Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

FORGING / MAINTENANCE

CHOOSING BETWEEN HFC AND HFDu HYDRAULIC FLUIDS

COMPANY PROFILE ///

Horizon Performance Technologies LLC

AUGUST 2022
thermalprocessing.com

aichelin group

AFC HOLCROFT

industrial furnace solutions

Batch Integral Quench Furnaces and Endothermic Gas Generators "Built for Stock"

Leading the Industry with the Fastest Delivery Available

AFC-Holcroft Headquarters
Wixom, Michigan, USA
Phone: +1 248 624 8191

AFC-Holcroft Europe
Swiebodzin, Poland
Phone: +48 68 41 61 776

AFC-Holcroft Asia
Shanghai, P. R. China
Phone +86 21 5899 9100

www.afc-holcroft.com

Supply chain interruptions don't have to derail your valuable heat treating production. When you need a new batch integral quench furnace or endothermic gas generator, AFC-Holcroft's Built for Stock equipment will shave months off typical delivery timeframes.

We're always building our industry-leading UBQ (Universal Batch Quench) furnaces and EZ™ Series Endo Gas Generators for off-the-shelf delivery, ready for expedited shipment. The same standard equipment AFC-Holcroft is known for, but pre-built to speed up typical delivery by months. There is no compromise in quality to get this fast delivery.

Built for Stock equipment gets you in production faster.

Talk to our Sales staff to find out more.

GASBARRE
THERMAL PROCESSING SYSTEMS

RELIABILITY, EXPERTISE, SERVICE AND SELECTION

VERSATILE ***INTEGRAL QUENCH FURNACES***

- **Batch processing**
- **Compatible with existing equipment lines**
- **Highly efficient**
- **Precise control**
- **Meets AMS 2750 and CQI-9 Requirements**

Gasbarre takes a ***360° approach*** to ***servicing our customers***. From sales and applications engineering, to equipment design, manufacturing, commissioning, and never ending aftermarket support our team of engineers, metallurgists, and technicians ***understand your process*** from all angles. Gasbarre's technical capability and commitment to service will ***ensure your success*** today and into the future!

COMPLETE LINE OF THERMAL PROCESSING EQUIPMENT

Annealing ▪ Brazing ▪ Carbonitriding ▪ Carburizing ▪ Co-firing ▪ Drying ▪ Enameling
Ferritic Nitrocarburizing ▪ Glass-to-Metal Sealing ▪ Hardening ▪ Inert Atmosphere Processing
Nitriding ▪ Normalizing ▪ Quenching ▪ Sintering ▪ Soldering ▪ Spheroidize Annealing
Steam Treating ▪ Stress Relieving ▪ Tempering ▪ Vacuum Processes

734.656.2000
GasbarreIFS@gasbarre.com
www.gasbarre.com

GASBARRE
THERMAL PROCESSING SYSTEMS

CONTENTS ///

COVER PHOTO: SHUTTERSTOCK

MENTOR®
VACUUM HEAT TREATING FURNACE

HORIZONTAL CAR BOTTOM

VERTICAL BOTTOM LOADING

MENTOR® & MENTOR® PRO

INTERNAL QUENCH

EXTERNAL QUENCH

MENTOR®

MENTOR®

The Mentor®, model HFL-2018-2IQ, is a horizontal, front loading, compact, vacuum heat treating and brazing furnace generally designed and developed to accommodate small to mid-size furnace loads in an efficient and economic manner. It is a high temperature, high vacuum, batch-type furnace with electrical resistance heating elements. The Mentor® is mounted on a single, portable platform for easy shipment and maneuverability. Designed for heat treating, hardening, brazing, stress relieving, normalizing, annealing, tempering, sintering, homogenizing, degassing, diffusion bonding, and creep forming.

SOLAR MANUFACTURING

267.384.5040
sales@solarmfg.com

solarmfg.com

Give us a call to learn more about our vacuum furnace ingenuity.

DEPARTMENTS ///

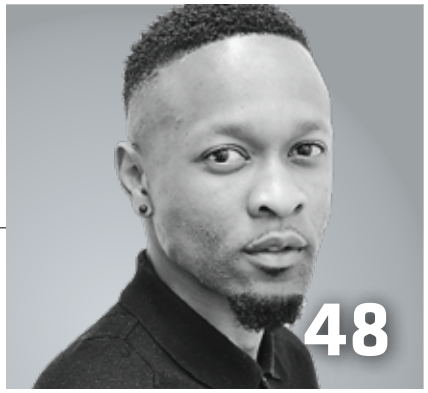
UPDATE ///

New Products, Trends, Services & Developments

Q&A ///

RAYMOND PIETERSEN

EXHIBITION MANAGER ///
CERAMICS EXPO



RESOURCES ///

International Federation for Heat Treatment (IFHTSE)

The international association whose primary interest is heat treatment and surface engineering shares news of its activities to promote collaboration on issues affecting the industry. **16**

Industrial Heating Equipment Association (IHEA)

The national trade association representing the major segments of the industrial heat processing equipment industry shares news of it's activities, training, and key developments in the industry. **18**

METAL URGENCY ///

An advanced PM FeCrAlMo-based alloy is candidate material for accident-tolerant fuel cladding due to its excellent high temperature oxidation resistance. **20**

HOT SEAT ///

Boron steels are used extensively as an inexpensive replacement for more highly alloyed steels. Small additions of boron can be beneficial in increasing in hardenability. **24**

QUALITY COUNTS ///

The best way to fix a mistake is by designing solutions with the correct actions, not covering up problems to avoid getting fired. **26**

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

LOOKING FOR WAYS TO TURN YOUR QUALITY PROGRAM UP A NOTCH?

If you would like a simple, cost effective way to **document** and verify the consistency of your thermal process, let us share how **TempTABs** can help you.

TempTABs are designed to help **put you in touch** with what is going on **"inside" your furnace**.

Spot trends in your thermal process before they impact product quality!

TempTAB Monitoring System

1. Place TempTABs in your furnace with the load.
2. Measure their dimension once they exit.
3. Translate the dimension into a TempTAB temperature.
4. Compare data from run to run with the easy to use TempTAB Trakker software.

CONFIRM YOUR PROCESS IS UNDER CONTROL!

Orton **The Edward Orton Jr., Ceramic Foundation**

"Validating thermal processing for more than 100 years"

www.temptab.com • 614-818-1338

FROM THE EDITOR ///

Be careful — COVID is still around!

Anyone who says COVID has run its course might want to do a quick double take — especially if you work for us.

If you're reading this right now, that means that *Thermal Processing* was able to put together another quality issue with almost half of its staff out sick with COVID-19.

Production week for us is a time for everyone to be "all-hands-on-deck," and proved a little difficult to do when many of us were nowhere near those decks.

Our saving grace was our ability to be able to work from home. That was a bonus gifted to us by the OG lockdown in 2020. Even through all of that, most of us were somehow diligent enough to avoid getting the 21st century plague known as COVID, but we *were* lucky enough — if the word "lucky" applies — never to be stricken during the busiest part of our month. That is, until now.

Do I sound like I'm complaining? Well, probably, but our modest staff produces, in addition to *Thermal Processing,* two more quality magazines for various industries each and every month. It's a fairly well-oiled machine, but when short-staffed, the month can definitely be a wild ride, to say the least.

But, as they say, we persevered, and I couldn't be prouder of my co-workers for stepping up and getting the job done, despite with some of them being under the weather and trapped at home.

That being said — and boy, does it feel good to get it off my chest — our August issue of *Thermal Processing* has some interesting pieces for you to sink your teeth into.

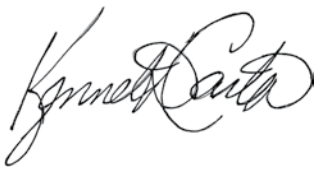
Our main Focus article is from the experts at Quaker Houghton, where they share their insights on how to choose between HFC and HFDu fire-resistant hydraulic fuels.

Our columnists have put together some fascinating reads on various heat-treating topics this week as well, so please make sure you give those an in-depth read.

Also, Ceramics Expo is coming up later this month in Cleveland, Ohio. To help you prepare for that show, I chatted with a show organizer about what attendees and exhibitors can expect.

All that and more awaits your attention, so I hope you enjoy reading it as much as I stressed over putting it together.

Stay healthy, and, as always, thanks for reading!



KENNETH CARTER, EDITOR
editor@thermalprocessing.com
(800) 366-2185 x204

CALL FOR ARTICLES Have a technical paper or other work with an educational angle? Let Thermal Processing publish it. Contact the editor, Kenneth Carter, at *editor@thermalprocessing.com* for how you can share your expertise with our readers.

Thermal processing

David C. Cooper
PUBLISHER

EDITORIAL
Kenneth Carter
EDITOR
Jennifer Jacobson
ASSOCIATE EDITOR
Joe Crowe
ASSOCIATE EDITOR | SOCIAL MEDIA

SALES
Dave Gomez
NATIONAL SALES MANAGER
Kendall DeVane
REGIONAL SALES MANAGER

CIRCULATION
Teresa Cooper
MANAGER
Jamie Willett
ASSISTANT

DESIGN
Rick Frennea
CREATIVE DIRECTOR
Michele Hall
GRAPHIC DESIGNER

CONTRIBUTING WRITERS
STEFANIE HOJA
RONALD KNECHT
D. SCOTT MACKENZIE
ARNOLD PRADHAN
TRIRATNA SHRESTHA
MATTHIAS STEINBACHER
TONY TENAGLIER
HEINRICH KLÜMPER-WESTKAMP

Media solutions

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

David C. Cooper
PRESIDENT

Teresa Cooper
OPERATIONS

WIRCO IS PROUD TO ANNOUNCE THE ACQUISITION OF **PERFORMANCE INDUSTRIAL PRODUCTS!**

Wirco and PIP join forces to bring to market a large scope of product offerings for the heat treat and steel mill markets for high temperature thermal processing applications.

With 3 facilities across the Midwest (Avilla, Indiana, Champaign, Illinois and Waupaca, Wisconsin) Wirco is positioned in the market to deliver 100% USA made products with industry best lead times and world class quality! The addition of PIP to the Wirco family provides increased stainless steel centrifugal casting and static casting capabilities along with the experienced PIP foundry team.

Reach out to Wirco today for any stainless steel casting and fabrication needs.

FANS | RADIANT TUBES | FURNACE ROLLS | ROD FRAMED BASKETS

sales@wirco.com

PARTNER WITH WIRCO, YOUR AMERICAN MADE ENGINEERED ALLOY SOLUTION.

WWW.WIRCO.COM

Bodycote's new HIP capacity in Greenville, South Carolina, which will be online by the end of 2022, will focus on developments in additive manufacturing and advanced materials.

Bodycote increases hot isostatic pressing capacity in the U.S.

Bodycote, a thermal processing services provider, is expanding its hot isostatic pressing (HIP) capability in Greenville, South Carolina, in the United States.

The new HIP capacity, which will be online by the end of 2022, will focus on developments in additive manufacturing and advanced materials. The two additional vessels further extend the company's comprehensive range of installed capacity across the world. Bodycote's Greenville site is a Nadcap accredited site and holds several core OEM approvals. The site consists of numerous vacuum furnaces and other capabilities well suited to support additive manufacturing customers. The Greenville site will serve the aerospace, defense, medical, and general industrial customers throughout the Southeastern region.

"We are pleased to address our customer needs by bringing HIP services closer to their facilities," said Stephen Harris, Bodycote Group chief executive. "With the largest HIP operational capacity in the world, our continued investment demonstrates Bodycote's commitment to align resources to serve our customers across North America."

Having established industry expertise over decades, Bodycote has more than 50 HIP vessels of varying sizes in multiple locations. Processing capabilities can accommodate components that are nominally up to 6.5 feet in diameter by 12 feet high and weighing more than 65,000 pounds.

Bodycote has facilities in 22 countries to provide heat treatments and specialist thermal processing services. Through classical heat treatment and specialist technologies, including hot isostatic pressing (HIP), Bodycote improves the properties of metals and alloys, extending the life of vital components for a wide range of industries, including aerospace, defense, automotive, power generation, oil and gas, construction, medical, and transportation.

MORE INFO www.bodycote.com

Magnetic Shields orders third Solar vacuum furnace

Magnetic Shields Limited (MSL) of Kent, United Kingdom has selected Solar Manufacturing to supply a Mentor® Pro vacuum furnace to MSL's subsidiary, MSL Heat Treatment.

The new Mentor® Pro vacuum furnace (HFL-3036-2IQ) will be manufactured in accordance with CE standards including the vacuum chamber being built to ASME/UKCA requirements. This furnace has a working hot zone area of 18" wide x 18" high x 36" deep (457mm x 457mm x 914mm) with a weight capacity of 1,000 pounds (455 kgs). Operating at a vacuum level of 10-5 Torr, this new furnace will be able to reach temperatures up to 2,400°F (1,315°C). It will feature a three-gas partial pressure system and an internal quench system designed for 2-bar (15 PSIG) positive pressure quenching.

"Solar Manufacturing is pleased to continue working with MSL as a supplier for their thermal processing needs," said Rick Jones, VP of international sales at Solar Manufacturing. " I believe that Solar Manufacturing's honest approach to business and our commitment to 100 percent customer satisfaction is a key element that helped to secure this order and continue the great relationship we have with MSL."

Magnetic Shields Limited (MSL) has had a partnership with Solar Manufacturing since 2016.

"MSL Heat Treatment specialize in brazing and controlled heat treatment for medical and scientific applications," said director Colin Woolger. "This latest furnace from

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 Mentor® Pro vacuum furnace has a working hot zone area of 18" wide x 18" high x 36" deep (457mm x 457mm x 914mm) with a weight capacity of 1,000 pounds (455 kgs). (Courtesy: Solar Manufacturing)

Solar Manufacturing will enable us to continue to provide high quality solutions to our growing customer base. The inclusion of hydrogen as a process gas also allows us to utilize the furnace for magnetic annealing to a very high specification. We are very excited to work with Solar Manufacturing again."

Solar Manufacturing designs and manufactures a wide variety of vacuum heat treating, sintering, and brazing furnaces. MSL Heat Treatment is a subsidiary of Magnetic Shields Limited. MSL Heat Treatment specializes in vacuum brazing and heat-treatment processes.

MORE INFO www.solarmfg.com
www.mslheattreatment.co.uk

CCAI recognizes award recipients at annual event

During the 2022 CCAI Annual Meeting in Avon, Colorado, the Chemical Coaters Association International held their annual awards ceremony to recognize the CCAI Chapter Users and Suppliers of the Year and announce the 2022 James F. & David J. Wright Lifetime Achievement Award recipient.

The prestigious James F. & David J. Wright Lifetime Achievement Award continues to be CCAI's highest honor and is awarded to deserving members of the association who have dedicated years of service to CCAI and the industrial finishing industry. This year the recipient was Bill Oney, who retired from Therma-Tron-X, Inc. in October 2021. Oney has been a CCAI member for the past 23 years. He is an active member of the Wisconsin Chapter and has served as its president, was a contributor to CCAI's Powder Coating and System Design training manuals, and shared his expertise at many technical and educational events. Oney has served on the CCAI National Board for 13 years, including every role on the CCAI Executive Committee.

"Of all the organizations I have belonged to over the years, CCAI is the most rewarding in that our mission is to give back to our industry by providing educational opportunities and great networking," Oney said. "I am humbled and very grateful to be recognized alongside a long list of great people who have received this prestigious award. I knew Dave Wright personally and worked with him for many years and to be given this award is an absolute honor. I am extremely thankful for our family of members within CCAI, for everything that CCAI stands for, and all that it has achieved."

Bill Oney

Bob Bonsall

CCAI also honored its Chapter User and Supplier of the Year recipients at the awards ceremony. Each year, chapters identify a user and supplier member for their service and dedication to their respective chapter.

The 2022 Chapter Award winners are:

›› Twin Cities Chapter: Bob Bonsall, Nordic Ware Inc., and Joel Lynch, Diamond Vogel, Inc.

›› West Michigan Chapter: Terre Bennett, DeWys Manufacturing, and Tom Farrington, The Sherwin-Williams Co.

›› Wisconsin Chapter: Matt Diker, Mercury Marine.

MORE INFO www.ccaiweb.com

OWZ Ostalb invests in Endoflex S generator

OWZ Ostalb bought a new electrically heated EndoFlex™ S endothermic gas generator to replace the company's old generator.

OWZ Ostalb is a commercial heat-treatment company in Aalen, Germany, with which UPC-Marathon, one of Nitrex's business units, has been in contact for several years.

The EndoFlex™ S is an advanced endothermic gas generator with numerous features to improve gas reaction efficiency, including sensors capable of diagnosing the most common gas generation issues before they become problematic. (Courtesy: Nitrex)

"The customer chose us because we offered the most valuable product with the best-in-class gas mixing and control system, the EndoInjector™, and the highly efficient ReactionCore™ multi-retort system to deliver a reliable, on-demand supply of quality endogas, resulting in significant CO2 savings for their heat-treating operations," said Daniel Panny, product manager at UPC-Marathon in Germany.

The EndoFlex S that was purchased is the electrically heated version with an air cooler, an automatic nitrogen purge system, and additional CH_4 monitoring to meet the highest safety standards.

The old generator had to be replaced because it had no automatic process control and was not able to control the dew point efficiency in situations where the ambient air changed too much. Furthermore, old components that were difficult or impossible to replace reduced the generator's overall efficiency even further.

The EndoFlex is a turnkey system that is pretested by UPC-Marathon and ready to start working at the push of a button. At startup, UPC checks that all safety features function perfectly and provides detailed training to customers.

OWZ Ostalb has been using the new EndoFlex S since September 2021, and it has been running nonstop ever since.

"The customer is very satisfied with our product and highly praised the system's availability rate of 100 percent since startup," said Panny.

MORE INFO www.nitrex.com

Horizon Performance Technologies acquires Perceptive Industries

Horizon Performance Technologies LLC (Horizon) has acquired all intellectual property of Perceptive Industries Inc. (Perceptive). Since 2002 Perceptive has been supplying industrial ovens to the metal fastener and coatings industry, and the thermal processing industry throughout the United States, as well as delivering equipment globally to international-based metal coaters.

This acquisition further expands Horizon's product line and geographic pres-

ence. The Perceptive product line is complementary to Horizon's already existing industrial oven and washer product lines for the metal finishing industry, thermal processing, and industrial cleaning lines. Horizon holds several patents in the thermal processing field that have proven to save electrical and natural gas operating costs.

"We're excited about this strategic acquisition of Perceptive's intellectual property," said Jeff Mitchell, president of Horizon. "This allows Horizon to continue to serve Perceptive's customer, provide equipment service and spare parts through our online portal, and will allow us to adapt our patented technology to the Perceptive equipment. Perceptive customers will benefit from energy-saving designs to be implemented on any new equipment purchases and it allows us to expand our geographic presence, product and service offerings, and customer base. We look forward to working with Perceptive's customer base and providing our first-rate service."

