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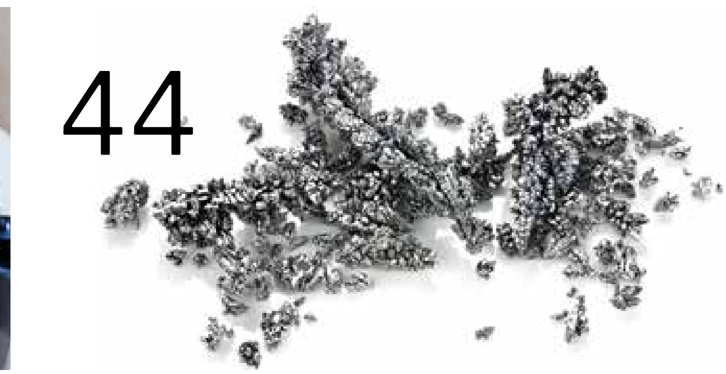
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DEPARTMENTS

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RESOURCES

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AMG

LETTER FROM THE EDITOR

Getting ready for FNA 2018

Heat treaters from every aspect of the industry will be headed to Indianapolis October 8-10 for the Furnaces North America 2018 trade show.

Attendees from more than 20 countries and 170 businesses will be on hand to share information and network their heat-treat knowledge, creating business opportunities as well as tackling challenges they may face on a daily basis back at the shop.

In addition to the near limitless networking possibilities, FNA will offer quality technical sessions where industry experts will be on hand to share their insights about the latest trends and technologies in equipment, processes, and materials.

The September/October issue of *Thermal Processing* is meant to be a primer for FNA, offering you technical articles, educational columns, and the latest product and industry news from companies from across the country and around the globe.

In this issue's Focus section, Grzegorz Moroz and Akin Malas from Linde have written an article about how industrial gases play a crucial role in advanced additive manufacturing processes.

Roland T. Warzel III, Bo Hu, Amber Neilan, and Madison Milligan share their expertise on the effect of sintering conditions on the mechanical properties of pre-alloyed vanadium powder metallurgy steels.

The issue finishes up the focus section with an article from E. Rolinski, R. Johnson, and M. Woods on plasma/ion nitriding and nitrocarburizing and their ability to form desired layers in alloys that cannot be easily hardened by other methods.

Our columnists are also bringing you some expert advice:

Maintenance Matters discusses how to keep wet pumps performing.

Metal Urgency talks about how nondestructive methods to determine hardening depth can be cost-efficient, but also challenging.

Hot Seat takes a look at welding, and how the metal fabrication and metallurgical process gets no respect, but can often determine a project's success or failure.

Quality Counts breaks down AMS2750E, Nadcap requirements.

As you can see, there's a lot of heat-treat knowledge to absorb.

So, as you count down the days to FNA 2018, let this issue of *Thermal Processing* keep you fired up for the main event in Indianapolis.

I hope it ends up being a productive time for all of you, and, as always, thanks for reading!

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OPERATIONS

Motor manufacturer buys L&L furnace for heat-treating parts

L&L Special Furnace Co., Inc., has supplied an electric box furnace to a Midwestern engine manufacturer that produces parts for large industrial engines, motor and steam generators.

The furnace has an effective work zone of 22" wide by 18" high by 22" deep, as well as a complete digital control system, overtemperature protection, and counterbalanced vertical door for ease of loading. It is used for larger structures that require thermal treatment along with running batches of multiple parts. The furnace is used for hardening and annealing of many varieties of components employed in equipment manufacturing.

L&L's Model XLE244 has an alloy fan that provides excellent uniformity (±10°F) from 300°F to 1,800°F. The alloy roller hearth and movable load table allow for larger heavy parts to be easily moved in and out of the furnace manually.

Detail of fan and cast alloy roller rails and tray on the Model XLE244 electric box furnace. (Courtesy: L&L Special Furnace Co. Inc.)

It is equipped with an inert blanketing atmosphere control system. This displaces oxygen in the system and helps keep the parts from scaling.

All L&L's furnaces can be configured with various options and specifically tailored to meet customers' thermal needs. It also offers furnaces equipped with pyrometry packages to meet ASM2750E and soon-to-be-certified MedAccred guidelines.

Options include a variety of control and recorder configurations. A three-day, all-inclusive startup service is included with each system within the continental United States and Canada. International startup and training service available by factory quote.

Precise temperature control and uniformity is a key to the L&L's XLE series' success.

More info: www.llfurnace.com

Grieve offers 2,000°F electric inert atmosphere furnace

No. 989 is an electrically heated, 2,000°F (1,093°C) inert atmosphere furnace from Grieve, used to process fabricated parts at the customer's facility. Workspace dimensions measure 30" W x 48" D x 30" H. 57KW are installed in nickel chrome wire coils supported by vacuum-formed ceramic fiber to heat the unit, while a roof-mounted, heat-resisting alloy circulating fan powered by a 2 HP motor with V-belt drive maintains the inert atmosphere for the workload.

This Grieve furnace features 7-inch thick insulated walls, comprising 5 inches of 2,300°F (1,260°C) ceramic fiber and 2 inches of 1,700°F (927°C) ceramic fiber, plus 7-1/2 inches floor insulation, comprising 4-1/2 inches of 2,300°F (1,260°C) firebrick and 3 inches of 2,300°F (1,260°C) block insulation. An alloy roller rail is supported by firebrick piers, and the alloy loading fixture with five 200-pound capacity alloy shelves is provided with an external support roller rack to hold the loading fixture directly in front of the furnace's workspace for easy loading/unloading. The unit also has an electrically operated vertical lift door.

Special Grieve inert atmosphere construction includes a continuously welded outer shell, high-temperature door gasket, sealed heater terminal boxes, inert atmosphere inlet, and inert atmosphere outlet.

Controls on No. 989 include an inert atmosphere flow meter and pressure regulator, digital programming temperature controller, manual reset excess temperature controller with separate contactors, and a strip chart recorder.

More info: www.grievecorp.com

The Grieve 989's alloy loading fixture, with five 200-pound capacity alloy shelves, is provided with an external support roller rack to hold the loading fixture directly in front of the furnace's workspace. (Courtesy: Grieve)

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.

Kanthal acquires heating elements maker Custom Electric

Kanthal acquired privately owned Custom Electric Manufacturing Co., headquartered in Wixom, Michigan. The company is a leading manufacturer of original equipment and replacement heating elements in North America.

"The acquisition further strengthens our footprint in the North American market. Custom Electric is a perfect match with regards to product portfolio, values, and vision," said Nicklas Nilsson, Kanthal president.

Robert H. Edwards, former president of Custom Electric, said, "The transaction represents the beginning of an exciting new chapter in Custom Electric's nearly 50-year journey. We are confident that the combination will represent a great outcome for the company's employees and customers over the long term."

In 2017, Custom Electric had revenues of $5.2 million, approximately 20 employees, and a strong sales network in North America. Custom Electric Manufacturing will continue to go to market under its own brand.

The transaction was closed on August 1, 2018.

More info: www.kanthal.com

All Metals & Forge Group promotes cost, quality benefits

All Metals & Forge Group manufactures high-quality seamless rolled rings with excellent tensile and yield properties for gear, bearing, and heavy machinery applications. It can produce forged rings in diameters up to 108 inches for steel alloys and up to 80 inches for other metals, with wall thickness ranging from 2 inches and up. All parts are rough machined and 100 percent UT tested (ASTM388).

Other forged shaft shapes produced include flanged shafts, round bars, spindles, and hubs.

All Metals offers these high-quality forged shafts in ferrous and non-ferrous metals including carbon steel, alloy steel, stainless steel, titanium, nickel, aluminum, and tool steel.

All Metals & Forge Group, an ISO registered forging manufacturer, has a vast inventory (300 alloys and grades) on the floor which will aid customers in the quickest deliveries, high quality, and extremely competitive products.

More info: www.steelforge.com

Can-Eng Furnaces chosen to deliver fastener hardening system

Can-Eng Furnaces International Ltd. has been contracted to design and commission a complete large-capacity fastener hardening furnace system for a Tier 1 automotive supplier based in Detroit. This contract is a result of successfully delivering multiple systems to this customer over a 20-year period and supports the capacity increases for this fastener manufacturing company, which offers wire processing, heat-treating, coating, and packaging services.

Can-Eng Furnaces International, Ltd. was contracted to see through the design and commissioning for a complete high-quality automotive fastener hardening furnace system that closely integrates a computerized part tracking and metering system, pre-washer, mesh belt hardening furnace, oil quench system, post washer, temper furnace, soluble oil system, endothermic gas generator and level 2 automation system. The contracted system is engineered to produce at a rated capacity of 6,000 lb. (2,700 kg) per hour.

Can-Eng's customers continue to enjoy the benefits associated with time-tested mesh belt furnace designs that promote soft loading and handling features that minimize part damage and mixing potential. Custom designs provide energy-efficient alternatives to forward-thinking users focused on the lowest cost of ownership procurement. This customization includes reduced energy consumption heating systems, reduced atmosphere consumption, and improved system maintainability and useful service life.

This project is being processed through manufacturing and is planned for commissioning Q1 2019.

Established in 1964, Can-Eng Furnaces International Limited is a leading designer and manufacturer of thermal processing equipment for ferrous and non-ferrous products for automotive, aerospace, forging,, and foundry manufacturing industries. Can-Eng is an ISO 9001:2015 certified company with its head office and manufacturing facility located in Niagara Falls, Canada.

More info: www.can-eng.com

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Ecoclean offers solvents as superior cleaning alternative

The task of industrial part cleaning is to achieve the cleanliness required for high-quality downstream processes – e.g., coating, adhesive bonding, welding, curing – in a reliable, but also cost-efficient and resource-saving manner. The success of this operation is critically dependent on the use of a suitably adapted approach in terms of chemicals, equipment, and process technology.

For selecting the cleaning fluid, the chemical principle "like dissolves like" may be taken as a guide. Aqueous detergents are typically employed for water-based (polar) contaminants such as aqueous coolant and lubricant emulsions, salts, abrasion residue, and other solid matter. For mineral oil-based (non-polar) contaminants such as machining oils, greases, waxes, and resins, a solvent (chlorinated hydrocarbon, non-halogenated hydrocarbon or modified alcohol) will normally be the right choice. Chips and particles present on the product will lose their adhesion to the surface

As a large-chamber solvent-based cleaning system operating under a full vacuum, the EcoCduty can be run with hydrocarbons or modified alcohols. The work chamber is designed for loads measuring up to 1,250 x 840 x 970 mm and weighing up to 1 metric ton. (Courtesy: Ecoclean GmbH) once the oil is removed and are then eliminated via an operation such as, e.g., injection flood washing and ultrasound.

For solvent-based cleaning, Ecoclean's product portfolio comprises fully enclosed machines carrying the fluid in a closed circuit. All solvent-based cleaning systems come equipped with an integrated distillation system and filtration systems for continuous automatic reconditioning of the solvent. As a result, operator exposure to the solvent is virtually eliminated and an unchanging cleaning quality and long solvent life is ensured.

Heat-treating contractors, metalforming shops, and companies from the automotive and aircraft industries in particular require cost-efficient part cleaning and degreasing equipment capable of handling high capacities. The solvent-based large-chamber cleaning system EcoCduty was developed to address this demand. This machine is designed for loads measuring up to 1,250 x 840 x 970 mm and weighing up to 1 metric ton. It uses hydrocarbons or polar solvents and operates under full vacuum. Its modular design provides adaptability to individual user needs. Configured as a vapor-degreaser in its standard version, the system is additionally available with one or two stainless steel flood tanks – e.g., for a process comprising vapor degreasing and injection flood washing or vapor degreasing, injection flood washing plus a preserving step. Vacuum drying is standard on all three versions. Chlorinated metalworking fluids can be effectively removed by means of appropriately stabilized solvents following oil compatibility testing. Moreover, the unit is perfectly suitable for cleaning off sulphur-containing oils.

The EcoCcore, working under a full vacuum, is designed for efficient cleaning of large quantities of parts to exacting cleanliness standards. It can be operated with non-halogenated hydrocarbons or modified alcohols (polar solvents) and it is easy to change from one solvent to another. This ensures its future viability even if the part range or specifications should change. Moreover, this solvent cleaning system shines with an extensive standard equipment level that includes, e.g., two flood tanks, heat recovery, full-flow and bypass filtration, plus a number of detailed features minimizing idle times. The innovative preliminary steam degreasing function, which delivers the oil-laden solvent straight into the distillation circuit (instead of into the flood tank, as is commonly the case), and the ability to use ultrasound and filtration at the same time, help to reduce per-unit cleaning costs while also enhancing cleaning quality. Contaminant particles are thus discharged while the cleaning process is still ongoing and will not settle at the bottom of the work chamber pending filtration.

The EcoCcompact, with two flood tanks as standard and a space-saving modular configuration, is suitable for cleaning and preservation processes using polar solvents or non-halogenated hydrocarbons. Operating under a full vacuum, this unit can be ordered with diverse options supporting a broad range of applications – from high-speed degreasing through intermediate cleaning to specification-compliant final cleaning. To assist with such challenges, a third flood tank can be retrofitted. The machine's design focus lies on a targeted reduction in per-unit costs combined with maximum cleaning efficiency.

A compact solution taking up minimum space, the Minio 85C provides reliable and economical de-greasing and cleaning with non-halogenated hydrocarbon media, either between or downstream of production processes. Both small businesses turning out low production volumes and large-scale operations using distributed cleaning stations will profit from its mature process technology involving the steps of immersion, steam degreasing and vacuum drying.

