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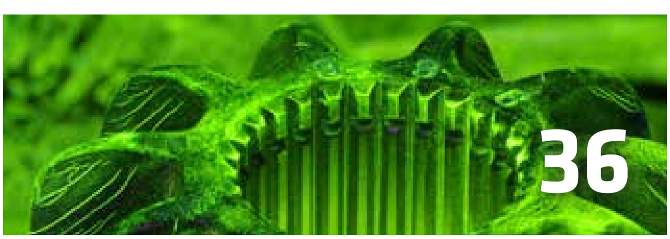

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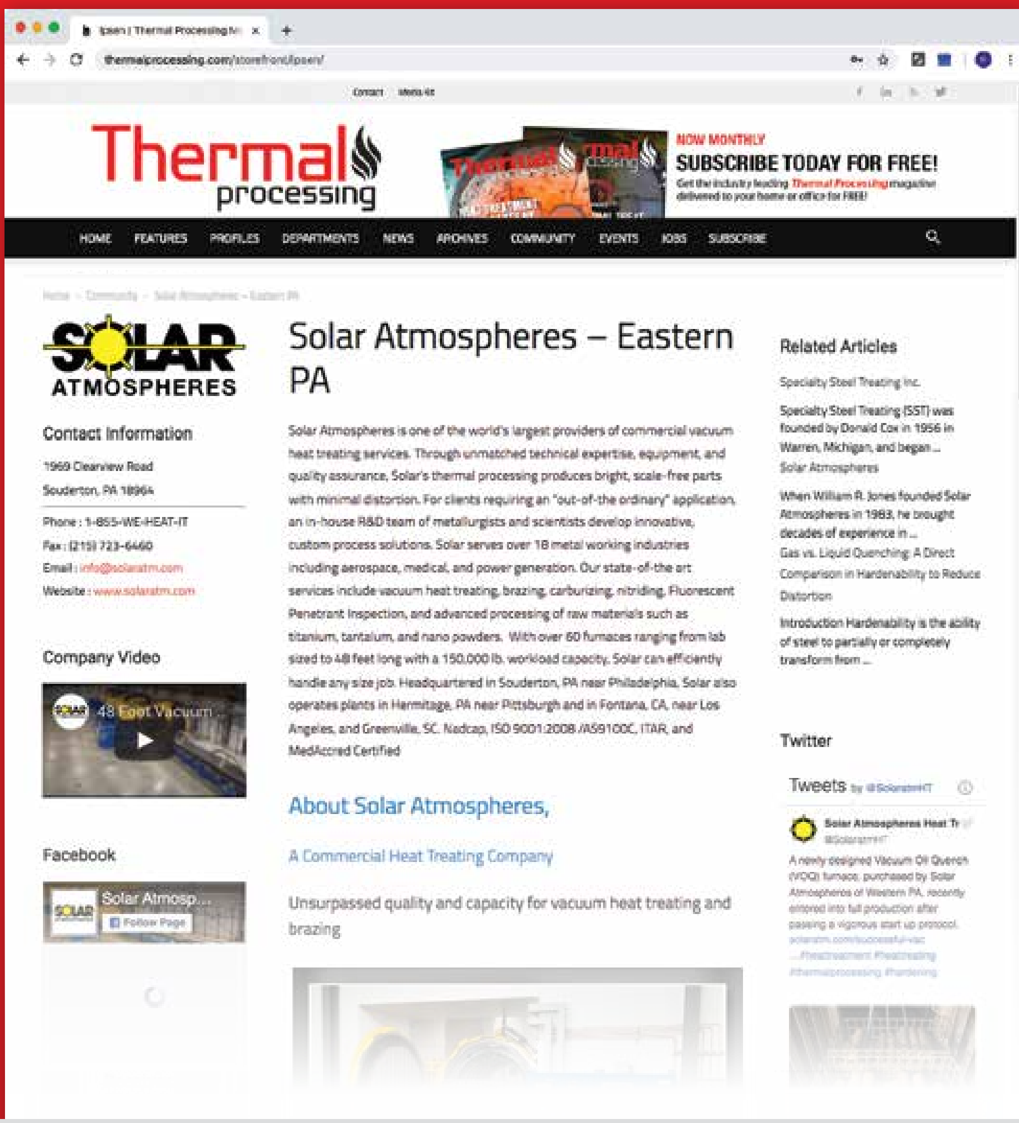

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FROM THE EDITOR ///

Spreading the word over multiple platforms

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

And if you need a sign that the industry continues to grow, look no further than the successful Thermal Management Expo North America. The show, which was April 30-May 1 in Nova, Michigan, recently released its post-show report, and the numbers are impressive.

The event attracted a record number of visitors, according to Exhibition Director Ipek Saltik, with 1,000-plus event attendees — a 7 percent increase over 2023. The show also had 50-plus exhibitors.

Tradeshows like this are a key element in interacting with the industry at large.

For example, at the Thermal Management Expo, industry leaders and experts provided attendees with valuable knowledge and practical insights to apply in their own operations, which can serve in driving innovation and efficiency in thermal management practices.

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

What do I mean by that?

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

What does that mean for you?

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

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

With that in mind, I hope you find the articles in our July issue — that takes a look at quenching and induction heating — of interest.

You'll also find advice from our monthly columnists, as well as insightful looks at what companies can offer throughout the industrial heat-treating sector.

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

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

KENNETH CARTER, EDITOR
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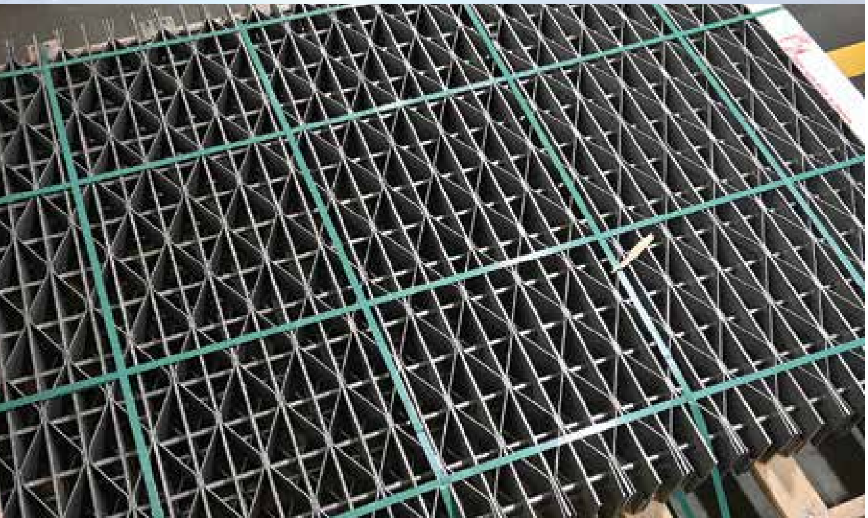

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The German Design Council presented Ipsen Global the German Innovation Award for the Atlas Green furnace platform. (Courtesy: Ipsen)

Ipsen Global receives German Innovation Award

The German Design Council, in recognition of Ipsen's pioneering innovation, has presented Ipsen Global the German Innovation Award for the Atlas Green furnace platform. The award ceremony was recently held in Frankfurt, celebrating the innovators that emerged from a field of 520 submissions from across 23 countries. Ipsen was recognized as a winner in the Excellence in Business to Business — Machines & Engineering category for the development of the Ipsen Atlas Green atmosphere furnace.

The Atlas Green was selected for its ability to provide a high-quality heat-treatment solution while reducing the end user's carbon footprint. The Atlas Green furnace achieves 100 percent CO_2-neutral operation through a smart combination of green electricity and green hydrogen. Intelligent software monitors the availability of green electricity and switches to green hydrogen when needed.

This hybrid electric/hydrogen energy approach is important for the future of an industry that has traditionally relied on the use of fossil fuels, and a correspondingly high CO_2 footprint. As many countries continue to tackle climate change, Ipsen Global and Atlas Green help companies find ways to reduce future carbon tax costs, while continuing to offer the same high-quality, reliable heat-treating solutions that industry demands.

"Targeted innovations are essential for success and sustainability," said Lutz Dietzold, CEO of the German Design Council. "They are indispensable for addressing the challenges of our time and driving the sustainable transformation of industry forward. With the German Innovation Award 2024, we make these outstanding and exemplary innovations visible. I am very pleased with the diversity of the awarded projects this year: They not only provide significant added value for the industry but also for society and the environment."

The 2024 German Design Council jury consists of independent experts from companies that represent emerging technologies, data management, and a variety of industry leaders across many scientific disciplines. Submissions are evaluated based on the criteria of innovation, end-user satisfaction, and economic viability.

MORE INFO www.german-innovation-award.de

Solar Manufacturing names new chief mechanical engineer

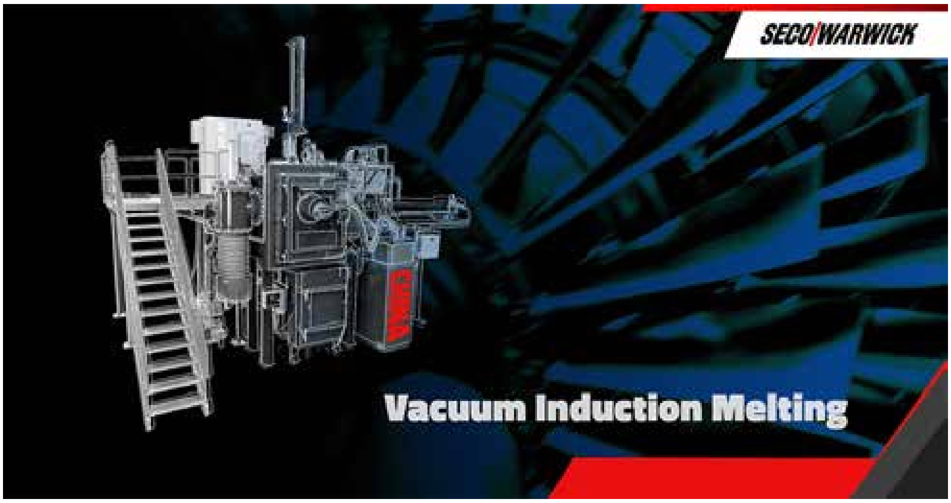
Solar Manufacturing, Inc. recently announced the hiring of Nicholas Max, BSME Drexel University, as its chief mechanical engineer to head up its vacuum furnace mechanical design group. Max is also pursuing an MBA at Lehigh University in Bethlehem, Pennsylvania.

Nicholas Max

Max will be tasked to lead the further development of Solar Manufacturing's energy efficient hot zones, vacuum vessels, high pressure gas quenching systems, and vacuum pumping systems. He was a program manager in his last position and led design engineers who were focused on the development of specialty battery technologies for space and defense applications.

"Nick will be an excellent addition to our design team from his rich, multi-disciplinary industrial experience of the past 10 years," said Bob Wilson, VP of engineering. "He will work alongside me for the next couple of years as I prepare for eventual retirement. The company will be well-positioned to continue its excellent reputation as an industry leader of robust vacuum furnace designs."

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 Seco/Warwick solution recently ordered is a VIM 50 kg induction furnace. It will produce gas turbine blade castings in an equiaxed structure. (Courtesy: Seco/Warwick)

Solar Manufacturing designs and manufactures a wide variety of vacuum heat treating, sintering, and brazing furnaces. They also offer replacement hot zones, spare parts, and professional service.

MORE INFO www.solarmfg.com

Gas turbine blades to be cast in a VIM furnace in China

A Chinese partner recently purchased a two-chamber VIM furnace with a 50 kg loading capacity for casting gas turbine blades from Seco/Warwick. The solution has already obtained an export license and will soon be delivered to China.

The solution on order is a VIM 50 kg induction furnace. It will produce gas turbine blade castings in an equiaxed structure. The furnace is unique due to its extremely high level of automation. It is one of the most frequently chosen solutions in the vacuum metallurgy field due to its innovativeness, reliability, and, thanks to a modern recipe system, process repeatability. It is distinguished by an innovative control system and precise melting temperature control.

Various metals can be processed in vacuum metallurgy furnaces, including titanium and its alloys, tantalum, tungsten, niobium, zirconium, silicon, nickel, and cobalt alloys. The solution ordered by the partner will be able to melt alloys of non-reactive metals, specifically nickel.

"The growing popularity of VIM furnaces and the increasing importance of vacuum metallurgy is a consequence of the heavy industrial production needs for constant change," said Sławomir Tomaszewski, Seco/Warwick Vacuum Melting team director. "We see a large increase in the demand for products from this segment throughout Asia. Thanks to the cooperation among our companies within the Seco/Warwick Group, we can supply induction furnaces all over the world. Our reliable service is also important. According to recent research, as many as 98 percent of our customers recommend Seco/Warwick after-sales services."

"This partner already owns our equipment from the vacuum segment," said MichałLitwin, sales manager from the Seco/Warwick Vacuum Melting Furnaces team. "We are glad that this time we also decided to cooperate with vacuum metallurgy technology."

It is difficult to imagine the modern world without the gas turbine. This device revolutionized industry, energy, and transport, giving people a powerful energy source.

A gas turbine is an internal combustion rotary heat engine that operates using liquid gas fuel or a dual-fuel system. The turbine's main element is a movable shaft with blades that are struck by the compressed gas, driving the entire unit operation. The principle of its operation is to suck in cold gas, compress it, heat it (by burning fuel), and then push it into the turbine, i.e., a shaft enclosed with blades, which, due to the gas expansion, starts to rotate and produce — using a generator — energy. The above process can be simplified as follows — the turbine works like a wheel in a water mill, with the difference that the installation is moved by compressed and heated gas (e.g., steam) instead of water.

The gas turbine operation is based on simple laws of physics. Their mechanics were initially developed in ancient Greece by Heron of Alexandria. In turn, in 1500, sketches of a steam turbine, which could be mounted on home chimneys, were made by Leonardo da Vinci. It was only during the industrial revolution that humanity learned to use the potential of this solution. The first gas turbine engine was patented in 1791. This solution was used to power ships a little over a hundred years later. In 1918, turbine wholesale production began, which helped revolutionize the energy industry. In turn, in 1930, gas turbines began to power aviation. Today, gas turbines are an essential element in many sectors. Their service life depends largely on the blades cast in Seco/Warwick VIM furnaces. Thanks to precise and repeatable operation, Seco/Warwick furnaces from the vacuum metallurgy segment ensure an excellent final product with a long service life.

"In the aviation industry, state-of-the-art jet engines use advanced single-crystalline cast blades," said Sławomir Woźniak, the CEO of Seco/Warwick Group. "The VIM furnace is famous for its high efficiency and low operating costs. The user-friendly control system ensures precise processes: casting, temperature control, as well as comprehensive data collection. These are some of the advantages of this unique solution. Thanks to its design, it ensures high repeatability and unrivaled throughput. New orders for VIM furnaces on the Asian market signal its recovery. We strongly focus our activities on this region of the world, taking care not only to provide efficient equipment for metallurgy and metal heat treatment but also to ensure the highest quality of service."

MORE INFO www.secowarwick.com

Gas spring manufacturer chooses Nitrex

T.Ş.T Lift Amortisör recently upgraded its gas spring manufacturing in Bursa, Türkiye, by integrating a Nitrex nitriding/nitrocarburizing system. (Courtesy: Nitrex)

T.Ş.T Lift Amortisör recently upgraded its gas spring manufacturing in Bursa, T rkiye, by integrating a Nitrex nitriding/nitrocarburizing system. This move signifies the company's commitment to adopting environmentally sustainable practices within its operations. Through this upgrade, T.Ş.T Lift replaces traditional salt bath nitrocarburizing with Nitreg® technology to enhance both the quality of its spring products and the efficiency of its manufacturing facility using a greener alternative.

The Nitrex system offers a comprehensive solution featuring three advanced heat-treatment technologies that enhance the customer's production capabilities: Nitreg® for controlled nitriding, Nitreg®-C for controlled nitrocarburizing, and ONC® for in-process post-oxidation, tailored specifically for treating gas spring rods for automotive, industrial, and furniture applications. These technologies ensure precise control over uniform case depths and nitride/nitrocarburizing layer formation, enhancing the mechanical properties of the gas spring rods. While Nitreg and Nitreg-C enhance surface hardness and fatigue resistance, ONC improves corrosion resistance and the aesthetic appeal of the finished product.

The batch-type furnace, equipped with an accelerated cooling system, is a nod toward efficiency. It shortens process times, expediting lead and delivery times while optimizing furnace use to drive cost savings. Additionally, since the system operates at lower temperatures compared to salt bath nitrocarburizing, it minimizes part distortion and eliminates the need for post-finishing operations by delivering a cleaner surface, streamlining the manufacturing process.

"In my experience with numerous Turkish clients, we prioritize delivering solutions that enhance manufacturing efficiency and sustainability," said Utku Inan, Nitrex sales representative in Türkiye. "The successful startup in March 2024 allowed T.Ş.T Lift Amortisör to transition seamlessly to new production, and we're dedicated to supporting them as they phase out their reliance on salt bath treatments."

"The need for today's manufacturers to improve product performance while keeping sustainability in mind has never been more apparent," said Marcin Stoklosa, technical sales manager — EMEA region at Nitrex. "T.Ş.T Lift Amortisör's adoption of Nitrex nitriding and nitrocarburizing technologies exemplifies this imperative. This transition isn't just about technological upgrades; it's about aligning production standards with global sustainability initiatives for a greener future."

MORE INFO www.nitrex.com

Allied breaks ground on $23.5 million Alabama expansion

Alabama Commerce Secretary Ellen McNair and other state and local officials joined executives and employees of Allied Mineral Products, LLC (Allied) recently in groundbreaking ceremonies at the site of Allied's major plant expansion in Pell City, Alabama. Allied is investing $23.5 million to launch an expansion of the plant that produces a variety of heat containment refractory products used in industrial applications.

The growth project will add a 200,000-square-feet production facility on the company's current site in Pell City and create 13 new manufacturing jobs, according to the Alabama Department of Commerce. The company's workforce at the time it entered into its partnership with the Department of Commerce was 81 full-time employees.

"Since its founding over 60 years ago, Allied Mineral Products has grown into a global company, serving multiple industries and registering sales to more than 100 countries," McNair said. "With a worldwide presence, the company could have selected another location for this investment, so this expansion in Pell City is truly a testament to the workforce there."

Construction on the new facility, now under way, will be completed in late 2025. In addition to the new building, the expansion will include installation of new manufacturing equipment including cranes, drying ovens, and mixers. Allied will increase the facility's production capacity, improve efficiency, prepare it for growth, and increase its ability to serve the company's Southern regions.