Horizon Performance Technologies LLC (Horizon) is an OEM engaged in the design and manufacturing of industrial capital equipment in the heat processing and finishing industries including ovens, washers, and material handling.

MORE INFO www.horizonpfm.com

Seco/Vacuum moves to accommodate growing business

Seco/Vacuum, a Seco/Warwick Group company, moved its office and shop to a new space. After their fifth year in the North American market, they decided it was time for a move.

The new location stays at the group's birth city — Meadville, Pennsylvania — but the place is different. At a nearby business park in Meadville, Seco/Vacuum will open a new chapter in the company's history.

The move was necessitated by continuing new business growth, a requirement to accommodate additional engineering and production staff, and the need to enhance manufacturing capacity to meet customers' aftermarket support and service demands.

"Our team needed a new home to manage our expansion efficiently," said Peter Zawistowski, Seco/Vacuum's managing director. Our prior space served us well for the past couple of years, but to accommodate new employees and increasing customer demands, it was time to move on. Our new offices are much more conducive to teamwork, while affording us generous meeting room space for customer collaboration. The new shop area will not only help us grow our manufacturing capabilities, but it will also increase our parts and service support and provide a research and development facility to test new technologies."

"Seco/Vacuum's move to larger administration and manufacturing facilities certainly validates our commitment to

the North American region as a primary marketplace for Seco/Warwick's proven technologies. We look forward to continuing customer acceptance and growth in the region," said Sławomir Woźniak, CEO of Seco/Warwick Group.

2022 marks the fifth anniversary of the Seco/Vacuum brand. In the most recent full year of financial reporting ended December 31, 2021, the company wrote orders for 40 percent of Seco/Warwick Group's total international vacuum furnace business. The company's portfolio of customers continues to grow in the first half of 2022 for both new equipment as well as support for its installed base.

Seco/Vacuum offers all-vacuum technologies that are engineered to run clean and cool, operate more efficiently than legacy furnaces, produce cleaner parts, and reduce environmental impact by eliminating toxic emissions.

MORE INFO www.secowarwick.com

Applied Test Systems announces promotions

Applied Test Systems, with more than 50 years of experience, continues to grow and make improvements with customer needs in mind. The company recently announced company promotions.

During his 22 years with ATS, Robert Antolik has worked in various departments and positions including as an engineer, sales engineer, and vice president of sales. He now brings that experience to his role as vice president of engineering.

Haylee DeFrancisis has been with ATS for four years. She has been sales engineer and process heating product manager before being named inside sales manager.

Lauren Ault has been with ATS for more than two years, creating all print and web advertisements, literature, social media strategies, and trade-show exhibits. As marketing manager, Ault is responsible for all ATS marketing.

From left, Applied Test Systems employees Haylee DeFrancisis, internal sales manager; Robert Antolik, vice president of engineering; and Lauren Ault, marketing manager. (Courtesy: Applied Test Systems)

ATS also has new sales representatives internationally. Zutek is representing ATS in South Africa and Sub-Saharan Africa, and

BTE is representing ATS in Iceland, Denmark, Norway, Sweden, and Finland.

MORE INFO www.atspa.com

SteelAsia chooses Tenova for its green technology

Tenova and SteelAsia Manufacturing Corporation recently inked a partnership for Consteel® Evolution, a state-of-the-art low-impact technology for steel manufacturing.

It will be the first of its kind in the country and will be employed in SteelAsia's new melt shop in Lemery, Batangas, in 2024.

Tenova is a leading developer and provider of sustainable solutions for the green transition of the metals industry, and SteelAsia Manufacturing Corporation is the flagship steel manufacturing company in the Philippines.

In order to guarantee the seamless operation of the entire line, Tenova's scope of work includes the EAF (Electric Arc Furnace) Consteel Evolution, the secondary metallurgy station, the billet caster, the fume treatment plant (FTP) and the material handling systems, along with all engineering services for the civil works and the balance of plant.

The new Consteel Evolution melt shop will recycle local scrap metal to produce high-grade billets for steel sections. The advanced Lemery facility will also be one of the cleanest steel plants in the world. It will generate the lowest carbon emission, providing Filipinos with top-quality steel sections produced with the most environmentally friendly technology.

The Consteel Evolution technology saves energy, decarbonizes steel production, and reduces environmental impacts through efficient energy recovery and pollution control innovations. Scrap metal is a vital national resource used in steel production with low carbon emission, and SteelAsia targets to increase its output by maximizing the use of scrap metal.

Across many countries, there has been a shift from ore-based steel production to scrap recycling-based due to the global industry's growing desire to reduce emissions and dependence on coal. SteelAsia's partnership with Tenova to further pursue its decarbonization efforts aims to make steel production more sustainable without compromising its output and financial returns.

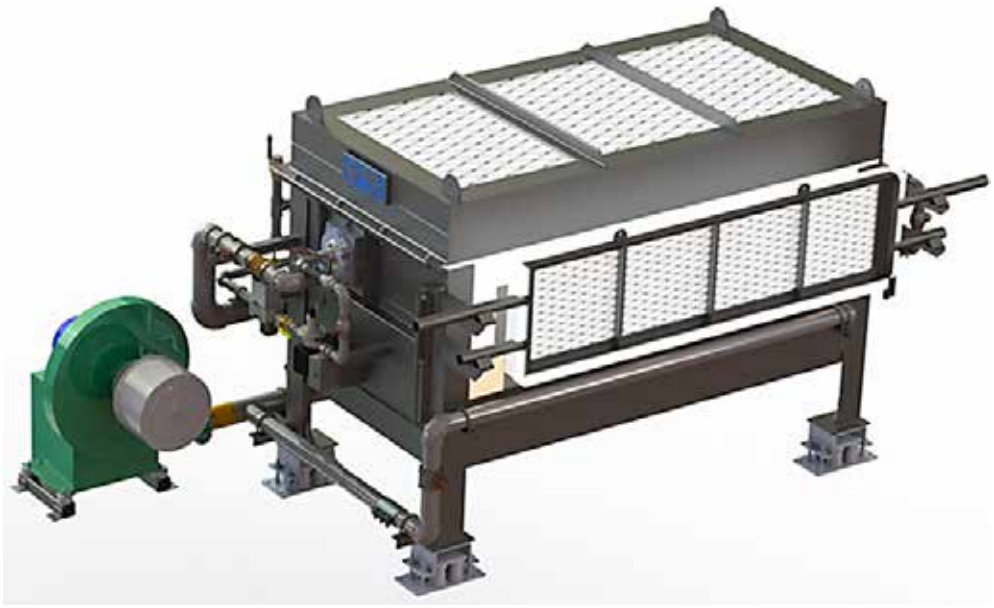
The company operates six manufacturing plants across the country, located in Bulacan, Batangas, Cebu, Davao, and Misamis Oriental. It is expected to open its seventh plant this year, located in Compostela, Cebu, and increase its output from 2 million metric tons of steel annually to 3 million metric tons.

"Our company's long-term vision is to develop the Philippine steel industry because this is the backbone of industrialization. We have seen our neighboring Asian countries grow faster because they can manufacture their

steel. The Philippines needs to catch up. As we do so, we want our technology to be at par with global standards in efficiency and environmental sustainability," said Benjamin O. Yao, president and CEO of SteelAsia. "Thanks to our partnership with Tenova, we can increase our steel productivity to support nation-building while ensuring that we also take care of the environment."

"Thanks to Tenova's continuous efforts to enable a more sustainable metals production, SteelAsia found in our portfolio the most suitable technologies to produce high-quality steel from recycled scrap," said Paolo Stagnoli, commercial director electric arc and ladle furnace in Tenova. "We are honored to support SteelAsia in the green industrial development of the Philippines."

MORE INFO www.tenova.com
www.steelasia.com



The Armil Tru-Forge™ slot forge furnace is ideal for forge shops with smaller runs or shops that forge a wide variety of shapes. (Courtesy: Armil CFS)

Nitrex delivers vacuum furnace to aircraft provider

Nitrex Vacuum recently shipped a new large vertical vacuum furnace to a major engine MRO (maintenance, repair and overhaul) shop/repair company in South America.

The customer repairs jet engines, components, and integrated systems for commercial and military aircraft. The vacuum system was ordered to expand production capacity, modernize the company's plant, and meet quality standards and accreditations.

The customer ordered the furnace from Nitrex's GM Enterprises division, which was acquired by Nitrex in 2020 and now operates under the Nitrex Vacuum Furnaces name.

COVID-19 delayed delivery of a number of systems in the aerospace sector and Nitrex sees the industry beginning a strong rebound.

"Shipment of this furnace system, after a number of COVID-related delays, was a milestone for Nitrex," said Mark Hemsath, vice president of sales and acting general manager, Nitrex Heat Treating Services, Americas. "It was an interesting project that was affected by the pandemic. We are excited to continue to collaborate with and support our many aerospace customers as the industry rebounds to pre-pandemic strength."

The vertical vacuum furnace (VVF series) is designed for vertical bottom-loading applications, and is ideal for processing high-stacked loads, as well as larger and taller workpieces like aircraft engine components.

The VVF measures 84 (diameter) x 84 (height) (2,134 mm x 2,134 mm), possesses a 6,000-pound maximum capacity (2,727 kg), and operates at temperatures ranging from 1,000°F to 2,500°F (540°C – 1,371°C).

It uses a circular hot zone with 360° gas cooling nozzles that ensure even gas distribution for optimal cooling. For heavy and large cross-section parts, an optional bottom cooling system helps to direct gas over the area for fast and more uniform cooling.

MORE INFO www.nitrex.com

Armil CFS launches Tru-Forge furnace product

Armil CFS introduces the Tru-Forge™ slot forge furnace, a pre-engineered gas-fired furnace with a temperature range of 1,500°F -2,450°F.

The furnace is fired by high-velocity burners with Honeywell UDC 2500 controllers and 7800 series flame supervision with UV scanners. Standard slot is 3" x 72", but other configurations are available. The production rate is 1,500 lbs/hr. The furnace has 12-inch thick high-efficiency composite lining with 12-inch thick Fiberfrax 2600 ceramic fiber roof.

Tru-Forge™ slot furnaces are ideal for forge shops with smaller runs or shops that forge a wide variety of shapes.

MORE INFO www.armilcfs.com

New ABB OmniVance FlexArc Compact adds flexibility

ABB launched its OmniVance™ FlexArc® Compact — a new, smaller welding application cell with greater flexibility, ease-of-use and better integration — to help businesses address labor shortages in welding.

"Welding is one of the fastest-growing applications for automation, and it's being driven by a lack of labor," said Marc Segura, ABB's Robotics Division president. "Rising costs and more challenging customer needs make production more complex, meaning manufacturers need simple automation solutions that can easily adapt to changing market needs. OmniVance FlexArc is our answer. We are making it even smaller, more flexible, and easier to use."

With the smallest footprint in its class, the OmniVance FlexArc Compact helps manufacturers optimize space while up to four robots can be added without altering the cell's structure, aiding flexibility.

This new, ready-to-deploy, modular solution incorporates robots, controllers, software, peripherals, and other key components into one simplified welding application-specific cell.

At 14.3m2, the OmniVance FlexArc Compact is the smallest arc welding cell in its class. Its innovative 45-degree gantry robot mount design maximizes the robot's working parameters by placing it in the center of a three-axis turntable, bringing it closer to the workpiece.

Every OmniVance FlexArc cell can be simulated before commissioning with RobotStudio®, ABB's industry-leading simulation and programming tool, reducing integration time and effort, while minimizing disruption. In addition, ABB's latest FlexArc software suite enables customers to collect and analyze data to refine performance and improve decision-making and welding efficiency by visualizing production data against specific key performance indicators.

Abb's the OmniVance FlexArc Compact helps manufacturers optimize space while up to four robots can be added without altering the cell's structure, aiding flexibility. (Courtesy: ABB)

AMRs, material-handling, and quality inspection equipment can also be easily integrated to enhance the functionality of the new cell to automate and speed up manufacturing logistics. If production increases, the OmniVance FlexArc Compact can be scaled up with additional cells. Both the hardware and the software programs used to operate the cells can be easily replicated, either at a single site or across multiple sites, reducing the time and potential risks of adding new cells.

The OmniVance FlexArc Compact is one of the latest offerings as part of ABB's new OmniVance brand, that unifies all ABB standardized application cells. By combining robot, gripper, controller, software, and other components into a single application-specific solution, OmniVance cells require minimal integration effort and reduce the potential for errors. The standardized design of OmniVance cells, coupled with ABB's global footprint, ensures quick changeovers, easy expansion, and timely support.

MORE INFO www.go.abb/robotics

Members to be awarded citations at European heat treat conference

The European Conference on Heat Treatment/IFHTSE 27th Congress, will be September 5-8 at the Wyndham Grand Salzburg Conference Center in Salzburg, Austria. The event is sponsored by ASMET, the Austrian Society for Metallurgy and Materials. At the conference, the following awards will be presented:

Hans-Werner Zoch

John G. Speer

Zoltán Koloszváry

Hans-Werner Zoch, IFHTSE Fellow

The citation is: "For his far-sighted coverage of novel fields in research and technology and for his sustained leadership giving heat treatment and surface engineering a strong position in the research landscape and firm links to neighboring fields."

John G. Speer, IFHTSE Medal

The citation is: "For his life-time achievement in physical metallurgy, development and heat treatment of advanced steel concepts from theory to practical application, with particular focus on his leading role in the development of the quenching and partitioning process."

Zoltán Koloszváry, IFHTSE Honorary President

"Appointed Honorary President of the International Federation of Heat Treatment and Surface Engineering at the 27th IFHTSE Congress in Salzburg, Austria, September 6 2022. For his outstanding leadership to IFHTSE and his dedicated, successful, and long-term service as its president and treasurer."

For more information, go to www.ifhtse-echt2022.org

The 5th International Conference on Heat Treatment and Surface Engineering of Tools and Dies will be in beautiful Hangzhou, China in 2023.

ADVANCES IN MATERIALS AND PROCESSING TECHNOLOGIES

October 10-14, 2022 | Portorož, Slovenia

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 since then its been held in many different countries. After being cancelled in 2020 due to the COVID pandemic, in 2022, the AMPT conference will be at the coast of Slovenia, in Portorož.

»For more information, go to www.AMPT2022.org

HTS – 14TH INTERNATIONAL EXHIBITION AND CONFERENCE ON HEAT TREATMENT

November 2-4, 2022 | Bombay Exhibition Centre, Mumbai

This three-day international concurrent conference on "Advances in Heat Treatment" will have sessions on equipment, process improve-

ment, 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 & control, and case studies with specific reference to different industry sectors including transport, power, defense, etc.

»For more information, go to htsindiaexpo.com/international-conference

5TH INTERNATIONAL CONFERENCE ON HEAT TREATMENT AND SURFACE ENGINEERING OF TOOLS AND DIES

April 24-27, 2023 | Hangzhou, China

This event, in beautiful Hangzhou, China, will be a complete exhibition and conference with researchers from around the globe.

Hangzhou is an industrial city with many diverse industry sectors. It is readily accessible from Shanghai by high-speed train or car. The high-speed train is available from the South Shaanxi Road station.

GLOSSARY AND TERMINOLOGY

One of the tasks IFHTSE has taken on is the creation of a web-based glossary available in different languages, including English, French, German, Russian, Japanese, and Chinese. Other languages are planned. This large effort comprises several thousand words with definitions and comparable wording in different languages.

SPOTLIGHT ON MEMBERS

Japan Heat Treatment Technology Association

The Japan Heat Treatment Technology Association is an academic organization approved by the Ministry of Education, Culture, Sports, Science, and Technology, and is engaged in research and education in fields from the basics to the cutting edge of heat-treatment technology. The purpose is to contribute to the development of academic technology by forming alliances. It was founded September 21, 1960, and has been a member of IFHTSE since its founding.

The society focuses on heat-treatment technology that makes the best use of materials, while being environmentally friendly.

The Japanese Heat Treatment Society is the sponsor of the 28th IFHTSE Congress November 13-15, 2023, in Yokohama, Japan.

IFHTSE UPCOMING EVENTS

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

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

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

APRIL 24–27, 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 | 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

IFHTSE LEADERSHIP

EXECUTIVE COMMITTEE

Prof. Masahiro Okumiya | President
Toyota Technological Institute | Japan

Eva Troell | Past President
RISE IVF Research Institutes of Sweden | Sweden

Prof. Massimo Pellizzari | Vice President
Dept. of Industrial Engineering, University of Trento | Italy

Dr. Stefan Hock | Secretary General
IFHTSE | Italy

Dr. Imre Felde | Treasurer
Óbuda University | Hungary

OTHER MEMBERS

Prof. Rafael Colas | Universidad Autónoma de Nueva Leon | Mexico
Prof. Jianfeng Gu | Shanghai Jiao Tong University | China
Dr. Patrick Jacquot | Bodycote Belgium, France, Italy | France
Prof. Larisa Petrova | MADI University | Russia
Prof. Reinhold Schneider | Univ. of Appl. Sciences Upper Austria | Austria
Prof. Marcel Somers | Technical University of Denmark | Denmark
Prof. Kewei Xu | Xi'an University | China

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

IHEA announces 2022-23 board of directors and officers

The 2022-23 IHEA Board of Directors: Back row, left to right; Brian Kelly, Scott Bishop, Gary Berwick, and Jason Safarz. Front row, left to right; Ben Garbarre, John Stanley, Jeff Valuck, and Jeff Rafter. Not pictured: Alberto Cantu, Bob Fincken, Doug Glenn, Francis Liebens, John Podach and Michael Stowe. (Courtesy: IHEA)

The Industrial Heating Equipment Association (IHEA) recently announced its 2022-23 board of directors and executive officers. Serving as president is Jeff Valuck of Surface Combustion, Inc.; vice president is Brian Kelly of Honeywell Thermal Solutions, and treasurer is Jeff Rafter of Selas Heat Technology Co. LLC. Scott Bishop of Alabama Power — a Southern Company assumes the past-president position.

IHEA President Jeff Valuck has been an active IHEA member for nearly a decade and has served as the Government Relations Committee chair for many of those years.

When asked what goals he has for IHEA, Valuck said he plans to focus on "working on a strategic sustainability plan that puts IHEA in the forefront of emerging trends that are impacting our industry and gaining increasing interest from customers, governments, shareholders, and even employees."

"I also look forward to increasing IHEA membership in all categories to give a greater fundamental 10,000-foot view of the industry," he said.