More info: www.ecoclean-group.net

Amsted Rail® buys furnace line from AFC Holcroft

Amsted Rail®, a global leader in fully integrated freight-car systems for the heavy haul rail market has added a new, complete AFC-Holcroft UBH line to meet a growing need for additional heat-treatment capacity. This latest purchase includes a batch style carburizing furnace, two expansion modules to increase endothermic generator gas output, a rotary hearth reheat furnace for press quenching, and a continuous integrated parts washer and temper furnace.

"The batch furnace itself has an effective load size of 72 inches by 72 inches by 56 inches with a gross load capacity of 13,000 pounds, which is considered very large for this type of equipment, but is in fact one of AFC-Holcroft's standard sizes," said Tracy Dougherty, sales manager at AFC-Holcroft. "The ability and experience to provide equipment for reliable processing of such large loads is just one of the benefits that AFC-Holcroft is able to offer, and one more thing that sets us apart from our competitors."

Amsted Rail® is headquartered in Chicago, Illinois, with locations worldwide in every significant railroad market. The equipment is scheduled to ship to a joint venture facility located in Eastern Europe in the third quarter of 2018.

More info: www.afc-holcroft.com/en

The E-1500 hand-held industrial combustion gas and emissions analyzer. (Courtesy: E Instruments)

E Instruments has new E1500 gas analyzer

E Instruments International's E1500 portable flue gas analyzer is designed for emissions monitoring, maintenance, and tuning of boilers, burners, engines, furnaces, turbines, kilns, incinerators, and many other industrial combustion processes.

The E1500 includes:

- Gas sensors for O_2 & CO.
- Built-in printer (non-fading paper).
- Automatic data saving feature.
- Temperature and pressure measurements.
- Efficiency, excess air, and CO_2 calculations.
- Internal data memory (2,000 tests).
- Software package with Bluetooth and USB.
- Droid & iOS compatible apps.
- Calibration certificate.

More info: www.e-inst.com.

TPS ships Gruenberg cabinet oven to R&D industry

Thermal Product Solutions (TPS), a global manufacturer of thermal-processing equipment, announced the shipment of a Gruenberg cabinet oven to the research and development industry. This Class B oven will process up to 5 gallons of water per batch from 1,500 pounds of metal powder.

The maximum temperature rating of this Class B cabinet oven is 250° F, and the work chamber dimensions are 48" W x 48" D x 48" H. This Gruenberg cabinet oven is constructed from a structural steel frame that supports the fully welded 304 stainless steel chamber liner and the exterior sheet metal. All interconnecting struts are non-continuous, which keeps the exterior cool.

The Gruenberg drying oven features one circulation blower direct drive in a conditioning plenum chamber in the top of the oven. This blower directs air through a diffusor panel on one side of the work chamber and flows horizontally across the product. The air exits the work chamber on the opposite wall back to the heaters for reheating and recirculation.

"This cabinet oven has the design capacity to dry 1,500 pounds of metal powder from 3 percent moisture to zero percent moisture content. Three 48" x 48" x 6" tanks were used in the oven, and the shelves were reinforced accordingly," said Denny Mendler, Gruenberg product manager.

Features of this Gruenberg cabinet oven include:

- Programmable temperature controller
- High limit controller to prevent overheating
- SCR power control
- End of cycle process timer
- Reinforced shelf slides (600 pounds each).
- UL508A control panels.
- Main power disconnect switch.
- Exhaust HEPA filter.
- Horizontal airflow to maximize heating and drying rates.

More info: www.thermalproductsolutions.com

Liftomatic releases below-hook drum handling system

Buffalo Grove, Illinois, Liftomatic Material Handling, Inc., an industry-leading material handling equipment manufacturer, recently expanded its line of innovative drum handling equipment to include the new model 3A-HD-BHDL, a below-hook drum handling system.

The 3A-HD-BHDL is a fully automatic and mechanical below hook attachment that can be used to lift 55-gallon drums from an overhead position for placement to or from many containment devices, scales, pallets, or similar handling requirements. Drums remain in a vertical position while lifted and/or transported with the 3A-HD-BHDL unit.

The 3A-HD-BHDL works with three radial arms that conform to the drum body and engage at the underside of the drum chime on nearly any 55-gallon steel or plastic drum. The unit has a working capacity of up to 3,000 pounds/drum. The 3-point connection assists to maintain the drum's integrity during the lifting process. A cutting-edge "intuitive-lock" engagement system ensures the radial arms remain in the locked position until the load is placed in its final resting location. Drums with a range of 21"-23" in outside chime diameter can be handled.

The 3A-HD-BHDL works with three radial arms that conform to the drum body and engage at the underside of the drum chime. (Courtesy: Liftomatic)

The 3A-HD-BHDL can be attached to any overhead lifting hoist, or can be affixed to Liftomatic's model FTB-3 forklift adapter, allowing the unit to be used from the underside of a set of forklift forks. The 3A-HD-BHDL is ideal for energy industries, environmental operations as well as general use where overhead lifting of drums is required. The unit was designed as a result of customer requests for a positive locking system assurance that eliminates the need for a manual locking and unlocking of the armature to a drum.

More info: www.liftomatic.com

Bodycote to open new heat-treatment facility in U.K.

Bodycote, the world's largest provider of heat treatments and specialist thermal processing services, has announced the opening of a new facility in the Advanced Manufacturing Park (AMP), Rotherham, Yorkshire, to support the aerospace and power generation markets in the U.K. and Europe.

Simon Blantern, vce president of sales Europe for Bodycote's aerospace, defense, and energy heat-treatment division, said, "This investment demonstrates Bodycote's continuing commitment to align resources to serve both the aerospace and power generation markets."

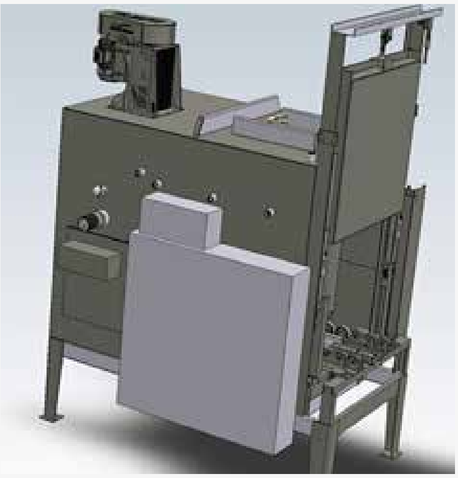
The new facility, fully operational in 2018, will offer a number of heat-treatment processes. Additionally, major OEM approvals will be secured along with Nadcap accreditation.

More info: www.bodycote.com

Gasbarre Furnace/J.L. Becker delivers temper furnaces

Gasbarre Furnace Group/J.L. Becker recently shipped a pair of 36" x 48" x 36" electrically heated temper furnaces to a major drive supplier in the Southeast. The furnaces are designed to preheat workloads before hardening and temper workloads after hardening. Their maximum workload capacity is 4,000 pounds. The furnaces are designed to operate from 300°F to 850°F with a temperature uniformity of ±5°F. Roller rails and a chain guide allow the furnaces to be loaded and unloaded by the company's existing powered transfer cart. A motorized damper aids the furnaces to quickly cycle between high and low operating temperatures. The control systems each incorporate an Allen Bradley CompactLogix PLC and ELO HMI which enable the furnaces to be installed in the customer's existing "lights out" automated system.

Located in Plymouth, Michigan, Gasbarre Furnace Group/J. L. Becker has been designing, manufacturing, and servicing a full line of industrial thermal processing equipment for more than 40 years. Gasbarre Furnace Group/J.L. Becker's product offering includes both batch and continuous heat processing equipment and specializes in temper, tip up, box, car bottom, and pit furnaces as well as a full line of replacement parts and auxiliary equipment which consists of atmosphere generators, quench tanks, and charge cars. The company custom designs and manufactures thermal processing equipment to meet specific needs.



A motorized damper aids the furnaces to quickly cycle between high and low operating temperatures. (Courtesy: J.L. Becker)

More info: www.gasbarrefurnacegroup.com or www.jlbecker.com

Thermal Product Solutions ships Gruenberg bench oven

Thermal Product Solutions (TPS), a global manufacturer of thermal-processing equipment, announced the shipment of a custom Gruenberg bench oven to the movable machinery industry. The bench oven is rated for Class B operation per the NFPA 86 specifications.

This bench oven will be used in the customer's testing and product development department to process various mechanical apparatuses affixed to a Ling Dynamic Electronic Shaker. The maximum temperature rating of this Class B oven is 550°C (1,022°F) and the work chamber dimensions are 36" W x 36" D x 36" H. This Gruenberg custom bench oven is constructed from a structural steel frame that supports the fully welded 304L stainless steel chamber liner and the exterior sheet metal. All interconnecting struts are non-continuous which keeps the exterior cool.

A custom Gruenberg bench oven will be used in the customer's testing and product development department. (Courtesy: TPS)

This Gruenberg custom bench oven features one belt-driven circulation fan in a conditioning plenum chamber in the rear of the oven. This fan directs air through a diffusor panels on both sides of the work chamber and flows horizontally across the product. The air exits the work chamber on the rear wall back to the heaters for reheating and recirculation.

"Our design team customized this bench oven to accommodate the customer's equipment through an opening in the oven bottom. At TPS, we pride ourselves on our ability to customize equipment to meet our customers' requirements," said Denny Mendler, Gruenberg product manager.

More info: www.thermalproductsolutions.com

Registration for Powder Metallurgy Sintering Seminar open

Registration is open for one of the powder metallurgy (PM) industry's most popular programs, the PM Sintering Seminar. The event will be held September 25-26, 2018, at the Penn Stater Conference Center Hotel, State College, Pennsylvania.

Held every two years, this two-day seminar is meant for industry professionals either new to sintering or with intermediate experience in the industry. Topics covered will include information from basic theory and practices to troubleshooting and how to drive down the costs of sintering.

Learn from industry experts about:

- Sintering parts at normal or elevated sintering temperatures.
- Increasing productivity by reducing rework and scrap.
- Improving properties of PM parts with sintering.
- The latest equipment capabilities.
- Troubleshooting sintering problems.
- Efficiency in daily sintering operations.

More info: www.mpif.org

MIM2019 Conference calls for presentations

An official call for presentations has been announced for MIM2019, International Conference on Injection Molding of Metals, Ceramics and Carbides, to be held in the Hilton Orlando Lake Buena Vista, Orlando, Florida, February 25-27, 2019. Authors have until September 28, 2018, to submit presentation abstracts on manufacturing innovations and material advancements. All abstracts accepted for presentation will require a PowerPoint submission before the conference.

Innovation is responsible for the rapid growth of the powder injection molding industry (metal injection molding, ceramic injection molding, and cemented carbide injection molding), a nearly $2 billion advanced manufacturing industry. MIM2019, sponsored by the Metal Injection Molding Association, a trade association of Metal Powder Industries Federation and its affiliate APMI International, brings together product designers, engineers, end users, manufacturers, researchers, educators, and students for technology transfer.

More info: mim2019.org

ITPS delivers outstanding presentations to industry executives

Industry leaders and executives gathered in Atlanta July 30-August 1 for the second ITPS — International ThermProcess Summit — and by all accounts and comments, the event delivered a wide array of timely and critical information. One attendee said, "had I known how good the content was going to be, we would have brought out entire management team. We certainly will next time."

Anne Goyer, IHEA's executive vice president, noted that attendee evaluations showed executives felt the speakers and their presentations were very valuable.

"I have been involved in organizing conferences and summits for more than 35 years," she said. "This year's ITPS was one of the highest evaluated events we've ever produced."

From the opening session, where attendees learned about the Factory of the Future from Dr. Irene Petrik of Intel, to the closing presentation on Transitioning Your Business to the Next Generation by Mike Brown, the audience was engaged throughout the event. The highest rated presentation came from Dr. Amber Selking of the Selking Performance Group. She addressed ways for executives to "Drive Consistent Performance Excellence!" within their companies. Dr. Selking dove into the science behind how the brain works and what leaders should do to develop their staff to drive a workforce that feels empowered. Her presentation was so well received that several people wrote in an "excellent plus" when rating her presentation.

IHEA has offered many conferences and educational opportunities over its 89-year existence, but ITPS this year was among the best rated events ever, if not the top-rated event. Diverse and unique in the industry, those who attended felt it was very worthwhile.

REGISTER NOW FOR IHEA'S FALL SEMINARS

Each Fall IHEA offers its series of outstanding training seminars. With the just-released NFPA 86 revisions, this is a year that everyone should join us in Indianapolis October 8-10 when IHEA's Safety Standards and Codes seminar is held alongside its Combustion and Induction seminars. Continuously rated very high by past attendees, this year's seminars will be in conjunction with Furnaces North America (FNA) at the Indiana Convention Center in downtown Indianapolis.

"Co-locating the seminars with FNA allows attendees to get great education from our seminars and take in the FNA exhibition,"

Dr. Amber Selking held the attention of attendees through her presentation on Building Championship Mindsets.

Attendees enjoyed plenty of great networking opportunities at ITPS 2018.

Great educational opportunities await those registering for IHEA's Fall Seminars.

Goyer said. "Registration for FNA is automatically included for those who register for an IHEA seminar. The timing of the seminars has been coordinated to allow attendees to be in seminars during non-exhibition hours."

