide → aluminum + oxygen

Higher tier only

Cryolite is used to lower the melting point of the aluminum oxide.

The aluminum ions are reduced at the cathode (they gain electrons):

$Al^{3+} + 3^{e+} \rightarrow Al$

While the oxygen ions at the anode are oxidized (they lose electrons):

$2O^{2-} \rightarrow O_2 + 4^{e+}$

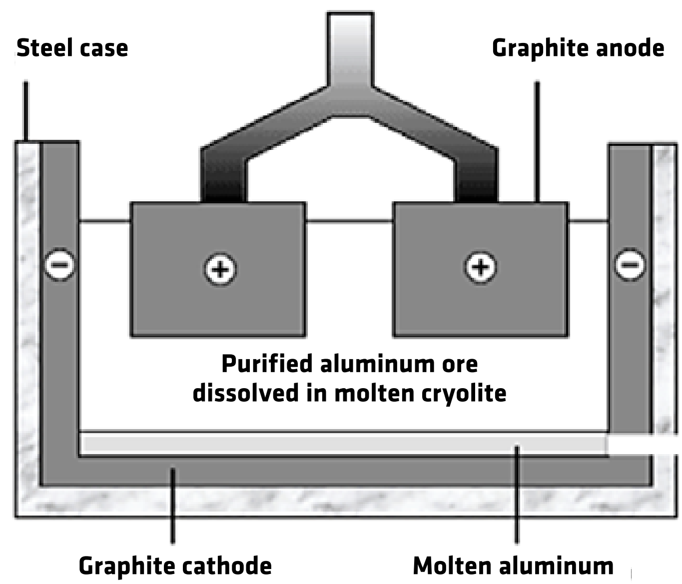

Figure 1

We will stick with A356.0 as we continue. Solution heat-treating of A356 produces the following effects:

- Dissolves Mg_2Si.
- Homogenizes the aluminum.
- Changes in morphology of eutectic silicon.

From a quality perspective, let's look at only the first one. To obtain the maximum concentration of magnesium and silicon, the solution temperature must be as close as possible to the eutectic temperature; ideally 10-15°F below the eutectic temperature. Control of temperature is critical. If the melting point is exceeded, incipient melting (localized melting at the grain boundary) may occur, and mechanical properties may suffer. This condition is only detectable by metallographic examination and is irreversible.

After quench, the aluminum may be aged. The process of aging causes the decomposition of various phases as the atoms dissolve in the aluminum matrix.

In other words, Mg_2Si precipitates out of solution (which was dissolved during solution heat treatment) in order to obtain hardening characteristics (hardness and conductivity). Figure 2 is a time-temperature plot for A356.0. Line A represents the time at which Mg_2Si precipitation begins. Line B represents the point at which maximum strength and hardness are achieved. An 18°F change in aging temperature changes the aging time by a factor of two.

HOW THIS TECHNICAL DESCRIPTION AFFECTS QUALITY CHARACTERISTICS

In relation to the previous information, a critical take-away should be the verification of raw material certifications. Quality personnel should design a system that will ensure all raw material received conforms to the purchase order requirements. This should include verification of each alloy element wt% as stated on the certification.

Another take-away should be solution temperature is typically 10°F-15°F below the eutectic temperature of the material. Therefore, aluminum solution heat-treating is required to take place in a furnace that has a uniformity of ±10°F (CL2 – AMS2750). When quality control is reviewing furnace charts to ensure conformance, the temperature achieved during processing is critical.

SUMMARY

It can be difficult at times for quality-control personnel to both ensure quality requirements are met and have a thorough understanding of the process itself. Understanding the technical aspects of any thermal process will better enable the quality representatives to ensure conformance.

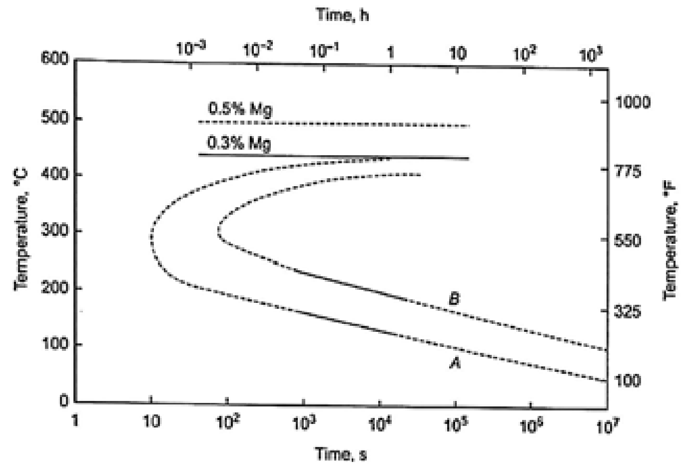

Figure 2: *D.Apelian, S. Shivkumar, and G.K. Sigworth, Fundametal Aspects of Heat Treatment of Cast Al-Si-Mg, AFS Trans., Vol 96, 1989, p 727-742.

ABOUT THE AUTHOR

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QUENCHING: A LONG AND VARIED HISTORY

There are a lot of hyperbole and myths regarding ancient heat treatment and quenching with much simply being wrong; however, this article looks at the works of possible quenchants used by ancient blacksmiths and how they may further the understanding of the technological and cultural contribution of the first metallurgists.

By D. SCOTT MACKENZIE, PHD, FASM

There have been many myths concerning the quenchants used by ancient blacksmiths in the heat treatment of swords and knives. Various liquids have been cited in the archeometallurgical literature as quenchants. Each of these quenchants is supposed to extend to the knife's special and even mythical properties. Some possible quenchants used by ancient blacksmiths will be discussed.

INTRODUCTION

Much of the early history of quenching is unknown prior to 1500 AD because it wasn't written down. There have been some texts written throughout the past that hinted at quenchants used, but very few detailed the process.

Much of the history of quenching is interlaced with the early production of iron. Probably one of the earliest references to smelting and blacksmithing is from the Old Testament in Genesis 4:22 [1] where Tubal-Cain is mentioned as "an artificer of bronze and iron."

It is not known when steel was first created, or who first created steel. It is suggested from tradition (Herodotus, Xenophon, and Strabo) and archaeological evidence [2] [3] that ironworking developed in the Middle East, in Turkey, near the plateau of Anatolia in 1400–1200 BC by the Hittites [4] [5]. Iron smelting was well known by the second millennium, and described by Homeric poems (880 BC), the History of Herodotus (446 BC), and Aristotle [6] (350BC). Because of ore variation, and the skill of the individual craftsman, the production of steel was often poor quality and limited in production [7].

One of the first mentions of quenching is from Homer (circa 800 BC):

"As when a man who works as a blacksmith plunges a screaming great axe blade or adze into cold water, treating it for temper, since this is the way steel is made strong, even so Cyclops' eye sizzled about the beam of the olive …." Odyssey 9.389-9394, translation by R Lattimore

This dramatic image of quenching indicates familiarity with the concept of quenching of steel. But, much of the history of quenching has been shrouded in mystery and magic.

QUENCHING MYTHS

One of the earliest myths perpetrated regarding quenching ancient steel was the idea that slaves or virgins were used as a quenching medium. The idea being that the hot sword or knife plunged into the body of a slave would impart special properties. Slaves as a quenching medium was first presented with a tongue-in-cheek reference by Douglas Fisher [8]. This was previously noted by John Sullivan [9]. From a practical perspective, it is not likely that slaves or virgins were used as a quenching medium. The physical force required to plunge a blade while hot would likely cause the blade to deflect and warp due to Euler Column Theory [10]. Further, it is likely that the slaves would tend to writhe about, causing distortion to the blade. Lastly, slaves and virgins are not renewable. Any large production would certainly exceed the available supply.

In the first millennium, few technological advances were made in Europe. Some Icelandic sagas spoke of searching through many kingdoms to find the proper water to harden the sword Ekkisax and weapons that are hardened in blood [11]. Predominantly, the advances in metallurgical technology were located in the Arab world, India, China, and Japan. While European armor blacksmiths were improving and gradually perfecting their craft, the Crusaders of the 12th century had no steel that was the equal of Islamic metallurgy. The Japanese sword was even better than the Islamic sword by an even greater margin [12].

In an account of Second Captain Massalski [13], it was indicated the Persians quenched their steel in pre-heated hemp oil. He further indicated that grease and bone marrow were sometimes added to the quenchant:

"If it is a dagger, it is held flat; if it is a sabre, it is quenched little by little, beginning by the end of the cutting edge, holding the latter toward the bath. This manoeuvre is repeated until the oil stops smoking, which proves that the blade has cooled. After quenching, the blade is always soiled with burnt oil. This dirt is removed by heating it enough to set light to a piece of wood and by rubbing with a rag from a bedsheet." — English Translation by Graham Cross.