IHEA also welcomes a new face to the board of directors — Ben Gasbarre. Gasbarre is the executive vice president of Sales & Marketing for Gasbarre Thermal Processing Systems. Gasbarre has been involved in the sales, engineering, and manufacturing of thermal-processing equipment for nearly 15 years. He received his management and economics degree from Penn State University and his MBA from the University of Michigan. Gasbarre Thermal Processing Systems provides thermal-processing equipment solutions for both atmosphere and vacuum furnace applications, as well as associated auxiliary equipment, and aftermarket parts and service.

"Being a part of the associations that drive the industries we serve forward has always been a core value of Gasbarre and our leadership," Gasbarre said. "I look forward to joining the IHEA board of directors and supporting the efforts that ultimately lead to improvements not only for member companies, but for the end users in our industries as well."

To complete the board of directors for 2022-2023, the following members continue their service: Gary Berwick, Dry Coolers; Alberto Cantu, Nutec Bickley; Bob Fincken, Super Systems, Inc.; Doug Glenn, Heat Treat Today; Francis Liebens, SOLO Swiss Group; John Podach, Fostoria Infrared; Jason Safarz, Karl Dungs, Inc.; Michael Stowe, Advanced Energy; and John Stanley, Karl Dungs, Inc.

In addition, IHEA is equally pleased to note the dedication and service of all members who serve on IHEA Committees and Divisions. Special appreciation goes to our current committee chairpersons: Government Relations Committee led by Jeff Valuck, Surface Combustion, Inc.; Safety Standards and Codes Committee led by Jason Safarz, Karl Dungs, Inc.; Education Committee led by Brian Kelly, Honeywell Thermal Solutions; Marketing Communication & Membership Committee led by Erik Klingerman, Industrial Heating Magazine. The Infrared Division is chaired by Scott Bishop, Alabama Power — a Southern Company; and the Induction Division is chaired by Michael Stowe, Advanced Energy.

Learn from the best: Join IHEA. Visit www.ihea.org for more information and membership application.

Established in 1929 to meet the need for effective group action in promoting the interests of industrial furnace manufacturers, IHEA has expanded and includes designers and manufacturers of all types of industrial heat-processing equipment used for the melting, refining, and heat processing of ferrous and nonferrous metals and certain nonmetallic materials and heat-treatment of products made from them.

IHEA 2022 CALENDAR OF EVENTS

SEPTEMBER 20–21

Powder Coating & Curing Processes Seminar

AR Iron LLC | Henderson, Nevada

OCTOBER 3–4

IHEA Combustion Seminar

Long the industry premier seminar for industrial process heating professionals, this two-day event offers attendees the chance to learn the latest in combustion technology and visit with industry suppliers.

Indiana Convention Center | Indianapolis, Indiana

OCTOBER 24

Fundamentals of Industrial Process Heating Online Course

Six-week online distance learning course is designed to give the student a fundamental understanding of the mechanisms of heat transfer within an industrial furnace and the associated losses and the operation of a heating source either as fuel combustion or electricity.

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

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

P.O. Box 679 | Independence, KY 41051

859-356-1575 | www.ihea.org

TRIRATNA SHRESTHA
MANAGER OF METALLOGRAPHIC LABORATORY AND CENTRAL COATINGS LABORATORY /// METCUT RESEARCH INC.

An advanced powder metallurgical FeCrAlMo-based alloy is candidate material for accident-tolerant fuel cladding due to its excellent high temperature oxidation resistance.

Kanthal APMT for nuclear-energy application

The major earthquake and tsunami that occurred in Japan in 2011 did serious damage to boiling water reactors of the Fukushima-Daiichi nuclear power plant. The accident was a loss-of-coolant accident event. The accident forced the international nuclear community to search for a new fuel configuration that would be more resistant to a loss of coolant accident than existing zirconium/UO_2 pellets [1]. The new strategy is to develop a fuel system that can tolerate and perform well in severe accident scenarios not comprising the reactor performance [2].

To develop an accident-tolerant fuel (ATF) system, there can be three possible methods. The first is to develop the existing Zr alloys to enhance stability and performance in high temperatures [3]. The second way is to choose a different cladding other than zirconium alloys with higher performance and oxidation resistance [2]. The third is to identify a fuel form consisting of additional barriers that can withhold the fission products [4].

The possible accident tolerant fuel material must have: (i) enhanced kinetics with steam, (ii) slower hydrogen production rate, (iii) improved retention of fission products, and (iv) improved cladding and fuel preposition [5]. In the event of loss of active cooling, if a cladding material can tolerate the reactor core for considerably longer time while maintaining the reactor performance then it can be considered as ATF cladding material [5]. Some of the leading materials to replace zirconium as cladding materials are alumina forming ferritic alloys and silicon composites [6].

Kanthal® APMT is an advanced powder metallurgical FeCrAlMo-based alloy developed by Sandvik material technology group. Chemical composition of the alloy determined via optical emission spectroscopy is listed in Table 1. The alloy contains dispersoids and constituent elements that form stable high temperature alumina and provide higher mechanical strength compared to traditional FeNiCr/NiCr alloys. Formation of dense and highly adherent alumina on the surface provides better oxidation protection than chromia layer. Apart from its traditional usage in various forms, such as high temperature crude processing tubes, heating elements, heat exchangers, etc., APMT is considered for ATF cladding material in nuclear power plants. Zirconium-based alloys are widely used as nuclear fuel cladding material; however, the alloys have higher reaction kinetics with steam and form hydrogen at elevated temperature — a major concern during a loss of coolant accident. Although Kanthal APMT has nearly 10 times the neutron absorption cross section of Zircaloy-2: 2.47 vs. 0.20 barns, it has good corrosion resistance and higher temperature stability property to act as a cladding material. This explains the versatility shown by Kanthal APMT at higher temperatures and extreme conditions. Advancement in fuel enrichment and fuel rod geometries can minimize the effect of higher neutron absorption.

The major earthquake and tsunami that occurred in Japan in 2011 did serious damage to boiling water reactors of the Fukushima-Daiichi nuclear power plant. (Courtsey: Shutterstock)

OXIDATION PROPERTY

Kanthal APMT has superior oxidation resistance at high temperatures. A study conducted by Sandvik [7] at 1,100°C (2,012°F) showed formation of an adherent passive alumina barrier layer and no mass gain for exposure of up to 900 hours, while high performance Fe35Ni25Cr alloys had corroded on the surface, see Figure 1, and had significant mass gain. Formation of a chromia and alumina oxide layer depends under different environment conditions. Figure 2 shows the oxide development on APMT under normal reactor conditions and accident conditions [1].

The oxide layer that gets developed under 288/300°C (550/572°F)

Element	Fe	C	Si	Mn	P	W	Cr	Mo	Ni	Al	Co	Ti	V	Zr	Ta
Wt. %	69.4	0.03	0.32	0.18	0.01	0.02	21.2	2.76	0.08	5.34	0.01	.01	0.03	0.07	>0.2

Table 1: Chemical composition of Kanthal® APMT using Optical Emission Spectroscopy (OES).

ARNOLD PRADHAN
GRADUATE RESEARCH ASSISTANT
IN NUCLEAR ENGINEERING /// UNIVERSITY OF IDAHO

water is a chromia layer. If the same experiment conditions have excess hydrogen, then a pure chromia oxide gets developed in the surface whereas, in excess of oxygen, Rebak [1] found that there was formation of dual oxide. The inner oxide layer was a chromia layer whereas the external layer consists of chromium and iron with no aluminum or molybdenum. When exposed to a steam-oxidizing environment at 1,200°C (2,192°F), a pure alumina layer develops on the surface. On being air-oxidized rather than steam-oxidized at 1,200°C (2,192°F), APMT grows a thicker and wider oxide layer than the steam-oxidized APMT [8, 9]. There is faster oxide growth on air-oxidized APMT than steam-oxidized APMT when exposed to respective corrosion environment.

Both the oxide layer consists of columnar grains. The higher frequency of grain boundary diffusion in APMT causes the rapid oxidation rate in air for APMT [10]. The evolution of oxides on the surface of APMT depends on the changing environment where it is exposed. Rebak [1] tested the alloy from water to steam and steam to water to test the stability of a pre-oxidized layer on the surface. It was found that the chromia layer on a pre-oxidized APMT was replaced by a pure alumina layer when exposed to high temperature steam whereas the alumina layer on a pre-oxidized APMT was replaced by a pure chromia layer when exposed to high temperature water. This explains the versatility of oxides formed by APMT in different corrosion scenarios and shows the benefits of using APMT as cladding material in the nuclear reactors. This key property shown by APMT would be very vital in dealing with loss-of-coolant accident situations as the material can switch the formation of oxide layer according to its environment.

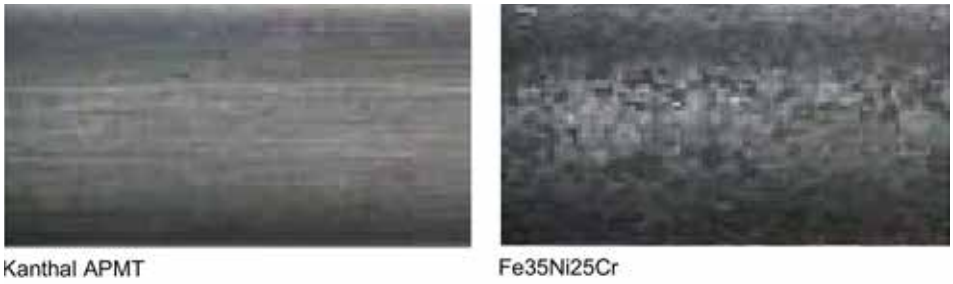


Figure 1: Oxidation property of Kanthal APMT VS. Fe35Ni25Cr.

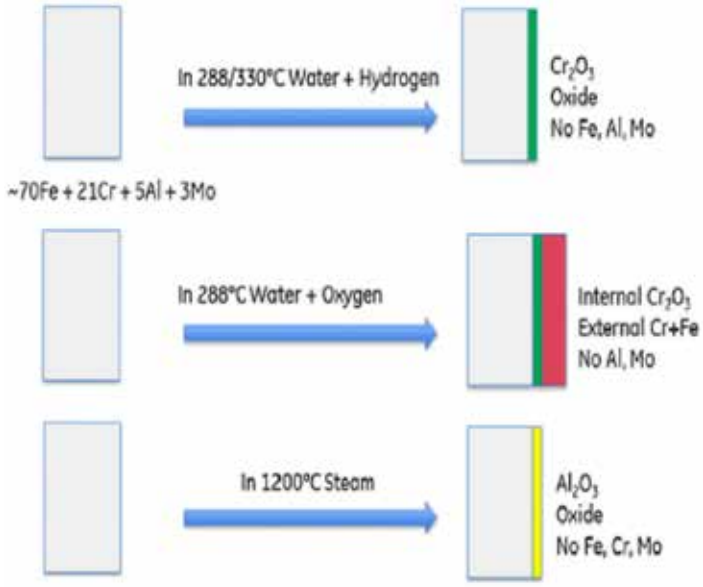


Figure 2: Schematic development of different oxides on APMT under normal reactor conditions and accident conditions [1].

CREEP PROPERTY

Creep deformation and rupture of metals is of great concern for prolonged service life at elevated temperatures. For an engineering structure operating in ambient temperature, creep is not considered as a significant deformation mechanism. However, in high-temperature applications, parameters like the duration of test, the grain size, subgrain size, precipitate size, effective stress, and environment all have a role in dictating the strength of the material. Creep is time-dependent plastic deformation in materials under constant load or stress, specifically observed at higher homologous temperatures. Kanthal APMT is likely to reach creep regime temperatures even under normal operating conditions.

A typical example of a creep curve for a Kanthal APMT specimen tested at 973 K (1,292°F) and 100 MPa is shown in Figure 3a, and the corresponding variation of creep rate versus time plotted in double logarithmic scale is shown in Figure 3b. The sample reached steady state creep rate in the 10-6/s range. The creep curve consisted of three distinct regimes: primary, secondary (steady state), and tertiary. During the primary creep, the creep rate decreases with increasing strain due to work hardening via dislocation multiplication and interactions. In the secondary stage, creep rate is stabilized as the work hardening effect is counter balanced by the dislocation annihilation and rearrangement.

The secondary stage, also known as steady-state creep, is of vital importance as it sheds light on the creep deformation mechanism. In the secondary creep stage, the material deforms plastically while there is a higher degree of strain hardening and increased dislocation density, resulting in a constant creep rate. Strain rate increases with time in tertiary creep. Increased strain rate results in necking, crack, and void formation. Finally, the creep rate accelerates as cavities start growing, leading to the tertiary stage and rupture ultimately. Tertiary creep stage is rapid, so engineering structural materials are designed not to enter this stage.

The solid solution strengthening, fine substructure, dense dislocation network, and dispersoids increase the creep resistance of Kanthal APMT. These strengthening mechanisms deteriorate over time during creep, and the material loses its inherent creep rupture strength. The creep strength of an alloy depends on its ability to withstand temperature and stress for a prolonged period. The formation of dense adherent chromia and alumina passive barrier protect the material from high temperatures degradation. Microstructure of a sample crept at

125 MPa and 923 K (1,202°F) was examined via optical microscopy. Figure 4 shows optical micrographs at various locations along loading direction of a sample crept at 125 MPa and 923 K (1,202°F). At the tip of the fracture surface, extensive microstructural damage was observed with porosities, cavities, carburization, and no defined grain structure. At quarter of fracture length away from the fracture surface, elongated grains with high aspect ratio along axial direction, increased carburization, and porosity were observed. At halfway from fracture surface, elongated grains along axial direction, increased carburization, and porosity were observed. Toward the grips equiaxed microstructure like as-received condition was observed.

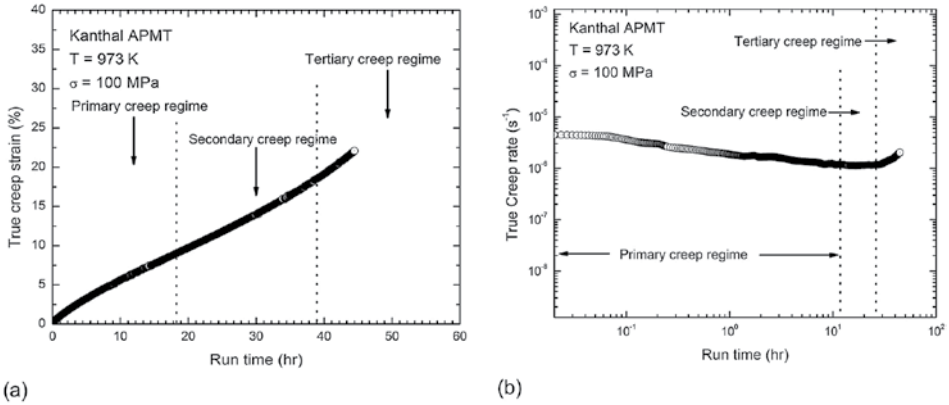


Figure 3: Creep plot of sample tested at 100 MPa and 973 K (a) true creep strain vs. run time and (b) double log plot of true creep rate vs. run time.

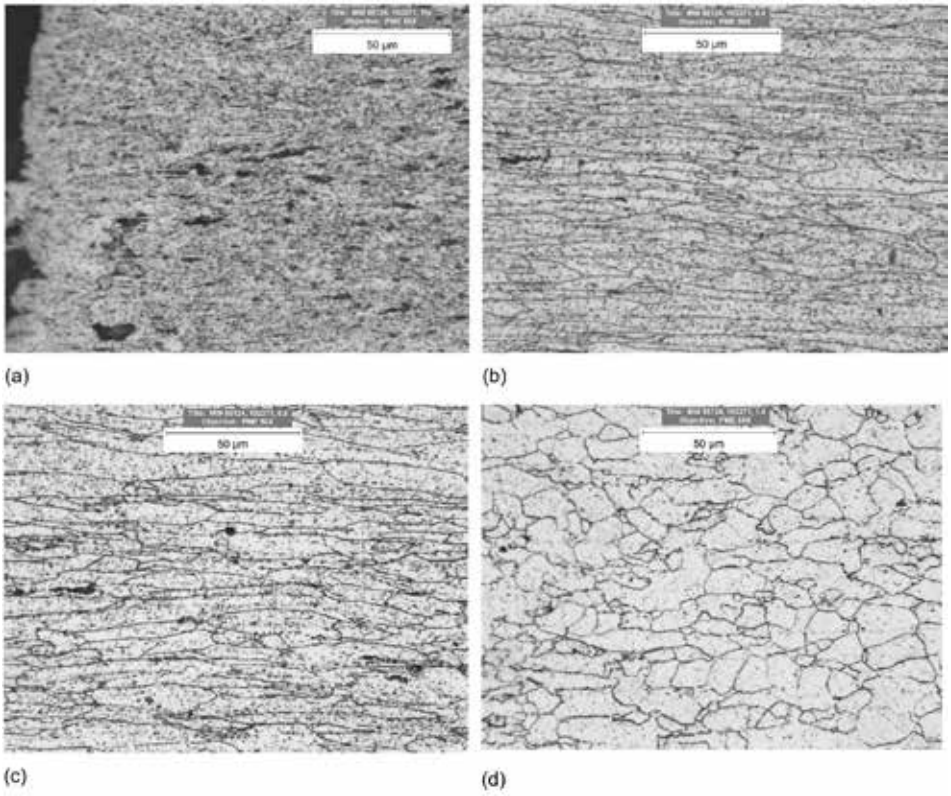


Figure 4: Optical micrographs sample crept at 125 MPa and 923 K: (a) at the tip of the fracture, (b) quarter of fracture length away from the fracture surface, (c) halfway from fracture surface, and (d) toward the grips.

CONCLUSION

Kanthal APMT is candidate material for accident-tolerant fuel cladding in nuclear energy application. Traditional Zr-based alloys used for fuel cladding, though they have lower neutron cross section, have lower thermal stability at extremely high temperatures, especially in case of loss-of-coolant accident. The alloy has excellent high temperature oxidation resistance as it can form dense, adherent, passive chromia and alumina layers depending on its environment. Creep study of the alloy showed reasonable high temperature/high stress creep property. The alloy needs to be further studied in irradiated and unirradiated conditions prior to industrial application.

REFERENCE

[1] R. B. Rebak, "Versatile oxide films protect FeCrAl alloys under normal operation and accident conditions in light water power reactors," vol. 70, no. 2, pp. 176–185.

[2] A. Naceur and G. Marleau, "Neutronic analysis for accident tolerant cladding candidates in CANDU-6 reactors," vol. 113, pp. 147–161.

[3] S. J. Zinkle, K. A. Terrani, J. C. Gehin, L. J. Ott, and L. L. Snead, "Accident tolerant fuels for LWRs: A perspective," vol. 448, no. 1, pp. 374–379.