COMBUSTION SEMINAR

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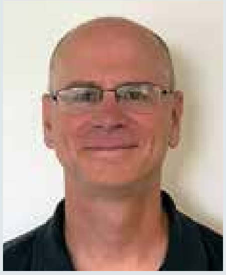
Nondestructive methods to determine hardening depth can be cost-efficient, but also challenging

By Robert M. Wolfe and Guang Yang



Surface hardening heat treatments are popular in the manufacture of steel products as a means of significantly improving strength and fatigue resistance and mitigating wear [1]. In the production of bearing components, manufacturers know it is important to control the case depth of the hardened surface layer to ensure safety and reliability. Most current state-of-the-art solutions for hardening depth measurement are based on a statistical sampling approach using the inspection of certain selected characteristics, followed by various destructive testing methods. However, some well-known nondestructive methods — such as eddy current, ultrasonic inspection and, more recently, Barkhausen noise techniques — have also been explored to determine hardening depth [2-3].

Nondestructive methods reveal hardened depth based on the material property differences, such as hardness and residual stresses, between the surface hardened layer and the core. Nondestructive solutions can be cost-efficient and can be applied to the entire production process without destroying valuable components. Each nondestructive method has demonstrated success in some specific applications. But nondestructive measurement of case depth is also a challenging task that can be significantly affected by surface condition, microstructure, grain size, and geometry variation. Each of these methods has advantages and disadvantages [2-4].

Some of the recent developments in nondestructive case depth measurement are presented below:

ELECTROMAGNETIC CASE DEPTH MEASUREMENT

The conductivity and permeability of bearing products change along with heat treatment and the hardening process. Therefore, case depth can be evaluated nondestructively by measuring characteristic differences in the bearings' electric and/or magnetic properties using electromagnetic methods [3]. The eddy current method is the most highly developed electromagnetic nondestructive technique applied to case depth measurement thus far. Traditional single frequency, multi-frequency, and pulsed eddy current methods have all been studied and reported for hardening depth measurement [5-7].

Another electromagnetic technique, the Barkhausen noise method (also referred to as the micromagnetic method), has been investigated to determine hardening depth as well [3]. Barkhausen noise measurement is sensitive to stress and microstructural changes and is based on the principle of inductive measurement of a noise-like signal generated when a magnetic field is applied to a ferromagnetic material. Barkhausen noise measurement has been studied and successfully correlated with hardness and case depth [3]. Other related approaches, including alternating and direct current potential-drop methods, have also been explored in hardening depth measurement [4].

EDDY CURRENT METHOD

When surface hardness is low, the steel microstructure exhibits high permeability with high eddy current density; as a result, substantial magnetic flux is induced. Conversely, when surface hardness is high, the permeability drops and the eddy current density decreases accordingly.

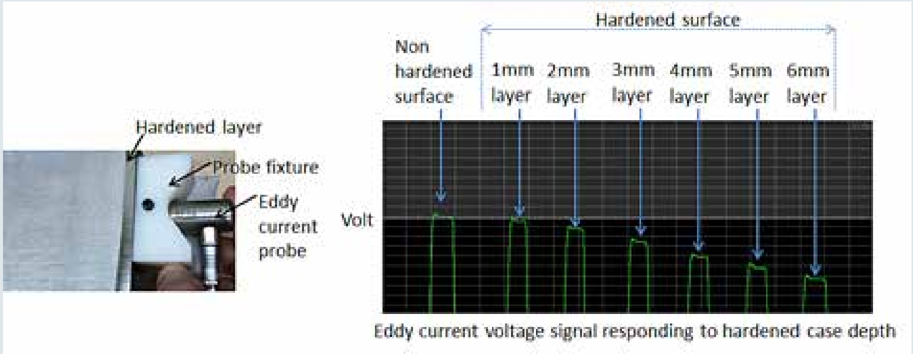


Figure 1: Eddy current method for case depth measurement: (a) Single frequency eddy current test setup. (b) Eddy current voltage signals responding to hardened case depths.

The induced magnetic flux that accompanies high surface hardness is less than that induced at low surface hardness. As a result, the voltage signal seen in Equation 1 that is determined by the magnetic flux becomes lower in accordance with the hardened layer depth [7].

$$V = -N\frac{d\emptyset}{dt}$$ **Equation 1**

where V = voltage signal of eddy current method; N = number turns of eddy current coil; Φ = induced magnetic flux.

The single frequency eddy current setup for hardened layer measure-

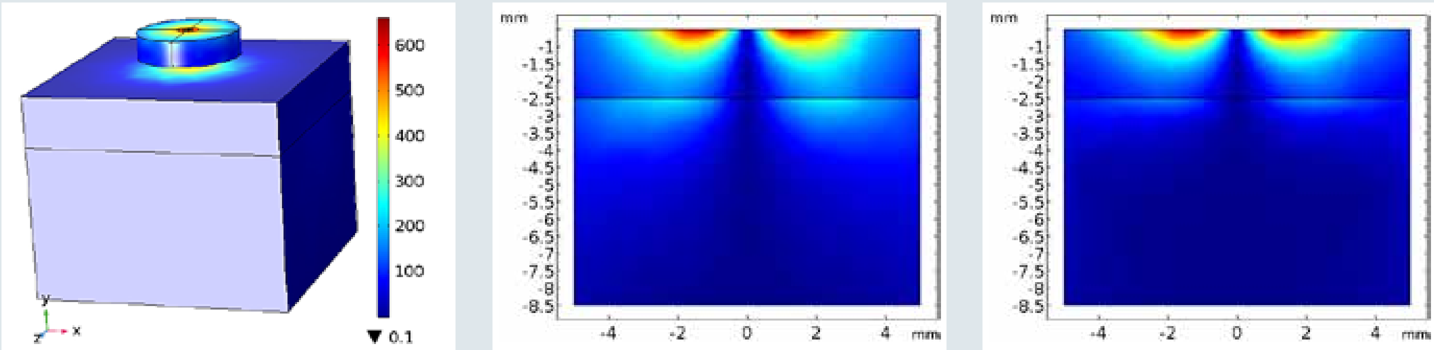


Figure 2: Numerical simulation of an ET probe over a steel specimen (hardened top layer): (a) Magnetic flux density distribution (Gauss). (b) Induced current density distribution along specimen depth at frequency = 100Hz. (c) Induced current density distribution along specimen depth at frequency = 1kHz.

ment and some corresponding signals are shown in Figure 1.

The critical parameter of the eddy current method is the eddy current penetration depth (also called skin depth), which is determined by frequency and material properties, as shown in Equation 2.

$$\delta\ (penetration\ depth) = \frac{1}{\sqrt{\pi \cdot f \cdot \mu \cdot \sigma}} \qquad \text{Equation 2}$$

where f = frequency; μ = permeability; σ = conductivity.

As the frequency increases, the induced eddy current is more concentrated near the surface. This principle is demonstrated in Figure 2, where an eddy current probe has been placed above a steel surface with a hardened layer. The lower frequency generates deeper penetration; thus, a lower frequency is preferred in order to perform deeper case measurement with superior sensitivity. On the other hand, higher frequencies produce strong sensitivity when the hardened layer is thin. As a result, multi-frequency eddy current methods have been explored to accommodate these observations [6-7].

ULTRASONIC CASE DEPTH MEASUREMENT

The metallurgical properties of surface induction-hardened medium- and high-carbon steel components can make them amenable to nondestructive case depth measurement using ultrasonic techniques. Development of this test method was explored by Good [8] in the early 1980s. Further refinement of the technique occurred in the early 1990s at the Fraunhofer Institute (IZFP) and Pacific Northwest National Labs, which led to respective patents [9-10]. Developments critical to industrial use included appropriate test frequencies, signal averaging, and filtering methods to allow consistent waveforms to be obtained from the ultrasonic signal.

The measurement principle is based on the propagation of ultrasonic shear waves applied at an angle to the test surface. The shear waves produce a backscattering effect as they reach the case/core transition because of the differences in the microstructure's acoustic impedance properties in this zone.

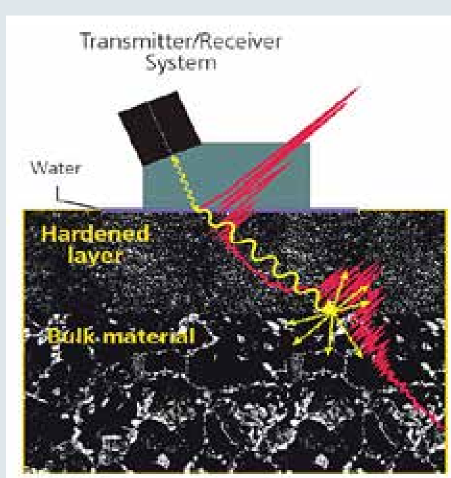


Figure 3: Illustration of ultrasonic backscattering from surface hardening.

In order to obtain a reliable signal from which a measurement can be made, a few conditions must be satisfied. First, the hardening must be deep enough so that the front surface and backscattered peaks are sufficiently separated in time. This assures distinct peaks from which time-of-flight can be calculated. Second, the transition zone between the case and core must be sufficiently discrete such that the backscattered peak is above noise levels (Figure 3) [11]. A good response is achieved by induction surface-hardening a component with an unhardened core, where the minimum depth of hardening is between 1.5 and 2 mm. In this instance, the fine-grained martensitic case zone is in sharp contrast to the coarse-grained ferrite/pearlite microstructure of the core. This condition results in a distinct backscattered signal peak (from surface hardening Figure 4).

Surface treating processes that are not suitable candidates for ultrasonic measurement methods include shallow hardening processes such as nitriding, diffusion hardening processes such as carburizing, and relatively slow conductive surface heating processes that produce a wide transition zone.

The depth of hardening is determined by the relationship:

$$d = \frac{\tau \times v_s \times \cos\alpha}{2} \qquad \text{Equation 3}$$

where τ = transit time from the front surface to the beginning of the backscattered peak; v_s = velocity of sound in steel; α = angle of sound incidence through the hardened zone.

Variations and errors in measurements may also be introduced by metallurgical conditions such as large amounts of secondary phases (e.g., retained austenite), segregation, and large or varying grain size in the hardened zone. The influence of these conditions on the ultrasonic signal is a function of the test frequency. Maximum attenuation and undesirable scattering occur when the feature dimensions approach the wavelength of the ultrasound.

In any discussion on case depth measurement, it is necessary to define the reference

Nondestructive case depth measurement has enabled significant cost reductions by reducing or eliminating destructive analysis. This is especially true for large and complex parts where destructive sampling is prohibitive.

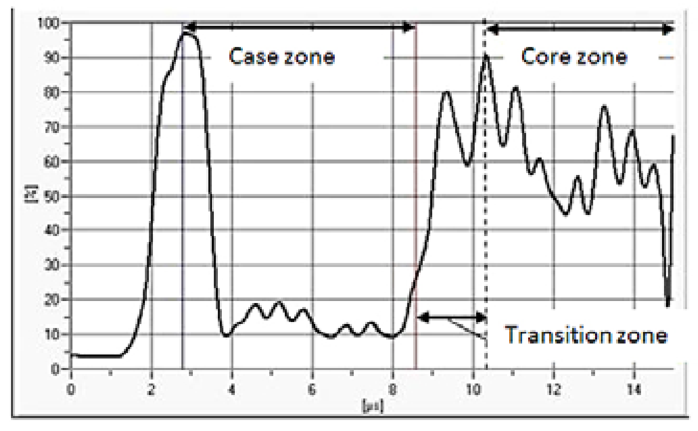


Figure 4: Typical ultrasonic A-scan showing backscattered signal from surface hardening.

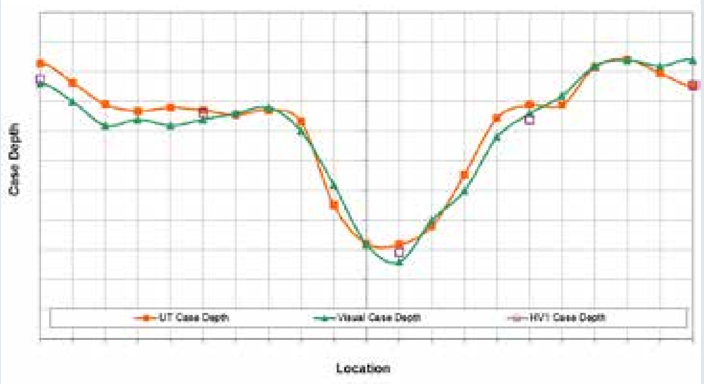


Figure 5: Comparison of UT backscatter, visual and hardened case depth.

method. This can vary depending on applicable standards, products or customer requirements [1]. One of the more common approaches is a specified hardness value to a measured depth. Since ultrasonic backscattering is typically dominated by microstructure effects rather than hardness itself, it is reasonable to assume that a measurement correction might be necessary to correlate these methods. After correction, good correlation between backscattered, visual, and hardness measurement methods is demonstrated, as shown in Figure 5 [12].

Nondestructive case depth measurement has enabled significant cost reductions by reducing or eliminating destructive analysis. This is especially true for large and complex parts where destructive sampling is prohibitive. Successful nondestructive inspection applications are contingent on understanding the details of the material's condition as well as the limitations of the test method.