"Our partnership with Alabama is strengthened yet again with the expansion of this plant which we originally built in 2019," said Paul Jamieson, president and CEO of Allied Mineral Products. "Our theme for this event is 'Growth Propels Us.' This is true for Allied globally but is nowhere more apparent than here in Pell City. Locating our facility in Alabama was part of a long-term strategy to expand our manufacturing presence in the South to be closer to our customers. Because of the quality of this workforce and the local support here, our growth in Alabama has been faster than we planned. We are excited to be expanding our facility so soon and are confident this will help us to continue that growth."

Joining Commerce to support the project were the Pell City Industrial Development Board and the Alabama workforce development agency Alabama Industrial Development Training (AIDT), which will provide services including skills training on automation technologies for company workers.

MORE INFO www.alliedmineral.com

Sousa Corp. expands with second Ipsen Turbo Treater furnace

Sousa Corp., based in Newington, Connecticut, recently installed its second Ipsen Turbo Treater vacuum furnace to its production line, expanding its capacity to meet a steady demand for metal treating services.

"We've had three large vacuum furnaces running twenty-four hours, seven days a week," said Andrew Sousa, vice president of Sousa Corp. "We had the workload to support purchasing another furnace, and there are always new customers coming out of the woodwork, finding us by word of mouth. Demand remains strong."

Sousa Corp. chose to add the second Ipsen Turbo Treater to their line because of their confidence in and success with their first Turbo Treater, purchased in 2016. The Ipsen Turbo Treater provides users with a square hot zone design, reaching temperatures of up to 2,400 degrees Fahrenheit, handles a capacity of up to 1,800 pounds, and is designed for energy efficiency with uniform heating and cooling. Ipsen Turbo Treater vacuum furnaces also provide users with high-pressure gas quenching up to 12 bar.

"Ipsen makes a really nice furnace," Sousa said. "The Turbo Treater does a lot of things really well. Ipsen's support has been very good for us, and we like to have spare parts that are interchangeable between the first and second furnace. Our operators didn't have to learn the ins and outs of a completely new machine. When you start with something familiar, you're ahead of the game when you already know how to run and maintain (the new furnace.)"

Sousa Corp. does heat treating for a variety of industries, including aerospace, medical, fasteners, defense, automotive, and machine parts. The Sousa Corp. is a third generation, family-owned business that traces its company's history back to its predecessor Bennett Metal Treating Co. that was incorporated in 1915.

MORE INFO www.ipsenglobal.com

L&L ships second FB435 model to Doncaster castings

L&L Special Furnace delivered the second FB435 model furnace to Doncaster Precision Castings of Groton, Connecticut, a global leader in the aerospace, industrial gas turbine, and automotive markets. This advanced furnace will bolster Doncaster's in-house annealing, tempering, and heat-treatment capabilities, significantly enhancing their production efficiency and cost-effectiveness.

The FB435 furnace from L&L Special Furnace features a maximum temperature of 1,850°F (1,010°C) and working dimensions of 44-inch width, 36-inch height, and 60-inch depth. The furnace operates in an air atmosphere, equipped with a vertical counterbalanced pneumatic door, and an 18-inch diameter cast alloy fan. Its cooling system is powered by an automated ventilation system with a 600CFM venturi air mover, ensuring efficient and uniform cooling

Doncaster's decision to add a second FB435 model highlights the reliable performance and trusted precision of L&L Special Furnace's products. The six-zone SSR control with digital biasing allows for easy balance of temperature gradients. Honeywell process controllers and a NEMA12 industrial control panel with fused disconnect underscores the furnace's advanced control and safety features. Additionally, the flat castable hearth and robust stack light audible visual annunciator system provide optimized operational functionality.

By choosing L&L Special Furnace's FB435 model for the second time, Doncaster demonstrates their commitment to maintaining high-quality production standards. The furnace's capacity to handle a typical load weight of 2,000 pounds reinforces its suitability for heavy-duty industrial processes within the aerospace and automotive sectors.

MORE INFO www.llfurnace.com

Ipsen hires new customer service operations manager

Ipsen has hired Max Stormo as the new Ipsen customer service (ICS) operations manager as the company streamlines its aftermarket services in Souderton, Pennsylvania. Stormo comes to Ipsen after an extensive career working as a manufacturing operations leader in Texas, and a recent role as vice president of operations at a manufacturer in the Philadelphia region.

Max Stormo

In this position, Stormo will be a hands-on leader who directs and coordinates activities of Ipsen's aftermarket business for the Souderton plant. This includes overseeing manufacturing activities, developing and implementing production plans, training and developing staff, and ensuring the delivery of high-quality aftermarket parts to Ipsen's customers.

"Leading organizations through a series of step changes leads to organizational transformation," Stormo said. "I'm a big believer in step change — which drives sustainability. These changes lead to bigger things and set new standards."

Born and raised in Spokane, Washington, Stormo received his Bachelor of Science degree in operations management from Arizona State University. In 2006, he followed a career opportunity to Houston, Texas, where he spent the next 17 years in leadership roles with two different companies.

Stormo reports to Jake Hamid, Ipsen USA's director and chief operating officer.

"Ipsen has genuine leaders who represent the type of people that I enjoy working with and the culture that I was looking to join," Stormo said.

Ipsen's Souderton location has more than 60 employees and is currently recruiting for 10 additional positions. "People are an investment and the most valued asset in the company. Everyone I've met at Ipsen has the same attitude — enthusiasm," Stormo said.

MORE INFO www.ipsenglobal.com

Wisconsin Oven ships drop bottom furnace

Wisconsin Oven shipped one electrically heated drop bottom furnace with traveling quench tank and maintenance platform. This system will be used for the solution heat treatment of aluminum parts for the aerospace industry.

The drop bottom furnace has a maximum operating temperature of 1,100°F and workspace dimensions of 3'6" W x 3'6" L x 4'0" H. An OSHA-compliant maintenance platform provides ease of access for personnel to service the equipment. The quench tank capacity is approximately 1,700 gallons and includes fluid level control (low, fill, high), a lockable water drain port at the bottom of the tank, and an agitator for water circulation. The traveling quench tank is enclosed with safety fencing for added safety during operation.

This drop bottom furnace is designed with sufficient capacity to heat 600 pounds of aluminum per load and provide a quench delay that does not exceed five seconds. The system also includes a slow drop speed program to be used for heating applications that do not require a quench.

"This drop bottom furnace was designed with a five-second quench delay, and a temperature uniformity of +/- 5°F at the set points 850°F and 1,100°F," said Mike Grande, vice president of sales. "In addition, the system was tested to be in compliance with AMS 2750F, Class 1 furnaces and Instrumentation Type C prior to shipment from our manufacturing facility."

Unique features of this drop bottom furnace include:

» Traveling quench tank five second quench from start of door opening until full submersion.

» Documented temperature uniformity of ±5°F at 850°F and 1,100°F.

» Compliance with AMS 2750F, Class 1 furnaces and Instrumentation Type C requirements.

» Bi-parting pneumatically operated doors.

» 10,000 CFM @ 10 HP plug-mounted recirculation blower.

» 12" HMI screen mounted to a pivoting swing arm (to allow operators better line of sight of automated functionality).

» Digital Eurotherm temperature controller with fast acting advanced auto-tune.

» Installation supervision for 10 days at the jobsite.

MORE INFO www.wisoven.com

Chris Constable joins Solar Atmospheres of San Diego

Solar Atmospheres' newest acquisition, Solar Atmospheres of San Diego, announced the addition of Chris Constable as their new vice president of operations. Constable brings with him nearly 25 years of heat-treating experience that includes quality, operations, management, plant safety, business development, and sales. Constable is well-suited to understanding the customers' needs and providing effective solutions to their most difficult challenges. Coupled with the Solar Atmospheres' knowledgeable and dedicated team, Solar Atmospheres of San Diego aims to provide high-quality heat-treating services with a focus on honesty and integrity, and a reliable customer service experience.


Chris Constable

"We are very fortunate to introduce Chris into the Solar Family of companies," said Derek Dennis, president of Solar

Atmospheres of California. "As a highly disciplined business leader, Chris has the experience and knowledge to lead the Solar San Diego team through the new acquisition and establish a solid foothold in the Southern California heat treat and brazing market. I enthusiastically welcome Chris to the Solar team and look forward to working with him in the growth of the Solar San Diego operation. Truly exciting times for Solar Atmospheres."

MORE INFO www.solaratm.com

Seco/Vacuum awarded record-breaking contract

Seco/Vacuum, a division of Seco/Warwick Group, was awarded the largest contracts to date for the division.

Fabrication has begun for three Vector® Vacuum Furnaces and six tempering furnaces with supporting auxiliary systems. They will be going to a returning heat-treat partner who is already operating 12 Seco/Vacuum furnaces at their various locations throughout North America.

These furnaces are a continuation of the heat-treater's strategic planning to modernize all their facilities from atmospheric heat-treatment to vacuum processes which offer cleaner, safer, more cost-effective operation while also allowing for finer process control and a reduced carbon footprint.

The Vector is a single-chamber gas quenching vacuum furnace using high pressure quench (2 to 25 bar) which can be applied to a wide variety of heat-treating processes and applications, including hardening, tempering, annealing, solution heat treating, brazing, and sintering. It provides important capabilities for producing high uniformity in heat-treated parts, high consistency in workloads, and high speeds in batch processing with low consumption of power and process gases. These particular Vectors will be used primarily for hardening.

Tempering is a process primarily used to increase the toughness of hardened ferrous-alloy parts. The tempering process is typically applied after a hardening process. Seco/Vacuum's line of tempering furnaces is designed for quick and efficient atmospheric tempering. Convection heating allows this tempering furnace to reach process temperatures and conditions, enabling smoother heat-treat process flow at an often-congested stage of the overall heat-treat process.

To maximize process throughput they chose to order six tempering furnaces to go with their three Vectors because, while the Vector is capable of tempering as well, for optimum throughput two dedicated tempering furnaces are required to keep up with the relatively shorter hardening cycle of a single Vector.

Each of the nine units, Vectors and tempering furnaces alike, are front-loading, horizontally configured furnaces with a 36 x 36 x 48 inch working volume and a 3300 lb. capacity.

Heat-treating operations will have to shut down entirely during the modernization changeover.

To minimize disruption and get the heat-treat partner back up and running as swiftly as possible, in addition to providing the furnaces, Seco/Vacuum will also serve as the general contractor, overseeing the installation of the new furnaces, auxiliary systems, wiring, piping, and ventilation needed prior to commissioning and operator training.

"Our relationship with this heat-treat partner goes back a long way," said Piotr Zawistowski, Seco/Vacuum managing director. "It is a testament to our commitment to our partner's success that they not only continue to return for more furnaces, but that they place their trust us in to manage the entire project in order to get them back to serving their customers as fast as possible."

MORE INFO www.secowarwick.com

Ipsen USA invests in parts department improvements

Ipsen USA continues its commitment to the growth of the Ipsen customer service (ICS) parts department, expanding staff and implementing strategic initiatives to meet a growing demand.

Christina Connelly, parts manager for Ipsen in Cherry Valley, joined the team in 2022, and has since hired six additional employees. Between veteran team members and new hires with strong technical backgrounds, Connelly and her team are focused on reducing turnaround time and increasing customer responsiveness.

"We had outgrown our existing structure as our organization has evolved, so we had to reimagine what our parts team needed to look like, operationally," Connelly said.

Ipsen's ICS parts team held an internal Kaizen event — a review of the processes used to complete customer orders and answer requests — and looked for immediate changes that would reduce delays, increase responsiveness, and allow for continuous process improvements. One place where the ICS parts team saw an immediate opportunity to reduce turnaround time came from asking the customers the right questions, right away.

"We started asking certain customers to fill out a detailed request form," Connelly said. "We wanted to see if we could turn a request into a quote sooner." By collaborating with users of the Ipsen Connect online customer portal, Connelly's team has gained better insight into this process and what information is most useful.

Automation, trend analysis, and artificial intelligence also offer hope for current and future solutions to ensure customer satisfaction. A centralized email system handles parts orders with a single point of contact. AI- powered customer service software automates phone order tracking, seamlessly integrating with sales platforms and managing case assignments. And Ipsen's commitment to developing digitized machine learning solutions for customers and internal sales specialists is being led by Ipsen's vice president of digital technologies, Aymeric Goldsteinas.

MORE INFO www.ipsenglobal.com

Topçesan A.S. invests in Nitrex system to enhance forging

Since its establishment in 1987, Topçesan Topbaş Çelik Sanayi ve Ticaret A.Ş. has stood tall in the Turkish steel forging industry.

Operating from its facility in Nilüfer/Bursa, the company has solidified its position as a leading integrated steel processing manufacturer, supplying forging, molding, and machining components to various industries.

As part of their strategic efforts to enhance forging capabilities, Topçesan recently invested in a Nitrex system. Specifically, they acquired the NXK-812 compact batch-type furnace with a 1,200 kilogram capacity, designed for nitriding and nitrocarburizing forging dies. These dies are used in the production of engine parts, transmission components, and chassis parts for vehicle manufacturing, catering to automotive clients such as BMW, Tofaş, Fiat, and ZF Group across Europe and Türkiye.

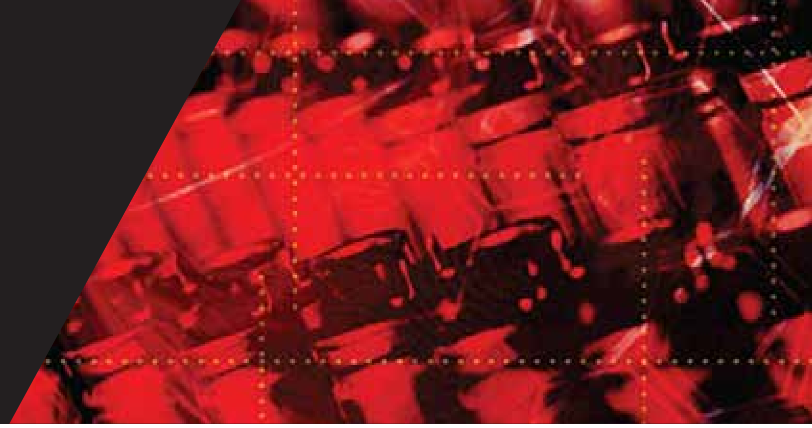
By integrating nitriding and nitrocarburizing processes into their operations, Topçesan aims to prolong the lifespan of their forging dies, increasing component production while reducing tooling costs. The system includes an ammonia dissociator, which is essential for precision control over nitriding potential, particularly when treating specific alloys that must align with AMS 2759/10 and AMS 2759/12 specifications.

Topçesan opted for Nitrex based on their favorable experience with a local commercial heat-treating company providing Nitrex nitriding services. Encouraged by the resulting performance improvements, they made the strategic decision to harness these advantages internally, integrating them into their operations.

Topçesan is making a strategic investment that will not only enhance its in-house capabilities and cost efficiency but also contribute to a more efficient and sustainable future.

"The operating software of the Nitrex system ensures optimal production media and utility consumption throughout the process, providing the customer with detailed analysis after each operation," said Marcin Stoklosa, Nitrex technical sales manager. "This technological advancement underscores our commitment to customer satisfaction and operational efficiency, ensuring superior performance."

MORE INFO www.nitrex.com



Alessandra Palombi wins Aichelin Young Speaker Award

Alessandra Palombi from the Department of Industrial Engineering of the University of Rome "Tor Vergata" was given the Aichelin Young Speaker Award at the 4th Mediterranean Conference on Heat Treatment and Surface Engineering in Lecce, Italy, in combination with the 5th International Conference on Thermal Process Modeling and Simulation.

Her talk on "Low temperature plasma assisted carburizing of 3D printed 316 L stainless steel" convinced the jury regarding the award. The award, sponsored with 1,500 euros by the Austria-based furnace manufacturer Aichelin, is given for the best talk by a speaker younger than 35 at an IFHTSE conference in Europe. The next Aichelin Young Speaker Award will be given at the Motion in Heat Treatment — Heat Treatment in Motion conference in Prague, June 4-6, 2025.

Alessandra Palombi is from the Department of Industrial Engineering of the University of Rome.

HANDBOOK ON QUENCHANTS AND QUENCHING TECHNOLOGY

ASM International, an IFHTSE member, recently released the latest volume in its ASM Handbook series, "Volume 4F Quenchants and Quenching Technology." This is a comprehensive update of the best-selling "Handbook of Quenchants and Quenching Technology" (ASM International, 1993).

Volume 4F discusses the design of quenching systems with emphasis on the method of agitation. It explains how to evaluate initial designs, assess manufacturing feasibility, and determine the root cause of quench-induced failures. It covers a wide range of quenching processes, including induction, spray, gas, pulse, and intensive quenching and addresses related issues such as residual stress, distortion, and cracking in different types of components. It also discusses the use of computational fluid dynamics and other modeling tools.

The editors include IFHTSE Fellow Lauralice C.F. Canale and former IFHTSE President and IFHTSE Medalist George Totten. Six IFHTSE awardees and officer holders are among the 33 contributors and reviewers. They include:

- **Imre Felde:** IFHTSE treasurer and winner of the Tom Bell Young Author Award.
- **Cemil Hakan Gür:** IFHTSE fellow.
- **Thomas Lübben:** IFHTSE fellow.
- **D. Scott MacKenzie:** Former IFHTSE president.
- **Valery Rudnev:** IFHTSE fellow.
- **Eva Troell:** Former IFHTSE president.

This volume is available through ASM International.

More info: dl.asminternational.org/handbooks/edited-volume/194/Quenchants-and-Quenching-Technology

CONFERENCE UPDATES

29th World IFHTSE Congress
September 30- October 3, 2024 | Cleveland, Ohio

The ASM Heat Treating Society (HTS) and the International Federation for Heat Treatment and Surface Engineering (IFHTSE) present the highly anticipated 29th IFHTSE World Congress, a premier global event dedicated to advancing the fields of heat treatment and surface engineering. It is co-located with ASM's Annual Meeting, IMAT 2024.

The 2024 IFHTSE World Congress revolves around the theme "Innovations in Heat Treatment and Surface Engineering for a Sustainable Future." Emphasizing the critical role of these technologies in shaping a sustainable world, the event will explore the latest

The 29th IFHTSE World Congress, a premier global event dedicated to advancing the fields of heat treatment and surface engineering, will be held Sept. 30 to Oct. 3 in Cleveland, Ohio. (Courtesy: Shutterstock)

developments, breakthroughs, and practices that can enhance the efficiency, performance, and environmental impact of heat treatment and surface engineering processes. In addition, traditional heat-treating topics will be offered.

›› **More info:** www.asminternational.org/ifhtse-congress

29th IFHTSE World Congress: Future of Heat-Treating Workshop

As part of the event, a special workshop on the Future of Heat Treating will be Monday, September 30, 2024, 3-5 p.m. This session will delve into three critical areas of heat treating and surface engineering: Data/IoT, Sustainability, and Education. Led by subject matter experts and facilitators from IFHTSE, participants will engage in round-table discussions, shaping a strategic plan for the global heat-treat community's needs over the next three to five years. With an interactive format and opportunities for networking, this workshop promises insightful exchanges and actionable outcomes. Reserve your spot now and be part of shaping the future of heat treating. There is no additional fee to participate, however, pre-registration is required.