[4] K. A. Terrani, L. L. Snead, and J. C. Gehin, "Microencapsulated fuel technology for commercial light water and advanced reactor application," vol. 427, no. 1, pp. 209–224.

[5] R. B. Rebak, "Alloy selection for accident tolerant fuel cladding in commercial light water reactors," vol. 2, no. 4, pp. 197–207.

[6] K. A. Terrani, "Accident tolerant fuel cladding development: Promise, status, and challenges," vol. 501, pp. 13–30.

[7] 6-C-1-3 APMT tube datasheet, www.kanthal.com

[8] T. M. Copeland-Johnson, C. K. Nyamekye, S. K. Gill, L. Ecker, N. Bowler, E. A. Smith, and R. B. Rebak, "Characterization of kanthal APMT and t91 oxidation at beyond design-basis accident temperatures," vol. 171, p. 108598.

[9] "Oxidation characteristics of two FeCrAl alloys in air and steam from 800°c to 1300°c | SpringerLink."

[10] Hauffe, "High temperature oxidation of metals," P. Kofstad John Wiley and Son, New York 1966, 340 s," vol. 18, no. 10, pp. 956–957. eprint: https://onlinelibrary.wiley.com/doi/pdf/10.1002/maco.19670181017.

ABOUT THE AUTHORS

Triratna Shrestha is the manager of Materials Analysis and Central Coatings Laboratory at Metcut Research Inc. He has worked with coatings for aerospace, petrochemical, and power-generation applications and has expertise in materials testing and evaluation. He manages Central Coatings Laboratory for GE Aviation and is involved in failure analysis and continuous improvements. He received his B.S and Ph.D. in Materials Science and Engineering from the University of Idaho. He can be reached at tshrestha@metcut.com.

Arnold Pradhan is a graduate research assistant in nuclear engineering at the University of Idaho, Idaho Falls. His areas of interest are nuclear materials, neutronics, and simulation.

ceramics expo

NORTH AMERICA'S LEADING ADVANCED CERAMIC INDUSTRY EXPO AND CONFERENCE

AUGUST 29 - 31, 2022 // HUNTINGTON CONVENTION CENTER OF CLEVELAND, OHIO, USA

*AUG 29: EXHIBITOR AND VIP NETWORKING RECEPTION | AUG 30-31: EXHIBITS AND CONFERENCE

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

In partnership with

The American Ceramic Society
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.

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

Boron steels are used extensively as an inexpensive replacement for more highly alloyed steels. Small additions of boron can be beneficial in increasing in hardenability.

Understanding the effect of boron in steels

In this column, we will discuss the effect of boron additions to steel and its influence on properties.

Boron, B, is an element with an atomic number of 5, adjacent to Carbon, C, on the periodic table. Boron has an atomic weight of 10.81 g/cm^3 and is a solid at standard temperature and pressure. The typical crystal structure is rhombohedral and was discovered by Joseph Gay-Lussac and Louis Jacques Thenard in 1808. Elemental boron is difficult to produce because it readily oxidizes.

Boron is most found as borax ($Na_2B_4O_5(OH)_4{\cdot}8H_2O$) or boric acid. There are approximately 100 borate minerals known [1]. Boron is not found in uncombined form on Earth but is occasionally found as a metalloid in meteoroids.

Boron is used in many different applications. When woven as a fiber, it is used in aerospace to create lightweight composite structures. These woven fibers have also been used to create high-end consumer shafting, such as lightweight fishing rods and golf club shafting.

Borosilicate glass is another use of boron. This type of glass has a low coefficient of expansion and is used for telescope lenses and mirrors. It has good resistance to thermal shock and is used for labware and cookware. In the United States, it is trademarked as PYREX™.

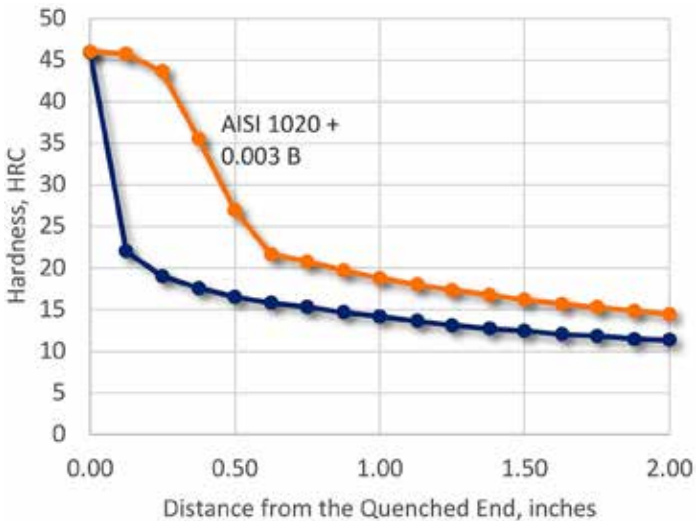


Figure 1: Comparison of the Jominy curves, as calculated by JMatPro for an SAE 1020 containing 0.2% C, 0.25% Si, and 0.5% Mn and an identical steel containing 0.003% B.

APPLICATION IN STEEL

Boron is commonly added to steels to increase hardenability. Boron is added at a very low concentration of 0.0015 to 0.003 percent to increase the hardenability of low carbon steel. Boron is added to molten steel as a ferro-boron which can contain as much as 20 percent boron. The ferro-boron is typically added to the ladle after all the deoxidizers and other alloying elements have been added because boron reacts strongly with oxygen, carbon, and nitrogen.

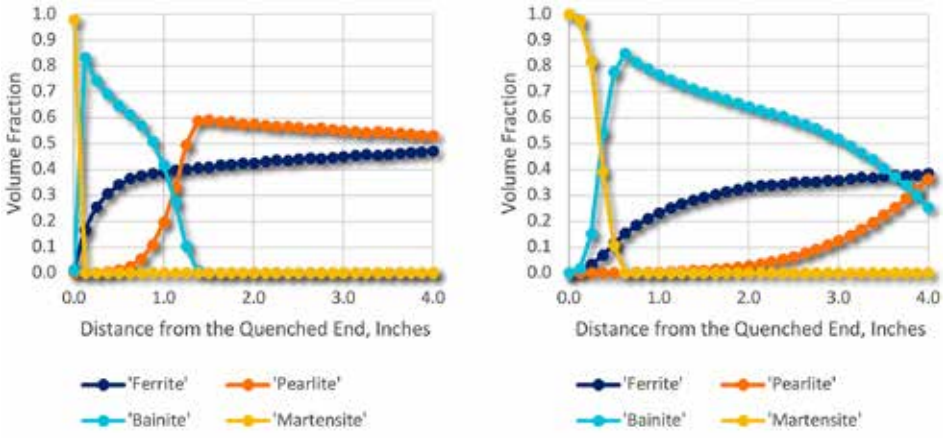


Figure 2: Comparison of phases present as calculated by JMatPro as a function of the distance from the quenched end for a SAE 1020 steel containing 0.2%C, 0.25% Si, and 0.5% Mn and an identical steel containing 0.003% B.

Boron reacts with oxygen to form B_2O_3, and reacts with carbon to form a boron cementite, $Fe_3(CB)$. Or an iron boron carbide, $Fe_{23}(CB)_6$. Boron reacts with nitrogen to form boron nitride (BN). To prevent loss of effectiveness of boron due to loss to oxidation, the use of higher aluminum or titanium content is usually used during melting.

During rolling and hot working, boron steels are like carbon steels. Carbon and boron have similar diffusion coefficients, so loss at the surface can occur at high temperatures and oxidizing atmospheres. Use of low nitrogen atmospheres is recommended to prevent the formation of boron nitride (BN).

If the boron content exceeds approximately 0.007 percent, hot shortness during rolling or forging can occur. Poor impact properties also occur at this higher boron content. The hot-shortness and poor impact properties are due to a low-temperature iron-carbon-boron eutectoid ($Fe/Fe_3C/Fe_2B$) that forms when the boron content exceed 0.007 percent [2]. Boron steel usually has a "B" in its description, for instance, an SAE 1035 steel that has had boron added to increase hardenability is designated as a SAE 10B35 steel.

Boron can have different locations in the iron lattice. Like carbon, boron has been found to occupy interstitial sites [3]. This was based

on X-ray diffraction measurements of the austenite lattice parameter [4]. As temperature is decreased, the austenite lattice parameter of boron-containing steel was increased. This suggests that the boron migrates from the interstitial sites to the grain boundaries.

The biggest advantage to adding boron to a steel is the increase in hardenability that occurs. Even very small amounts of boron can drastically increase the hardenability of even low carbon steels. Boron tends to segregate to austenite grain boundaries, which then retards the austenite to ferrite, pearlite, and bainite transformation [5]. Because of the segregation of boron to the grain boundaries, embrittlement can occur. A reduction in toughness and ductility can also occur [6].

The increase in hardenability is illustrated by Figure 1. In this figure, the Jominy curve of a simple SAE 1020 steel (0.2 %C, 0.25% Si, 0.5% Mn) is compared to the calculated Jominy curve of an identical steel with 0.003 percent boron added.

As can be seen from Figure 1, the very low hardenability of SAE 1020 is increased substantially by the addition of 0.003 percent boron. The depth of hardening is increased approximately from J = 1/16" to J = 4/16". This is a large improvement that can be readily achieved.

Looking at more detail into the microstructure make-up (Figure 2), as a function of quench rate (distance from the quenched end), it can immediately be seen that the boron-containing steel at the quenched end is entirely composed of martensite, while the non-boron steel has a reduced martensite content. In the boron-containing steel, the microstructure is predominantly martensite out to approximately 0.25", while at 0.25" from the quenched end, the non-boron sample contains only bainite and ferrite.

Boron is unique in that it has no effect on the martensite start (M_s) transformation temperatures. During tempering, an increase in embrittlement can occur, and different temperatures are required for tempering to achieve the same hardness [6].

CONCLUSIONS

In this article, we have shown the beneficial increase in hardenability by small additions of boron. Boron steels are used extensively as an inexpensive replacement for more highly alloyed steels.

Should there be any questions or comments regarding this article, or suggestions for other articles, please contact the editor or myself.

REFERENCES

[1] C. Klein and B. Dutrow, Manual of Mineral Science, New York: John Wiley & Sons, 2007.

[2] S. K. Sarna, "ISPAT Guru," 21 11 2014. [Online]. Available: https://www.ispatguru.com/boron-in-steels/.

[3] J. E. Morral and T. B. Comeron, "Boron Hardenability Mechanisms in Steel," TMS/AIME, p. September, 1979.

[4] R. M. Goldhoff and J. W. Spretnak, "Distribution of boron in gamma iron grains," JOM, vol. 9, pp. 1278-1283, 1957.

[5] Key to Metals AG, "Total Materia - Boron in Steel: Part Two," November 2007. [Online]. Available: https://www.totalmateria.com/page.aspx?ID=CheckArticle&site=kts&NM=214.

[6] B. M. Kapadia, "Effect of Boron Additions on Toughness of Heat Treated Low-Alloy Steels," Journal of Heat Treatment, vol. 5, no. 1, pp. 41-53, 1987.

ABOUT THE AUTHOR

D. Scott MacKenzie, Ph.D., FASM, is senior research scientist-metallurgy at Quaker Houghton. He is the past president of IFHTSE, and a member of the executive council of IFHTSE. For more information, go to www.houghtonintl.com.

TONY TENAGLIER
HEAT TREAT PROCESS ENGINEER ///
HITCHINER MANUFACTURING

The best way to fix a mistake is by designing solutions with the correct actions, not covering up problems to avoid getting fired.

The process of problem solving

The corrective action. That dreaded tally on one's personal record at work that is available for all of upper management to see a mistake that you made and got caught. Everything was going fine until it got exposed in an audit or customer escape. Now, the work of fixing it seems more like a way to protect your job instead of realizing its potential to capture a process improvement in a robust way.

No one likes to get called out for doing something wrong. It can be embarrassing. Sometimes, though, employees are relieved by mistakes being caught so the process can finally be made right. In the world of heat treat, AMS2750 clearly indicates a corrective action must be taken to get the process/equipment back running. So, there is no running away. But there really should be no hiding from issues that go wrong. The rules are there to protect the players and the customers. Just as with soccer's yellow and red cards, it's obviously not the goal to get one — but it protects players' safety. Same too in manufacturing. The goal isn't to get Corrective Action Reports (CAR), but they happen. It's part of the "game." So instead of seeing a failure as something to dread, see a failure as a potential to correct and put the right action in place. The correct action.

A common method is the 8D (D = discipline) corrective action system most companies use in identifying a problem, correcting the problem, and determining if the corrective action is effective.

D0 – IMMEDIATE ACTION

Corrective actions can be defined according to RM13000 8D Problem Solving Method as getting out to the customer, an internal issue, or a simple find-and-fix the problem. RM13000 suggests when to use a full 8D, 4D, or even a 2D problem-solving approach. Whichever approach, it is about discipline in completing the steps. That is what makes the difference.

D1 – DEFINE TEAM

Once the finding is established, a cross-functional team is then assembled. RM13004 Defect Prevention Quality Tools to Support APQP & PPAP Figure 21 indicates four to five people have the best effectiveness for a cross functional team.

D2 – DESCRIBE PROBLEM

In the aerospace industry, there is the mantra: "Do what you say, say what you do." Procedures will say what operations need to be performed, while the team will do the actual work to accomplish the necessary tasks to make conforming parts. Often what happens is that a corrective action is implemented because something is being done that isn't stated in a procedure. Or it states that something should be done but is not actually being performed. In describing the problem, it is important to be specific with the actual requirements.

D3 – INTERIM CONTAINMENT

Containment is critical, especially since AMS2750 makes clear the expectation of containment on a corrective action. This is where it is helpful to have items such as logbooks, trouble reports, and other data that ensures specific work orders that have been affected are OK. Sometimes in heat treat, the containment action is simply a review of a potentially failed TUS on past orders from the last successful due date. What is good about knowing the importance of corrective actions is that in the design of the process, measures can be put in place. E.g., Instrumentation Type B requires a workload thermocouple and aerospace requirements for heat treat often require these workload thermocouples placed in the cold and hot zone of the furnace. Even with a failed TUS, review of orders with successful run charts of the hot and cold thermocouples within temperature tolerance along with metallurgical testing, can be deemed successful while necessary furnace repairs are made to get the furnace back to working condition.

D4 – DETERMINE CAUSES

Root cause analysis is the step regarding the questions of "why" something failed to meet requirements. A 5-Why approach is commonly used. But a common root cause analysis is often deduced to human error. Human factor is not a root cause as indicated in RM13010

Human Factors. In the process of asking why, consider human error as skill-based errors or mistakes implying there is a deeper root cause in the process.

D5 – DEVELOP CORRECTIVE ACTION(S)

From the root cause, the corrective action resolves the root cause. If the "5-Why" approach is used, the last "why" should correspond to the specific corrective action. E.g., Why – Calibration requirements were not flowed properly to the contractor. Corrective Action: Develop purchase specification to attach automatically with PO on those gauge types for future orders.

D6 – IMPLEMENT CORRECTIVE ACTION(S)

Once a corrective action is developed and defined, it must be implemented. A good root cause and clear corrective action makes for a clear pathway to successfully implement the corrective action. If work instructions are updated, always remember to train the team!

D7 – PREVENTIVE CORRECTIVE ACTION(S)

In this step, it is important to verify the corrective action to properly identify affected parts of the process and to even determine if other areas could be potentially impacted from such a similar corrective action. This is also an opportunity for reflecting on the lessons learned. Who wants to make the same mistake twice in a different area?

D8 – RECOGNIZE TEAM

Companies sometimes experience droughts of positive affirmations to their team. Becoming complacent to what made them successful. It is important to recognize the work each team player makes to the company's overall success.

CHECK EFFECTIVENESS

In following up on the entire corrective action, it is beneficial to follow up months down the road to see if the process changes were indeed effective. Setting calendar reminders with questions for follow-up is a good way to objectively show the proper effectiveness review.

Even though corrective actions point out areas of improvement and mistakes in a process, they are also opportunities for the team to gather, collectively design a better process, and celebrate the forever process of continual improvement. Companies should embrace corrective actions not as tallies against their work performance, but rather opportunities to document and improve upon the process.

Suggested further reading

» "Managing the Risks of Organizational Accidents," by James Reason.

» "The Goal," by Eliyahu Goldratt.

» RM13000 8D Problem Solving Method.

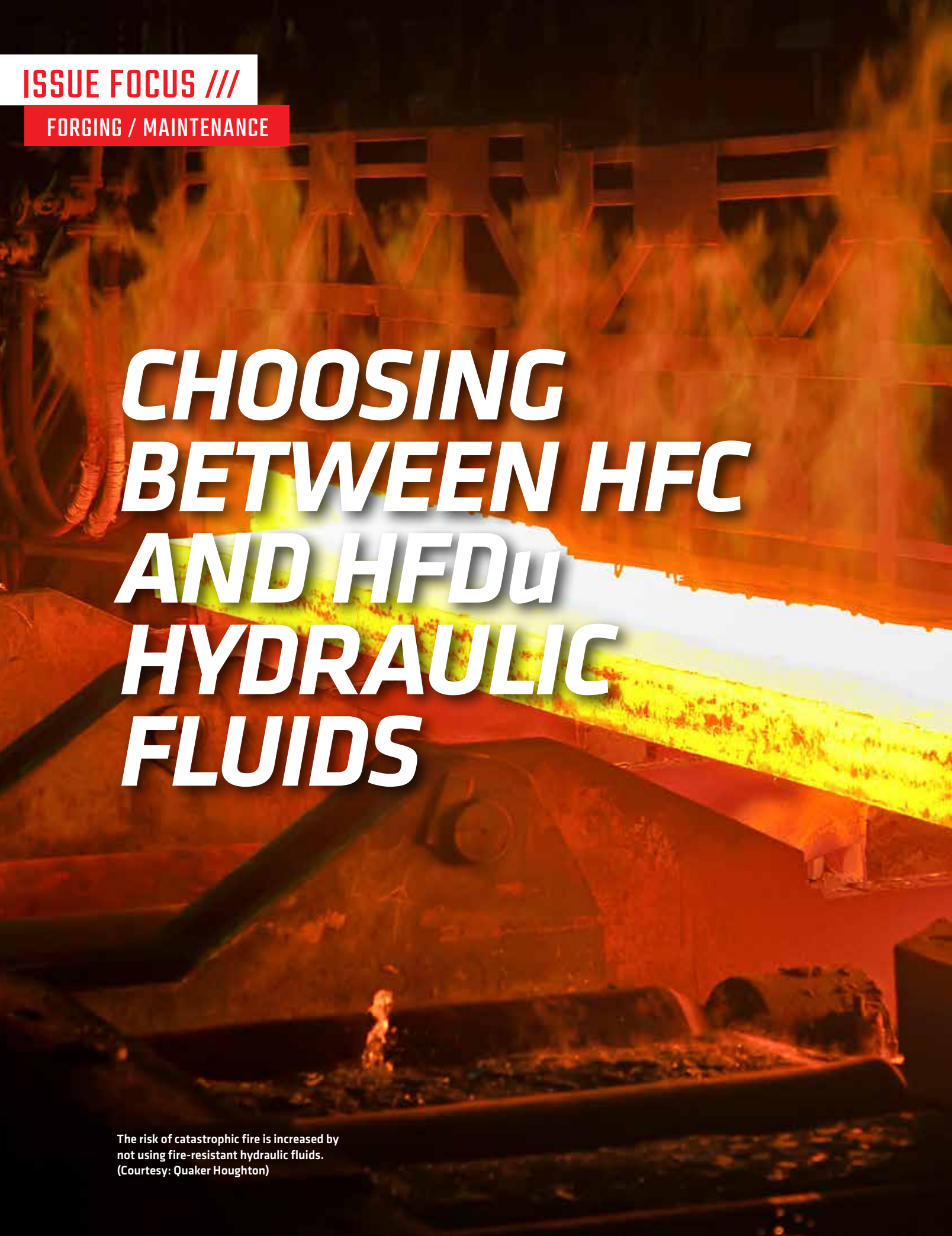
» RM13004 Defect Prevention Quality Tools to Support APQP & PPAP.