Pretextat-Lecomte is a French painter and mosaic artist who lived at the end of the 19th century and was invited to Istanbul for the restoration and reconstruction of some historical art pieces. He spent many years in Istanbul, and from his studies of oriental arts, he wrote the "Arts and Crafts of the Orient" in 1902. (*Les Arts et Metieres de la Turquie de l'Orient*, published in Paris in 1902) [14]. He described the process of quenching a blade:

"… Now it was required to quench it in order to give it the necessary strength, and that was the interesting point of the procedure: Europeans quench the steel in water, vegetable oil, or cattle fat, but in the East they were doing it on air. When the craftsmen were done with the processing of the metal, they heated it until totally red and gave it to a cavalry man waiting on his horse, ready for a ride. The cavalry man rode his horse in the wilderness, waving the blade in the air with crazy screams to make his horse ride faster."

On the other hand, "air quenching" was certainly not the only method for making "superior steel" in the Ottoman period. Kemankes (translation is Bowman) Mustafa Aga gives a special formula in his book, *The Book of Arrow* [15], for making armor-piercing arrowheads and sword blades. His quenching medium consists of:

- 1 okka Quick Lime (CaO)
- 1/2 okka Soda (NaCO)
- 1/2 okka Carbonas Cupricus (Copper Oxide?)

» 1/2 okka Arsenic Sulphate (AsS)
» 2 okka Radish juice
» 1 okka Wild Onion juice
» 1/2 okka Valonia ash
» 1 okka Tar
(Okka is a weight unit and corresponds to 1,283 grams.)

CHINESE QUENCHING

The earliest known Chinese word for quench-hardening is cui [16] and is still used in the modern term for quenching cuihuo [16]. Water was predominately the preferred quenchant:

"When a skilled metallurgical worker 'casts' [zhu] the material of a Gan Jiang [sword], quench-hardening [cui] its tip with pure water and grinding its edge with a whetstone from Yue, then in the water it can slice water-dragons, and on land it can cut rhinoceros hide as quickly as sweeping and sprinkling or drawing in mud." — Sheng zhu dexian chen song presented to the Emperor Xuan-di (73 BC to 49 BC) by Wang Bao [16]

There is some thought that the idea of quenching was a Han Dynasty innovation [16]. Early Tang texts indicated the Yunnan quench-hardened steel in "the blood of a white horse" [16]. Various texts indicate that different waters were good for quenching, while others were inadequate. The Qingzhand and the Longguan Rivers were noted for being good for quenching [16]:

"The Han River is sluggish and weak and is not suitable for quench-hardening. The Shu River is bold and vigorous…"

Quenching in vinegar was poor practice "making it brittle and easy to break" [16]. It seems that quenching in urine was a common practice, with quenching in the urine of five sacrificial animals or the fat of five sacrificial animals. It was given that "such a sword could penetrate 30 layers of armor" [16].

There was also an understanding of the effects of different quenchants and the effect on performance. In 6 AD, the blacksmith *Qiwu Huaiwen* used animal urine and animal grease to affect different quench rates. The characters used differentiated like this: *Cui* was denoting quenching in animal grease, while *yu* was designated for quenching in urine. *Song Yingxing* discusses quenching in oil, which provides a softer quench, "since the strength of steel lies in quenching." Further, it was noted that barbarians quench in di son, the "urine of the earth," a kind of oil not produced in China [16]. This perhaps is the first possible mention of quenching in petroleum-based oils.

ADVANCED METHODS IN JAPAN

The metallurgical state-of-the-art was very advanced in Japan. The science and craftsmanship of the Japanese sword is still revered today for being beautiful and effective, capable of maintaining a sharp edge and the unique curve of the blade.

Swords made by the traditional method are manufactured from steel produced by the *tatara* method. This steel, or *tamahagane*, is produced from iron sands that have very low phosphorus and sulfur.

The basic process is like that practiced by the Europeans in the fifth to sixth century AD. The sharp edge consists of high-carbon steel to retain an edge, and the interior of the blade consists of lower carbon steel for toughness and ductility. However, the Europeans immersed the entire sword in the water, with the entire surface of the sword quenched rapidly. In the Japanese method, controlled quenching is achieved at specific rates at different locations on the blade.

Prior to heating, the Japanese sword maker applied a closely guarded secret clay mixture (called *yakiba-tsuchi*), that consisted of stone powder, clay, and charcoal. The stone powder helps prevent the clay from cracking during heating of the blade; the charcoal is burned out during heating, producing a site for initiation of nucleate boiling, depressing the formation of the vapor phase. The thickness

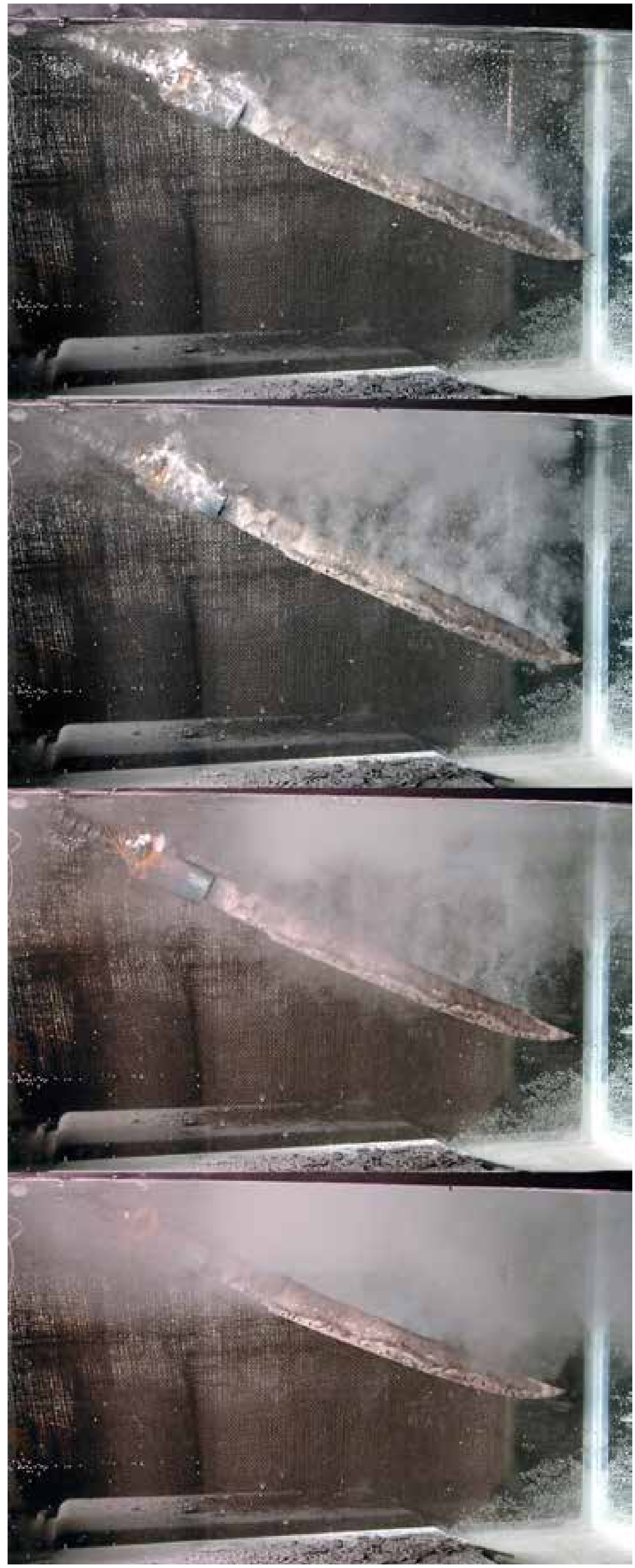

Figure 1: Sequence of quenching a Japanese Tanto: This blade was coated with clay (yakiba-tscuchi); the nose or tip of the blade (kissaki) is down showing gyaku-sori; blade is now straight again; nose is up as in the typical final curvature of a Japanese blade (sori). (Courtesy: Jesus Hernandez and Walter Sorrells)

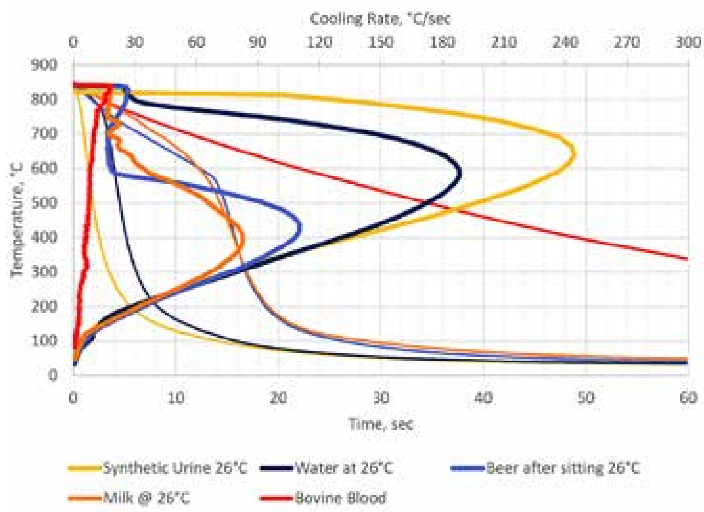

Figure 2: Comparative cooling curves for different ancient quenchants [29].

of the clay determines the quench rate. The clay is thinnest at the edge of the blade and thickest at the ridge of the blade—opposite the edge. The blade is immersed in water in the water box or *mizubune*. The edge is quenched with the highest heat-transfer rate and produces martensite, while the ridge experiences a much milder quench and transforms to a mixture of pearlite and ferrite. The interface between the pearlite and martensite is called the *hamon*.