Third International Conference on Quenching and Distortion Engineering
May 6-8, 2025 | Vancouver, Canada

The Third International Conference on Quenching and Distortion Engineering will be in conjunction with AeroMat 2025. This is a continuation of the successful Distortion Engineering conference series and the Quenching and Distortion conference series. The first QDE was in Chicago, Illinois, in 2012 and has occurred at approximately five-year intervals. There is a strong focus on the effects of residual stress during manufacturing and methods to control distortion and residual stress. The call for papers is expected in the next few months.

Motion in Heat Treatment – Heat Treatment in Motion
June 4-6, 2025 | Prague, Czech Republic

The Motion in Heat Treatment — Heat Treatment in Motion is the fifth in its series and sponsored by AZTK (ASOCIACE PRO TEPELNÉ ZPRACOVÁNÍ KOVU). It will be at the Kaiserstein Palace. This event follows the 3rd conference in Prague in 2016 and the 4th conference in Spartanburg, South Carolina. While the previous focus of the event was primarily on automotive applications, the focus has been widened to all transport applications including automotive, rail, and aircraft and marine applications of heat-treated and surface-engineered components. The event is combined with the European Conference on Heat Treatment.

IMPORTANT DATES

- ›› **Abstract submission:** November 15, 2024.
- ›› **Full paper submission:** March 15, 2025.
- ›› **Submission of presentations:** May 15, 2025

30th IFHTSE World Congress
August 18-21, 2025 | Suzhou, China

This event, sponsored by the Chinese Heat Treatment Society (CHTS), follows the 25th World Congress in Xi'an in 2018. More details are forthcoming as available.

IMPORTANT DATES

- ›› **Deadline for abstract submission:** February 28, 2025.
- ›› **Notice of acceptance:** March 10, 2025.

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

2024 Annual Meeting was a success

Association annual meetings allow members to come together, exchange ideas, learn from expert speakers, work on committee initiatives, and network with others in the industry. This year, IHEA's 95th Annual Meeting was in the historic town of Savannah, Georgia, and accomplished all those things and more. In addition to the excellent presentations and business discussions, members and guests enjoyed social activities and time to explore the beautiful squares and shops sprinkled throughout the city.

The meeting included a series of outstanding presentations that were very highly rated by those in attendance. Each year, the program includes timely and valuable content. This year's titles included Unlocking an Innovative Mindset, How AI is Reshaping the Sales & Marketing Battlefield, Securing the Future: Navigating Cybersecurity Challenges in Manufacturing, and the ever-popular, Economic Update: Where are We Headed?

In addition, IHEA's sustainability efforts were addressed with an informative presentation on the DOE's decarbonization initiatives. To conclude the meeting, IHEA presented a Decarbonization Fireside Chat that included Chad Spore from John Deere and Dr. Joachim Wünning of WS Thermal Process Technology, Inc. The session was led by IHEA Past President Brian Kelly of Honeywell Thermal Solutions, who conducted a Q&A with the audience and panelists. Discussions revolved around navigating the decarbonization movement.

"The great value in this is the diversity of the attendees and their willingness to share their experiences," Kelly said. "With so much talk of sustainability and decarbonization in the heat-processing industry, IHEA's focus on this during the meeting was critical."

IHEA had a record number of first timers at the meeting, which made the Explorer Theme Dinner a fun adventure for newbies and veterans alike. Channeling the spirit of the meeting location at the DeSoto Savannah, the evening brought members, guests, speakers, and staff together to discover new connections and learn about the explorations of others.

The event ended with the President's Reception and Gala. Attendees toasted to IHEA's 95th year and a successful future.

There was excitement during the meeting surrounding IHEA's sustainability initiatives including the monthly webinar series and the highly anticipated Industrial Heating Decarbonization SUMMIT to be held in the fall.

»**More info:** summit.ihea.org.

IHEA's 95th Annual Meeting was in the historic town of Savannah, Georgia. The first IHEA meeting was in 1929.

REGISTRATION OPEN FOR IHEA 2024 FALL SEMINARS

IHEA continues to educate the heat processing industry with its outstanding training seminars. This fall, IHEA will conduct its annual Combustion and Safety Standards and Codes Seminars September 17 and 18 at the Westin Poinsett in Greenville, South Carolina. The fall seminars also feature a joint Tabletop Exhibition & Reception on Tuesday afternoon, September 17. This allows attendees of both seminars the chance for additional one-on-one interaction with suppliers from across the industrial heating marketplace.

IHEA's Combustion Seminar features 16 sessions designed to give attendees vast exposure to combustion technology. Some of the topics covered include chemistry and efficiency of combustion, flame safety requirements of combustion systems, process and ratio controls with exposure to micro-processor equipment, types of industrial burners available, supply and control of the fuel and air for systems, and preheated combustion air and furnace recuperators. The seminar also features a session on hydrogen combustion and decarbonization. This two-day course is led by subject matter experts in a non-commercial environment.

The Safety Standards and Codes Seminar provides a comprehensive overview of the NFPA 86 standard. The seminar will highlight the recent updates that appear in the 2023 edition of NPFA 86 Standards for Ovens & Furnaces. This class will be taught by several instructors who were heavily involved with the 2023 revision and will include

Attendees receive valuable technical information at IHEA's fall seminars.

IHEA fall seminar attendees take advantage of visiting with tabletop exhibitors during the networking reception.

discussion of the updates as well as an extensive explanation of several critical safety topics. Sessions will cover the required uses of the American National Standards governing the compliant design and operation of ovens and furnaces.

A Tuesday evening joint Tabletop Exhibition & Reception will be at the conclusion of the first day of seminar sessions. The tabletop exhibition showcases a variety of products and services for the heat-processing industry and includes a networking reception with hors d'oeuvres and drinks. The event allows attendees to meet with speakers, exhibitors, and other attendees to further discuss the concepts learned during the seminars. Tabletop space and sponsorships are available now. Reserve your tabletop and sponsorship today, so your company can benefit with listings in promotional materials from now until the event.

›› **More info:** www.ihea.org/event/TT24.

Registration fees for the seminars include admission to one seminar, seminar materials, breakfast, lunch, and refreshment breaks on Tuesday and Wednesday, and the tabletop exhibition & reception. Upon completion of the seminars, attendees will be issued a certificate documenting 15 Professional Development Hours (PDHs). There is a group discount available for two or more registrants from the same company who register at the same time. The first registrant will pay the full registration fee, and each subsequent registrant will receive a $125 discount.

›› **More info:** www.ihea.org/Fall24.

Discounted hotel reservations for both attendees and exhibitors are available at the Westin Poinsett Greenville. The group rate is $229/night plus tax and destination fee. The discounted group rate is good through August 26, 2024, or until the room block is full. Reserve your room early to receive the group rate at: tinyurl.com/IHEAhotel.

IHEA 2024 CALENDAR OF EVENTS

JULY 18

Sustainability & Decarbonization Webinar Series — Industry Adoption: U.S. Codes & Standards

AUGUST 15

Sustainability & Decarbonization Webinar Series — Renewable Fuels

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

JASON MEYER
MECHANICAL ENGINEER /// DANTE SOLUTIONS

Induction hardening is a contactless and effective process for case hardening steel. Modeling the process with respect to residual stress is increasingly important.

Inducing heat treatment for case hardening

Induction hardening has become an increasingly popular heat-treatment method for steel due to its extremely fast processing speeds. Compared to other case hardening methods, the processing times are on the scale of seconds or minutes compared to hours in a carburization furnace. Typically a per-piece method, the processing speeds rival that of batch processing and, when done right, there is often no worry about scaling or decarburization due to the rapid heating and cooling. The process provides a hard, compressive surface suitable for high-wear and fatigue applications and the process can be done selectively, focusing on regions of interest instead of having to process the entire part.

Disadvantages include a higher potential for cracking and localized distortion from the high rates of heating and cooling, the initial investment cost and maintenance required for the copper coils, and reduced diffusion and carbide dissolution from the severely reduced processing times. Another disadvantage is the relatively high-tension stress state just under the hardened case, often transitioning from compression to tension abruptly in the case-core region. This abrupt change in stress can lead to internal cracking or failure in high-cycle fatigue applications such as drive shafts or powertrain components if the heat treatment is not properly designed.

Modeling the induction process becomes increasingly important as the complexity of the part and mechanical requirements increase. Induction processes are multi-physical in nature, involving electromagnetics, heat transfer, solid mechanics, and metallurgical phenomena, which lends itself well to numerical simulation through Finite Element Analysis (FEA). Simulating the electromagnetic response involves modeling the interaction between the part and the coil to obtain the magnetic field (eddy currents) that generates the joule heating within the part. This is a popular method used in coil design and initial process development but is also computationally intensive, especially when considering the thermal, mechanical, and metallurgical response of the part being modeled as well. Another useful method for modeling the induction process is to focus on the part itself and on the heat generated from the magnetic field, which is described as an internal heat generation, or flux, in the elements that define the case. This method is less intensive computationally as the coil itself is not modeled and is most useful when the profile that the coil produces is well-known and small changes in part geometry or heating recipes are to be explored. In general, power regulates the amount of heat that is provided to the part and is highly dependent on the surface area being treated. The frequency of the inductor controls the depth of the case, with lower frequencies increasing depth and higher frequencies providing a shallower case. For the flux method, the profile generated by the frequency can be described by a flux profile based on the depth from the surface, typically starting high at the surface and dropping sharply with increased depth. Once developed and validated, the FEA models can be used to modify and optimize the residual stress profile of a part through process modifications, such as applying a preheat step prior to hardening.

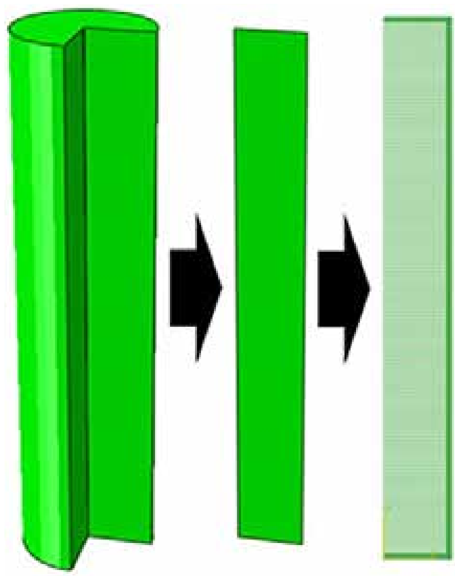


Figure 1: Schematic of the modeled section of the three-inch bar.

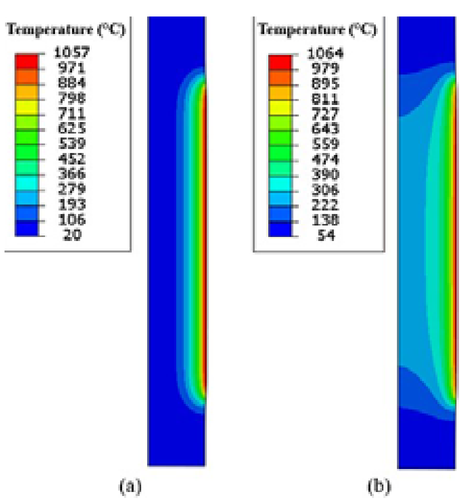


Figure 2: Temperature contours after induction heating for the single-shot (a) and preheat (b) models.

CASE STUDY

Finite element models were developed for two example single-shot induction hardening processes. The geometry consists of a three-inch diameter shaft, made from normalized AISI 4140 steel, which is modeled with axis-symmetry along the longitudinal and radial axis and meshed with 3358 elements and 3528 nodes (Figure 1).

The case depth is between 1.5-2mm, and the as-quenched hardness is required to be above 55 HRC. The example heat-treatment schedules for the induction processes include:

» Single-shot recipe
» Induction heating at full power for 6.5 seconds.
» Spray quenching for 60 seconds.
» Air cool to room temperature.
» Preheat recipe
» Induction preheating at 1/10th power for 60 seconds

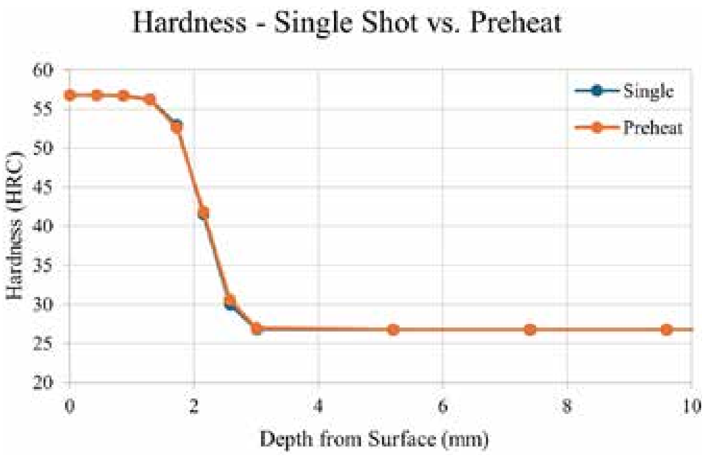


Figure 3: Hardness profiles for the single-shot and preheated models.

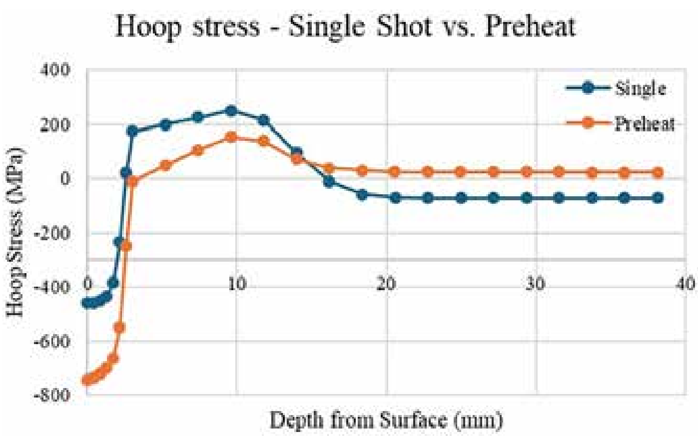


Figure 4: Hoop stress results for the single-shot and preheat models.

- Induction heating at full power for 3 seconds
- Spray quenching for 60 seconds
- Air cool to room temperature

The modeling assumptions include a constant frequency, or flux profile, for both processes while only the power is adjusted. Heat transfer boundary conditions include convection coefficients for hot air during induction, water spray during quenching, and still air for the final air cool. Radiation was not modeled to simplify the analysis. Figure 2 shows the simulated temperature profile in the shaft for both the processing conditions after induction heating, just before spray quenching. The single-shot model shows a room temperature core while the preheat model shows the core to be about 250°C, while the surface temperatures for both the models are about 1,060°C.

The sequential thermal and stress models were executed using Abaqus standard and DANTE material models on a standard laptop, using four cores of an Intel i7 processor. Each analysis was complete in under one minute. For post-processing, path plots were taken from the mid-height of the axis, from the surface to the core, to avoid any end effects from heating or cooling.

RESULTS

The results of the executed models show a surface hardness of about 56 HRC and matching case depths and hardness profiles (Figure 3). The case depth, as measured at 50 HRC, is shown to be about 1.8mm from the surface. At roughly 2.5-3mm from the surface, the hardness drops to the annealed core values, just below 30 HRC.

The sharp drop in hardness at the case-core interface is caused by the austenite to martensite transformation in the case. The volume expansion caused by this transformation is often the cause for concern with respect to residual stress. The larger martensite phase leads to compression in the case, but also pulls on the material just below the case, causing residual tension. Figure 4 shows the residual stress profile in the hoop direction, circumferential, after the spray quench and air cool steps. The single-shot process produces a surface compression of about 450 MPa, while the preheated model shows higher surface compression with a magnitude of about 740 MPa. The preheated model also shows a decrease in residual tension just under the case compared to the single shot model. At three millimeters, the preheated model is relatively neutral while the single shot model shows about 170 MPa of tension. The preheated model continues to show a reduced magnitude of compression until about 14mm from the surface, where the model shows slight tension to the core and the single-shot model shows slight compression to the core.

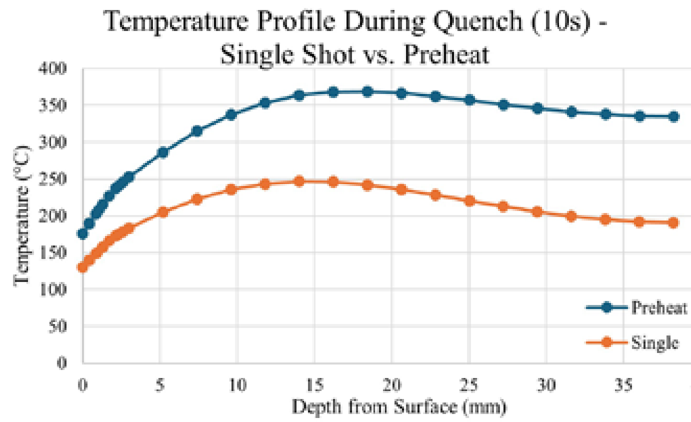


Figure 5: Temperature profiles for the single-shot and preheat models, after 10 seconds of quenching.

The mechanism that causes the higher magnitude of compression in the case, and reduced case-core tension, with the preheated model can be understood through thermal expansion. Both models form the same amount of martensite in the case; however, the core of the preheated model is warmer, and therefore larger, than the cool core of the single shot model. The preheated shaft shrinks after the case is formed, inducing compression throughout the part as the core is finally cooled to room temperature. Figure 5 shows this temperature difference after 10 seconds of quenching time, where the martensite transformation is complete for both models.

CONCLUSIONS

The induction-hardening process is a contactless and effective process for case hardening steel. The short process times and advancements in automation improving consistency allow for quick and reliable results. Residual stress is a concern due to the sharp transition from compression to tension at the case-core interface. The FEA models have been used to tailor the stress profile as required by preheating to increase surface compression and reduce the magnitude of tension at the case-core interface. Simulation is effective in testing new processes and viewing the part response to new methods before running physical trials.

ABOUT THE AUTHOR

Jason Meyer joined DANTE Solutions full time in May 2021 after receiving his Master's degree in mechanical engineering from Cleveland State University. His main responsibilities include marketing efforts, project work, and support and training services for the DANTE software package and the DANTE utility tools. Contact him at jason.meyer@dante-solutions.com.

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

Aqueous salts offer a solution when oil, water, or polymer aren't appropriate. Benefits include very fast quench rates and relative immunity to agitation. The primary disadvantage is corrosion.