REFERENCES

1. Rothleutner, "Metal Urgency: Case Depth Determination," Thermal Processing, March-April, 2018.
2. Y. Salchak, et al., "Method of case hardening depth testing by using multifunctional ultrasonic testing instrument," Materials Science and Engineering, Vol. 81, 2015.
3. M. Deveci, "Nondestructive determination of case depth by Barkhausen noise method," Master of Science thesis, Tampere University of Technology, May 2016.
4. C.X. Zhang, "Assessment of depth of case-hardening in steel rods by electromagnetic methods," Iowa State University, 2009.
5. R. Palanisamy, "Prediction of eddy current probe sensitivity for the sizing of case depth in ferrous components," IEEE Transactions on Magnetics, Vol. 23, No. 5, September 1987.
6. J. Cuffe, et al., "Eddy Current Measurement of Case Hardened Depth of Steel Components," 17th World Conference on Nondestructive Testing, 25-28 October, 2008.
7. A. Banno, "Development of hardening penetration depth evaluation technique," JSAE Congress (Autumn), 27 October 2004.
8. M.S. Good, et al., "Evaluation of Feasibility for the Ultrasonic Measurement of Case Depth in Case Hardened Steels," technical report, http://www.dtic.mil/dtic/tr/fulltext/u2/a117901.pdf
9. Herbert Dipl Phys Willems, "Apparatus for non-destructively measuring the thickness of a hardened layer," Patent DE4239159C2.
10. M.S. Good, et al., "Ultrasonic material hardness depth measurement," Patent US5646351A.
11. W. Theiner, et al., "Process Integrated Nondestructive Testing of Ground and Case Hardened Parts," Fraunhofer IZFP, PINT NDT — ECNDT, Barcelona, 2002.
12. Internal Timken research report.

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Robert Wolfe is Group Leader – NDE in The Timken Company's R & D department. He has more than 30 years of experience in materials, steel processing, and NDE-related development activities.

The metal fabrication and metallurgical process that gets no respect can determine projects' success or failure

By Jack Titus

Heat-treating and metallurgy are topics that attract the overwhelming interest of attendees of technical conferences and are written about in numerous articles. However, a subtopic of the genre that is too often overlooked and is just as critical is welding.

Furnace casings and their internal components rely on welding to connect subassemblies. Steel structures that support the refractory are fabricated from steel plate that in the case of atmosphere furnaces is generally 3⁄16″ to ¼″ thick. Structural members such as I-beams and channels are also welded to form the rigid skeleton providing the integrity to keep the structure square and aligned for successful operation, and to create the stiffness required for transport from the OEM to the final destination — which can be an ocean away.

Welding metal can be categorized by the following four primary methods:

Shielded Metal Arc Welding (SMAW) or 'stick' welding was the early process employed for decades for steel, aluminum, and other metals. It consists of a ferrous or other applicable electrode rod coated with flux, a carbonate and silicate material similar to slag in the steel making process. The molten slag, being less dense than the metal, floats on top of the weld bead protecting it from oxidation. Pros: It's a forgiving process and can be used for many different thicknesses of metal. Cons: It's a slow and messy process. The method creates slag and metal splatter that must be mechanically removed before adding additional passes and for appearance. As one 12-inch long welding rod or stick is consumed, the welder must stop and use another. The resulting stop/start crater creates potential failure points when not treated properly.

Metal Inert Gas (MIG) eliminates the flux and uses a continuously fed consumable wire as the filler metal. However, for mild steel, a mixture of 75 percent argon and 25 percent CO_2 provides the shielding to reduce potential oxidation of the weld bead. Where stainless steel is concerned, a tri-mix of 90 percent helium, 7.5 percent argon and 2.5 percent CO_2 is used. Pros: MIG is the fastest process since the welder does not have to stop and replace the weld rod. No cleanup is required. Cons: The welding area must be protected by curtains or otherwise shielded from room air currents that can displace the shielding gas without the welder's knowledge resulting in porous (leaky) welds and reduced structural strength.

TIG (Tungsten Inert Gas) employs a hand-held tungsten torch, as it's called, held like a pencil or air brush in one hand while a manually fed filler rod is melted by the tungsten arc. The torch also provides the shielding gas to protect the weld from oxidation. The filler rod has no flux covering but is longer than the typical 12-inch long stick rod, so fewer stop/start craters result. TIG welding is generally used for thin sheet metal where the power to the arc is kept low so the arc does not melt through the material being welded. Like MIG, the shielding gas is selected according to the metal being welded. It's a slow process where the filler rod is manually applied to control the quantity of weld metal required. Pros: Highly controllable and can be very precise for application such as jewelry making and welding extremely thin components. Cons: A slow process. Can be difficult to master. TIG is sometimes referred to as heliarc welding.

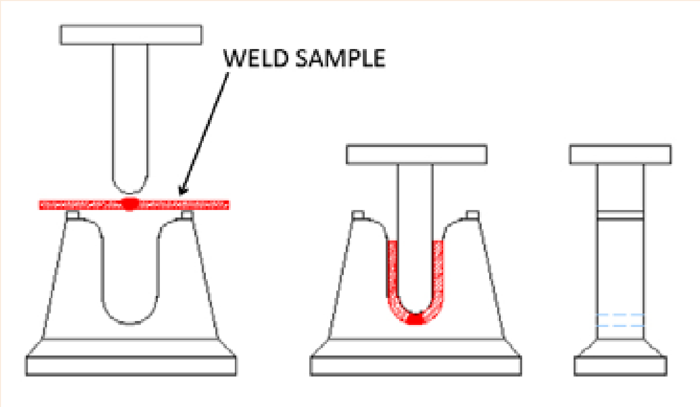

Figure 1: Weld bend fixture. (Drawing based on accepted device designated by ASTM E190)

Flux-Cored Arc Welding (FCAW) combines the benefits of stick welding and the MIG process and is the most forgiving welding method. Continuously fed like the MIG process, the consumable wire is filled with a flux in addition to using inert gas. It's a fast process but provides the additional oxidation reducing result of flux. Pros: Fast, forgiving, and easy to learn; produces high-quality weld bead. Cons: Requires slag cleanup due to spatter.

Welding is a lot more than striking an arc and laying down metal.

The purpose of welding is twofold: Connect one or more subassemblies in a seamless manner. To eliminate fluid leaks between assemblies or components where mechanical fasteners cannot eliminate gas or liquid leakage or provide continuous connected strength where rivets or threaded fasteners can't.

The most critical applications for welding are for vacuum systems, pressure vessels, and petrochemical applications. Vacuum furnaces, as well as non-heated low-pressure structures, must have weld integrity of strength and leak tightness. MIG welded components can look completely acceptable from a physical appearance but can have significant leakage through microporosity. Quality tests for vacuum systems consist of helium testing, in which a helium mass spectrometer measures the quantity of helium gas that migrates through the welds and other mechanical fasteners. Where pressure vessels are

2a 2b

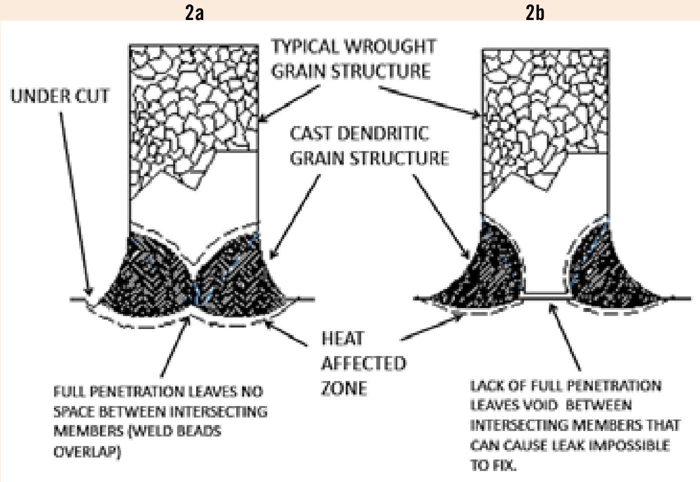

Figure 2: Fillet weld, 2a, with undesirable undercut but good penetration, and 2b, with a lack of full penetration. (Courtesy: Jack Titus)

concerned, welds are commonly X-rayed to detect internal porosity or other imperfections. For example, when heat-treating furnaces are indirectly gas fired the burner fires into radiant tubes straight or U shaped. Heat-resisting alloy U tubes are centrifugally cast and a statically cast return U bend is welded to each straight tube. After welding, each tube assembly is pressure-tested to find and repair any leaks.

Testing for weld quality after welding is complete is typically done by liquid penetrant or dye testing. The procedure consists of the following:

- Thorough removal of all remnants of slag, and then make sure the weld is completely dry.
- Spray or brush the dye penetrant on all welds and areas affected by the welding heat.
- Let the penetrant reside on the weld for the appropriate time per the penetrant instructions.
- Thoroughly wipe away the residual penetrant from all areas of the weld.
- Spray the developer onto the weld area and let stand again per the instructions.

Any surface imperfections will result in the penetrant via capillary action to discolor the developer revealing cracks and/or porosity. The downside of this technique is it only reveals surface anomalies, not subsurface issues.

When a weldment's strength is important — and it always should be — two primary destructive tests are completed to determine the weld's integrity. The first is a simple tensile test in which two approximately two-inch wide by four-inch ¼″-thick steel sections are butt welded together. After cleaning, the welded sample is pulled apart to failure. The failure must not occur in the weld bead but in metal plates or the heat affected zone (HAZ), which is the area where the weld connects to the ¼" plate. The second test is for ductility. It consists of placing a similar test sample on a U-shaped fixture and the sample is pushed into the cavity creating compressive and tensile stresses on opposing sides of the weld bead. Figure 1 is a typical bend test fixture.

Just as the microstructure determines the successful result provided by heat-treating of metal, the microstructure of the weld is of uppermost concern for metallurgists. As discussed in previous columns, all wrought ferrous alloys such as sheet, plate, rod, bar, etc. begin as castings. A weld is a casting and as such retains all of the benefits and disadvantages of all castings, i.e. a brittle nature, low ductility, and subject to fatigue failure in certain applications and high strength.

One of the critical skills possessed by good welders is the ability to set the appropriate power settings so the weld and surrounding metal do not overheat. The two negatives produced by too high a heat setting are undercutting and the exaggerated direction of the dendrite microstructure from the root of the weld to the surface. Both examples are shown in Figure 2a.

Undercutting produces a notch in the HAZ that can reduce the already increased potential for fatigue failure of the weld's cast structure. The directional dendritic grain structure from root to surface produced by high heat tends to enable cracks to follow along the longitudinal grain boundary unimpeded by the smaller grain structure of the wrought metal. Being a casting, overheating also allows the concentration of carbon-forming iron-carbide Fe_3C in the grain boundary due to the slower cooling of the weld area.

Conversely, if the power to the electrode is too low, producing a cold weld, it will lack the penetration required to fill the material cross-section, weakening the assembly and possibly creating a void at the root of each weld bead — disastrous for vacuum systems as the void can produce a leak from trapped air that's impossible to find. Figure 2b shows an example of a less-than-full penetration weld.

Although the four welding techniques discussed above satisfy the overwhelming applications today, there are other specialty processes that have been developed. They are as follows:

LBW (Laser Beam Welding) is a technique that is used where near-finished machined components are joined with or without a filler metal. The weld bead is small in comparison to MIG, TIG, or stick processes. A shielding gas is used or the operation can be performed in purged enclosure. Generally, LBW is automated with a robot, as the process can be very fast and must be precise due to the small arc and resulting weldment.

Friction welding (FW) really isn't welding at all. It's sometimes called forge welding since the parts to be joined are pressed together with extremely high force and the mechanical motion between the parts creates high heat concentration but not enough to melt; instead the parts are more or less forged together.

SAW (Submerged Arc Welding) is an automated form of SMAW; however, the flux is added separately in granular form, not attached to the 'stick,' while the filler metal is fed. It's primarily used when the steel plate is thick and requires uninterrupted welding. Always performed horizontally, the electrode can move relative to the part in a straight line or the part can rotate under the electrode when pipe sections are connected. The granular flux is automatically fed from an annular opening surrounding the wire electrode. When the seam to be welded is circular, such as around the circumference of a pipe, the weld takes place at the very top. The flux slides off the weld as the pipe rotates. Molten slag is created where the flux contacts the weld and helps to remove impurities. However, the flux that isn't melted slides off the weld as the pipe rotates. Since slag is created, it must be removed before additional passes can be applied. Oil pipelines and wind turbine towers are typical recipients of the SAW process.

Welding, in essence, is a fastening method just like bolts, nuts, and the like, but in which a continuous connection is required for either strength or to prevent leaks. However, bolts, screws, and other threaded fasteners go through a quality check for strength traceable to a standard; a weld's quality is more subjective, relying only on the competence of the technician.

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Combining pyrometry procedures to conform to current factors blends processes, materials, furnaces, and prime parameters logically

By Jason Schulze

When I consult, I will periodically perform a gap analysis on a supplier's heat-treat process to either obtain Nadcap approval or as a check-and-balance to maintain and/or improve their process. While performing this task, I examine the supplier's procedures and work instructions in detail to ensure all required items are contained within the documents. Over the years, I've been able to notice those procedures that flow in a logical, easy-to-understand format and those that have been pieced together whenever a supplier inserts new statements due to findings or a major specification revision. The latter creates a document that does not flow in a matter conducive to comprehension for the staff who must follow the instructions.

When documenting the necessary instructions to ensure product and/or process conformance, the aggregation of the specification must be well understood.