This unique and ingenuous method of quenching also produces the characteristic curvature of the blade. As the blade is quenched, the edge contracts, and reverse bending occurs, called *gyaku-sori*. At the martensite transformation, the *sori*, or normal bending occurs, due to the volumetric transformation of martensite. *Gyaku-sori* appears again at the pearlite transformation at the ridge of the blade. Finally, the final curvature or *sori* appears as the pearlite contracts due to thermal contraction, contributing to strong compressive residual stress at the blade edge. Final tempering of the blade, or *aidori*, is done in a charcoal fire. This understanding of the quenching process, practiced since the fifth to sixth century, shows the advanced nature of the Japanese metalsmiths.

MEDIEVAL QUENCHANTS

Focusing on Europe, and specifically early medieval Anglo-Saxon and Viking knife manufacture, several quenchants were identified. Some Icelandic sagas spoke of searching through many kingdoms to find the proper water to harden the sword *Ekkisax* and weapons that are hardened in blood [17]. Probably the first significant work in medieval Europe was written by Theophilus [18] (1125), a 12th century German Monk. The "Diver Arts" describe several good quenchants. His recommendations for quenchants were very specific:

"Tools are also given a harder tempering in the urine of a small, red-headed boy than in ordinary water." [18]

Other recommendations for quenchants included the urine of goats fed ferns for three days.

Giambattista della Porta (ca. 1535-1615) in his books *Natural Magic* [19] showed an excellent understanding of the reason why many quenchants were effective, and some of the underlying principles:

"If you quench red hot iron in distilled vinegar, it will grow hard. The same will happen, if you do it into distilled urine, by reason of the salt it contains in it. If you temper it with dew, that in the month of May is found on vetches leaves, it will grow most hard. For what is collected above them, is salt, as I taught elsewhere out of Theophrastus. Vinegar, in which Salt Ammoniac is dissolved, will make a most strong temper. But if you temper Iron with Salt of Urine and saltpeter dissolved in water, it will be very hard. Or if you powder Saltpeter and Salt Ammoniac, and shut them up in a glass vessel with a long neck, in dung, or moist places, till they resolve into water, and quench the red hot Iron in the water, you shall do better. Also iron dipped into a Liquor of Quicklime, and Salt of Soda purified with a Sponge, will become extreme hard. All these are excellent things, and will do the work."

There was also an understanding of the cause of quench cracking, and the results of quenching in other than water for Porta's "The Temper for Instruments to let blood":

"It is quenched in oil, and grows hard, because it is tender and subtle. For should it be quenched in water, it would be wrested and broken."

Various authors describe other quenchants including: pigeon droppings, flour, honey, olive oil, and milk [20] [21] [22]. Other quenchants, including urine, water and solubilized animal fats and whale oil, are described by Smith [23], Biringuccio [24], Agricola [25], and others:

"Take clarified honey, fresh urine of a he-goat, alum, borax, olive oil, and salt; mix everything well together and quench therein."

Von Stahel and Eysen (1532) [26] also discussed quenchants to be used for heat-treated parts:

"Take varnish, dragon's blood, horn scrapings, half as much salt, juice made from earthworms, radish juice, tallow, and vervain and quench therein. It is also very advantageous in hardening if a piece that is to be hardened is first thoroughly cleaned and well-polished."

Other modern researchers [27] [28] have indicated that oil, milk, urine, and blood have been used as quenchants.

COOLING CURVES OF VARIOUS QUENCHING MEDIA

A paper by MacKenzie and Graham [29] evaluated the cooling curves of synthetic urine, water, beer, milk, and bovine blood.

The synthetic urine was a very fast quenchant and greatly exceeded the cooling rate of water. This is caused by the salts precipitating on the surface of the probe, resulting in nucleation sites for nucleate boiling to occur. This cooling curve was like commercial quenchants containing inorganic salts.

The water quench is like the synthetic urine, but much slower. Some stable vapor phase is present.

Beer showed a quench rate like a fast-accelerated quench oil, with a similar maximum cooling rate. However, a long-extended vapor phase occurred due to the residual carbonation present in the beer. This acts to stabilize the vapor phase.

Milk showed a moderate vapor phase, with a slow overall maximum cooling rate. This is thought to be the result of the butter fat present in the quenchant.

Blood showed a very unusual cooling curve. There was an initial vapor phase like the other quenchants; however, this was followed by a very long and prolonged stable cooling rate from approximately 750°C to 100°C. Virtually no nucleate boiling occurred. In a typical cooling curve, virtually all the quenchants reached nearly ambient temperature within 60 seconds. Blood on the other hand, at the end of the 60 seconds, the probe was at a temperature of 341°C. It took three minutes for the cooling curve probe to reach 80°C. This is an extremely slow cooling curve. It was thought that quenching cooked the fat and blood insulated the probe, slowing heat transfer. This insulating later drastically slowed the heat-extraction rate.

CONCLUSIONS

There are a lot of hyperbole and myths regarding ancient heat treatment and quenching. Much is simply wrong. While blood was claimed to produce magical properties to a blade, it has been shown to have a very slow cooling curve and not capable of hardening the simple steels available to early blacksmiths. Water and urine are really the only quenchants that would be able to heat treat the simple steels [30] heat treated in early times.

It is hoped that this work on possible quenchants used by ancient blacksmiths can further the understanding of the technological and cultural contribution of the first metallurgists.

REFERENCES

[1] A. Guillaume, "Metallurgy in the Old Testament," Palestine Exploration Quarterly, vol. 94, no. July/Dec., pp. 129-132, 1962.

[2] T. A. Wertime, "Man's First Encounters with Metallurgy," Science, vol. 146, pp. 1257-1267, 1964.

[3] T. A. Wertime, "The Beginnings of Metallurgy," Science, vol. 182, pp. 857-887, 1973.

[4] L. Aitchison, A History of Metals, Volume I, London: MacDonald & Evan Ltd., 1960.

[5] K. A. Yener, "Swords, Armor and Figurines," Biblical Archaeologist, vol. 58, p. 2, 1995.

[6] J. N. Friend, Iron in Antiquity, London: Charles Griffin & Co., 1926.

[7] A. R. Williams and K. R. Maxwell-Hyslop, "Ancient Steel from Egypt," J. Archeological Sciences, p. 97, 1976.

[8] D. Fisher, The Epic of Steel, New York: Harper & Row, 1963.

[9] J. Sullivan, The Story of Metals, Ames, IA: American Society for Metals and The Iowa State College Press, 1951.

[10] T. H. Megson, Aircraft Structures for Engineering Students,, 7th ed., London: Elsevier B.V., 2022.

[11] A. G. Drachmann, "De navngivne sværd i saga, sagn og folkevise. Gad, København, 1967 (Studier fra sprog- og oldtidsforskning udgivet af det Filologisk–Historiske".

[12] National Academy Supplementary Report of the Committee on the Survey of Materials Science and Engineering, Materials and Man's Needs: Materials Science and Engineering -- Volume I, the History, Scope, and Nature of Materials Science and Engineering, National Academy of Science, 1975.

[13] Massalski, "Preparation de L'Acier Damasse en Perse," Annuaire du Journal des mines de Russie, pp. 297-308, 1841.

[14] Prétextat-Lecomte, Les Arts et Métiers de la Turquie et de l'Orient, Paris: Société d'Éditions Scientifiques, 1902.

[15] G. K. Alpay, "Lamii Chelebi and His Works," J. Near Eastern Studies, vol. 35, no. 2, pp. 73-93, 1976.

[16] D. B. Wagner, "Ferrous Metallurgy," in Science and Technology in China, vol. 5, Cambridge, Cambridge University Press, 2008.

[17] A. G. Drachmann, "De navngivne svaerd i saga, saga og folkevise," in Filogisk-Historiske Samfund, Copenhagen, 1967.

[18] Theophilus, De Diversis Artibus, C. R. Dodwell, Ed., London: Thomas Nelson & Sons, 1941.

[19] J. P. Porta, Magiae Naturalis, 1584.

[20] J. Anstee, "A study in Pattern Welding," Medieval Archaeology, vol. 5, pp. 71-93, 1961.

[21] C. S. Smith, Sources for the History of the Science of Steel 1532-1786, Boston, MA: MIT Press, 1986.

[22] H.-U. Haedeke, Metalwork, Universe Books, 1970, p. 227.

[23] C. S. Smith, A History of Metallography: The development of Ideas of the Structure of Metals before 1890, Cambridge, MA: MIT Press, 1988.

[24] V. Biringuccio, Pirotechnia, Toronto, Canada: General Publishing Company, 1990.

[25] G. Agricola, De Re Metallica, New York, New York: Courier Cover Publications, 1950.

[26] Von Stahel und Eysen, 2002.