Aqueous inorganic salt quenchants

In this column, I will discuss the inorganic salt quenchants and how they can be used effectively to quench lean hardenability steel parts.

Often, a heat treater is presented with a situation that neither oil, water, nor polymer can solve. Situations such as having a very lean alloy, with a very high hardness requirement, that requires a faster quenchant than water, oil, or polymer quenchant can provide. The use of aqueous salt quenchants can provide the answer in this situation.

Aqueous inorganic salt quenchants are quenchants that use small amounts of inorganic salts to achieve faster and more uniform quenching compared to water. Even small amounts of dissolved salt in water can drastically change the quenching characteristics. These changes due to the presence of inorganic salts can overcome many of the disadvantages of water. These types of quenchants are often referred to generically as "brine" quenchants, the term being coined due to the use of salt water in older quench tanks.

Salts, acids, and alkalis readily dissolve in water. These act to reduce the stability of the vapor phase during quenching. If the concentration is high, then the vapor phase will not form at all. This type of contamination can be taken advantage of to create quenchants with very fast quench rates.

During quenching, minute crystals of salt precipitate on the surface of the part (Figure 1). This causes water to be displaced and the waters of hydration to escape. The localized high temperatures cause these crystals to fragment violently, and this creates turbulence, which destroys the vapor film and initiates nucleate boiling [1]. This yields very high maximum cooling rates.

The most common aqueous inorganic salt quenchant is a solution of sodium chloride and water. As the concentration of sodium chloride increases, the faster the cooling curve. This in turn, increases the hardness of quenched steel (Figure 2). The vapor phase disappears as the concentration is increased to 10 percent or greater.

Concentration	Water	NaCl	$CaCl_2$	Na_2CO3	NaOH	HCl
0	102–120	-	-	-	-	-
5	-	170	170	.. .	202	153
10	-	195	193	170	202	-
15	-	-	-	-	207	-
20	-	-	170	-	-	100

Table 1: Maximum cooling rates (°C/s) of a 12.5 mm probe quenched in water solutions at different concentrations [2].

Other salts behave in a similar manner to sodium chloride. Alkali solutions such as NaOH show a similar response (Table 1).

While the use of sodium hydroxide or sodium chloride is effective, it is also hazardous. Sodium hydroxide (lye) and sodium chloride are very corrosive. To answer that need, proprietary salt mixtures such as Aqua-Salt™ A and Aqua-Salt™ F were developed to overcome the deficiencies of traditional salt of alkali quenching and provide more efficient quenching (Figure 3).

The quenching power of aqueous inorganic salt solutions is not affected by temperature to the same extent that water is. While the temperature range of inorganic salt solutions is wide, the optimal temperature is approximately 20–40°C.

The concentration of aqueous inorganic salt solutions is expressed usually by specific gravity. The concentration of aqueous salts can be determined in several ways; however, the simplest method is using a simple hydrometer measuring the specific gravity of the solution (Figure 4).

A hydrometer is a simple instrument that operates using the Archimedes principle. That is, a solid body will displace its own

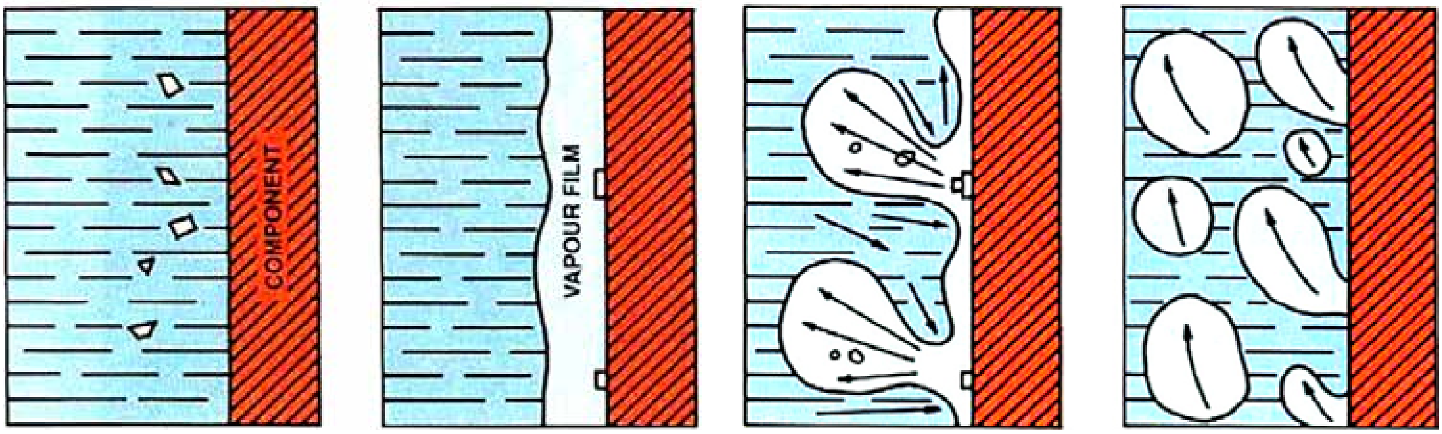


Figure 1: The mechanism of quenching with aqueous salt solutions. Left: Salt crystals form and deposit on the part surface. Right: Crystals fragment causing disruption of the vapor film.

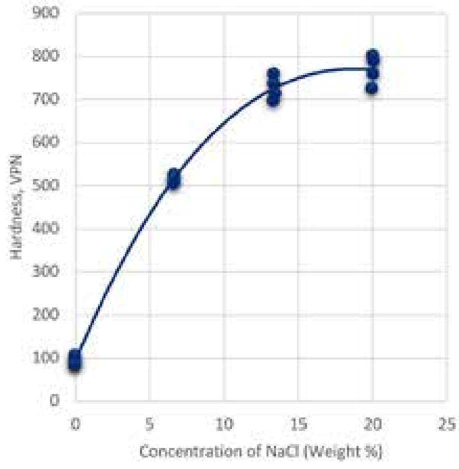


Figure 2: Effect of salt concentration on large diameter medium carbon (0.4% C) steel [3] [4].

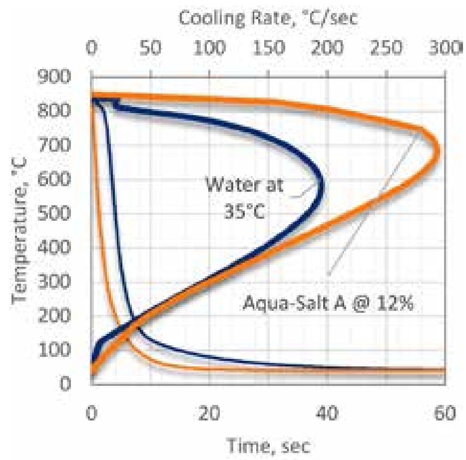


Figure 3: Cooling rate curves of Aqua-Salt™ A compared to water.

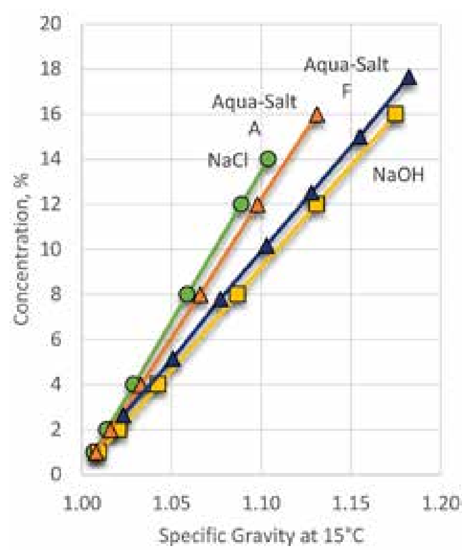


Figure 4: Typical specific gravity values of aqueous salts as a function of concentration [5].

weight within a liquid. There are two types of scales — one for liquids lighter than water and another for liquids heavier than water. For the case of aqueous salt solutions, the scale for liquids heavier than water is used. In other words, for a specific gravity greater than 1.000.

A hydrometer is usually made from a tall glass stem that is weighted at one end to make it float upright. The liquid to be tested is placed into a tall container, such as a graduated cylinder. The hydrometer is gradually lowered into the fluid. There are usually graduations along the side of the hydrometer. The hydrometer floats in the fluid, and where the liquid surface touches the stem of the hydrometer is noted. Usually, the specific gravity of the fluid can be read directly from the hydrometer.

The accuracy of the hydrometer depends on three main factors: the cleanliness of the hydrometer, the temperature of the fluid, and ensuring proper immersion.

The cleanliness of the hydrometer is very important. It should be properly cleaned after each use so that the fluid will properly wet the surface.

The hydrometer is calibrated for a certain temperature (usually 15.5°C). The fluid should be at this temperature for accurate readings.

Lastly, the graduated cylinder, or other container, should have a diameter approximately 2.5 cm greater than the diameter of the graduated cylinder height to minimize meniscus effects.

The major advantages of aqueous salt solutions for quenching are:

» Aqueous salt solutions are relatively not affected by bath temperature to the same degree that water is.

» The vapor phase is eliminated. Quenching is more uniform, even in dense loads.

» Uniform quenching is more readily achieved. Soft spots and distortion are not usually an issue, provided that proper low alloy steels are selected.

» The quench rate is substantially greater than water. As-quenched and hardness uniformity is increased.

The disadvantage of aqueous salt solutions as quenchants are:

» The quench tank and the support equipment (hoists, racks, agitators, etc.) must be protected from corrosion. Quench tanks are most often constructed of stainless steel. More attention must be paid to proper grounding to prevent stray currents, and material compatibility. Increased use of rust inhibitors is required, unless quenchants are chosen that incorporate the necessary corrosion inhibitors.

» Hoods and exhaust stacks are necessary to remove aqueous salt vapors. Stacks and exhausts should be made of stainless steel to prevent excessive deterioration of the ductwork.

» The material and labor costs associated with brine quenchants are higher. This is because of the costs of concentration control, preparation of solution and raw material costs. Maintenance costs are also higher because of corrosion.

» Environmental costs are also higher, as the cost of disposal is increased.

Many of these issues can be overcome with proper engineering controls.

CONCLUSIONS

In this article, the mechanism of quenching for aqueous salt or brine quenchants is described. Precipitation of the salt initially forms on the surface of the part, defeating the vapor phase, starting nucleate boiling early. This results in a very fast quench.

Aqueous salt quenchant concentration is commonly determined by using a common hydrometer to measure specific gravity of the solution. The concentration of the salt is linearly dependent on the specific gravity of the solution, so concentration can be simply determined.

The biggest benefits of aqueous salts are their very fast quench rates and relative immunity to agitation and temperature effects. This simplifies quench tank design.

The primary disadvantage is corrosion. However, proper design can mitigate many of the corrosion issues.

REFERENCES

[1] L. H. Zordao, V. A. Oliverira, G. E. Totten and L. Canale, "Quenching power of aqueous salt solution," Int. J. Heat Mass Transfer, vol. 140, pp. 807-818, 2019.

[2] D. S. MacKenzie, "Quenchants Used for Heat Treating of Ferrous Alloys," in Steel Heat Treating Technologies, vol. 4B, J. L. Dossett and G. E. Totten, Eds., Materials Park, OH: ASM International, 2014, pp. 255-280.

[3] M. Ahmadin and D. K. Pratiwi, "Effect of Cooling Water Fraction of Salt in Low Carbon Steel Properties," Journal of Mech. Sci. Eng, vol. 2, no. 1, pp. 1-5, 2015.

[4] L. W. Pietrasz, Zakajocznyje sriedy, Moskwa: Maszgiz, 1959.

[5] J. C. Hughes, "Testing of Hydrometers," U.S. Government Printing Office, Washington D.C., 1954.

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THE FUTURE OF VACUUM OIL QUENCHING

The NEO™ vacuum oil quench furnace. (Courtesy: Solar Atmospheres)

Case study: Solar Atmospheres has developed a vacuum quench furnace that addresses the demands for metallurgical precision, safety, and environmental sustainability.

By **ROBERT HILL**

Despite decades of relentless innovation, the constraints of high-pressure gas quenching have become increasingly evident. Even with the utilization of specialized inert gas blends and heightened gas pressures, the gas cooling efficacy compared to liquid quenchant cooling particularly for heavier cross sections has its limitations. It is also undeniable that certain aerospace alloy steels governed by stringent liquid quench AMS specifications will never change.

Instead of consistently "no quoting" AMS governed oil quench alloys over the years, Solar Atmospheres of Western PA, Solar Manufacturing — along with Solar Atmospheres engineers — embarked on a journey of ingenuity during the tumultuous period of the pandemic. Their dedication culminated in the birth of the NEO™ vacuum oil quench furnace. With a unique 36" x 36" x 48" hot zone that operates up to 2,000°F maximum while accommodating a weight capacity of 2,000 pounds, the NEO represents a paradigm shift in vacuum oil quenching technology.

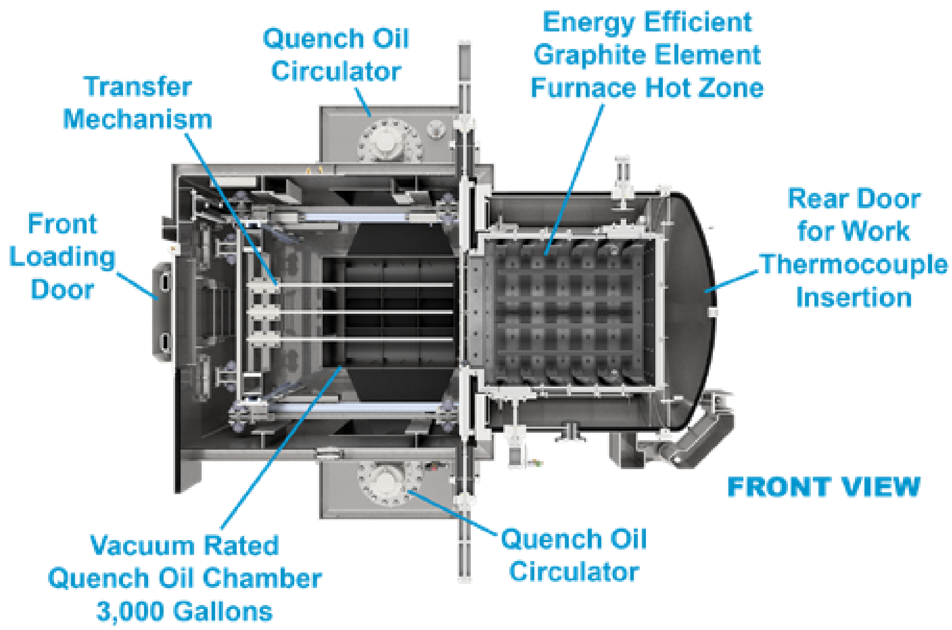

Figure 1: Cross section view of the NEO.

CHALLENGES

The creation of the NEO was not without its formidable obstacles. Foremost among these challenges was the development of a robust transfer mechanism capable of seamlessly relocating heavy workloads from the hot zone to the oil quench chamber under high-vacuum conditions. Solar Manufacturing engineers surpassed this hurdle with the implementation of a groundbreaking "lift and place" mechanism, which has since demonstrated flawless performance for nearly two years. (See Figure 1)

Additionally, concerns regarding oil back-streaming in the new multi-chambered vacuum system were meticulously addressed. With Solar's strong acumen in vacuum technology, a solution was discovered. The hot zone remains pristine and oil-free to this day.

METALLURGICAL BENEFITS

The NEO heralds a new era of metallurgical excellence. By effectively getting rid of any surface contamination, both intergranular oxidation (IGO) and decarburized or carburized surfaces on oil quenched components are eliminated. These critical metallurgical features are unattainable in traditional gas-fired endothermic batch furnace equipment. (See Figure 2)

Furthermore, the NEO provides the metallurgical engineer the ability to finally thermocouple oil quenched parts in accordance with AMS 2750 Rev G standards. Being able to monitor part temperature with up to 12 data points ensures thorough and precise thermocouple monitoring, bolstering control and repeatability.

Figure 2: Surface photomicrograph – 52100 Material 500X.

At the completion of the automated austenitizing cycle, the newly designed transfer mechanism delivers precisely heated parts from the hot zone to the 3,000-gallon oil quench chamber consistently within 20 seconds — all without the expulsion of flames and the discharge of smoke.

Since the NEO is a hermetically sealed furnace, the engineers wanted to give the furnace operator "eyes" into the furnace. An internal camera was designed for the operator to watch the load transfer in real time from the control panel.

To eliminate the potential of part cracking, quench oil temperatures are maintained between 140°F to 180°F at ±5°F, which enhances consistent and repeatable metallurgical results. In addition, the quench oil recirculates within a closed loop oil to air cooling system, never allowing water contamination to infiltrate the oil.

Finally, the NEO consistently produces bright, clean work (See Figure 3). This ultimately leads to less costly downstream processing for the customer.

PRODUCTION BENEFITS

Processing within an atmosphere totally devoid of oxygen, the NEO finally eliminates the need to match atmospheric carbon potentials to the carbon content of the alloys being processed. This not only eliminates costly oxygen probe purchases, but it also gives the operator the ability to mix and match various materials of various customers. Production efficiencies have been realized when multiple materials with varying carbon contents, which are similar in cross section and austenitizing temperature, are processed in one load. (See Figure 4)

This newfound flexibility is augmented by practices such as cold loading and unloading, which not only prevents detrimental oxidation but also extend the lifespan of the hot zone, thus minimizing downtime.

While building the NEO, Solar's R&D department performed their own laboratory experiments on the vaporization of various quench oils at different pressures and temperatures. It was decided to purchase 3,000 gallons of traditional Houghton G quench oil vs. the costly "vacuum-only" quench oils on the market today.

HEALTH AND SAFETY BENEFITS

At Solar, the safety and well-being of the workforce are paramount. By operating within a hermetically sealed furnace environment, the NEO effectively eliminates the risks associated with open-flame exposure, explosivity, and skin burns.

Moreover, at the completion of every cycle, the NEO opens at both ends to the atmosphere. Full air exchange mitigates the potential hazards of confined spaces.

Most recently at the Hermitage PA facility, a power outage was experienced at the exact moment a 1,500-pound load at 1,550°F was being transferred to the oil quench. The hydraulically controlled transfer mechanism stopped on a dime; the internal door from the hot zone to the oil quench vestibule remained open, and the hot-load vacuum cooled harmlessly under vacuum. The environs to the furnace remained unchanged — no smoke, no flames. With pneumatically controlled traditional Batch IQ furnaces, the loss of air pressure during such an event often causes doors and elevators to drop unexpectedly with loads in precarious positions. The chance of an accident increases exponentially with unexpected power loss — not the case with the NEO. Once power was restored, the load was successfully reprocessed with a decarburized-free surface.