» RM13010 Human Factors.

ABOUT THE AUTHOR

Tony Tenaglier is the heat treat process engineer at Hitchiner Manufacturing. He earned both a B.S. in material science engineering and an M.A. in psychology. You can contact Tenaglier at tony_tenaglier@hitchiner.com.

CHOOSING BETWEEN HFC AND HFDu HYDRAULIC FLUIDS



The risk of catastrophic fire is increased by not using fire-resistant hydraulic fluids. (Courtesy: Quaker Houghton)

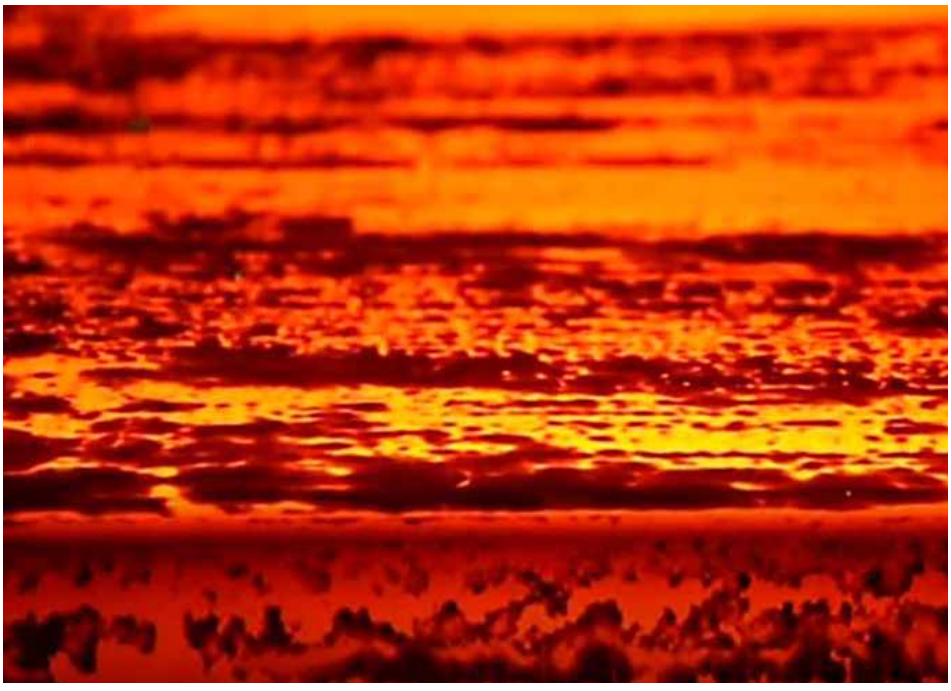
When a mineral oil-based lubricant leak occurs in an area where there is an ignition source or near equipment running at high temperatures, it could lead to a catastrophic fire; using HFC or HFDu hydraulic fluids can improve safety and enhance performance; however, there are pros and cons to each.

By RONALD KNECHT

While both HFC and HFDu hydraulic fluids reduce fire risk, improve operation safety, and enhance environmental performance, significant differences exist. Standing at 50 to 55 percent market adoption, HFC is a water-based fluid that can be used in all industries where there is a major risk of fire. In contrast, HFDu is a water-free fluid that's designed to replace anti-wear, mineral oil-based hydraulic fluids and has a market adoption of 20 to 25 percent.

While the key role of both fluids is to protect against fire and the consequential financial losses caused by application downtime, choosing which to adopt primarily comes down to the specific needs of the application. For example, in applications where workers are present such as die casting, the uncompromising fire resistance of HFC will often be favored. While in applications free of any human presence such as a blast furnace, the enhanced system reliability offered by HFDu will generally drive decision-making.

While there is scope to convert applications from HFC to HFDu, the process is costly, requiring extensive flushing and testing. It's therefore important to understand which hydraulic fluid makes the most sense from a safety, cost, and environmental perspective from the beginning to optimize the associated benefits of increased productivity, reduced downtime, and enhanced work safety.



HFC and HFDu hydraulic fluids are becoming more common within the engineering and manufacturing industry. (Courtesy: Quaker Houghton)

MAKING THE CASE FOR HFC WATER GLYCOL HYDRAULIC FLUIDS

HFC, or water glycol fluids, are the most widely used fire-resistant hydraulic fluids because of their cost-effectiveness and their combination of excellent fire-resistant properties with good lubrication performance. Widely used in steel making, die-casting foundries, pressure-molding applications, and the automotive industry, HFC remains the market standard.

In addition to offering uncompromising fire resistance, other factors for choosing HFC include its OEM endorsements and comparable pricing with mineral oil. Unlike HFDu, HFC is also miscible with process water, which remains a key environmental consideration. However, some compromises do exist with HFC that need to be taken into consideration.

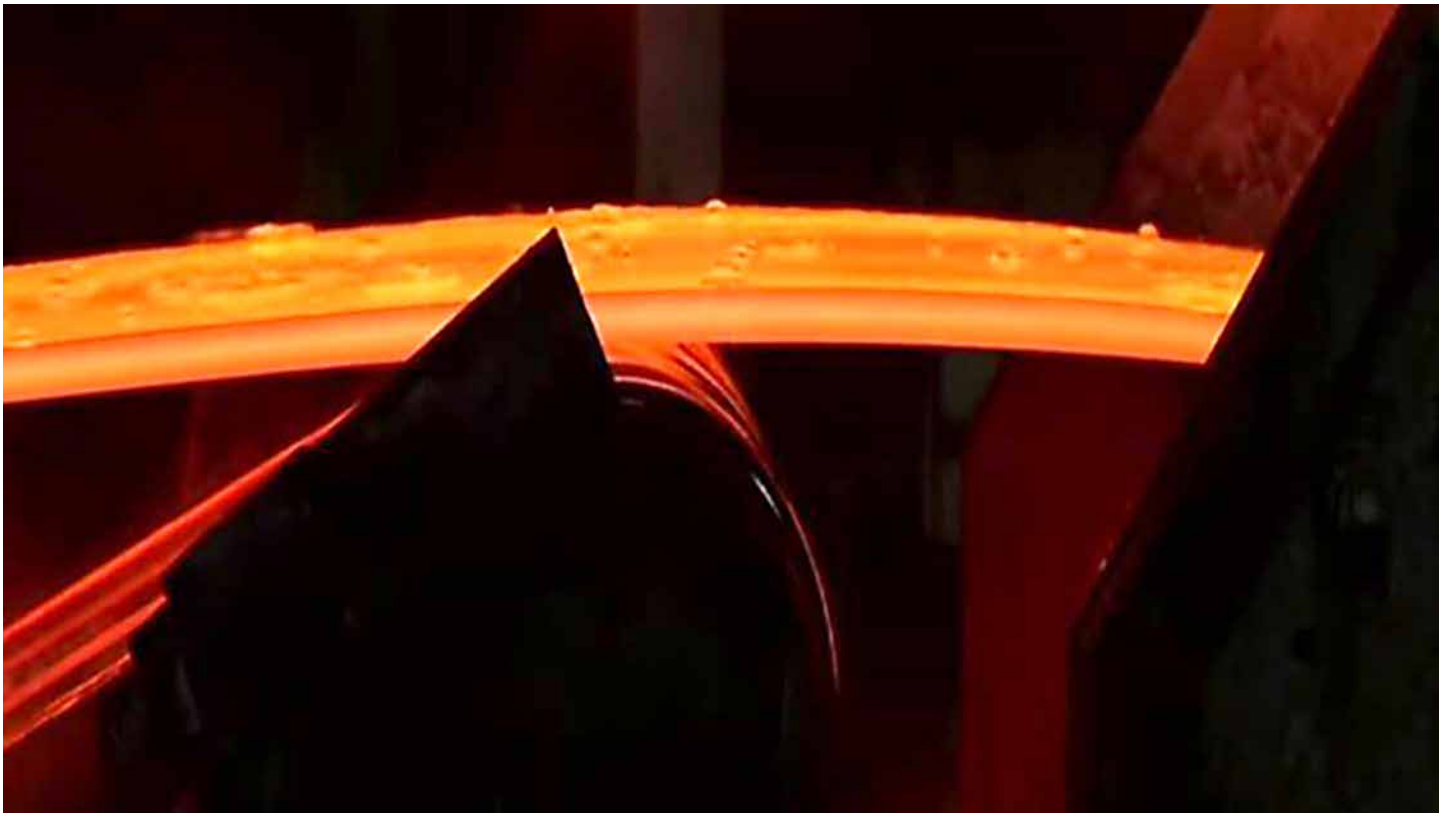
Ongoing maintenance of HFC is essential, with regular sampling and analysis required to protect against costly component damage. A properly maintained HFC operated system can behave very reliably.

The impact of neglected maintenance will often be a period of unplanned downtime, which needs to be meticulously scheduled to minimize the associated inconvenience and revenue losses. However, with an effective maintenance plan in place, the long-term cost efficiencies and safety benefits of HFC are beyond question.

While their fire protection credentials are enviable, water-based fluids can result in a shorter service life for components due to corrosion and cavitation when maintenance is neglected. Hydraulic design limitations also exist in terms of pressure limitations, galvanized pipes, and paint inside tanks. In terms of limitations on flow and pressure, this can be resolved with the introduction of an HFDu, yet the associated costs may make HFDu a more viable long-term option.

THE ARGUMENT FOR HFDU SYNTHETIC WATER-FREE HYDRAULIC FLUIDS

Widely acknowledged as the best fire-resistant alternative to mineral oil despite being more expensive, HFDu fluids are designed to replace



A single spark from hydraulic machinery can cause costly production downtime if fire-resistant fluids are not used. (Courtesy: Quaker Houghton)

anti-wear, mineral oil-based hydraulic fluids used in applications where fire hazards exist. Additionally, they can be used in environmentally sensitive hydraulic applications without compromising the overall hydraulic system operations and design.

HFDu fluids are based on high-quality, synthetic, organic esters and carefully selected additives and do not contain water, mineral oil, or phosphate ester. HFDu fluids deliver excellent and reliable hydraulic fluid performance. While initial fluid investments may be higher, HFDu fluids generally result in a total lower cost of ownership due to reduced downtime from maintenance and better lubrication, resulting in less energy consumption. Additionally, HFDu products have a long fluid life, can perform at higher pressure, and enhance system reliability.

Some compromises do exist, however, as HFDu is two to three times more expensive than mineral oil. Its fire resistance meets international standards like Factory Mutual but is also not equal to its water-based alternatives, which is why HFDu fluids are often chosen for applications where there is less risk to human life such as blast furnaces and where reliability of the system is prevailed.

Finally, HFDu is not miscible with water and, as such, doesn't mix with wastewater. It can be skimmed off, which can have an impact on chemical oxygen demand (COD) and more positive environmental and regulatory consequences. As ever, there needs to be a holistic view taken when weighing the relevant benefits of water-free and water-based solutions.

BEST-IN-CLASS AND FIT FOR PURPOSE

In conclusion, it's clear both HFC and HFDu hydraulic fluids offer a wealth of benefits. Deciding which makes the most sense to use ultimately comes down to what's best for any specific application. Therefore, fire resistance, environmental impact, thermal stability, fluid maintenance, system reliability, the total cost of ownership, and price all need to be given serious consideration.

It's clear both HFC and HFDu hydraulic fluids offer a wealth of benefits. Deciding which makes the most sense to use ultimately comes down to what's best for any specific application.

It's here that Quaker Houghton's expertise in fire resistant hydraulic fluids can provide clarity and guidance. The company has the world's leading brands of fire-resistant hydraulic fluids. HOUGHTOSAFE for HFC includes excellent corrosion inhibition, excellent lubrication, and low heat release. While HFDu QUINTOLUBRIC has properties that strongly limit the spread of fire, reduce environmental impact, and lower the total cost of operation. By being able to offer both best-in-class HFC and HFDu products, Quaker Houghton can be completely objective in its recommendations, taking onboard the unique requirements and challenges of every application.

ABOUT THE AUTHOR

Ronald Knecht is global OEM manager – Hydraulics & Lubricants at Quaker Houghton. Quaker Houghton is a global leader in industrial process fluids. With a presence around the world, including operations in more than 25 countries, its customers include thousands of the world's most advanced and specialized steel, aluminum, automotive, aerospace, offshore, can, mining, and metalworking companies. For a closer look at the full Quaker Houghton range of fire-resistant hydraulic fluids, go to www.fireresistantfluids.com.

THERMAL
TECHNOLOGIES EXPO

AUGUST 29* – 31, 2022
CLEVELAND, OHIO, USA

NORTH AMERICA'S ONLY FREE TO ATTEND EXHIBITION AND CONFERENCE DEDICATED TO THE THERMAL ENGINEERING SECTOR

SOURCE the latest thermal technology and innovations from leading suppliers & manufacturers

UNDERSTAND the latest industry developments from expert speakers and game-changers

GAIN A 360° VIEW of the thermal engineering sectors: including automotive, aerospace and defense, energy/ energy storage, telecom/5G and electronics

STAY INFORMED on the industry needs and latest trends through the free-to-attend conferences

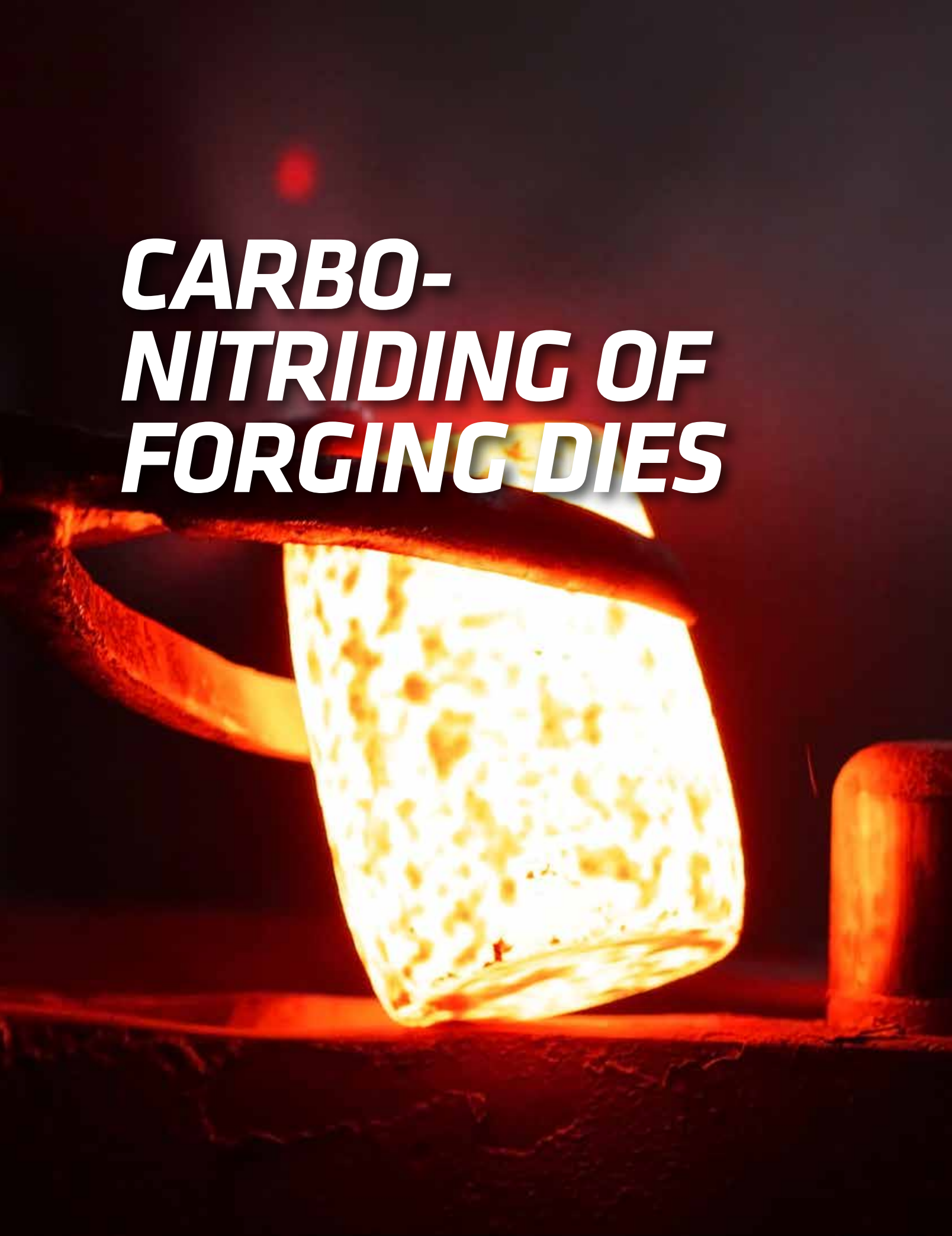
Discover more at
THERMALTECHEXPO.COM

Co-located with

ceramics expo

HIGH PERFORMANCE PLASTICS EXPO
North America

AUG 29: VIP & EXHIBITOR RECEPTION (INVITE ONLY)



CARBO-NITRIDING OF FORGING DIES

The wear resistance of forging dies can be improved by carbo-nitriding; in order to produce a sufficiently deep surface layer hardened with nitride precipitates and at the same time achieve sufficient core strength, the heat treatment must be adapted to the die material.