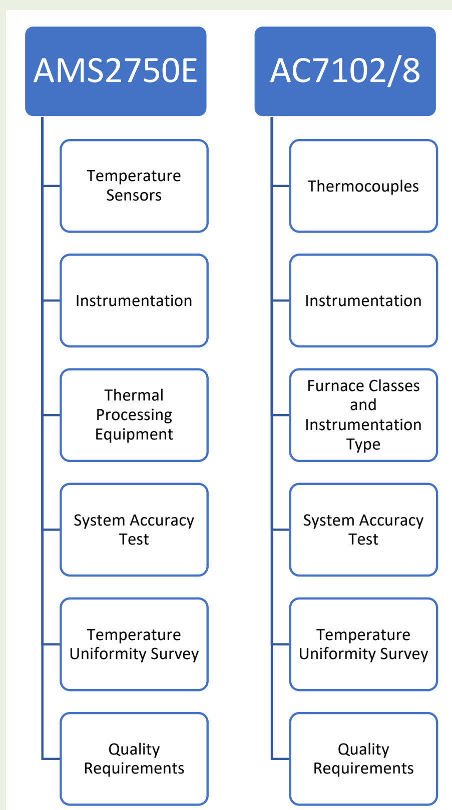
In this article, we will explore the aggregation of AMS2750E and Nadcap requirements regarding pyrometry.

UNDERSTANDING AMS2750E & NADCAP REQUIREMENTS

I've written several articles regarding the technical requirements of AMS2750E; documenting how a supplier conforms to those requirements is just as important. As I've stated before, AMS2750E is written in a manner that a novice or someone new to pyrometry may have a difficult time comprehending the statements within the specification. Understanding the statements within AMS2750E takes training in both the technical terms used as well as the actual testing itself. Having a good understanding of different types of furnaces is also imperative in ensuring the correct requirements are being applied to your operations. Once these items have been accomplished, your understanding of AMS2750E will be at a level where you may feel comfortable drafting a pyrometry procedure that will, hopefully, reflect conformance to the aspects of AMS2750E and Nadcap that apply to your operations.

THE LAYOUT

When writing a procedure, it's important to visualize the content and its flow from the perspective of the readers. With regard to pyrometry, following the flow of AMS2750E will be helpful to the reader as this will help when a comparison is made between the specification and the procedure. An example of this method can be seen when examining Nadcap's Pyrometry checklist AC7102/8 against AMS2750E. As you can see in the example, the two documents progress in parallel with regard to topic.



This is not to say that AMS2750E and Nadcap's AC7102/8 are identical in their layout and flow (including topic titles), but they are close enough in the major categories to ensure readers of both can make quick comparisons.

SINGLE POINT OF REFERENCE

Over the years, I've performed many gap-analyses and internal audits for suppliers looking to obtain or improve (merit process) their Nadcap accreditation. While performing these tasks, I often see suppliers who have separate work instructions/procedures for each category. For example, they may have a single document intended to account for sensor (thermocouple) requirements and the same scenario for both system accuracy testing and temperature uniformity surveys. This would mean that, if a requirement for an SAT sensor changes, this particular supplier may need to modify two procedures to account for the changes; the sensor procedure as well as the system accuracy testing procedure. This scenario increases the opportunity for error when modifications must be made.

With this in mind, it may be more logical to place all pyrometry requirements within a single work instruction/procedure to ensure that, when a requirement changes, it can be accounted for in all of the pyrometry requirements that the change may affect, rather than have separate documents for each AMS2750E topic.

CONTENT APPLICABILITY

When writing a procedure to account for AMS2750E, it should not be a copy of AMS2750E. In other words, if a specific topic within AMS2750E does not apply to your operations, you may be better served to omit the topic altogether. As an example, if your heat-treat operation consists of vacuum furnace brazing only, and each furnace is a Type B instrumentation type, it wouldn't be logical to include Types A, C, or D within your procedure. With this example in mind, it would also be logical to omit retort furnace requirements since this example includes none. On the face of it, this may seem to be common sense, but in practice, I see this scenario from time to time. This type of practice may have several repercussions: 1) an auditor who is knowledgeable may see this as a lack of training, and 2) that the supplier did not take the time to write the procedure as it applies to their operation. This may, in turn, push the auditor to examine items more closely as errors will be more likely to exist within not just documentation, but the processing of parts within the equipment.

SUMMARY

There are many different suppliers who must conform to AMS2750E Nadcap, all of whom have an infinite combination of processes, materials, furnaces, and prime requirements. Therefore, attempting to use a cookie-cutter procedure template to merely fill in would be detrimental to the core purpose of a procedure/work instruction. It would be beneficial to include applicable requirements within a single procedure which accounts for all requirements which flow in the same manner as AMS2750E.

I will be presenting this topic at the Furnaces North America Show 2018.

ABOUT THE AUTHOR Jason Schulze is a metallurgical engineer with 20-plus years in aerospace. He assists potential and existing Nadcap Suppliers in conformance as well as metallurgical consulting. He is contracted by eQualearn to teach multiple PRI courses, including pyrometry, RCCA, and Checklists Review for heat treat.

Plan routine checks, stick with them, and be open to considering dry-pump technology

By Ipsen USA

Performing routine maintenance on a wet pump is critical not only to its life span but, more importantly, to its performance. One commonly recommended procedure for improving or maintaining cycle time is to make sure vacuum pumps are running at optimum levels. This column will discuss recommended practices and frequency for wet-pump maintenance — and when it may be time to switch to newer dry-pump technology.

CREATE A PREVENTATIVE MAINTENANCE SCHEDULE

On a weekly basis (or monthly, depending on how often you run your furnace), inspect the roughing and booster vacuum pumps for oil quality, perpetual leaks, and abnormal noise and temperature from the pumping system. By becoming familiar with your pumping assembly, you will begin to notice anomalies. In addition, on a weekly basis when the furnace is out of cycle, evaluate the ultimate vacuum on your roughing line to determine the pumping performance.

From your assessments, you will be able to deduce when a repair is required and can begin to develop a preventative maintenance program for your pumps. Simple repairs such as replacing the oil and seals or changing out a belt can be completed with low risk of furnace downtime. Having a spare parts kit on hand allows for quick maintenance between production cycles and will help save valuable furnace production time. Some basic parts to consider keeping in stock include the proper type of pump oil, oil filters, exhaust filter components, belts, and seals.

CHECK THE OIL QUALITY

Check the oil color for signs of discoloration. Discoloration in the oil is the first sign of contamination or overheating. As materials are vaporized in the furnace during heat-treatment cycles, they will exit the furnace and eventually reach the pumping system components. All pump manufacturers adhere to a general color scale of the oil to note its current quality.

New oil will appear almost clear with a champagne hue. As contaminants reach the oil, it will begin to rise in temperature, therefore changing color. Generally, most pump oil will appear new or possibly light gold. Eventually the oil will turn to a true gold or yellow, which is an early sign of deterioration. As the color changes to amber, it is time to plan an oil change in the coming days or weeks, depending on the cleanliness of the components entering the furnace, pump performance required, and — ultimately — the number of cycles run per day.

If the oil changes to more of a dark amber or brown color, the oil should be changed as soon as possible as it could cause permanent damage to the pump's internal components. At some point, the seals

Routine maintenance on wet pumps is critical to performance. (Courtesy: Ipsen USA)

An oil sight glass allows you to observe the health and level of lubricants with a clear view of oil clarity and color, and water contamination in the oil. (Courtesy: Ipsen USA)

will reach elevated temperatures and weaken, allowing oil to leak, causing a dramatic decrease in oil quantity and quality.

It is important to note whether the oil begins to appear cloudy or murky. This is a strong indicator that moisture or water vapor has begun to enter the pump. This is easy to remedy. Many pumps have a gas ballast valve that allows air to enter directly into the pump. By allowing air or inert gas at atmospheric pressure to enter the pump, the load on the pump will increase and cause a slight rise in the oil temperature. This will cause the moisture to evaporate and be pushed out of the pump exhaust. This should only be performed for 10-15 minutes and when the furnace is out of cycle. If after the first attempt the oil still appears cloudy, repeat the process until oil quality is improved.

By requiring less frequent maintenance, customers can expect high production throughput for their equipment and less unplanned downtime. If these metrics are critical for production needs, then it is worth researching to determine whether dry screw pumps are a more suitable solution for your furnace processes.

REPLACE OR REPAIR PUMPS

Preventative maintenance can extend the life of wet vacuum pumps, but when they no longer operate at peak performance it may be time to consider rebuilding or replacing them. Depending on your furnace processes and parts and OEM recommended maintenance schedules, wet vacuum pumps can last for 4-6 years between rebuilds and 12-15 years before needing to be replaced. Several factors that affect the life span of vacuum pumps include:

Leaks: Seals can either overheat or become dry, allowing them to break down.

Poor oil quality: Contamination in the oil can cause overheating. As the quality degrades, it causes the pumps to work harder to maintain current performance standards.

Total operating time: Wet pumps have several components that can degrade over time. The longer the pumps run, the more frequently they will need maintenance.

A dry vacuum pump is a pump that does not use any fluids to create a vacuum or contact the process gas and can also discharge to atmosphere. (Courtesy: Ipsen USA)

CONSIDER DRY-PUMP TECHNOLOGY

With the development of newer technology such as dry screw pumps, dry vacuum pumps require little to no maintenance for nearly the first five years of use. At that time, it is recommended to have the bearing assembly replaced and returned to normal operation. The overall life expectancy of dry screw pumps is significantly greater than wet pumps. Early results show that dry pumps can last for 15-20 years, which is nearly twice as long as wet pumps.

By requiring less frequent maintenance, customers can expect high production throughput for their equipment and less unplanned downtime. If these metrics are critical for production needs, then it is worth researching to determine whether dry screw pumps are a more suitable solution for your furnace processes.

In the end, it is essential that regular inspection of your wet vacuum pumps fit into your preventative maintenance plan. Being proactive about pump maintenance and replacement can save you from unwanted downtime and higher operating costs — all of which can result from continuing to run a vacuum pump that exhibits signs of deterioration.

ABOUT THE COMPANY Ipsen USA designs and manufactures integrated heat treatment solutions for a wide variety of industries, including aerospace, automotive, energy, and medical. With an extensive network of global locations in America, Europe, and Asia, Ipsen continues to provide expert-driven solutions that strengthen heat treatment throughout the world. Learn more at www.IpsenUSA.com.

DeKalb Blower

Every fan is created with exact specifications and all of them start as a sheet of metal or alloy in DeKalb Blower's shop. (Photos courtesy: DeKalb Blower)

High-temperature fans made in the U.S.

For almost 20 years, DeKalb Blower has offered custom fan and blower solutions to the heat-treat industry.

By Kenneth Carter, Thermal Processing editor

Things can really heat up when an industrial furnace gets going — often surpassing temperatures of more than 2,000 degrees. In order to keep the work flow going between jobs, furnaces and ovens need to recirculate air to provide optimal uniformity and cool down quickly.

That's where Eric Johansen and his team at Dekalb Blower come in.

DeKalb Blower offers a variety of fans and blowers for the thermal processing industry, as well as the ability to do custom work and repairs on existing models or problem fans that may be slowing production.

"Our niche is the high-temperature market, so we cater to industrial furnace applications," said Johansen, president of DeKalb Blower. "The products we offer are up to 2,200 degrees Fahrenheit construction. We offer water-cooled and air-cooled designs. Many of our patented and patent-pending features on our products are geared specifically for these harsh environments or repetitive thermal cycling the fans will be exposed to, and will then be able to provide years of smooth, hassle- and maintenance-free operation."

DeKalb Blower also offers fan arrangements for gas-tight sealing used to contain toxic or explosive atmospheres. Other products use vacuum-sealed and hermetically sealed electric motors for direct drive applications (often ideal for cooling fans on vacuum furnaces), O-ring sealed applications, as well as products including axial flow fans, backwards inclined fans, FHD forward curve fans, and radial blade fans.

CATERING TO SPECIFICS

"We have our standard product line, and we kind of cater, since the high temperature market is typically manufactured to the customers' specifications and individual applications," Johansen said. "It's almost like, you've got Ford, who would be our competitors in the lower temperature market, let's say. They standardize and make one Model T. But if you want them to make a Model T with certain provisions to the design, that would cost the customer an arm and a leg to go outside of their standard 'Model T' design. That's where we come in. Because many of our designs are suited specifically to the customer's exact application, we can offer these changes or requests that best suits our customers' needs — many times for no additional costs outside of our standard offerings."

DeKalb Blower gives its clients the capability to use state-of-the-art 3D CAD modeling down to 2D CAD drawings and even to a dimensional PDF, according to Johansen.

"What's unique with us is that you can download the CAD files of our standard products right from our website," he said. "What they can do is instantly download the size of the fan that's going to accommodate their application or specific sizing requirements. They can mark off things like a 10-inch wall or a 12-inch panel, for example, and then we accommodate to their design. We'll take our standard design; they'll mark it up to what would best suit their application, and then we can manufacture the product to exactly what they need without any extra costs associated with it. Our customers really like that feature a lot, and that we are very easy to work with."

WORKING WITH OEMS

Since DeKalb Blower has such a good relationship with the actual manufacturers of the original equipment, the company often deals with the OEMs directly instead of the actual end user, according to Johansen. From being able to offer customized fan solutions to meet the OEM's exact application needed, also offering the fastest lead times and response times in the industry provides great assistance. Instant quoting offered by DeKalb Blower

DeKalb Blower offers a variety of fans and blowers for the thermal processing industry.

often gives the OEM's applications engineer a jump start with things on their project.

"We do deal some with the end user, but we're more specifically geared toward the OEM furnace designer or oven designer with the products we offer and manufacture," he said. "To help our customers streamline their production, we not only offer the impeller or fan type that will best suit their application, we also offer the airflow accessory to accommodate all of our product impeller series and sizes. From our scroll housings to radial air diffusers, this can optimize the flow rates, and assist with the manufacturers plenum sizing restraints, as the airflow accessories also come complete with mounting sleeves and studded flange plates to provide ease of installation."