Unfortunately, the heat-treating industry has not been immune to disasters in the past. There have been multiple "total losses," mostly due to oil quench fires and explosions (See Figure 5). Recently, it is well known that if an insurance adjuster sights a flame or smoke within a plant, they are reluctant or may even refuse to write the policy. With the NEO, this concern could be eliminated.

SUSTAINABILITY BENEFITS

In alignment with the global imperative to combat climate change, the NEO assumes a pivotal role in reducing the heat-treatment industry's carbon footprint. According to a 2019 article by Kanthal, an estimate of 80 percent of fuel used for heat treatment could ultimately be replaced by electricity, thus drastically reducing CO_2 emissions.

"When you burn something that contains carbon, you get carbon dioxide that you either must take care of or release into the atmosphere. With electric heating, you do not have any exhaust." [1]

The second column of the chart in Table 1 addresses the multiple environmental concerns associated with traditional batch IQ gas-fired oil quenching furnaces. The third column outlines the advan-

Figure 3: Bright, clean 4340 fittings post-oil quench.

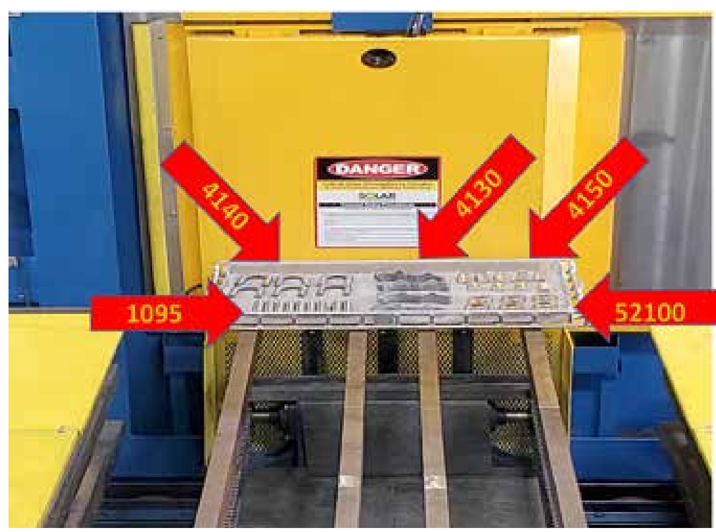

Figure 4: Various materials, similar thickness, processed together.

Figure 5: Catastrophic oil quench fire.

Environmental Issues - Oil Quench Furnaces

Issue:	Gas Fired Atmosphere Oil Quench Furnace	NEO Vacuum Oil Quench Furnace
Heating the load	Yes (NG/Endo increases CO_2 footprint)	No
Oil Burn off (Smoke and Carbon particles in air)	Yes (Increases Carbon Footprint)	No
Oil Mist Into Plant or vented to Atmosphere	Yes (increase CO_2 footprint and health hazard)	No (N_2 atmosphere in tank keeps mist inside)
Oil Drag off from load	Yes	Yes
NOx emissions	High	No
CO_2 Emissions	High *400 Tons Annually	No

Table 1: Environmental issues — oil quench furnaces. [2]

tages of the NEO, which embraces electric heating as a sustainable alternative to fossil fuels. As sustainability pressures continue to mount, governments, customers and primes alike will continue to flow down requirements on how heat treaters plan to reduce their carbon footprints.

CONCLUSION

As the demands for metallurgical precision, safety, and environmental sustainability continue to mount, the NEO emerges as the undisputed vanguard of vacuum oil quenching technology. While gas-fired batch IQ furnaces remain entrenched, the NEO heralds a new dawn characterized by unparalleled efficiency, precision, and sustainability. Solar's commitment to innovation ensures the NEO will continue to lead the industry toward a future defined by cleanliness, safety, and environmental stewardship.

REFERENCES

[1] Kanthal (2019, 04) Heat Treatment CO2 Emissions cut by 50 percent by using electricity. https://www.kanthal.com/en/knowledge-hub/inspiring-stories/heat-treatment-co2-emissions-cut-by-50-percent-by-using-electricity.

[2] Aichelin Group (2024 01) CO2 Footprints and the Heat Treat Industry/The Monty.

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Robert Hill, FASM, is president of Solar Atmospheres of Western PA, Inc. and Solar Atmospheres of Michigan, Inc. Hill has more than 45 years of metallurgical experience involving a wide range of heat-treating methodologies. He has published numerous articles and has publicly presented papers at ASM Heat Treating Conferences, Furnaces North America trade shows, Society of Manufacturing Engineers events, International Titanium Association conferences, and across various ASM Chapters in North America.

NITROGEN GAS QUENCHING PRESSURE EFFECT

ON BS S155 ALLOY STEEL IN A VACUUM FURNACE

Findings from this study provide useful insights for industries that rely on BS S155 alloy steel, enabling them to optimize their heat-treatment processes for improved dimensional control.

By AGUS MULYADI HASANUDIN and EDDY SUMARNO SIRADJ

The production of metal and alloy products requires the use of heat treatment. During the heat-treatment process, quenching is a crucial step. The quenching medium can be anything from water, a salt bath, oil, air, or gas. In a vacuum furnace, pressurized gas, most frequently nitrogen (N2) gas, serves as one of the quenching media. One of the drawbacks of the quenching process is the distortion and dimensional change of the parts. This article aims to investigate the influence of nitrogen gas quenching pressure on the distortion and dimensional change of aerospace actuator gear planet parts made from BS S155 alloy steel. BS S155 is the British aerospace equivalent of U.S. steel grade 300M (4340M); it is a vacuum-melted grade supplied in the normalized and softened condition to allow for final heat treatment and widely used in undercarriage components, gears, and shafts. Gear-planet parts were heat treated and quenched with pressurized nitrogen gas as an independent variable of the experiment, then double tempered as required by the specification. Following this, optical microscopes, tensile, and hardness tests in accordance with ASTM E8 and ASTM E92, as well as dimensional analysis, were used to characterize the parts. The results demonstrate that nitrogen gas quenching at 1.5 bar pressure improves dimensional stability without degrading the mechanical properties of the part, with the maximum dimensional distortion being 0.06% or 20 µm, while the mechanical properties result for the two nitrogen gas quenching pressures were less significantly different.

1 INTRODUCTION

Heat treatment is a crucial process for manufacturing metal and alloy parts and offers many long-term benefits. From increasing strength and ductility to increasing resistance to corrosion, heat treatment offers safety, durability, and cost efficiency for companies that use any kind of metal part, whether it is in the aerospace, automotive, oil and gas, alternative energy, or even forged wheel industries. Heat treatment is the process of heating and cooling a material to alter its physical and chemical properties. Although heat treatment offers several benefits, including increased strength, improved wear resistance, and reduced stress, it also has several conditions that can occur if the heat treatment process is not appropriate or not well controlled, that should be considered before undertaking this process, including distortion, surface oxidation or other contaminants, increased expense, and the possibility of material or part cracking or breaking (Abed Serhan, 2022). Non-uniform heating, austenitizing temperatures that are too low or too high, phase changes during heating and cooling, and non-uniform quenching can all cause distortion (Pye, 2022; Hartoyo et al. 2022).

During the quenching process, residual stresses and distortions develop in response to non-uniform cooling and phase transformations (Mackerle, 2003; Canale and Totten, 2005; Civera et al. 2014). Several methods have been used to evaluate and simulate the distortions that are promoted after quenching (Nugraha & Mochtar 2023). Imam Basori (Basori et al. 2019) investigated the quenching and tempering effect on the microstructure and mechanical properties of steel armor applications made from AISI 4340 alloy steel, and the result showed the quenching process promoted the phase transformation of the shape like a needle of martensite, while the tempering process promotes the transformation of martensite to bainite. M.M. Nunes et. al. (Nunes et al. 2018) investigated the relationship between austenizing temperature, soaking time, and quenching medium and their impact on mechanical properties as well as material distortion. However, the quenching media in this study were only oil and water, and the final result showed the material distortion was mainly affected by the variation of the austenizing temperature and soaking time, and the material distortion that was affected by the variation of the quenching media (oil and water) was less significant.

The aim of this investigation was focused on the dimensional change of the aerospace actuator gear planet parts made from BS S155 alloy steel as an effect of different nitrogen gas quenching pressure as part of the improvement from quality issues. BS S155 is the British aerospace equivalent of U.S. steel grade 300M (4340M / AMS 6257), which is a vacuum melted grade supplied in the normalized and softened condition to allow for final heat treatment and widely used with undercarriage components, gears, and shafts (Aircraftmaterialsuk.com Ltd, 2023).

2 RESEARCH METHODOLOGY

A vacuum furnace with gas pressure quenching was used for the investigation, with a hot zone size of 600 mm x 600 mm x 900 mm, maximum temperature of 1,200°C, and a maximum gas quenching pressure of 10 bar from SECO Warwick Poland. To heat the actuator gear planet part, BS S155 alloy steel material with a hardening temperature of 870°C ± 6°C with a soaking time of 30 minutes (-0, +15) minutes, followed by a double temper at 285°C ± 6°C with a soaking time of 2 hours and 30 minutes (-0, +20) minutes. The independent variable of the experimental method was only the nitrogen gas quenching pressure, and the dependent variable was the dimensional change, while the other heat-treatment parameters such as temperature, soaking time, heating rate, and cooling rate, remained the same as the controlled variable.

2.1 Material Preparation

Aerospace actuator gear planet parts made of BS S155 alloy steel were used as specimens for this experiment. The specimens were machined to standardized dimensions to ensure uniform dimension across the specimens. Two types of actuator gear planet parts were used as specimens: actuator gear planet parts type 1 and type 2. An illustration of these specimens is shown in Figure 1, and the dimension requirements of the actuator gear planet part of the type 1 and type 2 specimens are listed in Table 1.

2.2 Dimensional Measurement

The dimensions of the specimens were measured using precision measurement techniques (Klingenberg Precision Measuring Machine) before and after the heat treatment. Measurements include length (L), outside diameter (OD), and inside diameter (ID).

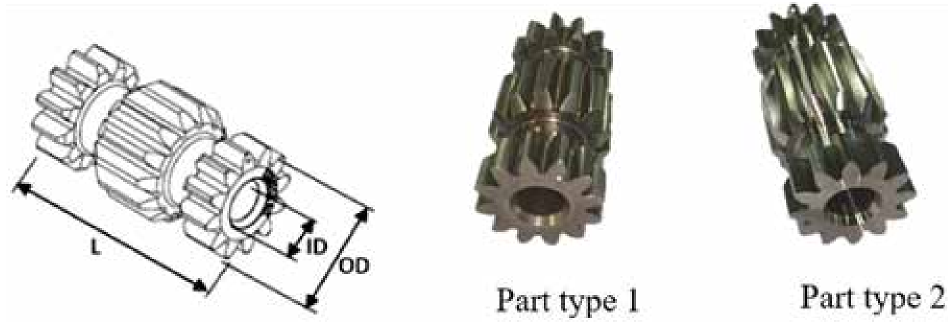

Figure 1: Illustration of an actuator gear planet. Part types 1 and 2 are different in L (length)

2.3 Heat Treatment

The specimens were divided into two groups: One was quenched using nitrogen gas at a pressure of 1.5 bar, and the other was quenched using nitrogen gas under a high pressure of 4.5 bar. The specimens were heated to a predetermined temperature and subsequently quenched with pressurized nitrogen gas. Gas quenching parameters, such as the nitrogen gas composition, pressure, and quenching duration, were carefully controlled.

From Table 2, specimen 1 is for an actuator gear planet type 1 and specimen 2 is for an actuator gear planet type 2. A and B in Table 2 refer to the low and high pressures of nitrogen gas quenching. The chemical composition of the type 1 and type 2 specimens are listed in Table 3.

Dimension	Gear planet type 1	Gear planet type 2
OD	30.51 - 30.56 mm	30.51 - 30.56 mm
ID	10.952 ± 0.025 mm	10.952 ± 0.025 mm
L	60.50 - 60.60 mm	69.57 - 69.67 mm

Table 1: Requirements of dimension for actuator gear planet parts.

No.	Specimen No.	Nitrogen gas quenching pressure
1	1-A	1.5 bar
2	1-B	4.5 bar
3	2-A	1.5 bar
4	2-B	4.5 bar

Table 2: Test specimen variations.

3 RESULT AND DISCUSSIONS

3.1 Chemical Composition Analysis

The chemical composition of the actuator gear planet parts was characterized to comply with material requirements. The actual chemical composition was determined using an ELANIK handheld-laser-induced breakdown spectroscopy (LIBS) analyzer.

From Table 3, it can be observed the chemical composition of these types of actuator gear planet parts are obtained in the range of standard requirements according to BS S155 specification.

Content	BS S155 Specification	Actual Type 1	Actual Type 2
C	0.39 - 0.44	0.421	0.432
Si	1.50 - 1.80	1.661	1.672
Mn	0.60 - 0.90	0.732	0.817
P	0.015 max	0.008	0.005
S	0.015 max	0.009	0.008
Cr	0.70 - 0.95	0.838	0.878
Mo	0.30 - 0.45	0.382	0.417
Ni	1.65 - 2.00	1.970	1.773
V	0.05 - 0.10	0.089	0.065

Table 3: The chemical composition (Weight %).

3.2 Dimensional result

The dimensions of the specimens were measured before and after nitrogen gas quenching under different gas pressure. The results of the measurements are shown in Figure 2, whereas it can be seen from the figure that the distortion dimension of the outside diameter does not seem to be much different under low- and high-pressure nitrogen gas quenching; however, the distortion dimension of length is likely different, where, when both are under low and high pressure, the distortion is high. The distortion dimension of the Type 1 specimen was lower than that of the Type 2 specimen. Looking at the distortion of the inside diameter for both types 1 and 2, as can be seen in the figure, it seems both specimens have high distortion results; however, for the Type 2 specimen, the distortion is slightly smaller than Type 1, and all the distortions of the part of the specimen is shrinkage when compared with the outside diameter and length, which are likely expanded. The quenching pressure plays a significant role in determining the rate at which the material is cooled. Higher quenching pressures generally result in faster cooling rates. The microstructure of a material is influenced by the cooling rate during quenching; rapid cooling can promote the formation of a fine-grained microstructure. In the case of steel, for example, it can lead to the formation of martensite, a hard and brittle phase associated with high hardness and strength. High-quenching pressure can cause non-uniform cooling across the material. Variations in cooling rates across the material can result in differential thermal contractions, leading to distortion. Distortion may manifest as warping,

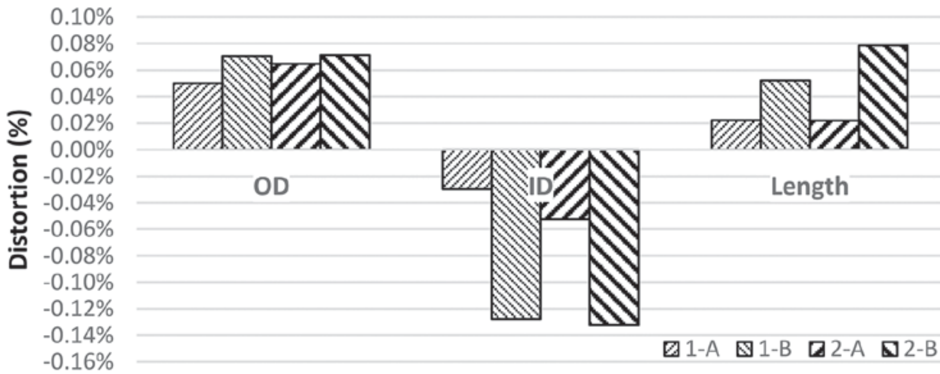

Figure 2: Distortion of dimension specimen type 1 and type 2 under gas quenching pressure

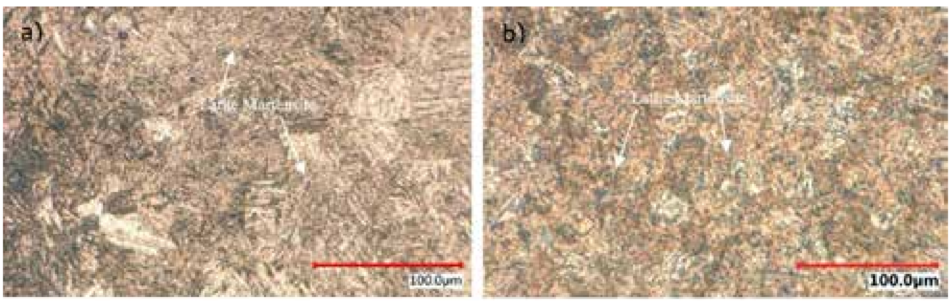

Figure 3: Microstructure of specimen type 1 after heating at 870°C, soaking time 30 minutes, and under nitrogen gas quenched pressured of (a) 1.5 bar (b) 4.5 bar.

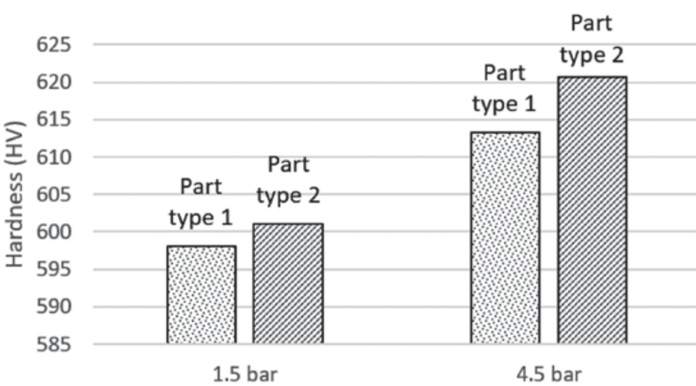

Figure 4: Hardness vs. gas quenching pressure.

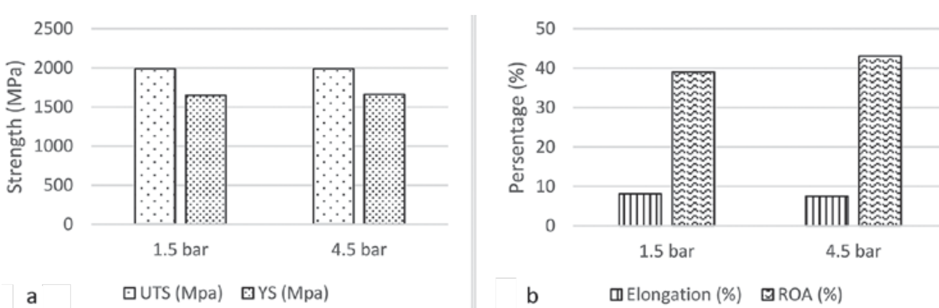

Figure 5: Correlation between tensile properties and gas quenching pressure a) UTS and YS vs. gas quenching pressure. b) Elongation and ROA vs gas quenching pressure.

bending, or uneven dimensional changes in the material.