[27] R. F. Tylecote, Scientific Examination and Analysis of Iron Objects, Oxford: Oxford University Press, 1990, pp. 140-154.

[28] R. Maddin, "The Early Blacksmith," in Symposium of the UISPP Comite' pour la Sidrurgie Ancienne, Belfast, 1987.

[29] D. S. MacKenzie and G. Graham, "Beer, Blood, and Urine - Mythological Quenchants of Ancient Blacksmiths.," in IFHTSE 2016: Proceedings of the 23rd IFHTSE Congress (April 18-21), Savannah, GA, 2016.

[30] E. Blakelock, PhD Dissertation: The Early Medieval Cutting Edge of Technology: An Archaeomettallurgical, technological and social study of the manufacture and use of Anglo-Saxon and Viking iron knives, and their contribution to the early medieval economy, Bradford, West Yorkshire: University of Bradford, 2012.

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PREVENTING OXIDATION
IN THE MANUFACTURING
OF COPPER-TITANIUM ALLOYS

New furnace innovation allows efficient production of high-purity melts by using vacuum-induction technology on an industrial scale.

By NICKI TEUMER

Due to their resistant and highly conductive properties, copper-titanium alloys become increasingly important in the field of industrially manufactured electrical components such as connectors, power switches, jacks, or camera modules.

This trend is even more accelerated by the fact that titanium — as an alloying element — provides an excellent alternative to beryllium with its harmful characteristics. However, the production of copper-titanium alloys is quite demanding and, in the case of open furnaces, hardly feasible, since titanium reacts strongly with almost all atmospheric gases, resulting in significant quality and yield losses.

ALD Vacuum Technologies GmbH recently has succeeded in developing a compact furnace concept that allows for cost-efficient production of such high-purity titanium-copper alloys without any risks of formation of inclusions by air contact, excessive heat loss, or non-feasible cycle times. To achieve this, vacuum treatment is applied. By preventing oxidation and with the help of special stirring as well as degassing techniques, the melt is kept as pure as possible. By sampling, alloy addition for adjustment of the melt chemistry and temperature measurement are possible without interrupting the process. If continuous casting is used, the melt transfer can also be carried out under controlled conditions. The proven concept is already operating successfully in two plants in Asia.

Wherever alloys with high conductivity and robust material properties are required, copper-titanium combinations become increasingly popular and represent a promising addition to the product portfolio of the copper-processing industry. Major applications include conductive springs, connectors in automotive as well as electronics, and camera modules in electronic devices such as smartphones and PCs. Furthermore, copper-titanium alloys are replacing the conventional copper-beryllium alloy series due to an increasing demand to replace beryllium with its highly harmful properties.

While nowadays there are various process approaches for the production of copper-titanium alloys, thus far little attention has been paid to vacuum induction melting.

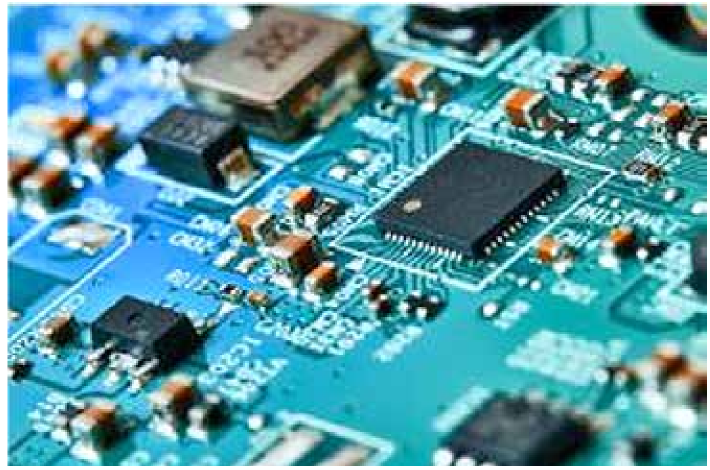
"Most conventional induction furnaces are quite large and not very practical for the batch sizes that are common in copper-titanium alloy manufacturing," said Andreas Eich, product manager melting at ALD Vacuum Technologies GmbH. "Additionally, conventional induction melting usually takes place under atmospheric conditions. Thus, the air's oxygen and nitrogen will react with the titanium and form harmful non-metallic inclusions."

Consequences of contact with air will be a reduced melt cleanliness and deteriorated material properties as well as higher production cost due to a reduced titanium yield. Therefore, the furnace has to be adapted extensively. Among other things, especially an inert gas atmosphere needs to be created and maintained. Here the use of induction melting under vacuum (VIM) provides a very promising alternative processing route.

The production of copper-titanium alloys is quite demanding. ALD Vacuum Technologies recently has succeeded in developing a compact furnace concept that allows for cost-efficient production of such high-purity titanium-copper alloys without any risks of formation of inclusions by air contact, excessive heat loss or non-feasible cycle times. (Courtesy: ALD Vacuum Technologies GmbH)

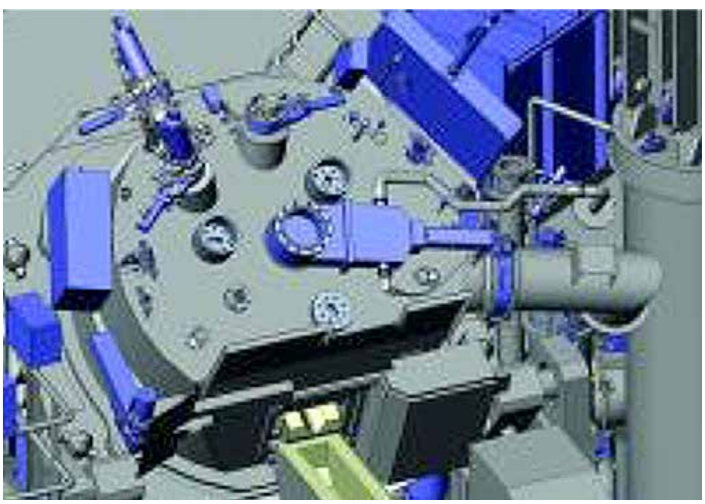
Wherever alloys with high conductivity and robust material properties are required, copper-titanium combinations are increasingly used as a promising addition to the product portfolio of the copper processing industry. (Courtesy: ALD Vacuum Technologies GmbH)

However, the (possible) need of transporting the copper-titanium melt to a continuous casting machine, where it is again exposed to ambient air, poses a technical challenge. Experts at ALD Vacuum Technologies have succeeded in using vacuum induction melting for the production of titanium-copper alloys on an industrial scale without these limitations. For this purpose, the company's so-called VID (vacuum-induction degassing) or VIDP (vacuum-induction degassing and pouring) concept was applied to a compact plant design, whereby,

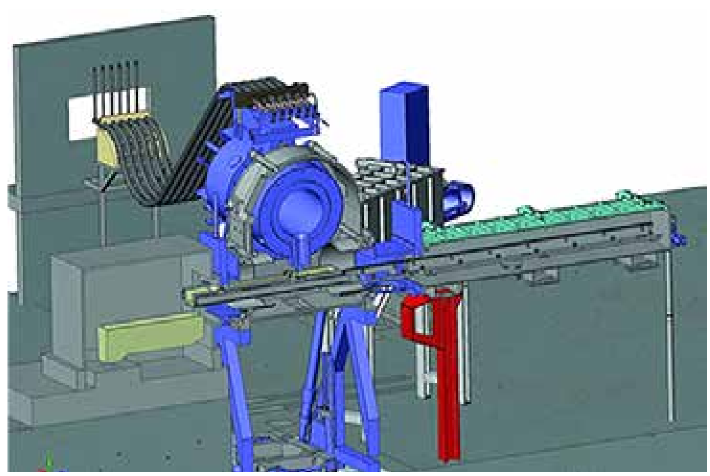


Major applications include conductive springs, connectors in automotive and electronics, and camera modules in electronic devices such as smartphones and PCs. (Courtesy:Shutterstock)

The vacuum-tight process environment of this concept allows for highly reproducible results and a predictable yield as interference on the material purity can be reduced to a minimum.



Furnace with a capacity of eight metric tons is installed in the reference plant. However, depending on the target quantity, variants of up to 30 metric tons can be implemented for vacuum melting. (Courtesy: ALD Vacuum Technologies GmbH)



In addition to the actual induction furnace, the mandatory launder chamber of ALD as well as the tundish chamber and the caster equipment used by the plant operator are integrated in a common vacuum tight housing. Sampling and temperature measurement are possible without interrupting the process. (Courtesy: ALD Vacuum Technologies GmbH)

depending on chosen equipment configuration, melting and casting of slabs can take place completely under controlled atmosphere. The proven design is currently in operation at two different plants in Asia and can be easily adapted to existing melting infrastructure at other production sites in the future.

VACUUM-TIGHT PROCESS ALLOWS FOR HIGHLY REPRODUCIBLE RESULTS

In general, the copper-titanium melt is manufactured under a controlled atmosphere in a vacuum-induction furnace. It is then cast in a semi-continuous vertical casting machine to produce high-purity slabs as starting material for further processing through subsequent steps such as hot forming, annealing, and cold forming. The vacuum-tight process environment of this concept allows for highly reproducible results and a predictable yield as interference on the material purity can be reduced to a minimum.