By DR. STEFANIE HOJA, HEINRICH KLÜMPER-WESTKAMP, and DR. MATTHIAS STEINBACHER

Forging dies have to resist high mechanical and thermal loads. Therefore, they are usually nitrided. Former investigations showed that the abrasive wear at the critical parts of the dies is much higher than the nitriding hardness depth. Carbo-nitriding offers the possibility to increase the hardness depth in shorter treatment times because of the higher treatment temperature. The (carbo-)nitrided surface region obtains a better hardness at elevated temperatures and a better wear resistance than the untreated steel. In order to create a wear- and corrosion-resistant compound layer at the surface, a nitriding process step can be conducted after carbonitriding. The present work deals with developing a carbo-nitriding treatment for forging dies and investigations on the wear resistance of the created surface zones in model wear tests and tool life time experiments under industrial conditions. The aim of this work was to produce heat- and wear-resistant precipitation layers in hot working tool steels in economical treatment durations.

1 INTRODUCTION

Forging dies are usually used at temperatures above 200°C. The requirements for such tools result from the specific stress and are generally of a high tempering and heat resistance, a sufficient wear resistance, a high ductility, a high thermal conductivity, a low hot cracking sensitivity, good sliding properties of the surface, and a low tendency to stick [1].

Nitriding and nitrocarburizing can optimize not only the wear behavior but also the temperature resistance of the tool surface areas [2,3]. At the same time, the toughness in the core remains largely unaffected, provided the nitriding temperature is below the tempering temperature. The increased tempering resistance and high-temperature strength of the nitrided tool-edge zone compared to the unnitrided material result from the high hardness and residual compressive stresses in the diffusion layer [4].

Although nitrided hot working tools are very brittle and tend to crack due to the thermal and mechanical stresses during forging, the average tool life of nitrided tools is about 40 percent higher than that of tools that have only been quenched and tempered [3,5].

Depending on the load, the compound layer or the precipitation layer are decisive for the wear behavior. The high hardness of the iron nitrides and carbo-nitrides in the compound layer causes an increase in resistance to abrasive wear. However, in previous investigations, it was shown the compound layer in the most heavily stressed areas is no longer present after only a few forming operations [6].

In higher alloyed steels such as tool steels, the precipitation layer also exhibits high hardness and thus high resistance to abrasive wear due to the alloying element nitrides. The precipitation layer is also responsible for the increased hot and fatigue strength of nitrided components and tools. The residual compressive stresses generated by the nitride formation can be equated to a mean stress in their effect on fatigue strength and act as a stop for cracking [5,7].

Although nitrided hot working tools are very brittle and tend to crack due to the thermal and mechanical stresses during forging, the average tool life of nitrided tools is about 40 percent higher than that of tools that have only been quenched and tempered. (Courtesy: Shutterstock)

Together with the knowledge of the mechanisms involved in nitriding and nitrocarburizing [8], it is possible to selectively set very different surface conditions in components and tools [9]. In [5], when a series part made of 100Cr6 was forged with nitrided tools made of the material X38CrMoV5-3, an increase in tool life of 18 percent was achieved by increasing the diffusion depth from 0.03mm

to 0.43mm with approximately the same compound layer.

In former investigations, it was shown the tolerated abrasive wear at mostly loaded parts of the dies is much higher than the nitriding hardness depth [10]. Because an increase in the nitriding hardness depth needs treatment times for several hundreds of hours, an increase in the nitriding hardness depth is uneconomical in most cases. Another possibility to improve the wear- and heat-resistance of the boundary layer is carbo-nitriding. Carbo-nitriding is a variant of case hardening, in which a simultaneous diffusion of carbon and nitrogen into the treated material occurs. In contrast to nitriding, the carbo-nitriding is carried out at temperatures above A_{C1} and A_{C3}, and only a diffusion layer but no compound layer is formed. Typical temperatures for gas carbonitriding are 850-950°C. Thanks to the higher temperature compared to nitriding, higher hardening depths can be reached in economical treatment times.

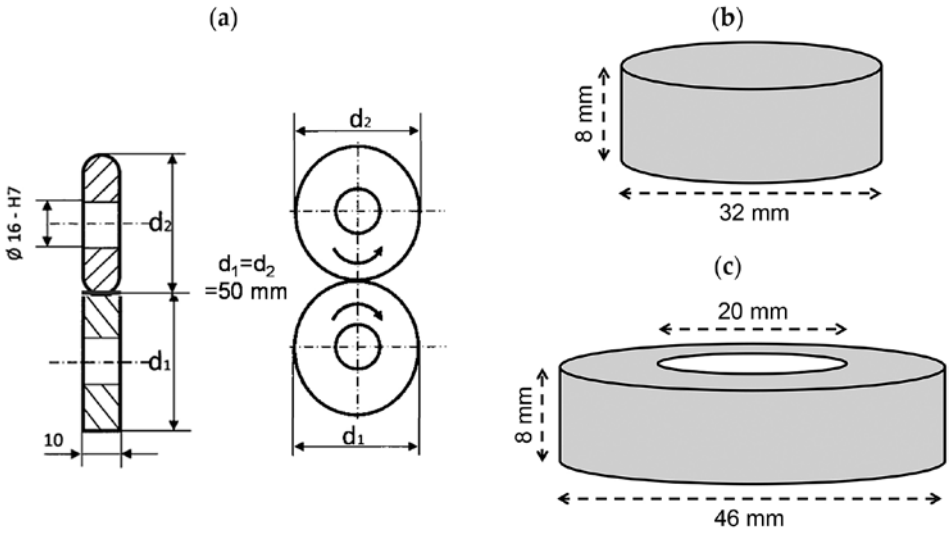


Figure 1: Geometry of the specimens for the model wear tests. (a) Two-disc test. (b) Ball-on-disc test. (c) Thermal fatigue test.

The increase in hardness during carbo-nitriding is based on the formation of carbon-rich martensite in the material's surface during quenching. Due to the high carbon content in the carbo-nitrided layer, there can also occur an amount of retained austenite, which leads to a lack of hardness. However, the retained austenite can also improve the possibilities of carbo-nitrided parts. For gearings, it was shown that retained austenite together with fine distributed carbonitrides and the compressive stresses in the carbo-nitrided layer can stop both the crack growth by absorbing deformations and the transformation into martensite [11].

Carbo-nitriding is mainly used for machine parts of steels with carbon amounts lower than 0.2 percent and low concentrations of other alloying elements in order to improve the mechanical properties and heat resistance of the surface layer and to replace more expensive high-alloy steels [12].

Since hot working steels have a high amount of nitride-forming elements in addition to the martensitic hardening, a precipitation hardening takes place by fine distributed nitrides and carbo-nitrides [13,14]. These precipitations are stable at augmented temperatures during service and can improve the wear resistance.

Although carbo-nitriding implies a high potential to improve the boundary area of hot working steels as well, there are only a few investigations with this aim [13,14]. The steel that was investigated by Jasinski et al. formed a martensitic-bainitic microstructure with chromium carbides of the types M_7C_3 and $M_{23}C_6$, chromium nitrides and retained austenite. The mechanical properties of this microstructure were not investigated.

The investigations of the present work concern the development of a carbo-nitriding treatment for the hot working steel X38CrMoV5-3 (1.2367) in order to form heat-resisting peripheral areas with fine distributed precipitations for improved wear and tempering resistance as well as the investigation of the wear behavior of the carbonitrided layers. For the evaluation of the mechanical properties, model wear tests and life-time investigations on forging dies under practical conditions were conducted. The aim of this work was to produce heat- and wear-resistant precipitation layers in hot working tool steels in economical treatment durations in order to improve the nitriding hardness depth already prior to nitriding or replace the nitriding treatment by carbonitriding.

T in C	800	850	900	950	1000
Res. NH3 in ppm	3500	3500	2000	800	300
Nitrogen concentration in ma. %	1.71	1.76	1.47	1.26	0.18

Table 1: Measured NH_3 concentration during carbo-nitriding in the Solo system for 8 hours with C_P = 0.6% and a target residual ammonia concentration of 3,500 ppm at different temperatures and resulting nitrogen concentration at the surface of the material X38CrMoV5-3.

No.	Heat Treatment
A	950 C 8 h CP = 0.35% NH3 = max./oil
B	950 C 8 h CP = 0.35% NH3 = max./ 1000 C 0.5 h CP = 0.35% NH3 = max./oil
C	950 C 8 h CP = 0.35% NH3 = max./oil 1050 C 1 h vacuum/oil

Table 2: Heat-treatment parameters for the carbo-nitriding of the material X38CrMoV5-3.

2. MATERIAL AND METHODS

2.1 Material

As an investigation material, the frequently used hot working steel X38CrMoV5-3 (1.2367) with 0.41 ma.%C, 4.88 ma.%Cr, 2.87 ma.%Mo, and 0.60 ma.%V was chosen. The chemical composition was determined by OES.

For the investigations of the wear behavior, special samples like those shown in Figure 1 were needed. The ball-on-disc sample geometry was also used for the development of the heat treatment.

2.2 Heat Treatment

For the carbo-nitriding heat treatment, two heat-treating systems were available: the Solo system with a steel retort and the Aichelin system with a brickwork interior. The carbo-nitriding in the Solo system (useful volume 30L) was carried out in a gas atmosphere of nitrogen-methanol (approx. 40% N_2, 40% H_2, and 20% CO) with 2% propane and ammonia as a nitrogen carrier. The total gassing was 500 L/h. The C-potential was controlled by a nitrogen probe. The measured variable for the ammonia was the residual ammonia in the exhaust gas. The ammonia addition in carbo-nitriding was selected to be as high as possible. The carbo-nitriding in the Aichelin system

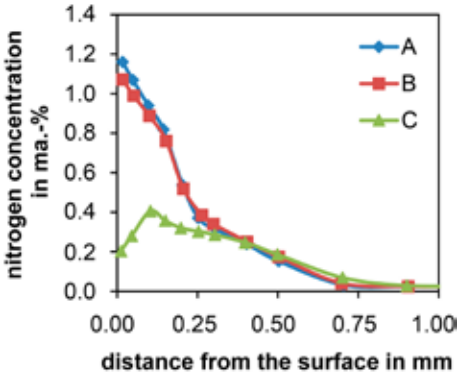


Figure 2: Nitrogen profiles after carbo-nitriding of the material X38CrMoV5-3 with different process management (for heat-treatment parameters of A, B, and C see Table 2).

(useful volume 400L) was carried out in a gas atmosphere of nitrogen-methanol-propane. The total gassing was 3m^3/h. As a nitrogen carrier, 35 vol.% ammonia was added. The resulting residual ammonia was approximately 2,500 ppm at 850°C and approximately 300 ppm at 950°C.

For the discussion of the microstructure, the specimens were only carbo-nitrided (and hardened) in order to compare the differences in the microstructure of the carbo-nitrided layers after different processing. The specimens for the wear tests were also tempered after carbo-nitriding to obtain a practical relevant state. Tempering was conducted three times for 2 hours at 560-600°C.

Some specimens (and forging tools) were also nitrided after carbo-nitriding. The nitriding treatment of the specimens for the wear and forging tests was performed for 8 hours in a gas nitriding system with a controlled nitrogen potential of $K_N = 3$. The nitriding temperature was 520°C. In addition, the only nitrided specimens investigated as a reference were vacuum hardened and tempered prior to nitriding.

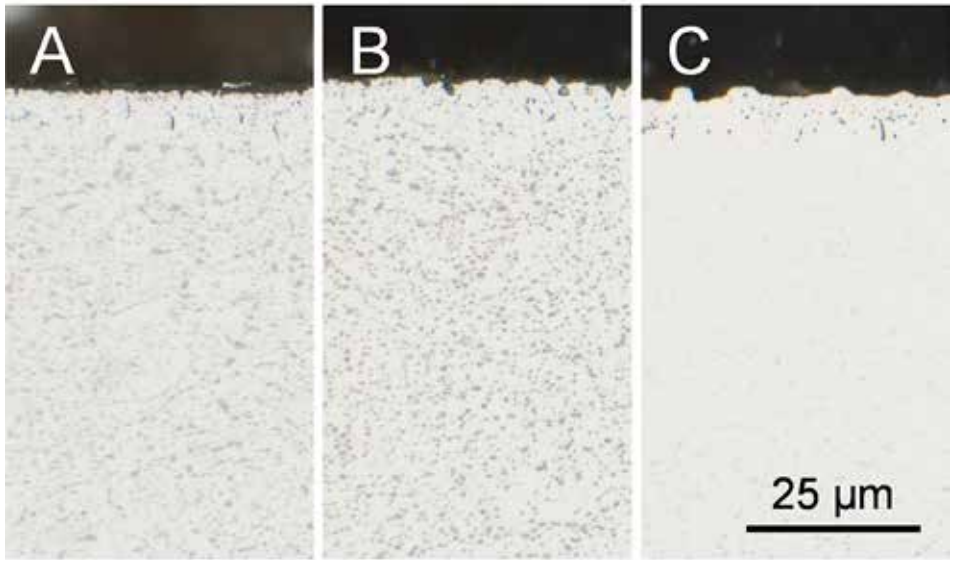


Figure 3: Unetched cross sections of the material X38CrMoV5-3 after the carbo-nitriding treatments (for heat-treatment parameters of (A–C) see Table 2).

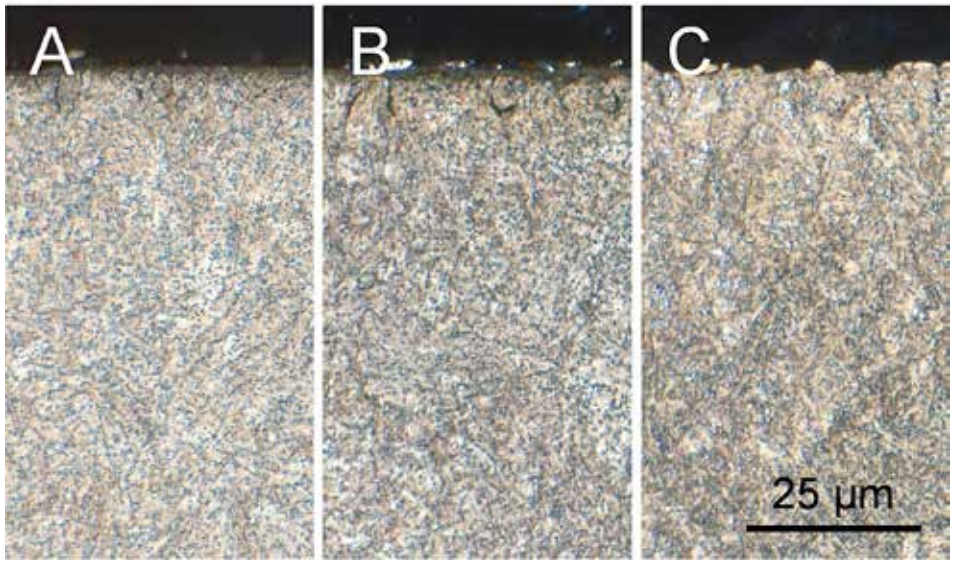


Figure 4: Cross sections of the material X38CrMoV5-3 after the carbo-nitriding treatments etched with Nital (for heat-treatment parameters of (A-C) see Table 2).

2.3 Model Wear Tests

The wear behavior was investigated by model wear tests and under industrial forging conditions. A combination of abrasion and Hertzian stress was realized by the two-disc test. The ball-on-disk test focused the adhesion and the tribo-oxidation. The thermal fatigue behavior was investigated by cyclic induction heating and quenching. In the model wear tests, carbo-nitrided and tempered as well as carbo-nitrided and nitrided specimens were compared to quenched and tempered and nitrided specimens. For further description of the experimental setup, see [15].

2.4 Forging Tests

In order to investigate the wear behavior under practical conditions, the treatment combination of carbo-nitriding and nitriding was transferred to forging dies. The experimental dies were used at two forges in the serial production. Low-alloy steels were formed in each case at a temperature >1,200°C. The cycle time was 10-15 seconds. A graphite-free salt (white lubricant) was used as a lubricant. The lifetime of the carbo-nitrided and nitrided dies were compared with those in the relevant series tools.

3 RESULTS AND DISCUSSION

3.1 Carbo-nitriding Treatment

The usual hardening temperature of X38CrMoV5-3 is 1,030-1,080°C, whereas the carbo-nitriding treatment is usually carried out at 850-950°C. The high hardening temperature is necessary in order to bring the alloying elements in solution for the secondary hardening during tempering. An increase in the carbo-nitriding temperature is limited by the increasing ammonia decomposition at higher temperatures. Table 1 shows the results from carbo-nitriding experiments at different temperatures. As the measured variable for the ammonia concentration, a residual ammonia amount of 3,500 ppm in the exhaust gas was targeted. It is obvious that this ammonia amount could not be reached at temperatures above 850°C due to the increasing decomposition of ammonia.

The smaller amount of ammonia that was not thermally decom-

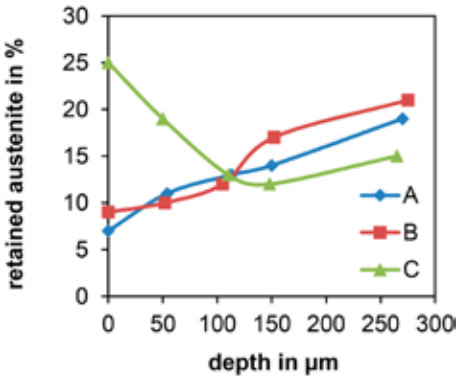


Figure 5: Retained austenite in the nitrogen-rich surface layers (for heat-treatment parameters of A, B, and C see Table 2).

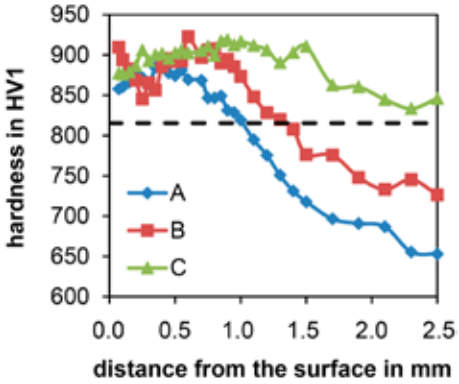


Figure 6: Hardness profiles after carbo-nitriding of the material X38CrMoV5-3 with different process management (for heat-treatment parameters of A, B, and C see Table 2).