A lot of the custom work DeKalb Blower finds itself doing is air cooling conversion, according to Johansen.

"Air cooling is pretty good," he said.

DeKalb Blower has the ability to do custom work and repairs on existing models or problem fans that may be slowing production.

"We've been converting a lot of older or problematic water-cooled competitions' plug fans. We've been doing a lot of air-cooling conversion to that stuff. That's a good maintenance eliminator right there. The furnace companies like it, because they can eliminate problematic water and the maintenance that comes with it. If they've got blocked water passages and then it backs up and the fan fails or overheats, we can convert that over and eliminate the water cooling altogether if the parameters are right."

CUSTOMERS FIRST

Johansen said the team at DeKalb Blower prides itself in putting the customer in front of its products, and it backs that up with a two-year guarantee.

All work is performed in DeKalb Blower's 30,000-square-foot shop and done by DeKalb Blower employees.

"If any issues do arise, we attack them instantly," he said. "We stand behind every blower we manufacture 100 percent. If they're getting a little more pressure in the system than they were anticipating, or even some slight system effect that may be affecting flow rates, and they need to speed the fan up, we'll go as far as recalculating the data and sending them a new set of pulleys on the house. In manufacturing, you're going to have some sort of issues at some point. We stand by the product, and if there's ever an issue, we'll resolve it immediately."

Every fan is created with exact specifications and all of them start as a sheet of metal or alloy in DeKalb Blower's shop. And all materials used in the company's products are made by industry leading, high quality suppliers of power transmission components.

"We don't use import materials, and we don't outsource the machining work; all work is performed in our 30,000-square-foot shop and done by DeKalb Blower employees, or our 'TEAM,'" Johansen said. "That allows us to have quick lead times and deliver a superior-quality product repetitively."

DeKalb Blower has jig and fixture sets for every fan it manufactures that will deliver repetitively to that specific capacity or that performance, according to Johansen.

"We have a state-of-the-art, high definition CNC cutting system for repetitive accuracy," he said. "If they've got a foreign fan or any hard-to-find part, we can run it through our manufacturing process with these manufacturing capabilities and the CNC machining centers that we have, and we can output a superior quality part that is ideal or even better than the original part."

PROUD ACCOMPLISHMENTS

As DeKalb Blower continues to deliver quality products and services, Johansen is quick to point out several accomplishments he is particularly proud of, including creating a fan capable of air cooling from 1,950 degrees Fahrenheit.

"That was quite a feat," he said. "No water with an auxiliary cooling source on the fan."

Fans for a hydrogen atmosphere also are on the top of Johansen's list.

"We've done a bit of hydrogen atmosphere," he said. "We've sealed hydrogen atmospheres. As you know, hydrogen and oxygen don't get along, so we've done some nice gas tight sealing arrangements to those where you need an absolute hermetic seal."

Johansen is also proud of his patented and many patent-pending designs that give ultimate durability and optimal results in these extreme atmospheres his products may be exposed to.

However, some of Johansen's best memories of his company come from the positive reviews he gets from his customers.

"Good moments come from people calling you and saying you stand by your product 110 percent," he said. "And being able to work with our customers to design a fan to best suit their applications. If they come in with these requirements like, 'we need 2,200 degrees continuous, or we need air cooled because our end user doesn't have water available, or it's going to be a whole other maintenance issue to have water,' we can design to meet this. And we go to the drawing board with our OEM customer and map the best solution using those state-of-the-art 3D CAD modeling tools."

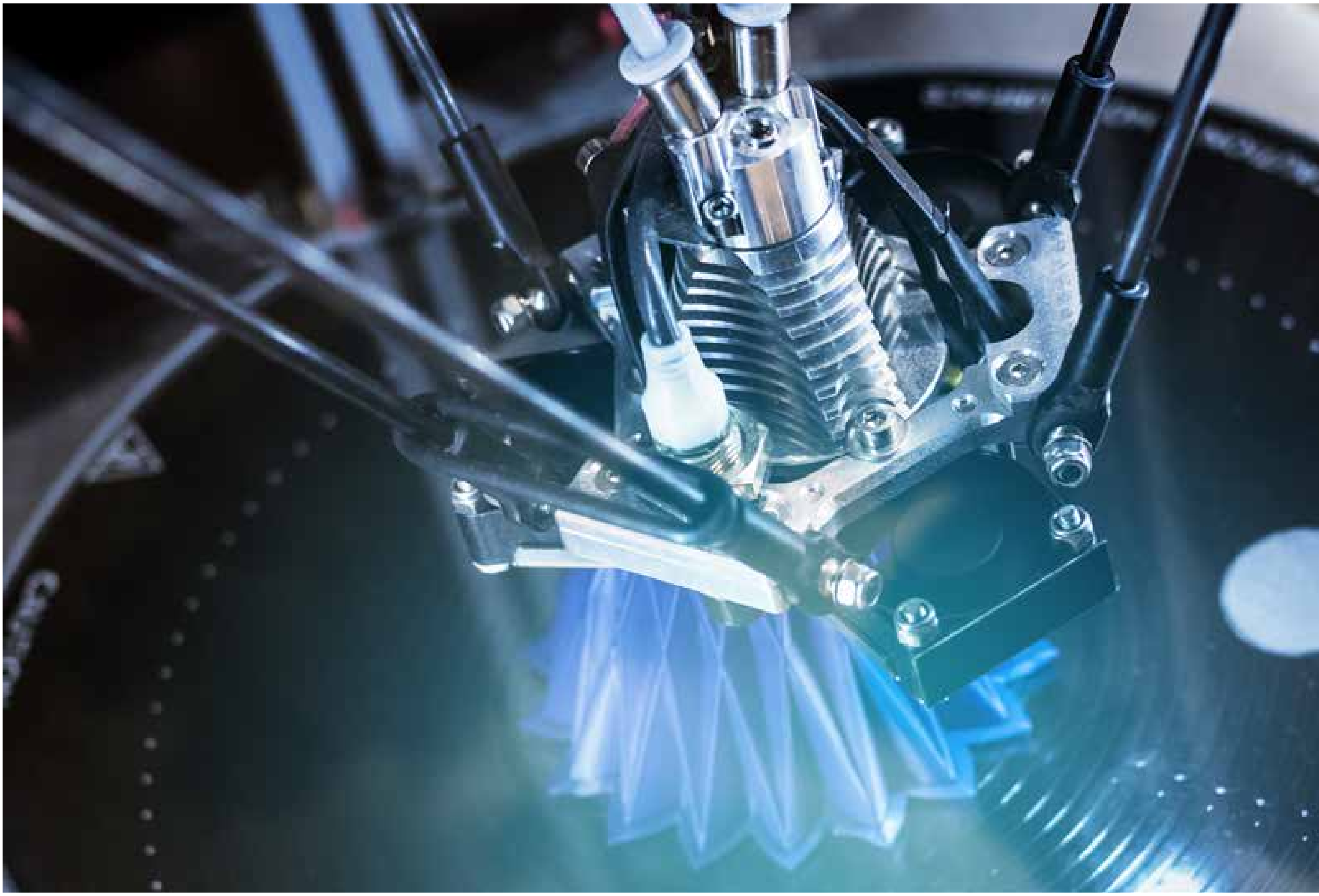
DeKalb Blower started in 2000 by Johansen's father, Chester, a well-known figure in the heat-treating industry, and as he looks to the future, Johansen said he expects the business to continue growing.

"I see growth and potential as manufacturing shifts its way back domestically," he said. "I see an increase in demand for products in our industry."

The company will be showing just what that future may hold at FNA 2018, where Johansen said DeKalb Blower will be demonstrating to attendees some interesting concepts for the potential customer that uses the company's products.

"They should definitely expect some great giveaways," he said.

MORE INFORMATION dekalbblower.com



Additive manufacturing and gas technology applications

Industrial gases play a crucial role in advanced AM processes.

By Grzegorz Moroz and Akin Malas

As the demand for additive manufacturing (AM) products has steadily increased, so have the many enabling technologies including laser powder bed fusion, laser metal deposition (LMD), wire arc additive manufacturing, thermal spraying, and electron beam melting (EBM). All of these rely — directly or indirectly — on industrial gases such as nitrogen, argon, and helium.

Although AM processes still constitute only a fraction of powder-metal (PM) parts applications, the AM sector is growing and is of special interest due to a number of unique advantages: freedom of design and alloying, short lead times, no need for additional tooling for different parts, and virtually 100 percent use of materials. At the same time, AM production processes are generally limited to certain alloys, parts of moderate size and weight, and to short series runs because processes are slow.

Medical and aerospace parts that can live within or leverage these limitations are currently the primary applications for AM processing. In the aerospace industry, these are mainly non-critical, low-stressed "static parts" made from traditional construction materials such as Ti6Al4V and Inconel 718, a high-strength, corrosion-resistant nickel chromium alloy. However, engine fuel nozzles, for example, are in serial production at both GE and Airbus AM manufacturing plants. In the medical and dental area, AM products include standard implants such as hip joints, external prostheses, hearing-aid shells, and dental crowns and bridges.

The automotive industry is also ramping up to a more prominent role. Advanced and complex parts produced in short series such as for racing cars, as well as certain spare parts, tools, and prototypes are a few examples. Up to now, automotive original equipment manufacturers (OEMs) and suppliers primarily used AM for rapid prototyping. Yet the pace of AM development coupled with quality improvements and machine redundancy are now making AM a candidate for direct manufacturing of some parts beyond a limited scale.

Industrial gases already play a crucial role in several PM process steps such as in inert-

gas atomization of metal melts, as a pressure medium in hot isostatic pressing (HIP), and as a controlled atmosphere to avoid oxidation and to maintain carbon content in sintering steels, etc. This paper focuses on steps that use industrial gases before, during, and after AM as summarized in Figure 1.

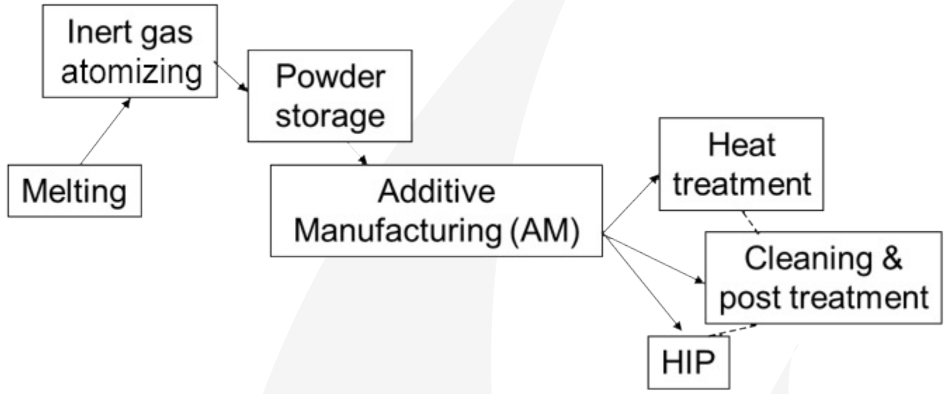


Figure 1: Steps involving the use of industrial gases related to additive manufacturing.

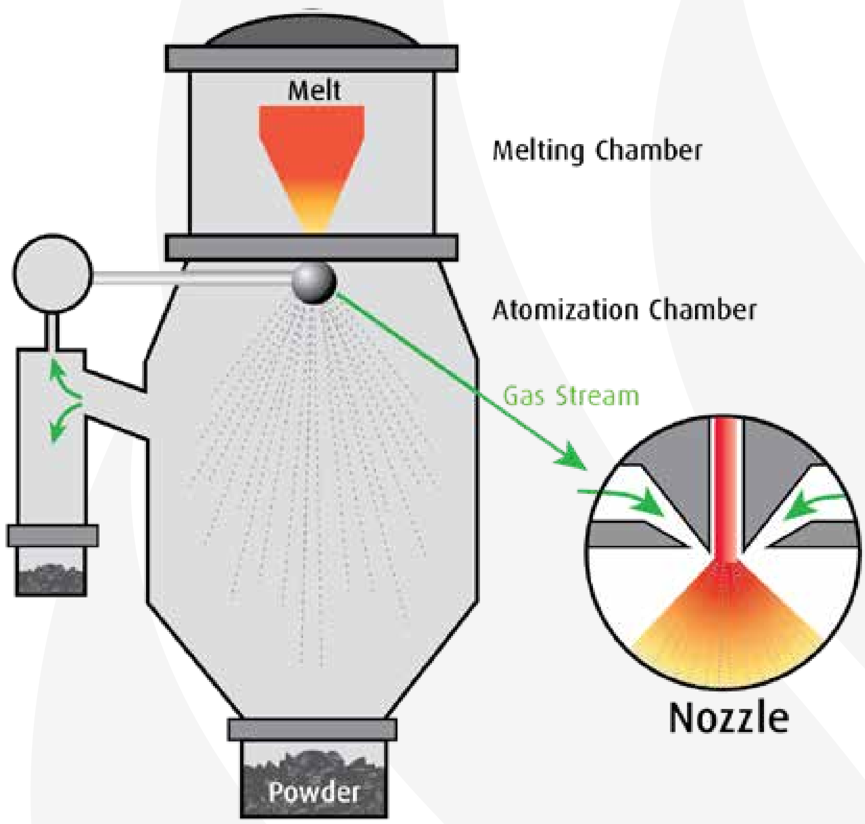


Figure 2: Atomization of molten metal with inert gas.