"The use of continuous casting is not standard in vacuum melting, because the combination is usually not possible within a vacuum," Eich said. "With our special solution, however, the melting process can be coupled to the downstream continuous casting in a process-safe manner."

In addition to the induction furnace itself, the mandatory launder chamber of ALD as well as the tundish chamber and the caster equipment used by the plant operator also are installed in the vacuum-tight housing and work under an inert gas atmosphere. However, this only applies to VIDP. In a derivative furnace concept called VID, melt transfer to the continuous caster is carried out via open-transfer launder in a normal ambient atmosphere with inert-gas shrouding. This setup can produce batch sizes of up to 30 metric tons, making the production of copper-titanium alloys via

In order to prevent formation of harmful non-metallic inclusions, the use of induction melting under vacuum (VIM) is a promising alternative. The VIDP concept can be adapted to on site existing melting infrastructure to fit into the process chain in the best possible way. (Courtesy: ALD Vacuum Technologies GmbH)

vacuum induction melting even more competitive.

To ensure highest melt purity standards and to secure a desired microstructure quality, these types of vacuum furnaces use additional process and monitoring features. First, the melt is kept very homogeneous by ALD's 3-phase electromagnetic stirring before it is passed on to the continuous caster. This ensures improved process kinetics for degassing and removal of non-metallic inclusions. Furthermore, grade specific quality requirements are achievable within reasonable process cycle times. Additionally, sampling as well as temperature measurement can be performed without interrupting the vacuum. "This helps calculating what needs to be re-alloyed and allows working within very tight analysis limits," said Henrik Franz, vice president Research & Development at ALD Vacuum Technologies GmbH. "Alloy addition can be carried out in a very controlled and reproducible manner, as erratic burn-off under air contact is avoided in this furnace concept."

CONCEPT ADAPTABLE TO THE EXISTING MELTING INFRASTRUCTURE

In order to offer vacuum-induction melting as a flexible solution, the company has deliberately developed two variants with regard to the connection of a continuous casting. Thus, customers can decide based on their requirements regarding purity and existing infrastructure, whether melt transfer to the caster equipment should also take place in a common vacuum tight housing completely under controlled atmosphere or transfer under inert gas shrouding is sufficient.

Two material manufacturers from Asia have each opted for one variant, with both recently set into operation. One plant in China is built according to the VID concept. This furnace is equipped with an eight-ton crucible and a melt-power supply of 2,500 kW. More than five metric tons per hour can be melted and fed to the caster under ambient atmosphere with inert gas protection.

The second plant allows casting under a controlled atmosphere in addition to melting according to the VIDP concept. Both concepts were customized and adapted to fit into already existing process route concepts. In close collaboration with customers and suppliers of continuous casters, slab dimensions, for example, were matched to the customer-specific further processing. ALD's design ensured the connection between furnace and continuous caster was accurate and safe. Initial results already show VID or VIDP can reduce quality mitigating inclusions and help to reduce process costs through better tolerance management and improved yield.

"The proven combination of vacuum-based melting with simultaneous sampling and an economically viable continuous casting system provides excellent product quality at suitable dimensions adapted to further processing," said Stefan Lemke, vice president melting and remelting at ALD Vacuum Technologies GmbH.

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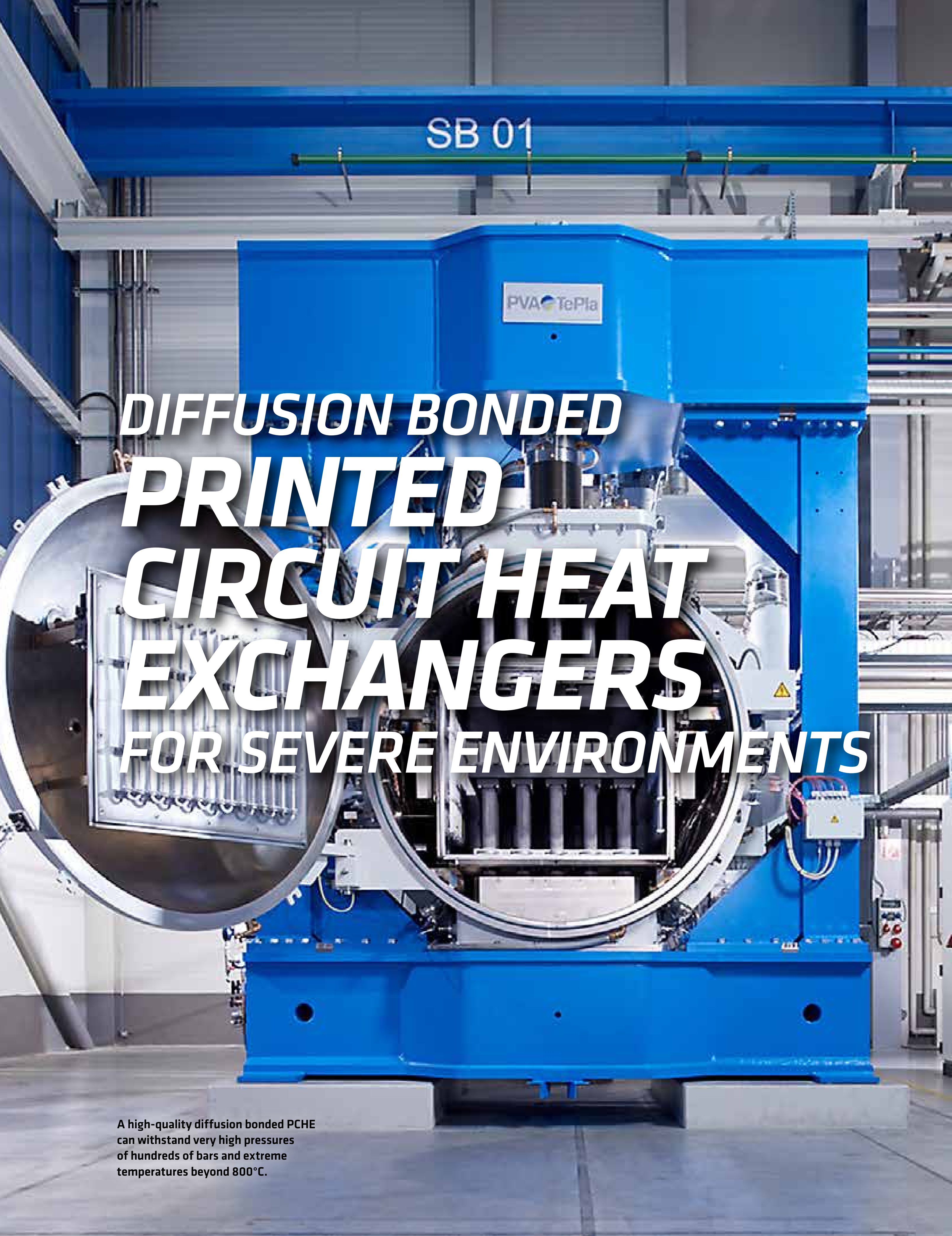


DIFFUSION BONDED **PRINTED CIRCUIT HEAT EXCHANGERS** *FOR SEVERE ENVIRONMENTS*

A high-quality diffusion bonded PCHE can withstand very high pressures of hundreds of bars and extreme temperatures beyond 800°C.

Compact printed circuit heat exchangers (PCHE) produced through a diffusion bonding process surpass traditional alternatives in extreme temperature and pressure environments.

By DEL WILLIAMS

Traditional plate or shell and tube heat exchangers have long been used in processing industries. Today, however, with many new applications involving high pressures, temperatures, and exposure to corrosive environments, more manufacturers are turning to compact printed circuit heat exchangers (PCHEs).

A PCHE is a multi-layer heat exchanger consisting of thin, flat metal plates into which fluid flow microchannels are chemically etched in each layer to form a complex flow pattern. The layers are then diffusion-bonded together to create a dense heat exchanger with superior airflow and heat-transfer properties.

When designed this way, a heat exchanger can be up to 85 percent smaller and lighter than traditional plate or shell and tube designs. In addition, PCHEs do not require excessive pipework, frames, or other associated structural elements, further reducing costs.

"A high-quality diffusion bonded PCHE can withstand very high pressures of hundreds of bars and extreme temperatures beyond 800°C," said Dr. Udo Broich, managing director of PVA Industrial Vacuum Systems GmbH in Wettenberg, Germany. "As a result, PCHEs are well suited for a wide range of demanding applications, including oil and gas, hydrogen vehicle fueling stations, and aerospace."

Dr. Broich, who wrote his doctorate thesis on joining technology, has focused on vacuum brazing and diffusion bonding for 25 years. PVA TePla AG is a global manufacturer of industrial furnaces and PulsPlasma nitriding systems.