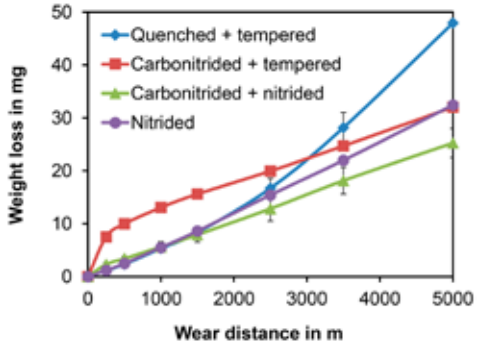


Figure 7: Weight loss of the different heat-treated specimens in the two-disc test dependent on the wear distance.

posed also led to a smaller nitrogen concentration in the material. However, since nitrogen diffusion is faster at higher temperatures, the treatment temperature should not be chosen too low. As the best compromise regarding a high nitrogen concentration in the surface zone and a high diffusion depth, the temperature 950°C was chosen for the carbo-nitriding treatments. Since the aim of the carbo-nitriding is the diffusion of nitrogen into the surface layer, the carbon potential was chosen to match the material's carbon content. The chosen carbon potential also includes the influence of the alloying elements on the equilibrium concentration [16].

The full parameters for the heat treatments are given in Table 2. The processing of carbo-nitriding was done with three methods. The first process (A) was a direct hardening at carbo-nitriding temperature where the core was hardened at too low a temperature. The second process (B) was a two-stage carbo-nitriding where the temperature was increased for the hardening step after carbo-nitriding followed by an oil quenching. The hardening temperature in this process was limited to 1,000°C by the equipment. The third carbonitriding treatment (C) was followed by a separate vacuum hardening where a sufficient hardening temperature for the material could be realized.

3.2 Microstructure of the Carbonitrided Layers

Figure 2 shows the nitrogen profiles after the three carbo-nitriding treatments with different processing. Due to the same treatment temperature and time of the carbo-nitriding step, the nitrogen profiles of heat treatments A and B were similar. The additional hardening step of 0.5 hours at 1,000°C did not lead to a higher diffusion depth because, at this temperature, most of the ammonia decomposes (see Table 1), and only a small amount of nitrogen is taken by the material (see Figure 2). A different nitrogen profile could be observed after treatment C where a typical vacuum hardening was added after carbo-nitriding and quenching. During the vacuum treatment, an effusion of nitrogen occurred, and the nitrogen content in the carbonitrided layer decreased.

The unetched cross sections in Figure 3 show the different distribution of the carbo-nitrides in the surface region after the three processing variants. The carbo-nitride distributions after treatments A and B were very similar. The additional processing step at 1,000°C was not high enough to solve the carbo-nitrides in specimen B. Instead, they were slightly coarsened. In specimen C, there were not any visible carbo-nitrides. They were dissolved at the higher hardening temperature of 1,050°C.

Figure 4 shows the cross sections of the three processing variants etched with Nital. Despite the different hardening temperatures

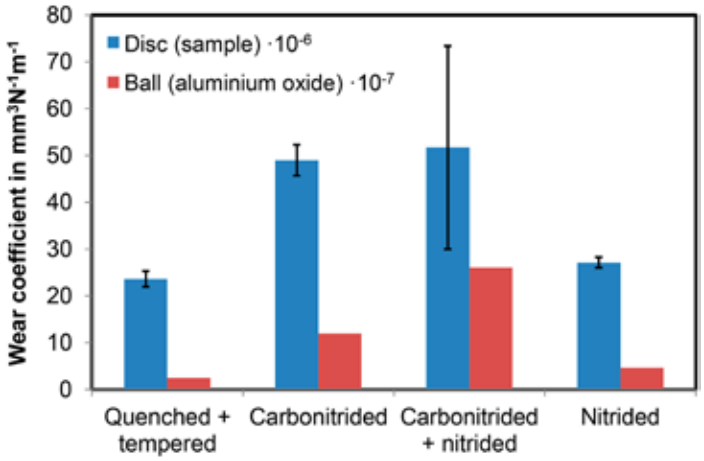


Figure 8: Wear coefficient from ball-on-disc test for the different heat-treated specimens.

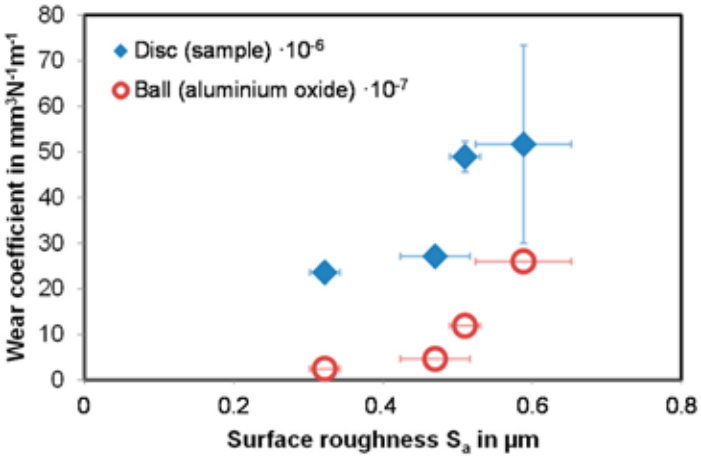


Figure 9: Wear coefficient from ball-on-disc test dependent on the surface roughness.

950°C (A), 1,000°C (B), and 1,050°C (C), the oxidation of the surface near the region was similar after the different treatments.

Due to the fact that nitrogen stabilizes the austenitic phase, retained austenite was expected in the surface region. Figure 5 shows the amount of retained austenite in the nitrogen-rich surface layer detected by X-ray diffraction. The treatment variant C had the highest amount of retained austenite at the surface, although the nitrogen content was significantly lower than the one of the two

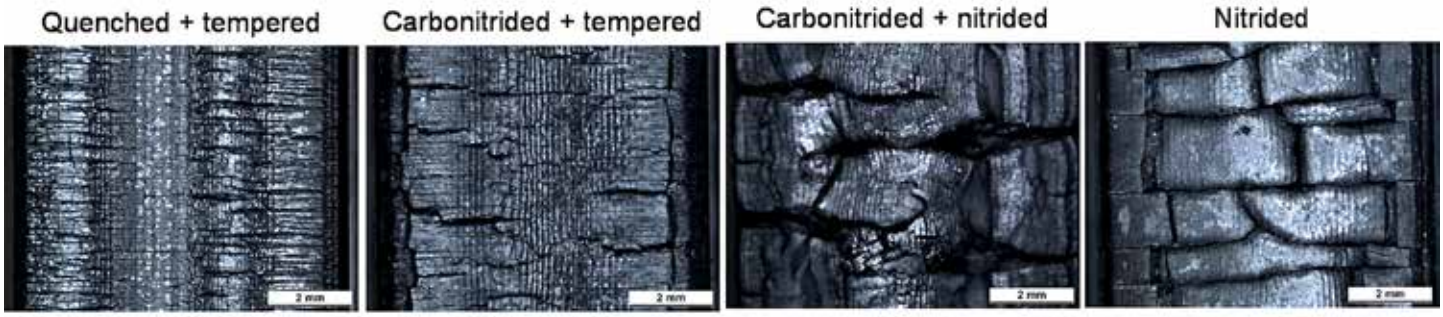


Figure 10: Surface of the different heat-treated specimens after 100 cycles of induction heating and quenching.

Heat Treatment	Nitrogen Content in ma.%
Quenched + tempered	<0.1
Carbonitrided + tempered	0.8
Carbonitrided + nitrided	9.2
Nitrided	8.8

Table 3: Nitrogen content of the specimens for the thermal fatigue investigations in the depth of 1 µm.

Heat Treatment	Retained Austenite in %
Quenched + tempered	0
Carbonitrided + tempered	0
Carbonitrided + nitrided	37
Nitrided	59

Table 4: Retained austenite in the surface area after one cycle of induction heating and quenching.

other treatments. This is due to the fact that the carbo-nitrides were dissolved during the hardening step at 1,050°C, and the nitrogen in the solution was higher than after treatments A and B where the most nitrogen was bonded in carbonitrides and therefore had no effect on the austenite stabilization.

The hardness of the carbonitrided layers is shown in Figure 6. The dashed line is the average hardness of a specimen that was only vacuum hardened and oil quenched. The hardness of the carbo-nitrided layer that had a thickness of approximately 0.7-0.8 mm (according to the nitrogen profiles) was similar after the different processing and in all three cases higher than the conventional hardened specimen. Beneath the carbo-nitrided layer, the influence of the different hardening temperatures can be observed. The hardening temperature of treatments A and B was too low. The hardness of the vacuum-hardened specimen could not be reached. Only treatment C, in which the hardening step was identical to the reference treatment, led to the same hardness of the uncarbo-nitrided material.

3.3 Wear Behavior

In the model wear tests, carbo-nitrided and tempered as well as carbo-nitrided and nitrided specimens were compared to quenched as well as tempered and nitrided specimens. The carbo-nitriding was carried out as a two-stage treatment with an austenitization temperature of 1,000°C directly after carbonitriding was chosen.

3.3.1 Two-Disc Test

In the two-disc test, the weight loss during the experiment was detected as a criterion for wear. Figure 7 shows the weight loss of the heat-treatment variants dependent on the wear distance. The quenched and tempered condition showed by far the greatest loss of mass under the experimental conditions. At the beginning of the experiment, the specimens wore relatively little until a wear distance of approximately 1,500 minutes. Then, the weight loss increased drastically.

The lowest total loss of mass was observed on the carbo-nitrided and nitrided specimen. The weight loss was also at its lowest at the beginning of the experiment and increased almost linearly along the wear distance.

The total weight loss of the carbo-nitrided and tempered specimen was similar to the one of the nitrided specimens, but these specimens showed a very different development of wear. In the nitrided state, the mass loss was also slight at the beginning and increased substantially after a wear distance of approximately 1,500 minutes. The carbo-nitrided and tempered specimen wore faster at the beginning of the experiment. After approximately 250 minutes of wear distance, the wear slowed down and then increased continually until the end of the experiment.

3.3.2 Ball-on-Disc Test

In the ball-on-disc test, the wear coefficients were determined based on the wear marks on the specimen and the ball (Al2O3). Figure 8 shows the wear coefficients that were obtained in this way. It is striking that the carbo-nitrided specimen as well as the carbo-nitrided and nitrided specimen had the highest wear coefficients. However, there was also an influence on the surface roughness of the specimens, which was different due to the different heat treatments. Figure 9 shows a clear connection between the wear coefficients and the roughness of the specimen surfaces: The wear coefficient rises as the roughness of the specimen surfaces increases.

3.3.3 Thermal Fatigue Behavior

The thermal fatigue behavior was investigated by cyclic induction heating and quenching. Figure 10 shows the specimens' surfaces of the differently heat-treated material X38CrMoV5-3 (quenched + tempered, nitrided, carbo-nitrided + tempered, and carbo-nitrided + nitrided), each after 100 load cycles. Already at first glance, a different risk network can be recognized. In the hardened condition, the cracks were fine and numerous, while a substantially coarser network of cracks was formed in the nitrided condition. The condition of the surface on the carbo-nitrided and tempered specimens looked similar to the hardened specimen, but the cracks were somewhat larger here. In the carbo-nitrided and nitrided specimens, the network of cracks looked similar to the specimens that were only nitrided with finer cracks between the coarser network of cracks.

It was suspected there is a relation between the nitrogen content in the surface layer and the cracking behavior. Table 3 shows the surface near nitrogen content measured by GDOES. Because of the mere thermal treatment, there was almost no nitrogen in the surface area of the quenched and tempered specimen. After carbo-nitriding and tempering, the nitrogen concentration was 0.8 ma.%. A significantly

Heat Treatment Variant	Carbonitriding (CN) Cp = 0.35% NH_3 = max	Tempering (T)	Nitriding (N)
CN + T	950°C 8 h, 1000°C 1 h	3 x 560°C 2 h	–
CN + T + N (1)	950°C 8 h, 1000°C 1 h	3 x 560°C 2 h	520°C 24h K_N=3
CN + T + N (2)	850°C 8 h, 1000°C 1 h	3 x 560°C 2 h	520°C 24h K_N=3

Table 5: Heat-treatment parameters for the experimental forging dies.

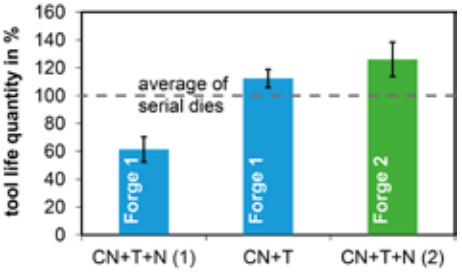


Figure 11: Tool life quantities of the carbo-nitrided and tempered (and nitrided) dies.

higher nitrogen concentration in the surface layer was found for the samples where the last heat treatment step was nitriding. The nitrogen contents of the carbo-nitrided and nitrided and the exclusively nitrided specimen were similar at approximately 9 ma.%.

During service, the surface zone of forging dies is heated up. Depending on the temperature and the material phase, transformations can take place under thermal load. The element nitrogen stabilizes the austenitic phase by lowering the AC1 temperature [15]. This means surface areas with a higher nitrogen content will form austenite at lower temperatures than surfaces with lower nitrogen content. This leads to different stress conditions and finally to different crack formations.

The retained austenite after one cycle of induction heating and quenching was detected by X-ray analysis (Table 4). In the variants "carbonitrided + nitrided" and "nitrided," retained austenite was actually detected because the austenite was unable to transform completely into martensite during quenching due to the high nitrogen content.

Figure 12: Forging die of forge 2 after use.

However, not only the phase transformations have an influence on the stress condition and therefore on the cracking behavior. Another reason is the increasing formation of nitride precipitations with increasing nitrogen content. The alloying element nitrides are more heat resistant than the corresponding carbides and remain at elevated surface area temperatures. This can also cause a different stress condition in the surface area.

3.4 Tool Life Quantities

For the forging tests, forging dies were specially heat-treated (Table 5). The dies of forge 1 were carbo-nitrided and tempered in a two-stage process at 950°C and 1,000°C. Additionally, some of the dies were nitrided subsequent to carbo-nitriding and tempering. The dies of forge 2 were carbo-nitrided and tempered in a two-stage process at 850°C and 1,000°C and then nitrided.

The experimental dies were used in the forges until the lifespan was reached. Figure 11 shows the lifespans achieved by the tools with regard to series life. In forge 1, similar lifespans were achieved with the carbo-nitrided and tempered tools as with the series tools. The carbo-nitrided and nitrided tools had a lower tool life quantity than the serial tools.

However, a not inconsiderable proportion of the test tools were not removed due to wear but because of cracks and fractures, which made it impossible to use them up to the wear limit. These tools were not included in the evaluation.

The change from nitrided to carbo-nitrided dies can shorten the process chain and thus save time and costs.

It is assumed the greater core hardness and the associated lower toughness of the tool base material was the cause of the high susceptibility to fracture. The hardness of the experimental tools was set to (50 + 2) HRC (approximately 560 HV1) following previous investigations [6], whereas the series tools were quenched and tempered to (48 + 2) HRC.

In comparison with the serial dies in forge 2, substantially greater lifespans were achieved with the experimental dies. However, it must be taken into account that the series tools in this case were only quenched and tempered and an increase in lifespan would probably be possible through conventional nitriding, too. Figure 12 shows a worn die from forge 2. Although the cracking network on the surface is clearly visible, the lifetime was higher than the one of the serial dies.

4 CONCLUSIONS

The wear resistance of forging dies can be improved by carbo-nitrid-

ing. In order to produce a sufficiently deep surface layer hardened with nitride precipitates and at the same time achieve sufficient core strength, the heat treatment must be adapted to the die material. A two-stage carbo-nitriding and hardening process is necessary for the hot working steel X38CrMoV5-3 because at the hardening temperature of this material, the nitrogen source NH_3 is not stable enough to realize a sufficient nitrogen amount in the surface layer. Experiments at different temperatures showed the ammonia content in the carbo-nitriding atmosphere decreases at temperatures of 900°C and higher. In addition, the nitrogen content in the surface region of the carbo-nitrided material decreases, too. Therefore, it is not possible to do a direct hardening from the carbonitriding temperature for the hot working steel X38CrMoV5 3. The two stages of carbo-nitriding and hardening can be carried out in different orders, but the order influences the microstructure and the hardness of the carbo-nitrided layer as well as of the core material.

The wear properties of the different surface-treated specimens were evaluated using model tests and life tests on forging dies. In the two-disc test, the carbo-nitrided and nitrided variants showed the lowest wear. In the ball-on-disc test, the carbo-nitrided specimens exhibited the highest wear coefficients, but this was attributable to the higher surface roughness of the specimens. The thermal-fatigue tests showed different thermal crack networks are formed on the surface depending on the nitrogen content of the X38CrMoV5-3 material, because the transformation process and the precipitation state of the surface change.

In the service life tests, similar tool life quantities could be achieved with the carbo-nitrided and nitrided experimental dies as with conventionally nitrided dies. Compared with quenched and tempered serial dies, the tool life could be significantly increased with carbo-nitriding and nitriding of the tools. The only carbo-nitrided and tempered dies also had higher tool life quantities than the serial dies, so subsequent nitriding treatment is not mandatory.

Since carbo-nitriding can be carried out together with hardening and since subsequent nitriding is not mandatory, the change from nitrided to carbo-nitrided dies can shorten the process chain and thus save time and costs. Restricting factors are the dimensional and shape changes that occur during carbo-nitriding. Carbo-nitriding is therefore only suitable for (pre-)forging dies with high tolerances, since the carbo-nitriding layer can only be reworked to a limited extent. It is essential to take the dimensional and shape changes into account when designing the dies or to use (pre-)forging dies with correspondingly high-tolerance ranges.

AUTHOR CONTRIBUTIONS

S.H.: project administration, conceptualization, investigation, methodology, writing — original draft preparation; H.K.-W.: funding acquisition, supervision, writing — review and editing; M.S.: funding acquisition, supervision, writing — review and editing. All authors have read and agreed to the published version of the manuscript.

FUNDING

The authors gratefully acknowledge support from the Forschungsgesellschaft Stahlverformung e. V. The project IGF 18394 N was funded by the AiF (Arbeitsgemeinschaft industrieller Forschungsvereinigungen „Otto von Guericke“ e. V.) through financial resources from the BMWi (Bundesministerium für Wirtschaft und Energie).

CONFLICTS OF INTEREST

The authors declare no conflict of interest. The funders had no role in the design of the study, in the writing of the manuscript, and in the decision to publish the results.

REFERENCES

[1] Luig, H.; Bobke, T. Beanspruchung und Schadensarten an Schmiedegesenken. Tribol. Und Schmier. 1990, 37, 76–81. [Google Scholar]

[2] Spies, H.-J. Kontrolliertes Gasnitrieren von Eisenwerkstoffen. Stahl 1992, 2, 77.

[3] Spies, H.-J.; Zimdars, H.; Müller, C. Erfahrungen beim Gasoxinitrieren von Werkzeugen für die Warmumformung; Meform: Freiberg, Germany, 2012.

[4] Spies, H.-J.; Berns, H.; Ludwig, A.; Bambauer, K.; Brusky, U. Warmhärte und Eigenspannungen nitrierter Stähle. HTM Härterei-Techn. Mitt. 1998, 53, 359–366.