MELTING AND ATOMIZATION

Induction vacuum melting is the preferred production process for powders to be used in AM. The melt is atomized with a high-speed jet of inert gas that creates fine metal droplets that cool as they fall into the atomizing chamber. A finer particle size is required for AM powders than for HIP or cold pressing and sintering. One reason is that finer particles improve powder flowability, an important parameter for AM processing. Sufficient flowability allows the roller to build up thin layers (see next section) in the powder bed chamber. If flowability is too low, it decreases the resolution of the fabrication process due to insufficient recoating. On the other hand, very high flowability does not provide sufficient stability for the powder-bed process. The proper gas pressure and nozzle design are required for generating the right size and form of atomized melt droplets to meet these demands. (Figure 2)

The inert gas disintegrates the melt into spherical powder particles and also protects the particles from reacting with air and oxidizing. Accordingly, the inert gas must be of high purity. Nitrogen is used with most metals or alloys. Some require argon and, in a few cases, helium. Argon is used when the powder material tends to pick up nitrogen, such as with titanium and certain high-chromium alloys, and including stainless steels. These materials can be inadvertently nitrided, making them brittle or, in the worst case, useless. Helium is used as an atomizing gas where its outstanding thermal properties can play an important role.

Strength and ductility of parts processed from powder will increase with decreased oxygen content in the powder. Therefore, a purity requirement should be valid for the gas supplied to the atomizing chamber, typically below 10 ppm. But even more importantly, there should be a purity requirement within the process chamber.

POWDER STORAGE AND QUALITY CONTROL

Screening and classification of the powder follows atomization, and then packaging or storage. Powder is typically stored on an open shelf or in a closed cabinet somewhere

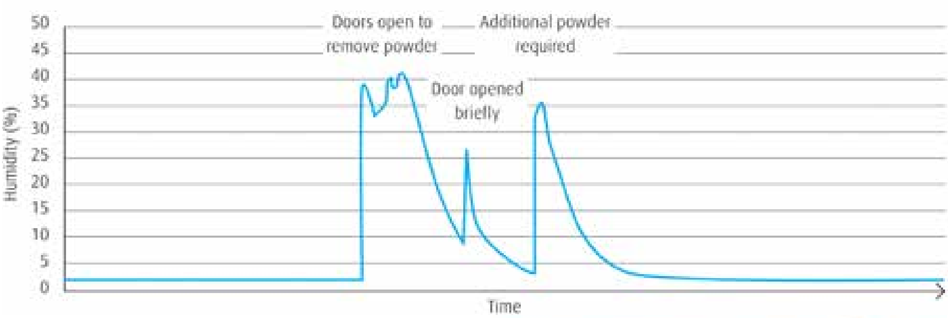
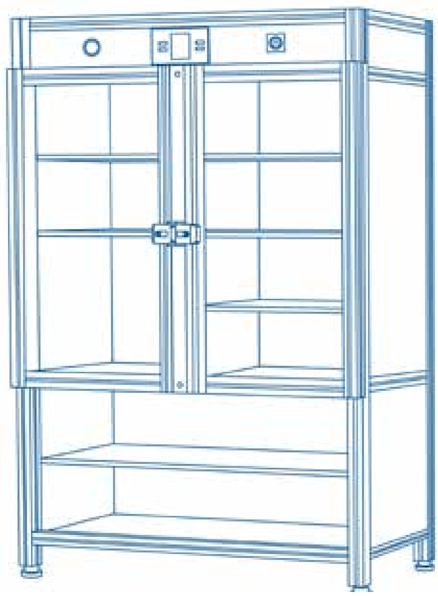


Figure 3: With automatic controls, the ADDvance powder cabinet from Linde can quickly reduce humidity and oxygen to normal low-level conditions after door openings.

near the AM equipment until it is needed. Oxygen in the ambient air and humidity in storage can negatively affect the chemical and physical properties of the powder. This is particularly true of sensitive powders such as aluminum and titanium alloys. Because the powder fractions used for powder-bed AM are much finer than traditional PM, HIP, or sinter powders, AM powders are especially vulnerable.

The ADDvance® powder cabinet addresses this storage issue with an atmosphere monitoring and control system that actively combats air infiltration and humidity. It works by continuously measuring the humidity level inside the cabinet and uses a stream of purge gas to maintain a non-critical moisture value. Whenever the cabinet doors are opened and humidity rises,



ADDvance triggers a high-volume purge gas flow as soon as the doors close again to rapidly remove moisture in the air (Figure 3). It then applies a lower stream of gas to ensure a consistently low level of humidity.

The control sequence is repeated whenever the doors are opened and closed to add or remove powder.

ADDvance uses a directional gas stream and a carefully selected flow rate to ensure the desired moisture value. The system is economical since it does not waste purge gas when the door is open. It only triggers the purge stream once the doors are closed again.

QUALITY AM PROCESSES

There are different several basic methods of metal additive manufacturing, but one of the most common uses a powder bed that is selectively heated with a laser or an electron beam. These include laser powder bed fusion and EBM.

The heat from the laser or the electron beam will sinter or melt the powder particles together, successively as shown in the left part of Figure 4, such as laser powder bed fusion. At the start of the production process the building platform is covered with a powder layer. A laser beam then is moved to sinter or melt the powder onto the object form. When that layer is fused (sintered or melted), then the building platform is lowered, and a new layer of powder is added and fused. This sequence is repeated until the object is completed.

The process chamber is filled with inert gas, nitrogen, or argon, to avoid detrimental oxidation of the heated powder. As with

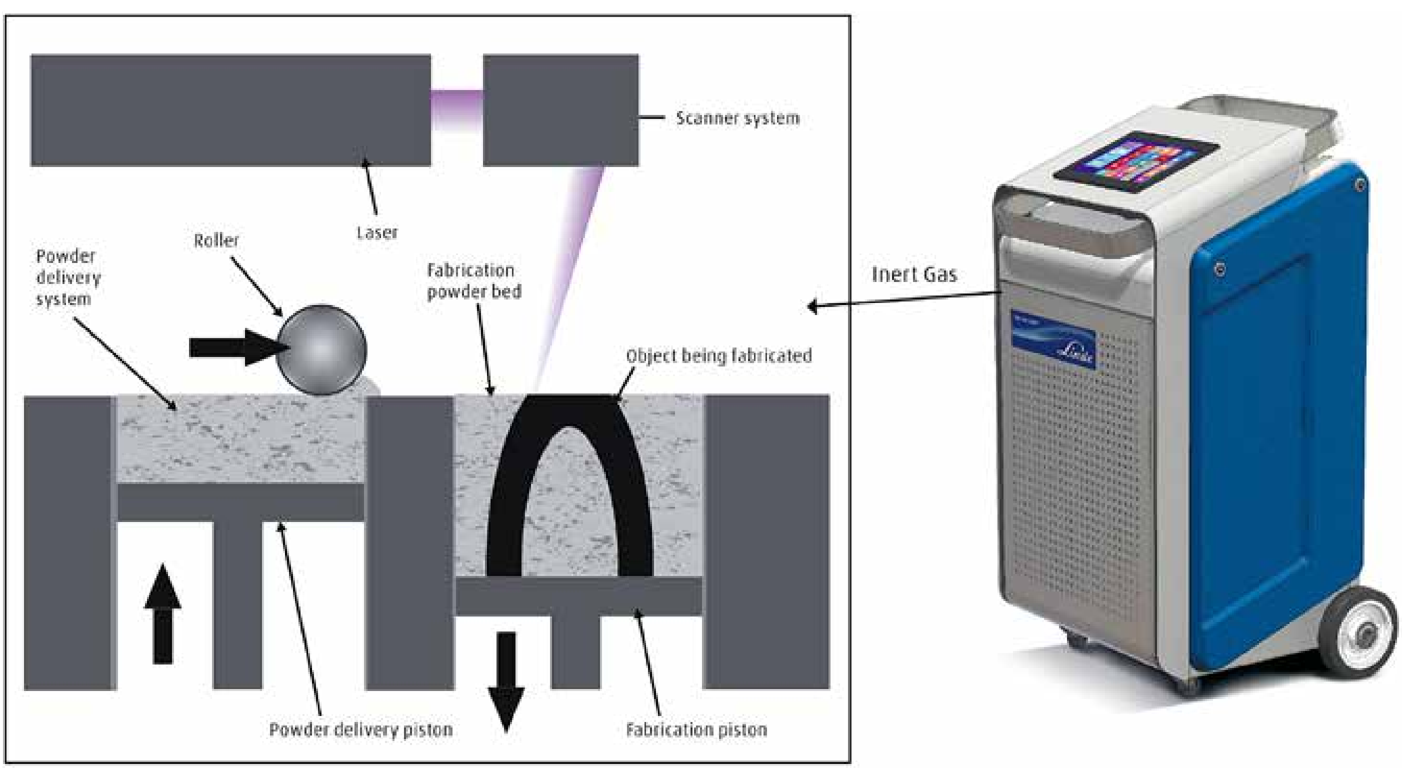


Figure 4: The ADDvance® O_2 atmosphere control system (left) can contribute to the quality of the laser powder-bed fusion process.

There are different several basic methods of metal additive manufacturing, but one of the most common uses a powder bed that is selectively heated with a laser or an electron beam. These include laser powder bed fusion and EBM.

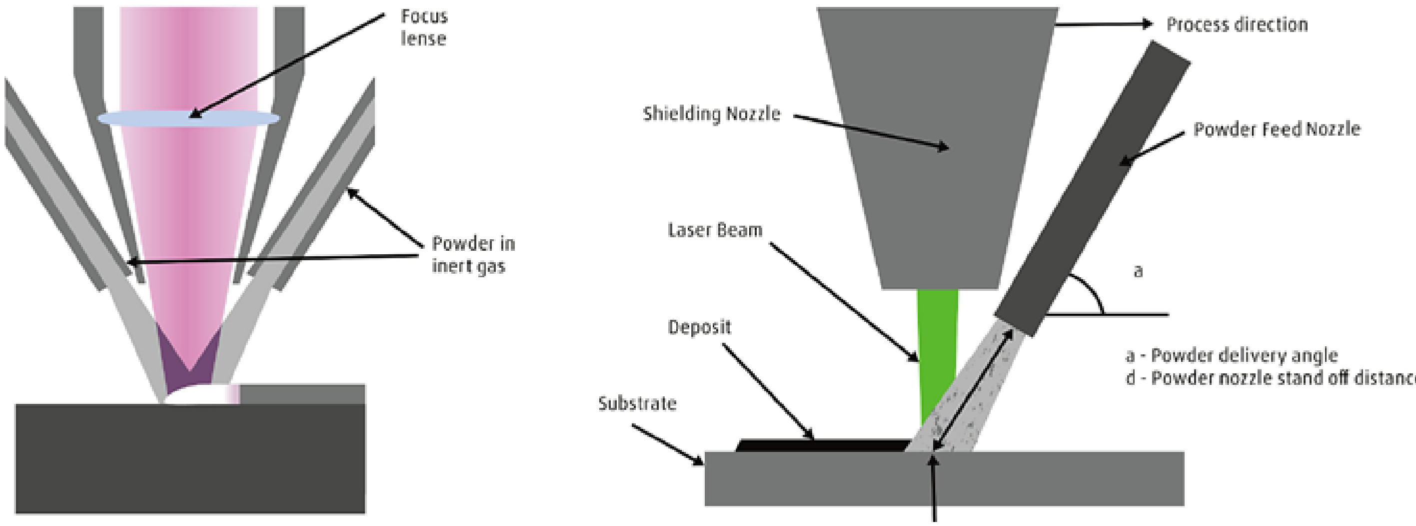


Figure 5: Electron beam deposition (left) and laser beam deposition (right) in a protective atmosphere.

atomization, it is important to define a purity for the gas supplied, typically below 10 ppm, but even more important to define a purity requirement within the process chamber. With the ADDvance® O_2 system, it is possible to define and maintain the oxygen (O_2) concentration inside the chamber to the level required by material and application (Figure 4). The system continuously analyzes O_2 levels in the process chamber to concentrations as low as 10 ppm. It automatically initiates a purging process to keep the desired atmosphere concentration level in case the atmosphere is disturbed. The system also monitors dew point and indicates trace levels of hydrogen.

As an alternative to using an inert gas atmosphere, it is possible to tailor the gas composition in the process chamber to actively influence the material to attain certain properties. Electron beam fusion, for example, uses helium in the process chamber because of its favorable thermal characteristics.

An alternative to building up parts in a powder bed is to supply material as a powder or from a wire that is melted and deposited onto the object (Figure 5). Laser Metal Deposition (LMD) and Electron Beam deposition are two of these methods. The powder is contained in a carrier gas and directed to the substrate through a nozzle. Alternatively, a wire can be fed from the side. The powder or wire is melted to form a deposit that is bonded to the substrate and grown layer by layer.