DIFFUSION BONDING VS. BRAZING

For many years, diffusion bonding has been used to join high strength and refractory metals that are either difficult or impossible by other means. The process involves applying high temperature and pressure to the bonding part in a high-vacuum hot press like those offered by PVA TePla; this causes the atoms on solid metallic surfaces to intersperse and join. The final piece will have little or no interface lines or striations if the materials are similar; the interface of one material blends into the other, and vice versa. The same result can also be achieved with dissimilar materials with the right equipment, material preparation, and process.

The key to the process is using diffusion bonding to join the layers over other alternatives, such as vacuum brazing. Although brazing is widely used for joining metals under normal conditions, it can be insufficient in high temperature, pressure, or corrosion situations. Brazing is a joining process in which two or more metal items are joined together by melting and flowing a filler metal into the joint. The filler metal flows into the gap between the layers through capillary action.

With a proper choice of filler material and process parameters, brazing can also create high strengths and thermal-resistant joints. However, as the filler metal always has a different chemical composition from the bonding part materials, the properties of brazed components usually cannot reach that of a solid part, according to Dr. Broich.

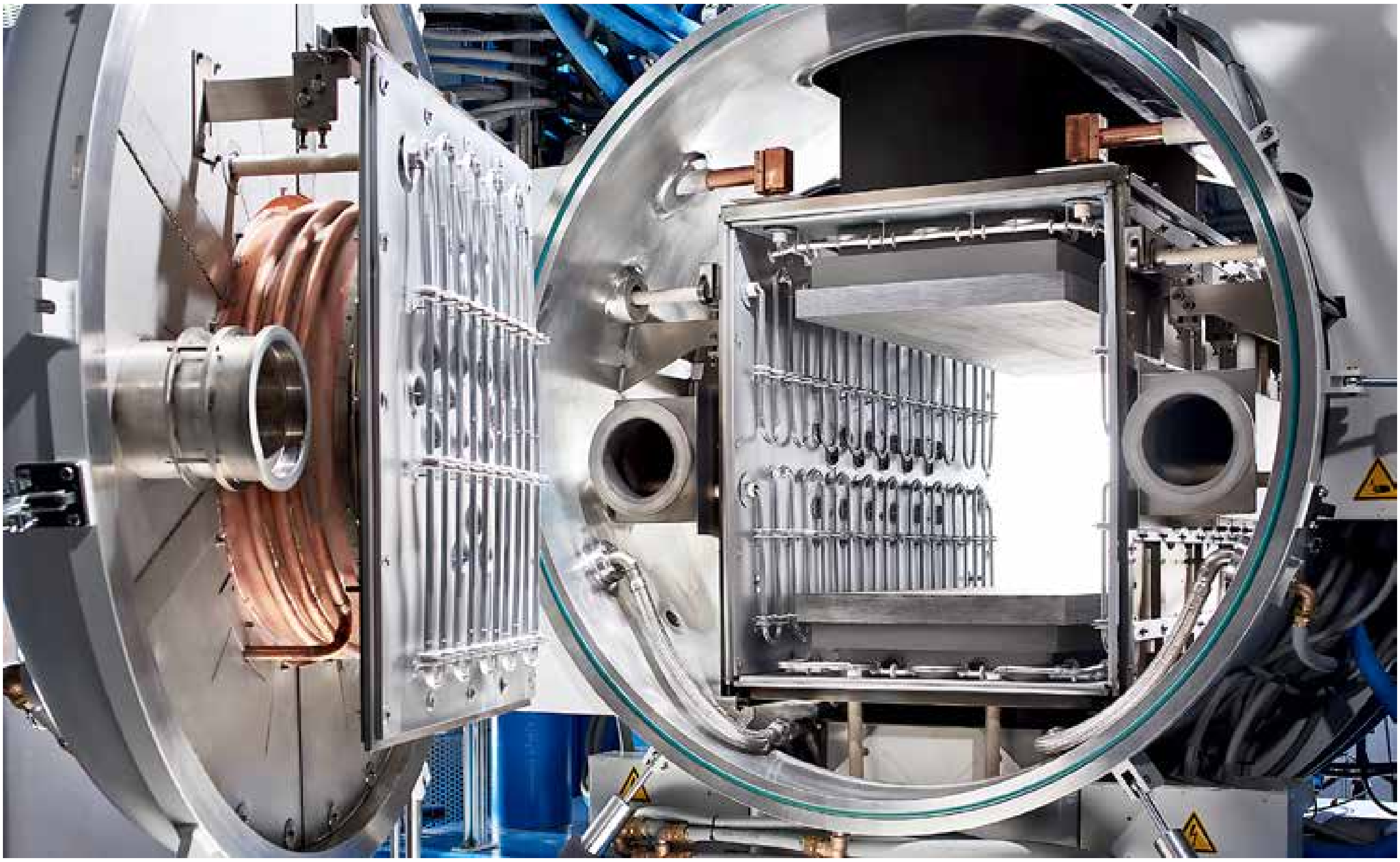
"In the case of brazing a PCHE, engineers must consider another issue: During brazing, molten filler metal can penetrate the microchannels and solidify, blocking the channels required for airflow. This can render the PCHE quite ineffective," he said. "Since diffusion bonding requires no filler metal and is a solid-state joining process, the microchannels remain intact."

The compact, efficient heat-transfer capabilities of PCHEs are ideal for many oil and gas applications.

"When the layers of a PCHE are diffusion bonded, the final product retains the parent material's mechanical, chemical, and thermal properties," Dr. Broich said. "Given the high strength and integrity of the material, PCHEs can withstand very severe operational conditions."

A significant advantage of diffusion bonded PCHEs is that it significantly reduces the size of the heat exchanger.

"PCHEs have about 85 percent less mass and volume of traditional heat exchangers, while the microchannels provide a large surface area for heat exchange," Dr. Broich said. "Achieving the same heat-transfer rate with a standard (plate or shell-and-tube)



The diffusion bonding process involves applying high temperature and pressure to the bonding part in a high-vacuum hot press like those offered by PVA TePla.

heat exchanger design requires much more mass and volume."

GROWING MARKETS FOR DIFFUSION BONDED PCHES

Due to the inherent advantages of diffusion bonded PCHEs, many industries are adopting this evolving technology to improve heat transfer in various applications.

Oil and Gas

The compact, efficient heat transfer capabilities of PCHEs are ideal for many oil-and-gas applications, including preheaters, superheaters, gas-compression coolers, high-temperature recuperators, and liquified natural gas (LNG) exchangers.

For example, in offshore LNG production, natural gas is converted to a liquid for safe transport or storage when pipelines are not available. LNG takes up only a fraction of the space in its liquid form, but the natural gas must be cooled to approximately minus-260°F as part of the process, generating heat. A PCHE is a practical, compact solution for small footprint areas like onboard ships.

Hydrogen Fueling Stations

PCHEs are a requirement in hydrogen vehicle fueling stations. Stored hydrogen must be pre-cooled to approximately minus-40°C before being transferred into the vehicle's tank. This cooling process prevents potential damage from the excessive temperature that can damage tanks during filling.

"To fill a tank, pressurized hydrogen is dispensed at roughly 1,000 bars; this process generates excessive heat," Dr. Broich said. "Because it is critical that the temperature not exceed the critical limits of the tank, hydrogen is pre-cooled to about minus-40°C. The PCHE in the fueling station's cooling loop must withstand 1,000 or more bars of pressure and temperatures as low as minus-50°C. The compact design of PCHEs also eases integration with the hydrogen dispenser casing."

Advances in high vacuum furnace hot presses allow superior pressure control and rapid cooling systems that improve bonding, increase yields, and significantly decrease cycle time.

Aluminum Heat Sink Applications: Electric Vehicle and Aerospace

Aluminum heat sinks are popular for the thermal management of many critical devices where weight is a factor, including automotive and aerospace. Aluminum heat sinks are also commonly used with electric batteries.

The most common aluminum alloys used in heat sinks and exchangers are the 6000 series alloys. However, magnesium and silicon are the primary alloying elements and are difficult to join with methods such as brazing.

"In many heat-sink applications, brazing flux is often prohibited," Dr. Broich said. "Therefore, vacuum brazing remains a joining technology using filler metals based on an aluminum-silicon eutectic alloy. However, these alloys have a melting point of 580°C, very close to the melting point of the base material, thus providing only a tiny process window to achieve high-quality bonds."

PCHEs are a requirement in hydrogen vehicle fueling stations.

He noted that PVA TePla has developed a diffusion bonding process to successfully join high alloyed aluminum materials like 6061 over the years.

OPTIMIZING FURNACE DESIGN FOR DIFFUSION BONDING

There are various approaches to furnace design and process implementation for diffusion bonding of PCHEs. Advances in high vacuum furnace hot presses allow superior pressure control and rapid cooling systems that improve bonding, increase yields, and significantly decrease cycle time.

Manufacturers such as PVA TePla offer multi-cylinder systems with large pressing plates that accommodate various parts. The largest, the company's MOV 843 HP, can process substrates as large as 950mm (37.4") x 1,300mm (51.18"), which is quite a large area for diffusion bonding. The pressing force is 8,000 kN. Research is underway to increase this geometrical limitation as well.