[5] Klümper-Westkamp, H. Load-adapted nitriding and nitrocarburising of forging dies for hot massive forming of steel. In Proceedings of the European Conference on Heat Treatment 2010 Nitriding and Nitrocarburising, Aachen, Germany, 29–30 April 2010.

[6] Hoja, S. Schmiedegerecht Nitrierte Gesenke. Ph.D. Thesis, University of Bremen, Bremen, Germany, 2017.

[7] Macherauch, E.; Kloos, K.H. Bewertung von Eigenspannungen. Eigenspannungen und Lastspannungen. Beih. HTM–Härterei-Techn. Mitt. 1982, 28, 175–194.

[8] Somers, M.A.J. Verbindungsschichtbildung beim Nitrieren und Nitrocarburieren–Wissensstand und zukünftiger Forschungsbedarf. HTM J. Heat Treatm. Mat. 2011, 66, 2.

[9] Winter, K.-M.; Hoja, S.; Klümper-Westkamp, H. Controlled Nitriding and Nitrocarburizing–State of the Art. In Proceedings of the European Conference on Heat Treatment 2010 Nitriding and Nitrocarburising, Aachen, Germany, 29–30 April 2010.

[10] Hoja, S.; Klümper-Westkamp, H.; Hoffmann, F.; Zoch, H.-W.; Baumgartner, N.; Weidel, S. Schmiedegerecht nitrierte Gesenke. Schmiede J. 2013, 32–35.

[11] Lombardo, S.; Steinbacher, M. Carbonitrieren von verzahnten Getriebebauteilen; FVA 513 I, Heft 970; Forschungsvereinigung Antriebstechnik e.V.: Frankfurt, Germany, 2011.

[12] Meinhard, E. Carbonitrieren–Warum und wie? Tech. Z. Für Met. 1982, 10, 2–8.

[13] Jasinski, J.; Torbus, R.; Jeziorski, L. Influence of the microstructure modification on surface layer of X37CrMoV5-1 steel after carbonitriding process. 2nd Int. Conf. In Heat Treatment and Surface Engineering in Automotive Applications; Associazione Italiana die Metallurgia: Riva del Garda, Italy, 2005. [Google Scholar]

[14] Jasinski, J.; Torbus, R.; Kasprzycka, E.; Bogdanski, B. Influence of the preheat treatment on the microstructure and properties of X37CrMoV5-1 steel. Steel. Mater. Manuf. Process. 2007, 22, 5–8. [Google Scholar] [CrossRef]

[15] Hoja, S.; Klümper-Westkamp, H.; Hasselbruch, H.; Skalecki, M.G.; Steinbacher, M.; Zoch, H.-W. Verschleißverhalten carbonitrierter und nitrierter Warmarbeitsstähle. HTM J. Heat Treatm. Mat. 2018, 73, 211–222. [Google Scholar] [CrossRef]

[16] Hoja, S.; Skalecki, M.G.; Klümper-Westkamp, H.; Steinbacher, M.; Zoch, H.-W. Carbonitrieren von warmarbeitsstählen. HTM J. Heat Treatm. Mat. 2017, 72, 187–198.

ABOUT THE AUTHORS

Dr. Stefanie Hoja, Heinrich Klümper-Westkamp, and Dr. Matthias Steinbacher are with the Center for Materials and Processes, Leibniz-Institut für Werkstofforientierte Technologien–IWT and MAPEX, Universität Bremen, 28359 Bremen, Germany.

COMPANY PROFILE ///

HORIZON PERFORMANCE TECHNOLOGIES LLC

FORWARD-THINKING, INNOVATIVE SOLUTIONS

Horizon Performance Technologies LLC is an OEM engaged in the design and manufacturing of industrial capital equipment in the heat processing and finishing industries including ovens, washers, and material handling.

By KENNETH CARTER, Thermal Processing editor

Finishing parts and materials using heat processing is often an essential step in ensuring those parts will perform as they should in the field. But that process has the potential to put a dent in a company's bottom line if the equipment doesn't perform quality products efficiently and economically.

Horizon Performance Technologies LLC takes the position that the equipment used to perform that task should be able to finish much-needed parts and materials without adversely affecting a company's budget.

To that end, Horizon builds energy-efficient washers and ovens for a wide range of industries, including automotive, aluminum, glass, energy, aerospace, military, and more.

"Horizon equipment, with its patented technology applied and compared to conventional technology, will save the customer between 60 to 70 percent on electrical energy while achieving the same amount of production," said Jeff Mitchell, Horizon's president. "On washers, as an example, the horsepower requirements per pump is 5 or 7.5 HP compared to 20 or 25 HP or larger. A washer can require anywhere from three to seven pump motors, so the savings over the lifetime of the equipment are significant. On a washer, this also translates into savings of chemicals and BTUs as the Horizon tanks are significantly smaller when compared to conventional tank sizes. On drying/curing ovens, the patent similarly saves electrical energy while delivering substantially more recirculation air. More air will drive more heat into the product. This enables the customer a better product temperature profile, more uniformity, and, ultimately, a better-quality product."

RECENT ACQUISITION

Horizon recently acquired Perceptive Industries, who had been supplying industrial ovens to the metal fastener and coatings industry and the thermal-processing industry throughout the U.S., as well as delivering equipment globally to international based metal coaters. Perceptive's product line is a good fit for Horizon's already existing industrial oven and washer product lines, according to Mitchell.

"Perceptive Industries equipment will benefit from these designs and will allow Perceptive's customers to equally benefit from these technologies," he said. "Perceptive Industries' current equipment users will benefit from the services and spare parts offered through Horizon's platform. They will be able to access their spare parts through the web portal specifically intended for these services."

By continually building on its portfolio, Horizon has positioned itself to provide the best the industry has to offer, according to Mitchell.

"Our mission is to provide our clients with superior customer service through innovation and efficiency," he said. "To execute this mission, we plan to continually evolve, allowing us to exceed the expectations of our clients, employees, and suppliers. We feel that for us to be successful, we need to treat each stakeholder in an ethical manner that builds a trusted win-win relationship. Our most valued assets are our clients, employees, and suppliers."

Cyclone Oven technology. (Courtesy: Horizon Performance Technologies)

Above: Internal view of Cyclone Oven technology. (Courtesy: Horizon Performance Technologies)

Right: A batch-style torrent washer. (Courtesy: Horizon Performance Technologies)

"We feel that our contribution to the equipment design and offering lower energy consumption on the oven side and washers will allow our customers to significantly improve their quality and thus increase their profitability."

A finishing system washer using torrent washer technology. (Courtesy: Horizon Performance Technologies)

CUTTING-EDGE TECH

That evolution also involves constantly improving with innovation and ingenuity, according to Mitchell.

"Horizon has developed cutting-edge technologies to help the customer reduce their carbon footprint," he said. "By reducing the energy consumption of the washer and oven products, the customer is able to lower their operating costs. Not only do we address the energy consumption but also the actual water needs (washers), the tanks sizes, the chemical requirements, and the exhaust needs."

And, Mitchell added, no customer's needs are exactly the same.

"All of our equipment is custom designed," he said. "We start with the customer's 'challenge' — their production needs and their specific plant constraints — and then we apply our technology to solve their production problems while, at the same time, make them aware of how our patented technology will also save them operating costs. In today's high-energy cost environment, this can be critical to their profitability. Depending on the size of the equipment or project, we can save the customer hundreds of thousands of dollars in operating costs annually." (Note: The costs for electricity and natural gas rarely go down year after year.)

CRITICAL PATENTS ACHIEVED

Constantly striving for that goal of excellence for its customers has brought on many achievements, including being awarded two design patents that lower the energy consumption of washers and ovens, according to Mitchell.

"As an organization, we worked very hard to receive those two patents on our design," he said. "When we were finally rewarded with the patent grants, we certainly achieved a major milestone in our company history."

Quite the accomplishments for a company that has only been working with industries for 15 years, but that short history is packed with a lot of work, according to Mitchell.

The company was started in 2007 by Jeff Mitchell; Jeff's father, John Mitchell, who has since passed away, was a co-founder of Wisconsin Oven and Industrial Heat Enterprises International (IHEI). Jeff Mitchell has been in the oven- and washer-equipment business for the last 40 years. He started the company by initially offering spare parts and has built up a spare-parts website with more than 10,000 parts. Any oven and washer equipment end user can find parts there. He then began work on several patents with the intention to improve on existing thermal-process technologies. He is the patent holder of those two critical design patents.

Those essential patents for lowering energy consumption will be just a few of the tools in Horizon's toolbox as it tackles a future beset with rising energy expenses, according to Mitchell.

"Energy costs, amongst other resources, will continue to increase," he said. "We feel that our contribution to the equipment design and offering lower energy consumption on the oven side and washers will allow our customers to significantly improve their quality and thus increase their profitability."

MORE INFO horizonpfm.com

MARKETPLACE ///

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

Contact **Thermal Processing** at 800-366-2185 to feature your business in the Marketplace.


YOU'VE GOT THE PRODUCTS.
YOU'VE GOT THE SERVICES.
NOW, LET US SHARE YOUR STORY.
Thermal Processing wants to make sure the best possible audience knows your company. Through our print, online, and social media presence, our experienced staff can get your message to an industry that wants to know what you can do.
Thermal processing
To learn more, contact national sales director Dave Gomez at dave@thermalprocessing.com or call 800.366.2185 ext. 207

ADVERTISER INDEX ///

COMPANY NAME	PAGE NO.
Aerospace Testing & Pyrometry	9
AFC Holcroft	IFC
Armil CFS, Inc.	13
Arrow Tank and Engineering Co.	44
Avion Manufacturing	44
C3 Data	12
Can-Eng	44
Ceramics Expo	23
Charles A. Hones, Inc	45
Conrad Kacsik Instrument Systems Inc	11
Dante Solutions, Inc	47
DMP CryoSystems	IBC
Edward Orton Jr. Ceramic Company	5
Gasbarre Thermal Processing Systems	1
GES-AGM	13
Graphite Metallizing Corporation (Graphalloy)	9
Harrop Industries, Inc	BC
Heat Treat Equipment	27
I Squared R Element Co.	47
L&L Special Furnace Co. Inc.	45
Noble Industrial Furnace	45
Solar Manufacturing	3
The Duffy Company	44
Thermal Technologies Expo	31
Thermcraft	15
W.H. Kay Company	45
Wirco	7

RAYMOND PIETERSEN /// EXHIBITION MANAGER /// CERAMICS EXPO

"Ceramics Expo offers exhibitors a platform to showcase their expertise and be seen at the No. 1 event for the technical ceramics industry."

Ceramics Expo is scheduled to take place at the Huntington Convention Center in Cleveland, Ohio, August 29-31. Exhibition Manager Raymond Pietersen recently talked with *Thermal Processing* about what attendees and exhibitors can expect from the show.

What about Ceramics Expo makes it a must-see event for people who work in the ceramics industry?

Ceramics Expo is an internationally recognized event that brings together the entire ceramics industry, showcasing the latest in industrial applications, new technologies, and a strong focus on material research and development.

For anyone who works in the industry, this event provides the excellent platform to learn about the latest industry trends, network with like-minded peers, and do business with key decision makers.

As a free-to-attend event, visitors have full access to our exhibition hall and conference sessions throughout the two days of the show.

What can attendees expect in the way of presenters?

The conference at Ceramics Expo features a first-class lineup of speakers from across the supply chain. We're very much looking forward to welcoming a selection of really exciting speakers back to Cleveland after the success of the 2021 show, including representatives from companies such as Lockheed Martin, GE Aviation, Kyocera, Morgan Advanced Materials, and many more.

When it comes to developing the program, we pride ourselves in featuring topics and themes that are driving the industry. This year, we will have a day dedicated to materials, manufacturing, and applications, with topics such as energy storage, ceramic matrix composites, and 3D printing. We've also got a day focusing on industry development, understanding the current and future market, looking at how to grow businesses, and collaborating for increased efficiency. It's definitely one not to be missed.

If I were a first-time exhibitor, what should I expect to gain by attending the show?

Ceramics Expo offers exhibitors a platform to showcase their expertise and be seen at the No. 1 event for the technical ceramics industry. In addition to being part of our extensive marketing campaign throughout the year, exhibitors will also have access to key sponsorship and advertising opportunities to help position their products, increase their visibility, and enhance their profile at the show.

Exhibitors will also be able to attend our invite-only VIP reception, which takes place ahead of the busy two-day exhibition. With complimentary drinks, canapes, and live music provided, this will be an opportunity for our exhibitors to do business and network with industry peers in a relaxed environment.

What methods will be available for attendees in order to network with their peers?

One of the key features at this year's show is our dedicated B2B Matchmaking Service. This will give our attendees access to other visitor, speaker, and exhibitor profiles ahead of the conference. This platform will also allow both our visitors and exhibitors to schedule meetings in advance. This service will be available through our official mobile app, which visitors can download for free. They will also be able to view the event schedule, conference agenda, full exhibitors listings, product showcases, and speaker interviews.

Attendees will also have access to our technical conference sessions and roundtable discussions where they can meet and network with industry experts and speakers.

Are you having to implement any last-minute COVID regulations for attendees and exhibitors?

We will have strict COVID regulations in place to limit the transmission of COVID-19. We will also be circulating some safety information for both our attendees and exhibitors (most of which can be found here: www.ceramicsexpousa.com/covid-safety) and will be encouraging things like printing badges in advance to ensure few lines and smooth access for all attendees. We will also have an extensive cleaning schedule in place, as well as sanitizing and cleaning stations throughout the venue.

The venues themselves have installed many additional safety and cleaning measures—such as an updated HVAC system, self-cleaning surfaces, elevator air cleaning technology, and touchless restroom door openers.

What are you personally looking forward to at this year's show?

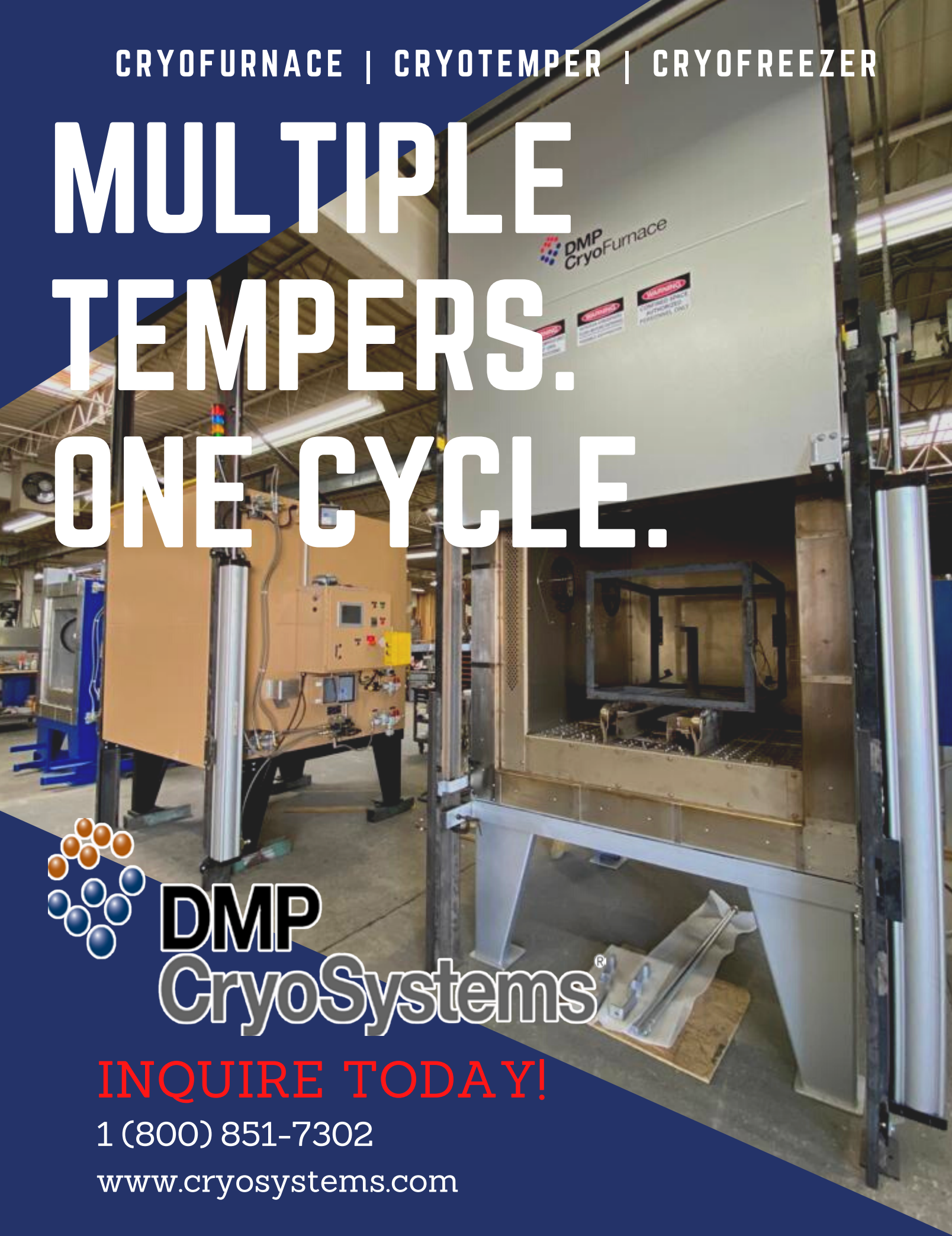
Finally being able to meet with our corporate partners, exhibitors, speakers, and visitors for what should be an action-packed couple of days.

It's also worth mentioning the drinks reception, which will take place at the end of Day 1 on Tuesday in the exhibition hall. Not to be missed!

MORE INFO www.ceramicsexpousa.com

CRYOFURNACE | CRYOTEMPER | CRYOFREEZER

MULTIPLE TEMPERS. ONE CYCLE.



DMP CryoSystems®

INQUIRE TODAY!

1 (800) 851-7302

www.cryosystems.com

Your Kiln... A CUSTOM FIT!

New process, new product? Old kiln no longer fits? When you outgrow your current kiln, call Harrop. Like a fine suit, Harrop kilns are made-to-measure so that they fit your exact needs. Harrop kilns are built to last so that you will enjoy "wearing" them for years to come. And like a fine tailor, Harrop can often alter your old kiln so that it fits your current needs.

Harrop kilns are designed and built at our facility in Columbus, OH. We can install your kiln at your site and provide commissioning and operator training – a true turnkey supplier.

Contact Harrop when an "off-the-rack" kiln won't do.

100th ANNIVERSARY 2019

HARROP

Fire our imagination

Visit us at
Ceramics Expo 2022
Booth 1020

www.harropusa.com

1.614.231.3621