The percentage dimensional change was determined and compared between the two- nitrogen gas quenching pressure value as shown in Figure 2.

3.3 Microstructural Analysis

Microstructural examination was conducted to observe any changes in the structure of material owing to different gas quenching pressure values. The microstructure of the heat- treated specimens was analyzed using an optical microscope (OmniMet / Olympus) with prior standard metallographic preparation according to ASTM E3 (ASTM International, 2023), while the microstructure was revealed using a 2% Nital etchant according to ASTM E407 (ASTM International, 2016).

BS S155 alloy steel has high hardenability; therefore, it was expected that all the analyzed specimens would present the martensitic phase. The micrographs in Figure 3a show a less lathe martensitic structure as a result of the nitrogen gas quenching pressure of 1.5 bar, while Figure 3b shows a more lathe martensite and sharper needle structure as a result of the nitrogen gas quenching pressure 4.5 bar. The quantity of martensite formed during heat treatment, especially in the context of quenching, is directly related to the mechanical properties of the steel. Higher martensite content generally leads to increased hardness but can also result in dimensional changes and potential distortion. Achieving the desired balance between hardness and dimensional stability requires careful control of the heat-treatment process, considering factors such as quenching rate and severity.

3.4 Mechanical Properties Evaluation

The selected specimens were characterized for their mechanical properties, such as hardness as per ASTM E92 (ASTM International, 2017) and tensile properties as per ASTM E8 (ASTM International, 2022), to determine any correlation between dimensional change and material properties. Table 4 lists the expected linear tensile and hardness results for each specimen. For a nitrogen gas quenching pressure of 1.5 bar, the mechanical properties result is lower than the result for a nitrogen gas quenching pressure of 4.5 bar, but all the results were still within the specification requirements.

The resulting distortions by the manufacturing processes, such as heat treatment, can increase the cost of producing a component by 20 to 40 percent, where additional machining steps are required. Consequently, it is important to predict and minimize distortions (Brooks and Beckermann, 2007).

The results indicate the gas quenching pressure differences have a distinct effect on the dimensional change of specimens (Dhaneswara et al. 2018). Nitrogen gas quenching with 1.5 bar pressure demonstrates a low dimensional distortion 0.03-0.05% in ID, 0.05-0.06% in OD, and 0.02% in length, which corresponds to a value of approximately a 3-to-6μm dimensional change in ID, a 15-to-20μm dimensional change in OD, and a 12-to-15μm dimensional change in length, and for a 4.5 bar gas quenching pressure result, it showed a 0.13% dimensional distortion in ID, a 0.07% in OD, and a 0.05% to 0.08% in length, which corresponds to a value of approximately a 14-to-15μm dimensional change in ID, a 20-to-25μm in OD, and a 40-to-50μm in length.

Specimen No.	Gas quenching pressure	UTS (MPa)	YS (MPa)	Elongation (%)	ROA (%)	Hardness (HV)
Reference (BSI, 2014; Aircraftmaterialsuk.com Ltd, 2023)	Max 5 bar	1930 min	1590 min	7 min	25 min	580 min
1-A	1.5 bar	1990	1650	8.1	39	598
1-B	4.5 bar	1990	1660	7.5	43	613
2-A	1.5 bar	1990	1610	8.9	38	601
2-B	4.5 bar	1995	1670	7	47	621

Table 4: Tensile and Hardness result.

The hardness difference of the nitrogen gas quenching pressure shown in Figure 4 has a 15.25 HV or 2.55% difference for part type 1 and a 19.58 HV or 3.26% difference for part type 2, which means the 4.5 bar gas quenching pressure affects the higher hardness value result, while all mechanical tensile properties results are still within the requirements as shown in Figure 5a. The correlation between strength (UTS and YS) vs. nitrogen gas quenching pressure is shown in Figure 5b, as well as the correlation between elongation and ROA vs. nitrogen gas quenching pressure. The gas quenching pressure of 4.5 bar affects the higher mechanical properties (hardness and tensile strength).

The correlation between dimensional change and mechanical properties suggests nitrogen gas quenching with 1.5 bar pressure provides enhanced dimensional stability without compromising the mechanical performance of specimens with a maximum dimensional distortion of 0.06% or 20µm dimensional change.

4 CONCLUSIONS

The influence of nitrogen gas quenching pressure on the dimensional change of the actuator gear planet part made from BS S155 alloy steel was investigated in this article. The results show a 1.5 bar nitrogen gas quenching pressure improves the dimensional stability over a 4.5 bar nitrogen gas quenching pressure. This article shows that, for heat treatment with 1.5 bar nitrogen gas quenching pressure, the maximum dimensional distortion is a 0.06% or 20 µm dimensional change. The findings provide useful insights for industries that rely on BS S155 alloy steel, enabling them to optimize their heat-treatment processes for improved dimensional control. However, this data will be used to determine the final dimension during the machining of the product prior to heat treatment. Since this investigation only focused on nitrogen gas quenching pressure, further investigation is required for other heat-treatment process parameters such as austenizing temperature, soaking time, and gas blower fan speed and its effect on the dimensional change and mechanical properties of the parts.

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REFERENCES

[1] Serhan, A 2022, "Heat Treatment Process: Stages, Types, Advantages, and Disadvantages," Available at: https://engineeringexploration.com/heat-treatment-process-stages-types- advantages-and-disadvantages/ (Accessed: 14 June 2023).

[2] Aircraftmaterialsuk.com Ltd 2023, "Hardenable Steel BS S155," Available at: https://www.aircraftmaterials.com/data/alstst/s155.html (Accessed: 28 May 2023).

[3] ASTM International, 2016, ASTM E407-07(2015) e1 Standard Practice for Microetching Metals and Alloys. 07 edn. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States: ASTM International.

[4] ASTM International, 2017, ASTM E92-17 Standard Test Methods for Vickers Hardness and Knoop Hardness of Metallic Materials. 17th edn. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428-2959, United States: ASTM International.

[5] ASTM International, 2022, ASTM E8/E8M-22 Standard Test Methods for Tension Testing of Metallic Materials. 22nd edn. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428- 2959, United States: ASTM International.

[6] ASTM International, 2023, ASTM E3-11(2017), Standard Guide for Preparation of Metallographic Specimens. 11th edn. 100 Barr Harbor Drive, PO Box C700, West Conshohocken, PA 19428- 2959, United States.: ASTM International.

[7] Basori, I, Surocaena, A, Dwiyati, S T, Sari, Y & Singh, B 2019, "Microstructure and mechanical properties analysis of quenched and tempered AISI 4340 steel," KnE Social Sciences, pp.675- 680.

[8] Brooks, B E & Beckermann, C 2007, "Prediction of heat treatment distortion of cast steel c-rings," Proceedings of the 61st SFSA Technical and Operating Conference, pp. 1–30.

[9] BSI, 2014, Specification for Nickel-silicon-chromium-molybdenum-vanadium-steel (vacuum arc remelted) billets, bars, forgings and parts - (1900–2100 MPa: limiting ruling section 75 mm) BS S155. 76th edn. London.

[10] Canale, L & Totten, G 2005, "Quenching technology: A selected overview of the current state-of- the-art," Materials Research, 8(4), pp. 461–467.

[11] Civera, C, Rivolta, B, Simencio-Otero, R, Lúcio, J, Canale, L & Totten, G 2014, "Vegetable oils as quenchants for steels: residual stresses and dimensional changes," Materials performance and characterization, 3(4), pp.306-325.

[12] Dhaneswara, D, Suharno, B, Ariobimo, R D S, Sambodo, D B & Fatriansyah, J F 2018, "Effect of coating layer of sand casting mold in thin-walled ductile iron casting: reducing the skin effect formation," International Journal of Metalcasting, 12, pp.362-369.

[13] Hartoyo, F, Fatriansyah, J F, Mas'ud, I A, Digita, F R, Ovelia, H & Asral, D R 2022, "The optimization of failure risk estimation on the uniform corrosion rate with a non-linear function," Journal of Materials Exploration and Findings (JMEF), 1(1), p.3.

[14] Mackerle, J 2003, "Finite element analysis and simulation of quenching and other heat treatment processes: A bibliography (1976–2001)," Computational Materials Science, 27(3), pp. 313–332. Nugraha, Y & Mochtar, M A 2023, "Effect of Austenization and Repeated Quenching on The Microstructures and Mechanical Properties of Wear-Resistant Steel," Journal of Materials Exploration and Findings (JMEF), 1(3), p.3.

[15] Nunes, M M, Silva, E M D, Renzetti, R A & Brito, T G 2018, "Analysis of quenching parameters in AISI 4340 steel by using design of experiments," Materials Research, 22.

[16] Pye, D 2022, "Dealing with Distortion from Heat Treatment," Available at: https://www.industrialheating.com/articles/96838-dealing-with-distortion-from-heat treatment (Accessed: 14 June 2023).

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CARBURIZING STEEL MECHANICAL PROPERTIES

Studying through-hardened core mechanical properties without the carburized case, as well as the effect of alloy content, carburized case depth, and carbon content on strength.

By **GREGORY FETT**

This article is a follow-up to the three articles on "Mechanical Properties of Carburized Steel" in the March [1], April [2], and May [3] 2023, issues of *Thermal Processing*. In the March article, it was shown the carburized case by itself is not as strong as predicted by the hardness, and that it fractures with little or no plasticity. This is a result of quench embrittlement [4] due to the high hardness and high carbon content. Different methods to reduce quench embrittlement were also discussed.

In the April article, the development of two different carburized (case-core composite) 3-point bend test bars were discussed. The behavior was significantly different depending on whether a radius or stress concentration was present. The bending ultimate and yield (Johnson Elastic Limit or JEL determined by 50 percent change in slope) strength of the smooth bar increased with increasing core hardness. The bending ultimate and yield strength of the shouldered test bar with a radius increased with increasing core hardness but leveled off at 30-35 HRC, then the ultimate decreased to meet the yield strength at 40 HRC where it remained with further increasing core hardness.

In the May issue, the development of a carburized U-Notch test bar, which more closely represented an actual axle gear, was reviewed. The data once again showed the bending ultimate and yield strength increased with increasing core hardness and leveled off at 30-35 HRC, then the ultimate decreased to meet the yield strength at a core hardness of 40 HRC unless a higher alloy steel or a lower-case depth was used. The data also showed the bending strength without the carburized case was greater than with the case.

In this article, through-hardened core mechanical properties without the carburized case will be discussed, as well as the effect of alloy content, carburized case depth, and carbon content on strength.

BENDING PROPERTIES OF CORE AND TRANSITION ZONE

Figure 1 shows the bending ultimate and yield strength for a series of U-Notch test bars that were neutral hardened, oil quenched, tempered, and tested under 3-point bending [5].

The dimensions of the U-Notch bar are shown in Figure 2. The steel grades used were 8615, 8620, 8630, 8640, 4320, and 9310. The bars were tested in the as-quenched (AQ) condition as well as with a 350°F, 600°F, 850°F, and 1,100°F temper. These samples were intended to represent the properties of the core and transition between the case and core.

The 8615 bending ultimate strength was 10,000 pounds for the AQ condition then increased slightly with the 350°F temper even though the hardness decreased slightly. This is likely the result of a minor degree of quench embrittlement. Figures 3 and 4 show the hardness of all samples at the surface and in the center of the core at the U-Notch respectively.

All samples were neutral hardened at the same time in the same batch. The furnace carbon level was set at 0.3%. As a result, the lower

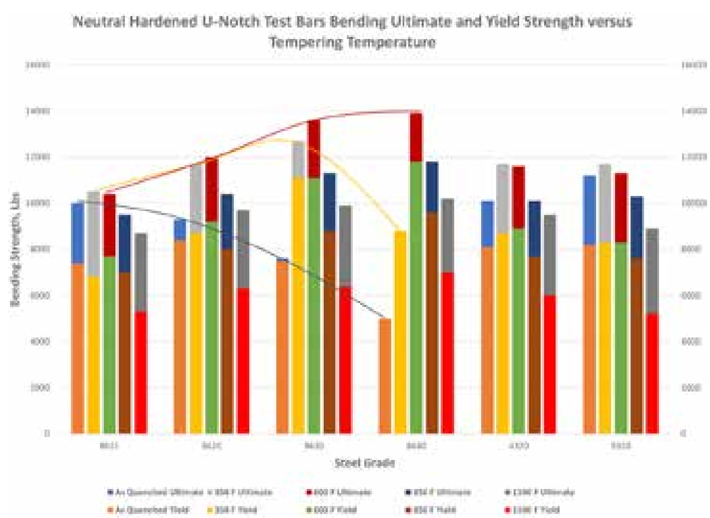


Figure 1

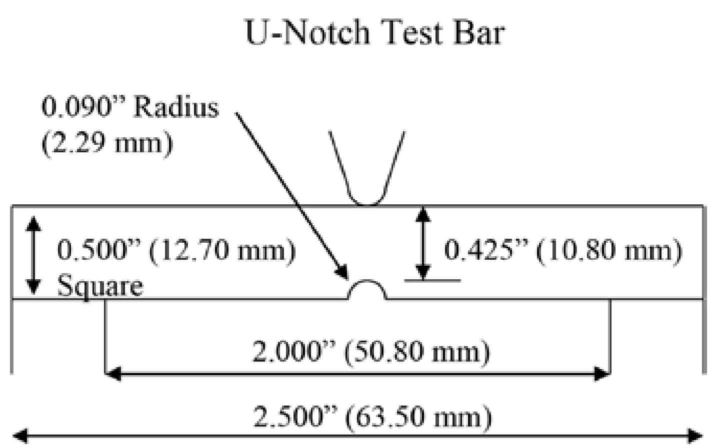


Figure 2

carbon steels had a slight case depth of about 0.005 inches with a surface hardness just more than 50 HRC. This low carbon case appears to have had no detrimental effect on bending strength as has been normal with a typical high carbon case. The bending ultimate strength with a 350°F temper was 10,400 pounds compared to 9,000 pounds in the May article. The May sample core hardness was 31 HRC and was copper plated rather than neutral hardened, so no case was present. The core hardness of the current sample was 34 HRC. The 8615 bending ultimate strength then further decreased for the 600°F, 850°F, and 1,100°F tempering temperatures as the hardness continued to decrease.

Steel normally has a very good relationship between hardness and ultimate tensile strength. As hardness increases, the ultimate strength also increases. Quench embrittlement can negatively affect this relationship especially at high hardness and elevated steel carbon levels. Essentially, the plastic portion of the stress strain curve is reduced or eliminated causing the steel to fail in a brittle manner. Typically, embrittlement can be eliminated by tempering at 600°F, but this also reduces the hardness, strength, compressive residual stress, and fatigue life.

Returning to Figure 1, 8620 steel with a higher hardness compared to 8615 would be expected to have a higher strength. However, in the AQ condition, the ultimate strength is lower than the 8615, and the deflection is also lower. This is a result of quench embrittlement. Figure 5 shows the deflection for all samples. The 8620 ultimate and yield strength is greater than the 8615 for all the remaining tempered samples. The strength is maximum at the 600°F temper and then decreases with increasing tempering temperature as the hardness also decreases.

The 8630 steel continues the same trend as the 8620 except the embrittlement in the AQ condition is more significant, and the spread between ultimate and yield strength has almost completely disappeared. A small reduction in strength is also present for the 350°F condition. The strength of the remaining tempered conditions is greater than the 8620 steel due to the higher hardness.

The 8640 steel continues the same trend as 8630, but now the AQ and 350°F temper conditions have become severely embrittled. The negative effect of increasing steel carbon level is evident with this sample configuration in bending. From this, it is easy to see why the carburized case at 0.80-0.95% carbon would suffer from quench embrittlement.

The next two steels in Figure 1 are 4320 and 9310. The first is a medium nickel steel, and the second is a high nickel steel typically used in the aircraft industry and for demanding applications elsewhere. The 4320 steel has higher strength and deflection compared to the 8620 only in the AQ condition. The 9310 steel has higher strength compared to the 4320 only in the AQ condition and higher deflection in the as-quenched 350°F and 600°F temper conditions. The ultimate core bending strength of 8620, 4320, and 9310 with a typical 350°F temper is the same. The only differences are the deflection increases with increasing alloy content for the AQ 350°F and 600°F temper conditions, and the AQ embrittlement is reduced.

BENDING PROPERTIES VS. ALLOY CONTENT

In the May article, there was a significant increase in bending strength and low cycle bending fatigue life for case carburized 9310 versus 8615 or 8620 steel. The 4320 steel also had the capability to provide increased performance depending on the core hardness and case depth. The U-Notch through-hardened core data does not seem to predict any increase in strength for 9310 and 4320 over 8615 or 8620, other than in the AQ condition.

TENSILE PROPERTIES OF CORE VS. ALLOY CONTENT

Figures 6 is core tensile and yield strength data vs. hardness from the AISI database [6] referenced in the March article. Tensile strength vs. hardness for four steels with increasing nickel content is shown. The no-nickel steel was 20MnCr5; the low-nickel steel was 8620; the medium-nickel steel was 4320, and the high-nickel steel was 9310. Three different hardness levels of each steel grade were tested. The hardness was controlled by the rough sample diameter that was vacuum pseudo carburized, oil quenched, and tempered at 350 F. Test bars were then machined from the rough samples. The ultimate tensile strength depends only on hardness, and the alloy content makes no difference. The high nickel steel doesn't provide any higher strength than the no nickel steel.