The integrated press provides remarkably consistent pressure across the entire surface by controlling and synchronizing each cylinder. The MOV also comes with built-in pressure transducers along the bottom of the pressing plate. The individual hydraulic cylinders can be adjusted in the software to achieve uniformity even over large areas based on sensor feedback.

Dr. Broich pointed out that high-bonding strength is critical for applications involving PCHEs in extreme settings.

"It requires a high-strength design (when a high-vacuum hot press is needed) of the pressing unit (pressing rams and platens) to transfer 800 or 1,000 tons at 1,000°C or even higher temperatures," he said.

In addition, the pressing unit should have a design that minimizes the mass within the hot zone while achieving uniform force distribution throughout the working space and pressing platen, according to Dr. Broich.

"The design of a diffusion bonding machine should enable the shortest cycle times possible while saving energy by reducing its thermal mass; this is very important to productivity and cost-effectiveness," he said.

To produce a high-quality diffusion bonded PCHE, working with an expert partner like PVA TePla can be essential for manufacturers that require process and technology support.

"Most of our customers are not familiar with this technology," Dr. Broich said. "We support them with basic process technical knowledge so they can correctly use the machine to produce a high-quality diffusion bonded PCHE."

Due to the rapidly expanding need for this precision technology in the U.S., PVA TePla is opening a diffusion bonding technology center in Corona, California. This summer, a full-scale industrial furnace that matches the capabilities offered in Germany is expected to be available. PVA TePla will be able to demonstrate the machine's bonding capabilities, run R&D samples, and provide processing services.

"In both the U.S. and Germany, we can demonstrate the quality of the bonds before a customer decides to invest in a machine," Dr. Broich said. "We handle most of the elements of process development to prove the technology and assist in scaling up to production volumes. Alternatively, we can provide full-scale contract processing for customers if they outsource production."

ABOUT THE AUTHOR

Del Williams is a technical writer based in Torrance, California. He writes about health, business, technology, and educational issues, and has an M.A. in English from C.S.U. Dominguez Hills. For more information, go to www.pvateplaamerica.com.

COMPANY PROFILE ///

AMBRELL CORPORATION

SOLVING PROCESS HEATING PROBLEMS

Induction brazing.
(Courtesy: Ambrell)

Ambrell Corporation, an inTEST Company, is a global leader in the induction heating market, offering custom induction-heating solutions to a wide range of industries.

By KENNETH CARTER, Thermal Processing editor

Induction heating can be used for a vast array of applications, but what may be surprising is that list continues to constantly grow. If you think your job can't use induction heating, then you might want to think again —by asking the experts at Ambrell Corporation.

"The success of this business has been our knowledge and our capability of helping our customers find the best solutions for the projects they have, and I can tell you, I'll attend two or three trade shows every year just to make sure I stay in touch with the customer base out there, and how many times we have customers that tell us, 'Oh, you can't heat this with induction,'" said Scott Nolen, president of inTEST's Process Technologies Division and head of Ambrell. "Next thing you know, we're selling them equipment because we've shown them, not only can we heat it with induction, but we can heat it so much better than the way they are doing it today; it's really just a game changer for a lot of people."

Ambrell, which was founded in 1986 but later purchased by inTEST Corporation in 2017, focuses on providing the best and highest technology in an induction heating system, according to Nolen.

"We work with a number of partners that will then purchase our equipment and then build their system around our induction heating equipment to meet their specific heat-treating application needs," he said.

Dr. Girish Dahake, SVP, Global Applications, inside THE LAB at Ambrell. (Courtesy: Ambrell)

PARTNERS IN HEAT TREATING

In the field of heat treating, Nolen said Ambrell doesn't sell equipment directly to customers, but, instead, it sells to the company's partners who then sell Ambrell's technology to end users in the heat-treat market.

"These partners can both be integrators in the United States, various companies that put together heating systems in the United States, or they can be our distributors overseas," he said. "We have a number of partners overseas that specialize in heat-treatment systems, and they build their value-add distributors and not just straight pass-through distributors. They build the systems that go around the heat-treatment requirements for customers and many other types of applications, too. It doesn't have to just be heat treatment."

Ambrell has been able to offer its technology across a wide array of industries, according to Nolen.

"The great thing about Ambrell is we don't supply to any one particular industry exclusively; we have numerous industries that we sell to, which really creates a business that can ride through some of the lulls in different industries," he said. "For example, if we just supplied exclusively to the aerospace industry today, we probably wouldn't be that busy, but we supply to healthcare and semi and automotive and EV (a big segment of automotive today) and oil and gas. We have many, many different applications out there; many, many different industries we participate in. Before I took this role leading Ambrell three years ago, I spent 29 years in the energy industry. It's very refreshing being in a business that isn't relying on the price of oil. We do sell quite a bit of equipment to oil and gas, but we have many other options when the price of oil goes very low. There are really very few industries that we do not sell to in the induction heating space."

FINDING THE BEST SOLUTIONS

That ability to be diverse has certainly been a driving force to making Ambrell the best induction heating solutions provider in the industry, according to Nolen.

"That comes not just from the core equipment that we manufacture — the power units, the work heads, the coil design, and manufacturer — but also in our knowledge of different applications," he said.

Preheating prior to forging. (Courtesy: Ambrell)

"Because we supply to so many different industries, there are just so many different types of applications that go in these industries and the components that need either heating directly or indirectly through use of susceptor or some other means. We specialize in meeting those solutions, and we have a very talented group of engineers based in Europe, in Mexico, and then we have partners that we've educated over the years, long-term partners in Asia that have that solution capability, and even in India. We're also developing some in Africa right now, too. We basically have them on every continent."

EMBRACING ADVANCES

And the technology that drives that company growth has, itself, grown over the decades, according to Nolen, which, in turn, has caused products to become more efficient in both power and size.

"The real technology has been in the improvement and the technology of the heating systems," he said. "The heating systems have moved from 30 to 40 years ago when they were tube based. They were very bulky, large, heavy components, and now they're solid state. We actually have one of our original units that we ever supplied that's 7 kW and about two thirds the size of a refrigerator, and now we can replace that with a unit that's the size of a Dell computer. The size has dramatically reduced. We just launched a new product this year that takes our unit that goes up to 125 kW, which was the size of a full refrigerator, and basically shrinks that down to 40 percent of that."

Those unit advancements in size and footprint and capability are extremely critical to Ambrell's partners who may need to bundle the company's units inside a bigger system, according to Nolen.

"We require less of a footprint when they build their system around it, and that makes it much more compact and, in many ways, cost effective both from a manufacturing and transportation standpoint," he said.

Nolen clarified that, although Ambrell's heat-treating experience deals mainly with its partners, the company does sell direct to customers every day.

"For heat treating, we mostly do that through partners because of

Ambrell EKOHEAT 45 kW induction heating system. (Courtesy: Ambrell) the complexity of heat treatment; every heat-treatment application is relatively complicated; there are a lot of other components that go with it — the water-quench system, the measuring system, the handling system, all of that is done by our partners,” he said. “One of my personal mandates to the business is we will not compete against our customers, and many of our customers are those integrators that put together these overall systems, and we do not want to go and compete directly with them. We want to sell what we do best to them and let them do that part.”

EXPERT DEVELOPMENT

Ambrell is capable of getting the best equipment to its partners by incorporating the company’s experts, according to Nolen.

“That’s the beauty of our labs,” he said. “We have these labs that are based here in Rochester, Europe, Mexico, and Asia, where our clients can bring components. We can show how we can heat it with our lab with our equipment. We can put together a coil that will match the heating needs of their component, and we can actually prove it out in THE LAB, both with the customer in the house, or they can do it virtually.”

That virtual component became a necessity during the COVID pandemic, according to Nolen.

“During the pandemic, that was very important because people couldn’t travel,” he said. “They would send us their components. We’d get on a Teams call with them and show them how we heat it in the lab. Really, it’s twofold: One, it shows them how the equipment will work, and, two, it also uses the knowledge that we have of being able to design heating systems for different applications. They get to take advantage of that knowledge when they partner with us, because we’ve seen a lot of these applications before with different customers and with different users, and we can bring that information to them.”

Ambrell EASYHEAT 2.4 kW induction heating system. (Courtesy: Ambrell)

“One of my personal mandates to the business is we will not compete against our customers, and many of our customers are those integrators that put together these overall systems.”

GREEN ADVANTAGE

One of the bonuses of using induction heating is its environmental fringe benefits, according to Nolen. By bringing clients into its facility, Ambrell can show them how induction heating can increase production speed, production accuracy, and — in almost all cases — that production doesn’t produce carbon dioxide nor a lot of waste heat.

“Especially now, one of the biggest initiatives I’ve launched in the last 14 to 18 months is making sure people understand — and it always has been, but we really haven’t stressed it before — induction systems are as green as your grid,” he said. “If you’re on a grid like we are here in western New York state, where 90 percent of our power is not producing CO_2, our induction heating systems that are running in this area are very, very low CO_2 producing. Whereas if you had big gas ovens, you just don’t get that type of benefit for the CO2 greenhouse gas reduction. And even better, our systems can have anywhere from 75 percent to 90 percent overall efficiency going into the heating of that part, because we’re not heating anything else. Whereas with gas ovens, you’re only going to be a really amazingly good gas oven at 30 percent to 35 percent efficiency. It’s just a really great story to be able to tell people as an energy guy that came out of the oil and gas sector, that I really have a nice green story to talk about now.”

MYRIAD OF SUCCESSES AND SOLUTIONS

And in a world where companies are pushing to reduce their carbon footprint, Ambrell’s ability to help solve those challenges only serves as a bonus to the company’s overall portfolio, according to Nolen.

“Our successes are just from everything from the small mom-and-pop shop that just needs to heat and do a brazing on a component where they’re doing 2,000 or 3,000 parts a month to a semiconductor company that’s doing epitaxy on wafer or growing silicon carbide crystals, and we’ve shown how we can do that successfully with their technology,” he said.

And as Ambrell moves into the future, Nolen said he expects the company to continue to expand its solutions, as well as its knowledge base.

“We’ll continue to shrink our products; we’ll continue to keep them as small and as cutting edge as possible so people can build efficient systems around them,” he said. “I see us going into different frequencies — lower frequencies, higher frequencies — depending on what the needs are. But even probably more importantly, we will continue to build out our partner network of people that need induction heating systems and are looking for a good partner while they design, while they do the work of how they handle it, how they quench it, how they test it, and all the other pieces that go along with the hardening process. Then, they can just leave the overall heating knowledge to us because that’s what we do best.”

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JOHN LUDEMAN /// DIRECTOR /// ADVANCED HEAT TREAT CORP.

"We're always looking for ways to gain a competitive advantage, and a lot of research and development went into adding these services."

Advanced Heat Treat Corp. (AHT) recently renewed its Nadcap accreditation in heat treating. What makes the Nadcap accreditation important to what AHT does?

Nadcap is basically another level of accreditation that enhances our ability to serve our customers. It gives us more options. It opens up a customer base that's out there that has to have Nadcap as an accreditation to generate a purchase order for us. It's also an indicator to our customers that quality is a big part of AHT. We value Nadcap, and it's not easy to achieve. We did achieve another 24 merit, which is a great indicator that Advanced Heat Treat lives these requirements every day. It's something we follow, and we love to do it, and it's a great way to serve our customers.

What steps were involved in renewing that Nadcap accreditation?

We live to work to the stringent Nadcap requirements every day. Nadcap is not something that you turn off and on. It's in our everyday standard operating procedures. To get to that point every year, every 18 months, or every two years – depending on your Nadcap merit status – you have an auditor come in and do an evaluation. (We've held Nadcap accreditation since 2013 and have earned merit status, so for us, it's every two years.) Prior to that assessment, you submit a list of documents — a self-assessment — and have to provide them a long list of documents and procedures.

During this assessment, we actually added some new processes and some new specifications. We had to do the background work of those and make sure that, when the auditor came in, there were some job audits to assess. There's a long standard operating procedure for AHT or other companies that we provide before they come in. When they're on site, they have another set of requirements that we have to go through to get qualified and to get those things passed. A Nadcap assessment or a Nadcap audit is really about the specifications and what the customer needs.

You've also added a few additional AMS specifications to your company's tool chest. What are they, and why were they needed?

AMS 2759/6 and AMS 2759/12 for gas nitriding and ferritic nitrocarburizing, respectively. Those were added, but they're really enhancing what we already had. We feel like we're a leader in ion and gas nitriding, and those two specifications complete those AMS 2759/ specifications for ion nitriding, gas nitriding, and ferritic nitrocarburizing. It, basically, allows us to better serve our customers and also find new customers needing these processes.

What types of services do these newly renewed and added specifications allow you to offer your customers?

It gives them more flexibility. A lot of the engineering requirements off of engineering prints for customers or within the customer specifications call out a certain processing type. They may call out AMS 2759/10 or /6, and you have to comply to those, or you can't do the work. It allows us to be more flexible, especially within the nitriding specifications to do either the /10 or the /6. We just thought it was a better way to serve our customers, and it gives customers a flexibility of coming to us no matter which requirements they need.

Were you doing ion and gas nitriding before these specifications?

Before we added the /6 and the /12, we were accredited to ion nitriding, which is the /8, 2729 and then the /10.

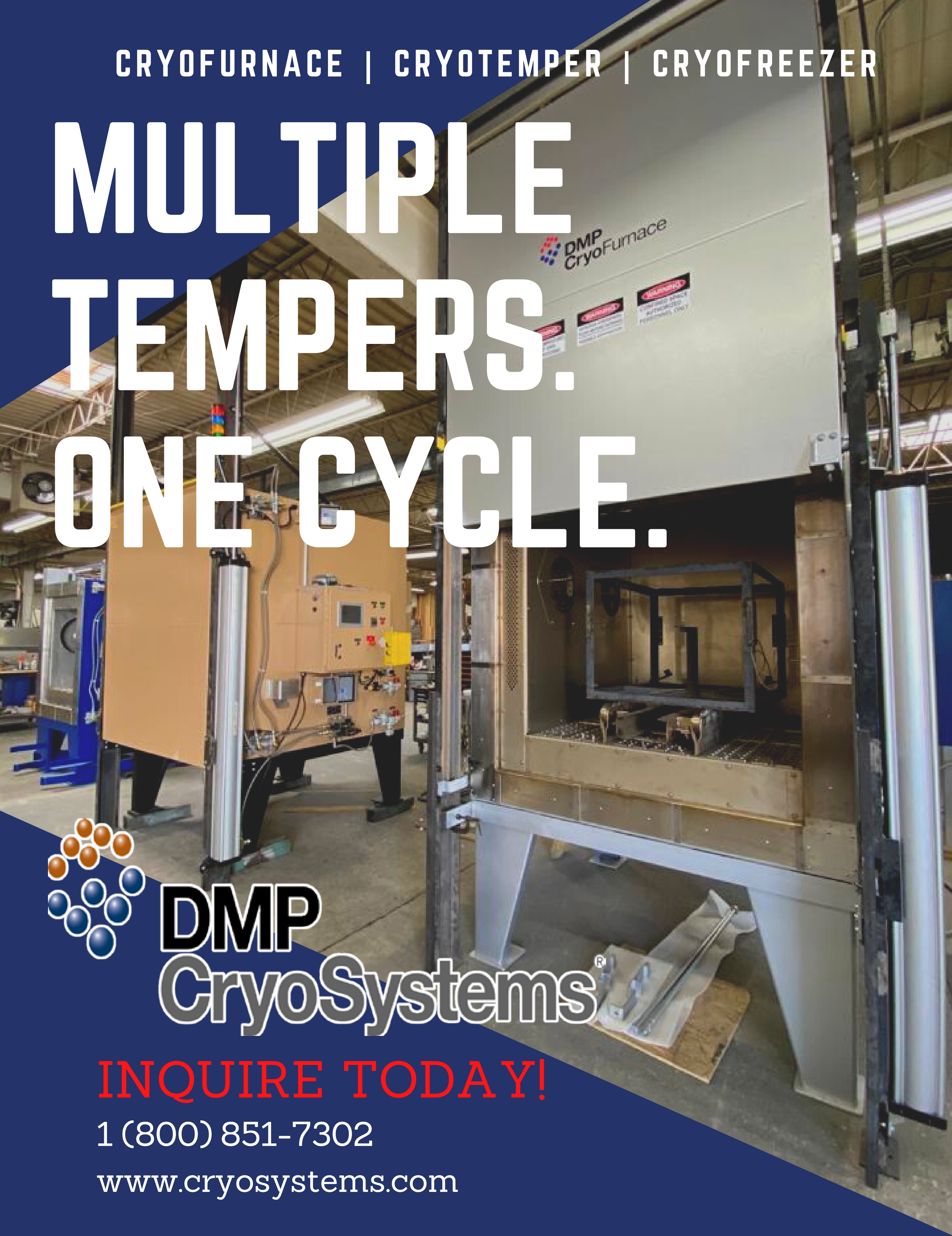
Will these specifications help to give you an edge over your competitors?

I believe it will. It allows existing customers with those requirements to come to AHT and not have to go elsewhere. They might be able to bundle shipping or those kinds of processes, those kinds of logistics. It gives them the ability to have fewer vendors in their approved vendor list. Or, if you've developed a good relationship with a customer, now this gives us the ability to do more for that customer.

Is there anything else about these accreditations you'd like to mention?

We're always looking for ways to gain a competitive advantage, and a lot of research and development went into adding these services. We listened to our customers. That's another reason why we added these: because customers were asking, "Can you do this specification? Can you do that specification?" So, adding these gives us a way to serve those people. The added specifications fit nicely within our current approved processes and expertise. We feel we're the leader in the industry for ion and gas nitriding, along with ferritic gas nitriding, and also ferritic nitrocarburizing with oxide. We're also in the process of reviewing induction heat treat as part of the Nadcap process; we're going through the discovery phase of that.

MORE INFO www.ahtcorp.com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