Figure 7 is elongation and RA data vs. hardness for the different steels. The elongation exhibits dependence on hardness but not on alloy content. There, the low nickel elongation data was not included due to a measurement error. However, the RA does indicate some dependence on the alloy content. The high-nickel steel has the highest RA followed by the medium nickel steel, and the low-nickel and no-nickel steels are the lowest and are both about the same. Like the U-Notch bars tested in bending, the tensile data shows the only differ-

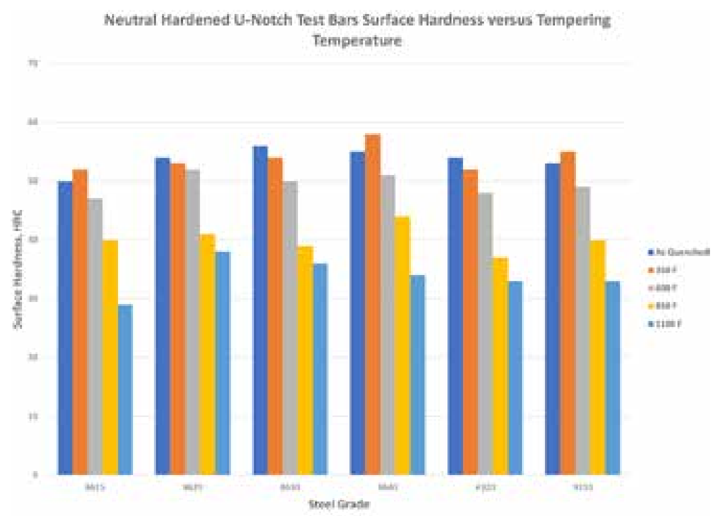
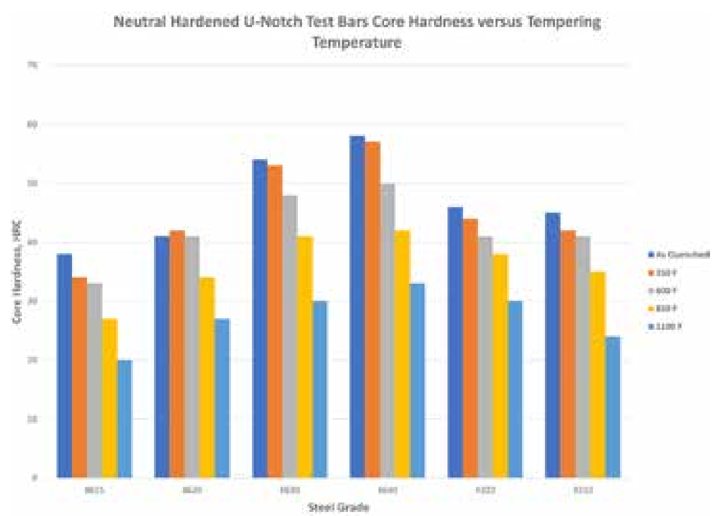


Figure 3



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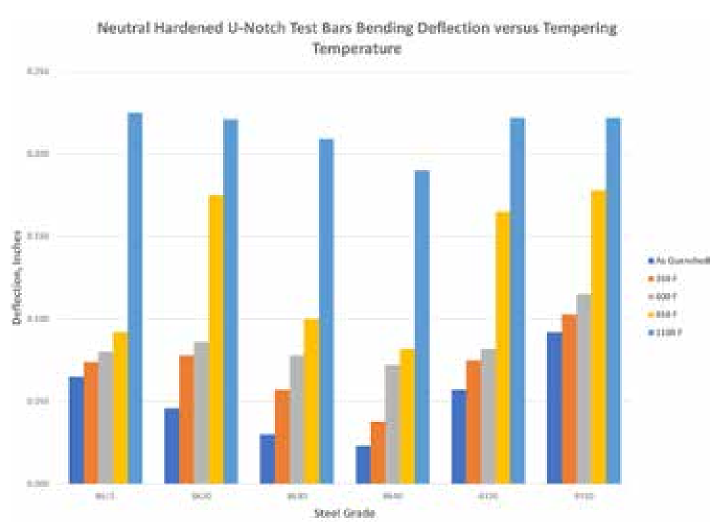


Figure 5

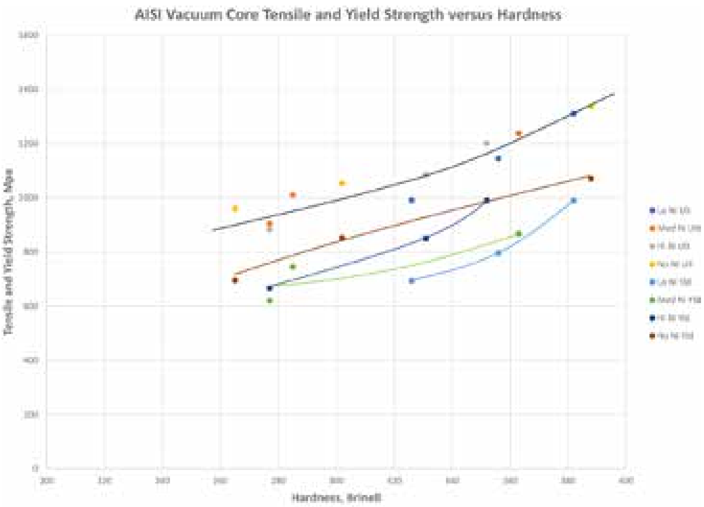


Figure 6

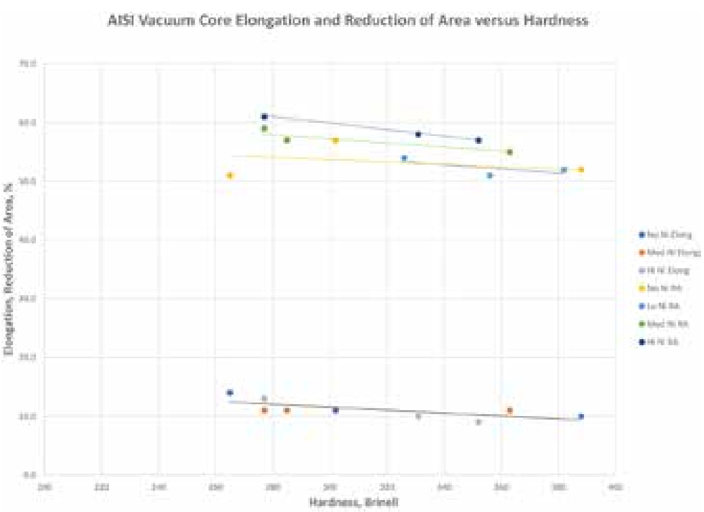


Figure 7

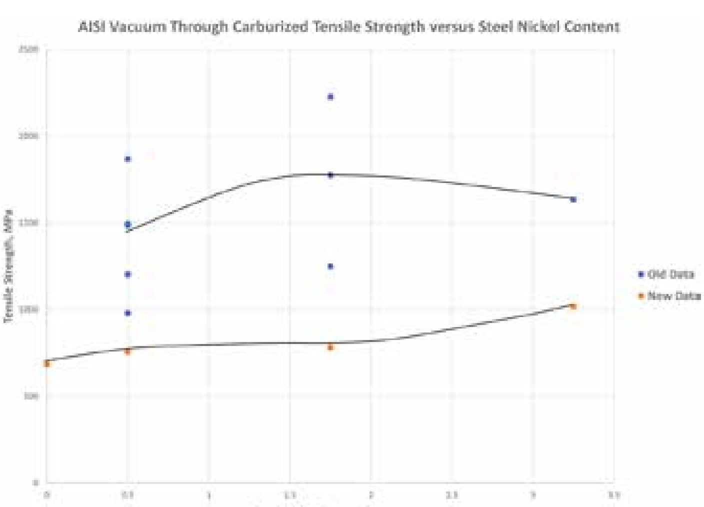


Figure 8

ence between grades is increasing RA with increasing nickel content.

TENSILE PROPERTIES OF CASE VS. ALLOY CONTENT

The AISI Bar Fatigue data referenced in the March article also included tensile strength for through-carburized test bars made from different steel alloys. Figure 8 shows tensile strength data for no-nickel

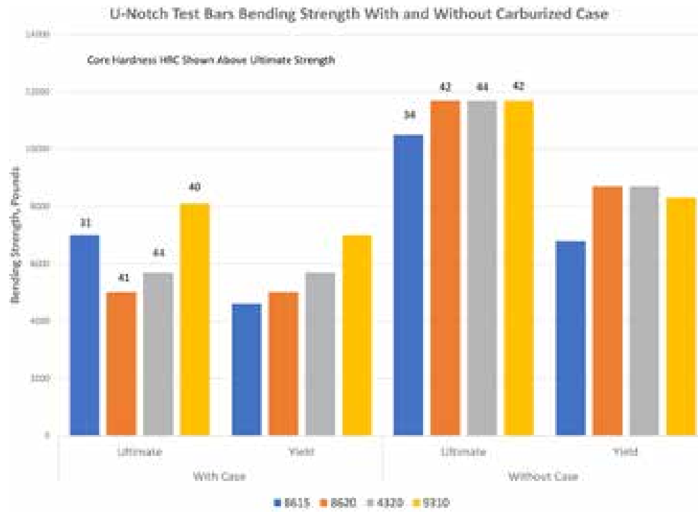
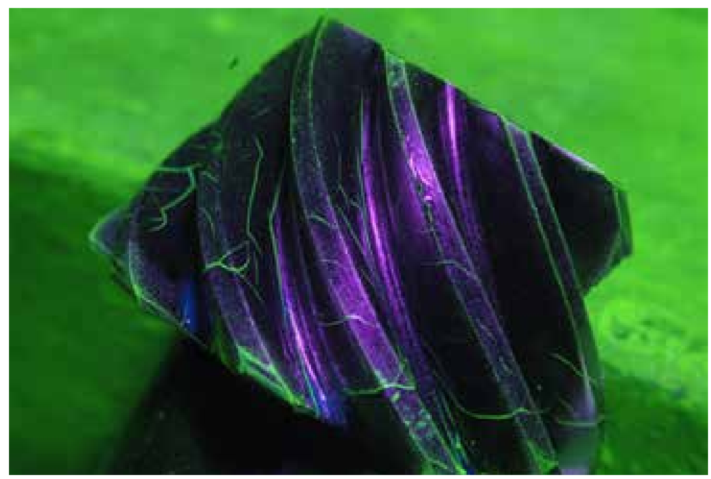


Figure 9



20MnCr5, low-nickel 8620 and 8695, medium-nickel 4620 and 4320, and high-nickel 9310 steel grades. There is too much scatter or variation in the old data to make any conclusions. However, more recent data does show a correlation. These samples were all vacuum-through carburized on the same 36-hour cycle and tempered at 350°F. The samples were machined and polished prior to vacuum carburizing, and no hard finishing or cleaning was done prior to testing. From a percent standpoint, there is a reasonable increase in strength from the no-nickel steel to the high-nickel steel. However, these values are all very low compared to the strength of the core. This, too, does not seem to explain the reason for the increase in case carburized bending strength as the alloy content increases.

BENDING PROPERTIES WITH AND WITHOUT CASE, EFFECT OF ALLOY AND CASE DEPTH

Figure 9 shows the difference in bending ultimate and yield strength for carburized U-Notch Test Bars with a carburized case vs. without from this article and the May article. The steel grades are 8615, 8620, 4320, and 9310. The core hardness is shown above the bars. It is evident the "without case" data on the right-hand side is significantly higher in strength compared to the "with case" data on the left-hand side.

The carburized case is detrimental toward bending strength in the presence of a radius at the surface. The case is not as detrimental with 8615 with a core hardness in the 31-34 HRC range compared to the 8620 with a core hardness in the 41-42 HRC range. The 4320 was able to provide a little higher bending strength than the 8620, and the 9310 was even better. The strength of the case carburized U-Notch

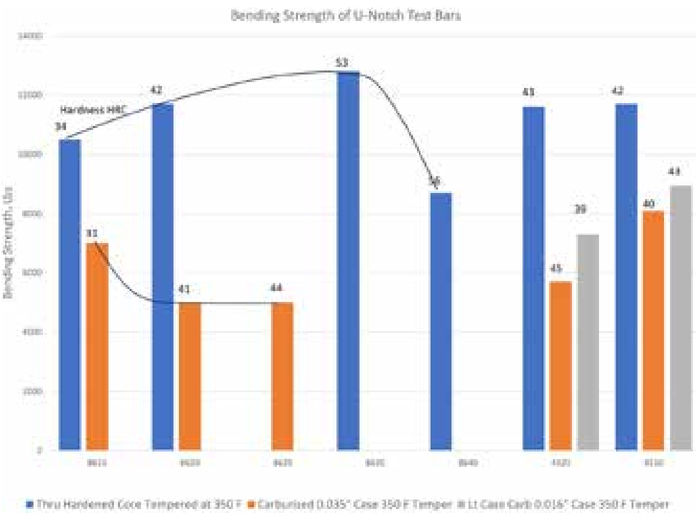


Figure 10

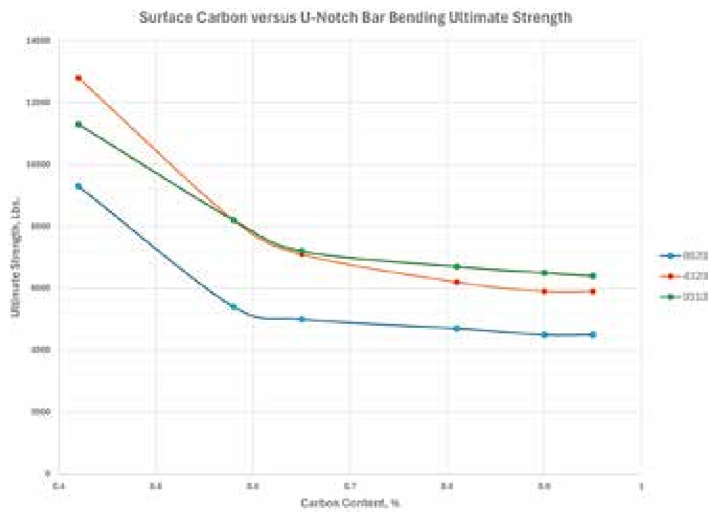


Figure 11

bars appears to be more than the sum of its parts. The properties of just the case or just the core do not predict what happens with the case core composite.

Figure 10 provides additional data to demonstrate the effect of the carburized case on bending ultimate strength from this article and the May article. The core hardness values are shown above the bars. The four blue bars on the left side of the chart show through-hardened 8600 steels with increasing carbon content and no case. The steel grades are 8615, 8620, 8630, and 8640. As the steel carbon content increases from 0.15% to 0.20% to 0.30%, the hardness and bending strength increased from 10,500 pounds to 11,700 pounds to 12,800 pounds. However, as the hardness further increased to 56 HRC at 0.40% carbon, the bending strength decreases to 8,700 pounds. This is a result of quench embrittlement, which becomes more severe at higher carbon levels. The orange bars on the left side of the chart show corresponding case-carburized data for 8615, 8620, and 8625 steels with an approximate effective case depth of 0.035 inches. The 8615 provided the highest bending strength at 7,000 pounds with a core hardness of 31 HRC. As the core hardness increased to 40 HRC and above for 8620 and 8625, the bending strength dropped to 5,000 pounds and remained constant. This relationship was presented in the May 2023 article.

On the right side of Figure 10, data is shown for 4320 and 9310 steels. The blue bars are through-hardened with no case depth; the orange bars are standard case carburized with an approximate effective case of 0.035 inches. The gray bars are light-case carburized with an approximate effective case of 0.016 inches. The through-hardened bars with no case depth are considerably stronger than the standard case carburized bars for both 4320 and 9310. The standard case-carburized samples have the lowest bending strength, and the light case-carburized samples provide a significant increase in strength. The case-carburized samples for the 9310 provided a significant increase in strength compared to the 4320 as well as the 8615, 8620, and 8625.

EFFECT OF CASE CARBON ON BENDING

Data was published in 2009 showing the effect of case carbon content on the bending strength, bending and contact fatigue life, and impact life of carburized gears and U-Notch test bars [7]. Figure 11 shows the bending strength vs. case-carbon content for 8620, 4320, and 9310 U-Notch test bars.

All test bars for each carbon level were carburized at the same time in the same batch with a target of 0.035 inches effective case depth for the 8620 samples. The bending strength at the typical 0.80-0.95%

carbon level is relatively constant. The 8620 steel is at 4,500 pounds while 4320 is at 6,000 pounds and 9310 is about 6,500 pounds. As the carbon level decreased to 0.65% and 0.58%, the bending strength gradually increased for each steel. Below 0.60% carbon, there is a more significant increase in bending strength. At 0.42% carbon, the bending strength is double that at 0.80-0.95% carbon. The 8620 steel is now at 9,300 pounds while 9310 and 4320 traded places and are at 11,250 pounds and 13,000 pounds, respectively. For comparison, the neutral-hardened 8615 sample in Figure 1 with a shallow 0.30% carbon case had a bending strength of 11,400 pounds. It is also interesting to note the through-hardened 8640 sample in Figure 1 is nearly the same strength as the 2009 case carburized 8620 sample with a surface carbon of 0.42%. Both samples had the same surface carbon, but the core hardness was 57 HRC vs. 42 HRC respectively. According to the shouldered test bars in the April article and the U-Notch bars in the May article, once the core hardness exceeds 40 HRC the bending strength remains low and constant with no ductility.

SUMMARY

The strength of the carburized case likely varies considerably from the surface into the core. The high hardness high carbon outer portion appears to be brittle and relatively weak. In terms of tensile strength, it is about 1,100 MPa or 160 Ksi. As the carbon content decreases toward the core and the hardness is still relatively high, the strength likely increases by a significant factor. The highest strength is likely around the effective case depth at 0.30% carbon with a hardness just above 50 HRC. This corresponds to a tensile strength around 1,900 MPa or 275 Ksi. The strength then decreases toward the core. At a core hardness of 33 HRC, the tensile strength would be about 1,035 Mpa or 150 Ksi. which is close to the outer-case properties. All of this happens in a relatively short distance. In bending, the carburized case typically cracks at or below the yield strength, and the remainder of the cross section continues to support the increasing load up to the ultimate. This is likely a function of the fracture toughness of what is remaining at that point. At the completion of successful vehicle durability testing, it is not uncommon to find cracks in the carburized case if abuse events have been included. Surprisingly, cracking of the case doesn't mean the vehicle can't live a long useful life.

It is important to remember what has been discussed here relates to carburized steel bending loads or stresses. To function properly, many carburized components must also account for contact or surface loads. What is good for bending may be the opposite of that which is good for contact. This may require a compromise to satisfy both requirements.

REFERENCES

[1] G. Fett, "Carburized Steel Mechanical Properties Case Tensile Strength," Thermal Processing, March 2023, Pages 33-35.

[2] G. Fett, "Carburized Steel Mechanical Properties Bending Ultimate and Impact Strength, Test Bars Vs. Actual Parts," Thermal Processing, April 2023, Pages 45-47.

[3] G. Fett, "Carburized Steel Mechanical Properties Bending Ultimate and Impact Strength," Thermal Processing, May 2023, Pages 39-41.

[4] J. Wong, D. Matlock, G. Krauss, "Effects of Induction Tempering on Microstructure, Properties and Fracture of Hardened Carbon Steels," Proceedings of 43rd Mechanical and Steel Processing Conference, ISS, October 2001.

[5] Unpublished work done by G. Fett, courtesy of Dana Corporation, circa 2007.

[6] https://fde.uwaterloo.ca/Fde/Materials/SMDIdbase/Steel/references.html.

[7] G. Fett, "The Effect of Carbon Content on the Performance of Carburized Steels," Proceedings of the 25th ASM Heat Treat Conference, September 2009.

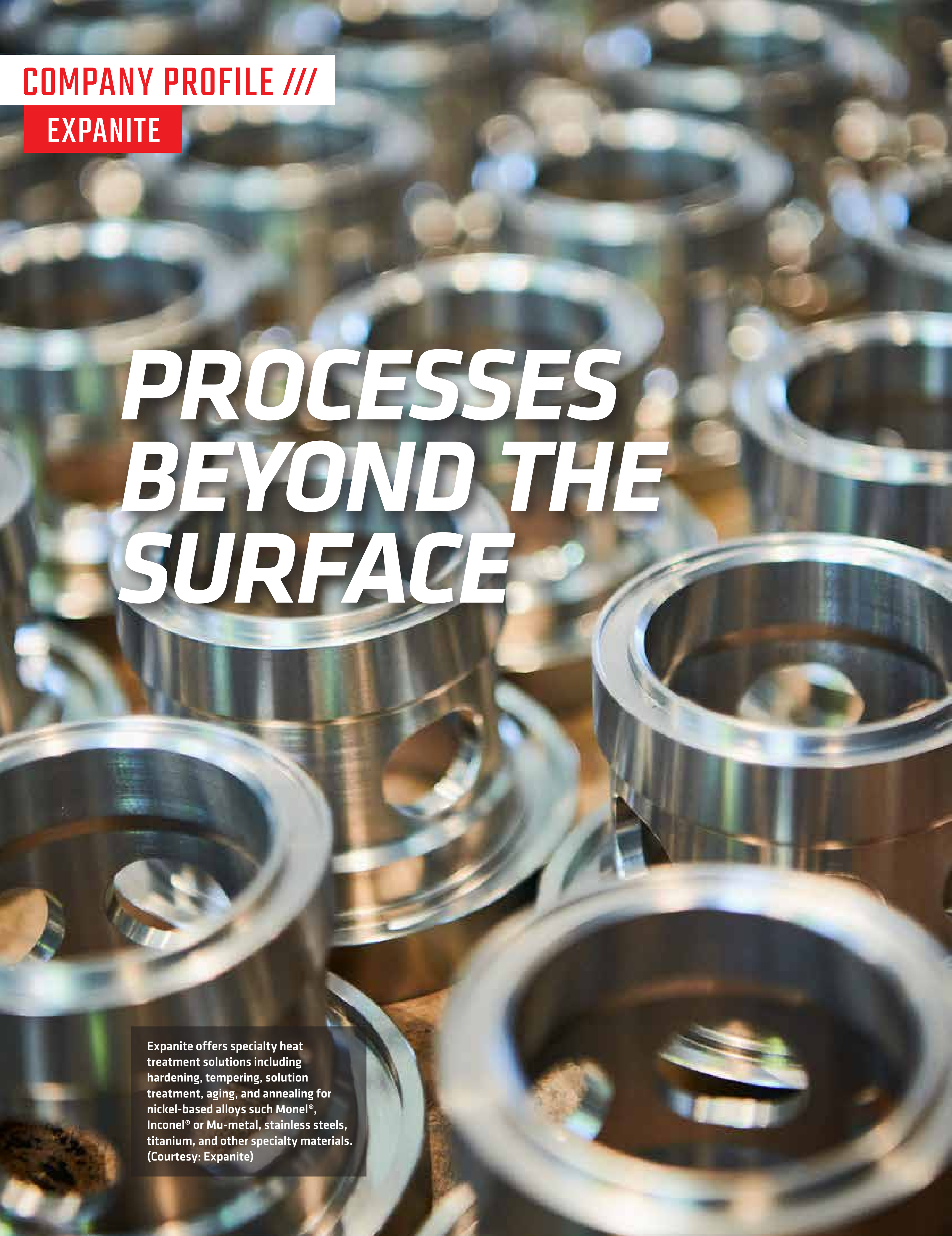
ABOUT THE AUTHOR

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

COMPANY PROFILE ///

EXPANITE

PROCESSES BEYOND THE SURFACE



Expanite offers specialty heat treatment solutions including hardening, tempering, solution treatment, aging, and annealing for nickel-based alloys such Monel®, Inconel® or Mu-metal, stainless steels, titanium, and other specialty materials. (Courtesy: Expanite)

Expanite offers an innovative technology that prevents wear, galling, and corrosion of components in stainless steel or titanium by hardening the material in a pure-gas environment without using harsh chemicals, leaving no toxic waste and with a low carbon footprint.

By KENNETH CARTER, Thermal Processing editor

Hardening of parts such as gears and other essential products made from stainless-steel alloys is a vital and necessary process to ensure those parts perform optimally.

Expanite, a company that was born from research at The Technical University of Copenhagen, has grown its innovative process of hardening stainless steel more efficiently than previous methods.

Besides the proprietary processes for stainless steel and titanium, Expanite offers specialty heat treatment solutions including hardening, tempering, solution treatment, aging, and annealing for nickel-based alloys such Monel®, Inconel® or Mu-metal, stainless steels, titanium, and other specialty materials.

"You can easily take stainless steel and put it in and harden it, but you lose corrosion properties right away if you don't know how to do it," said Claus Løndal, country manager North America with Expanite. "We do that without losing corrosion properties."

The beauty of Expanite's hardening process is it works with any stainless-steel alloy, according to Løndal.

"We can take all stainless-steel alloys — and I mean every stainless-steel alloy, as long as they are defined as stainless steel," he said. "That means that it has to have around 12 percent chrome in the alloy. And we can harden them all. We can also harden some other alloys and titanium."

HARDENING STAINLESS STEEL

Stainless steel is an amazing material, according to Løndal, but it isn't a very hard material.

"If you go out and — you probably have a refrigerator or a dishwasher that is a stainless-steel surface — and if you take a knife, you can scratch it, or you can scratch it with your fingers; that's how soft it is," he said. "We can harden it almost 10 times as hard as that in the surface. It's a surface hardening of the material. Our advantage is that you don't see a drop in corrosion properties after our process."

Corrosion is a common problem when dealing with stainless steels, and — if not dealt with — can become a hazard for industries using food and beverage equipment or medical and aerospace sectors, according to Løndal.

"You don't want your parts to corrode because, at some point, it will corrode so much that it goes to pieces," he said.

REMOVING THE OXIDE LAYER

Expanite's innovative process is a gas-based diffusion technology that removes the oxide layer from the stainless steel, according to Løndal.

"The oxide layer comes automatically when you have an alloy where there is at least 12 percent chrome in the surface," he said. "And when that chrome reacts to the environment and the air around it, it creates this oxide layer. That oxide layer is what prevents the part from corroding."

Expanite, a company that was born from research at The Technical University of Copenhagen, has grown its innovative process of hardening stainless steel more efficiently than previous methods. (Courtesy: Expanite)

If there is a lot of chrome present, then the oxide layer will be thick in relation to the part, although, in actuality, the layer is quite thin. If the alloy is heated — stainless steel 316, for example — the chrome will react with nitrogen to create chromium nitrites, according to Løndal.

"And those corrode right away," he said.

During Expanite's process, the oxide layer is stripped, diffusing nitrogen and carbon into the surface. Once cooled, Expanite makes sure there is enough chrome in the surface to again activate the oxide layer, according to Løndal.

"It's a little simplified, but that's in principle what we do," he said. "We strip off the oxide layer, which diffuses nitrogen and carbon and

Over the company's relatively short lifespan, the teams at Expanite have worked diligently to offer its customers its efficient hardening technology and ensure that their jobs are expedited as quickly as possible. (Courtesy: Expanite)

creates a hardened zone. We have a patented technology to do this, and once it's cooled down, the oxide layer is re-established."

UNIVERSITY ROOTS

This patented process was the brainchild of a professor and two senior researchers from the University of Copenhagen, who were working from different angles of surface technology. The professor had a few start-up companies that were trying to pursue this technology to efficiently harden stainless steel without losing corrosion properties, according to Løndal.

"These guys here started out at the university, and they had a little room down in the basement," he said. "At some point, something started working in the furnaces, and it worked so well that they managed to attract an equity fund that was working together with the university. It's a fund that takes new innovative technologies and puts some money into it to see if it can grow and become more than just a startup, but actually a growth company at some point. So, the mission was clear: Give them some money, be around for some time, and then sell the company. With that money in the bank, we started the company. I was employee No. 4."

The company was founded in 2010, but for the first two years, it was basically a one- or two-man band operation with a few students helping out. Eventually, a professional board was hired along with some sales representatives, according to Løndal.

GETTING A PATENT

"The first thing that was done was we filed for patents in order to protect our technology," he said. "It is fully patented more-or-less globally. Then we started moving on, and we established what still is our headquarters just north of Copenhagen in a small city called Hillerød where we have a lot of furnaces and R&D."

"We want to help people prevent wear, because, since stainless steel is so soft, it wears down quite fast. If you have a shaft, if you have a gear or a tooth, anything like that, it wears quite fast. We want to help our customers develop better and more sustainable parts that last longer."

From the beginning, the goal of Expanite has been clear: to make things hard, according to Løndal.

"We want to help people prevent wear based on that, because, since stainless steel is so soft, it wears down quite fast," he said. "If you have a shaft, if you have a gear or a tooth, anything like that, it wears quite fast. We want to help our customers develop better and more sustainable parts that last longer."

REPLACING OTHER PROCESSES

Expanite's process could be an important evolution to how parts are made and made to last longer, according to Løndal.

Expanite's innovative process is a gas-based diffusion technology that removes the oxide layer from the stainless steel. (Courtesy: Expanite)

"We can also use it on new applications. What kind of alternative do we have out there? In many cases, a lot of engineers have used different kinds of coatings," he said. "It could be hard chrome plating, which is something that a lot of companies in a lot of countries are trying to get rid of, because hard chrome plating is quite toxic and you don't want to have it. But the problem with coatings in general is that when you put it on that surface, that means it can chip off. Once you've got a small hole in that coating, water or the product it's handling gets in under the surface, and then it's really chipping up. And nobody wants hard chips in their ice cream or in their tomato juice or whatever they're using."

The process is also a good alternative to plasma nitriding, where poor corrosion properties are often seen, according to Løndal. Expanite's hardening process also can be ideal for products such as gears and any kind of application where there are moving parts.

QUICK TURNAROUND

Over the company's relatively short lifespan, the teams at Expanite have worked diligently to offer its customers its efficient hardening technology and ensure that their jobs are expedited as quickly as possible, according to Løndal.

"We are a heat treater; it's advanced technology, but it's still a heat treatment — that means that we are at the end of the food chain," he said. "It's finished parts. So, all the delays that have been in that chain from the engineers designing a part to the manufacturer actually producing the part and shipping it to us, all those delays are ending up at our place. So lead times are a very vital thing. We have a quick turnaround time. That's very, very, very important for our customers, and we have the market's best turnaround time; that's for sure."

Not one to rest on its laurels, Løndal said Expanite plans to continue to expand its technology in the coming years.

"Besides being the fastest and having the best product, we also actually have the best environmental footprint," he said. "We are a heat treater. That means that we have to have power, but the gases we use are non-toxic. We don't use any chemistry at all to do anything. We are very sustainable, and that is probably one of the things that we think will be a lot of focus on for the next years."

COMPANY EXPANSION

Expanite might not be a household name yet, but Løndal said his company has customers within a myriad of industries. It's already established in many industries, for example, food and beverage processing, oil and gas, pumps and valves, automotive, medical devices, and, ultimately, not so surprising, is the company's involvement in the watch-making industry.

"We have what we call the watch industries — all kinds of watches," he said. "You can imagine buying a very expensive watch. You always get them with these sapphire glasses, as the glasses are very hard, and scratch resistance is high, but the watch case itself is stainless steel, and it's soft, so they want to have the watch cases hardened."

Finding solutions for new industries is just part of what makes what Expanite do so exciting for Løndal.

"We like to be involved in our customers solving a problem and solving the technical issues of developing new fantastic equipment where we can be part of it," he said.

MORE INFO expanite.com/en

MARKETPLACE ///

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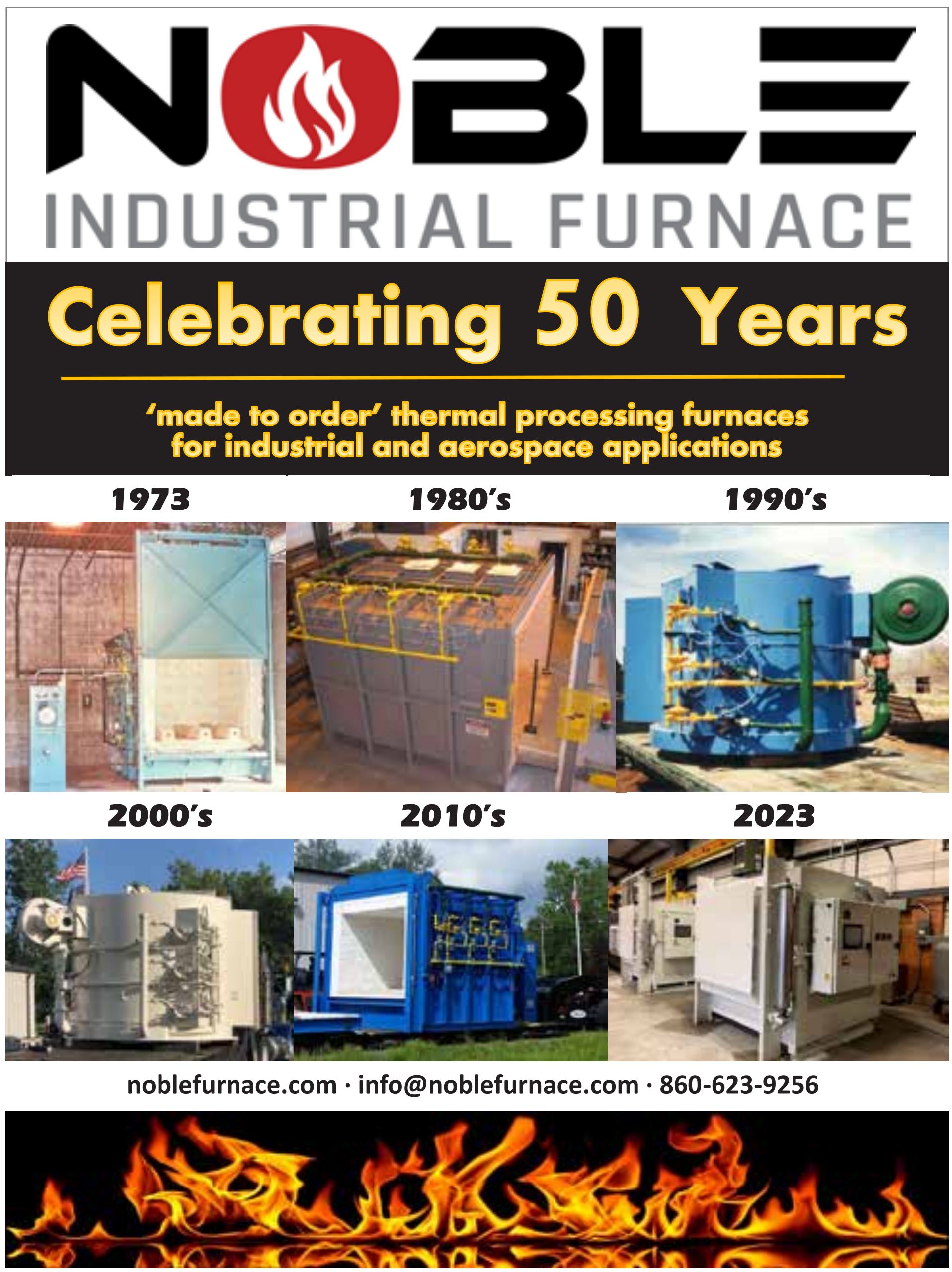

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KENNY MILLER /// PRODUCT ENGINEER /// KINEMATICS

"Kinematics widely uses austempered ductile iron output gears in solar application drives and case-hardened alloy steel in industrial drives applications."

Tell us about Kinematics.
For nearly three decades, Kinematics has delivered customized, robust solutions to customers with mission-critical applications. With a variety of motion-control solutions, there's virtually nothing we can't do to satisfy our customers' needs.

What is your role at Kinematics?
I'm a senior product engineer at Kinematics. I've been with the company just over eight years. My 40-plus years background and expertise is with gear design and manufacturing. I've worked in pretty much all aspects of gearing. I also provide roller bearing design and application analysis, plus structural design and analysis. My support function at Kinematics is current product support, customer applications support, and new product design.

What types of techniques and equipment does Kinematics use for its gear production?
We use industry standard equipment. Recently, we've totally relocated and retooled our factory in Jiangyin, China, roughly doubling the size of the plant. We're working toward approximately doubling the manufacturing output volume. It's a brand-new operation with majority new machine tools of all types, complete with automation. It's truly a state-of-the-art factory.

How do you provide extensive materials testing?
We have our own internal testing, but we also outsource much of our materials testing. Our company is headquartered in Phoenix, and we've partnered with an excellent metallurgical services company with full capability just around the corner from our Phoenix offices. We use them extensively for doing materials testing. We have exhaustively tested our own materials, heat treated to our specifications, to obtain a clearer definition of materials capacities rather than simply referring to published data.

What differentiates Kinematics product from the standard worm drives?
Kinematics customer applications demand more gearbox capacity than that of industry standard worm drives. Standard drives typically use a bronze worm wheel with a steel worm. Kinematics products use much stronger worm wheel/output gear materials for increased drive capacity. Kinematics widely uses austempered ductile iron output gears in solar application drives and case-hardened alloy steel in industrial drives applications. Our customers appreciate the higher capacities and reliability of our products.

What types of processes do you use to perfect your gearing?
We use a gear-design optimization process to maximize gear-mesh capacity. We use proprietary methods and means to optimize the available volumetric space for the gear pair, so that within a given space, you have maximized torsional output capacity. We utilize an iterative gear-design process where you're changing design parameters, looking at the resultant root fillet and Hertzian contact stresses. When you have iterated to the point that you have minimized the stresses, then you have optimized the gear design. Since my time at Kinematics, we have been able to increase drive capacities for some high- volume solar designs by as much as 30 percent.

Kinematics' latest generation slew drive designed specifically for the challenges of solar tracking uses a grease free dry bearing design for increased holding torque and lower maintenance. (Courtesy: Kinematics)

Do you use any types of heat-treating applications for the gearing after you create them?
Yes. We have worms, worm wheels, and output gear types; all of those gears are heat treated. In the case of our gear materials, it's either the quench and temper process for gear-alloy steels, or it's austempering process for the ductile iron that we use in many of our gears. We also use the nitriding treatment process on worm components.

What is low backlash gearing, and why is it important?
Low backlash gearing is gearing with minimized free angular movement between the worm and gear; that is, the clearance in the gear pair is minimized. This allows for more precise output gear positioning control. There is less arc distance between the worm and the output gear with a lower backlash gear mesh design compared to a higher backlash gear set. The reason it's important is because certain customers require better pointing or positioning accuracy depending on the application. An example of an application requiring good pointing/positioning accuracy is satellite ground station applications.

MORE INFO www.gokinematics.com

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