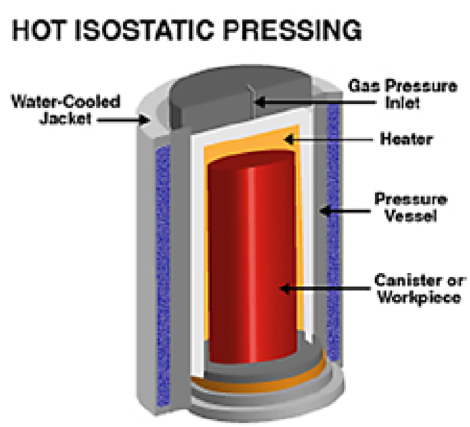


Figure 6: Hot Isostatic Press (HIP)

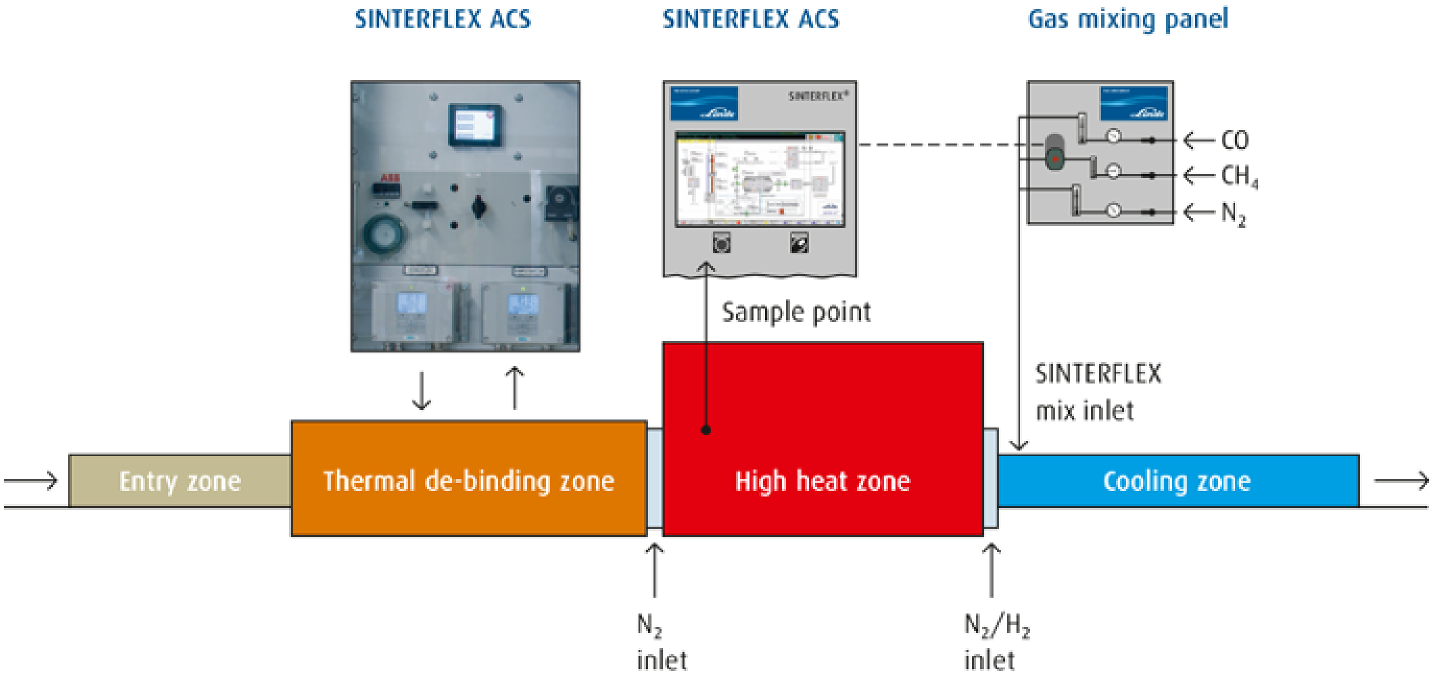
An additional gas jet, concentric with the laser beam, provides additional shielding or process gas protection. This method is suitable for larger components where a higher deposition rate is required. LMD is used for a range of applications including cladding and repair of high-value parts such as aerospace engine components and military equipment.

HIP, HEAT TREATMENT, AND CLEANING

There are high demands for reproducible parts quality in medical and aerospace applications. Post-HIP treatment, therefore, is used almost without exception for such AM products to achieve full density and freedom from defects. HIP takes advantage of the possibilities of simultaneous high pressure and high temperature in the production of parts from metallurgical powders. The equipment (Figure 6) comprises a furnace chamber enclosed in a pressure vessel adapted to withstand extremely high pressure and which can also be fully evacuated to vacuum levels. The processes are applied at different pressures and temperatures depending on the materials involved. HIP equipment is available with operational pressures up to 200 MPa (29,000 psi) and temperatures to 2,000 °C (3,600 °F). Gas is indispensable for HIP, and argon or nitrogen are used as the pressure medium.

Due to the steep thermal gradients created during AM, residual stresses remain in the parts after processing, so a stress relieving treatment is usually required. In addition, a columnar grain structure normally results from the repetitive layering of powders melted or sintered onto the surface. A heat treatment can restore the microstructure. Other post heat treatments may also be required to give adequate strength and toughness of AM produce parts. Hardening, carburizing, or nitriding are examples of the processes that may be required. Nitrogen, argon, hydrogen, specialty gases, and methanol are necessary supplies in these processes.

Linde offers a number of proprietary atmosphere control systems for annealing,



hardening, carburizing, carbonitriding, nitriding, nitrocarburizing, and sintering, under the tradenames HYDROFLEX®, CARBOFLEX®, CARBOJET®, NITROFLEX®, and SINTERFLEX® atmosphere control systems and solutions.

AM parts exhibit a certain surface imperfection with excess powder adhered to the surface after processing. Linde has developed the ADDvance® Cryoclean, a patented process for cleaning with the help of CO_2. The device creates dry ice particles by expanding liquid CO_2 directly. Using compressed air, the particles are accelerated in a de Laval nozzle up to sonic speed and shot onto the surface to be cleaned. The cleaning effect of this procedure relies on flash cooling, kinetic energy, embrittlement, and gas impact. An abrasive agent can be admixed with the dry ice particles to remove stubborn powder residue. It enables the operator to adapt the CO_2 snow/abrasive material ratio from gentle to abrasive. With this process, much less abrasive material is needed to remove adhering powder residue compared to conventional sand blasting.

Gas installation with liquid nitrogen, argon and acetylene for heat treatment (left), and atmosphere control system for sintering (above).

ADDvance Cryoclean is a specially designed cleaning unit for AM metal components. The encapsulated equipment design provides maximum health protection and safety for the operator. Alternative cleaning methods such as grinding or chemical cleaning are harmful to the environment and less productive.

SAFETY

Metal powders are not just sensitive to atmospheric influences, but they can pose hazards to human health and safety. Careful storage of powders in a blanket of inert gas such as nitrogen is a basic safety measure that also reduces risks for dust explosion or fire. Products and services provided by The Linde Group to customers around the world must meet high quality and safety standards. This applies not only to the "end" product or service, but to the company's whole value chain from gas production and supply to the commissioning of gas application technology — and safety training is part of every installation.

In the final analysis, successful PM production, including advanced AM processes, rely on the proper use and safe handling of industrial gases. So, the future of additive manufacturing will depend, in a very real way, on the quality application of gas technology to key facets of production — from supply and storage of materials, to atmosphere monitoring and control systems, to heat treatment and finishing of final parts.

ABOUT THE AUTHORS

Grzegorz Moroz is program manager, Heat Treatment & Atmospheres, for the Metals & Glass segment of Linde LLC. Based at Linde's Technical Center in Cleveland, Ohio, Moroz has more than 20 years of in-depth metallurgy and industrial gas industry experience. He earned an M.B.A. and a degree in Management from the University of Central Lancashire in Preston, U.K., and a Master of Science and Engineering degree in Foundry and Metallurgy from the University of Science and Technology in Cracow, Poland.

Akin Malas is head of applications technology for the Metals & Glass group of Linde, a leading global industrial gases company that provides industry-leading portfolio solutions for additive manufacturing applications. Based in Murray Hill, New Jersey, Malas has more than 20 years of experience in the heat-treatment industry and is a member of the ASM, IOM3, and MPIF. He earned a Bachelor of Science degree in metallurgical engineering and material science from M.E.T. University in Ankara, Turkey.

For more information, contact Linde LLC (www.lindeus.com), 1-800-755-9277.

Using vanadium alloys

The effect of sintering conditions on the mechanical properties of pre-alloyed vanadium powder metallurgy steels.

By Roland T. Warzel III, Bo Hu, Amber Neilan, and Madison Milligan

Vanadium is a commonly used alloying element in high strength low alloy (HSLA) steels because it improves strength and wear resistance through the precipitation of vanadium carbonitrides. The use of vanadium in powder metallurgy (PM) steels has so far been limited. A previous study demonstrated that by using a vanadium alloyed PM steel, the total alloying content could be reduced by 50 percent while maintaining similar or improved properties. This study will examine the effect of sintering conditions on vanadium pre-alloyed PM steels by varying the sintering atmosphere and temperature. Different material systems based upon pre-alloyed vanadium steel powders and plain iron powders were sintered in different sintering atmospheres. Mechanical properties and microstructure of each composition and sintering condition will be compared to understand the improvement in properties achieved through the use of vanadium alloying.

INTRODUCTION

Powder metallurgy (PM) steels rely on a variety of methods to introduce alloying elements in order to provide increased mechanical strength compared to wrought steels. The common methods used to introduce alloying elements include admixing of elemental powders or ferroalloys, diffusion alloying of elements to the outside of the base particle or pre-alloying of elements in the melt prior to atomization [1]. It is also possible to use more than one of these methods such as the mixing elemental powders to a pre-alloyed powder or diffusion alloyed powder. This type of material is referred to as a hybrid alloy. The method of addition plays a large role in the resultant microstructure and in turn the mechanical performance.

While techniques such as admixing and diffusion alloying are not able to be replicated in the wrought steel industry, pre-alloying is very similar to traditional steel making methods.

Pre-alloying consists of introducing the alloying elements during the melting process in order to evenly distribute these elements throughout the entire bulk melt. After atomi-

Base Powder	Mn	V	C	O-tot	N
ASC100.29	0.15	-	0.003	0.08	0.0010
V-1	0.15	0.07	0.002	0.10	0.0010
V-2	0.15	0.14	0.002	0.12	0.0007

Table 1: Chemical Compositions of Base Powders (w/o).

Mix ID	MPIF Code	Base Powder	Graphite	Lubricant
F-0000	F-0000	ASC100.29	-	0.6
F-0000V1	F-0000	V-1	-	0.6
F-0000V2	F-0000	V-2	-	0.6
F-0008	F-0008	ASC100.29	0.8	0.6
F-0008V1	F-0008	V-1	0.8	0.6
F-0008V2	F-0008	V-2	0.8	0.6

Table 2: Mix Compositions (w/o).

Code	Hydrogen	Nitrogen
0N	100	0
25N	75	25
50N	50	50
75N	25	75
95N	5	95

Table 3: Atmosphere compositions evaluated (v/o).

zation, the resultant powder particles each have the same chemical composition. This results in a homogenous microstructure after the sintering process [2]. The common alloying elements used with this method include chromium, manganese, molybdenum, and nickel. The downside of this alloying technique is the resultant decrease in compressibility due to the alloying increasing the hardness of the powder particles. The only alloying element which has a negligible impact on the compressibility is molybdenum leading to these families being one of the most popular in use today [3].

All of the pre-alloyed steels currently standardized in MPIF Standard 35 are classified as low alloy steels due to the amount of alloying used. The nominal alloying levels of the standardized materials range from a low of 0.48 percent in the case of the FL-3905 to a high of 3.6 percent in the case of the FL-5305 [4]. In wrought metallurgy, a class of steels has been employed for more than 50 years where generally between 0.05 and 0.15 percent of niobium, vanadium, and titanium are used for increased strength properties [5]. These steels are designated as micro-alloyed steels. In PM, the use of niobium and vanadium has been explored by a number of studies through the addition of ferroalloys or master alloys to a base powder [6-8]. As this technique may require high temperature sintering in order to achieve complete homogenization of the microalloying elements, a recent study showed the potential benefits when vanadium is added using pre-alloyed techniques [9].

In the most recent study where vanadium was added by pre-alloying, improved properties were achieved in a nickel-steel material. The improvement in properties was theorized to be the result of V(C,N) providing dispersion strengthening. Vanadium is of interest for PM due to the majority of PM atmospheres containing large amounts of nitrogen used as a protective atmosphere for sintering. The temperatures at which V(C,N) will go completely into solution is also well within standard PM sintering temperatures. It is established that nitrogen determines both the nucleation rate and density of the V(C,N) precipitates formed [5]. Glodkowki et. al provided an updated graphical model to predict the amount of V(C,N) precipitates formed and the increase in mechanical properties [5]. The model relied on empirical data from a thin slab direct roll mill and theoretical data to illustrate that as vanadium and nitrogen content increase, so do the mechanical properties. Therefore, it is important to understand the effect nitrogen content in the sintering atmosphere could possibly have on the mechanical performance of vanadium containing PM base powders.

In this study, two base powders with pre-alloyed vanadium were sintered in a variety of atmospheres containing various levels of nitrogen. The effect of the nitrogen content in the sintering atmosphere on the mechanical performance was evaluated. Through metallographic evaluation, the microstructures of the vanadium materials were found to contain finer grain size and decreased spacing on the pearlite lamellae, which in turn increased the strength and hardness properties compared to materials manufactured from a plain iron powder.

EXPERIMENTAL PROCEDURE

For this study, two pre-alloyed vanadium iron powders were manufactured using an electric arc furnace and water atomization under production conditions. These powders were compared against a commercially available water atomized iron powder. The compositions of the base powders used in this study are shown in Table 1.

The base powders were mixed with lubricant (Intralube® E, Höganäs) and natural flake graphite (PG-25, Imerys) in order to make the material systems F-0000 and F-0008 in accordance with MPIF Std. 35 [4]. The mix compositions are shown in Table 2.

From each mix, tensile and impact specimens were compacted to a green density of 6.8 g/cm^3 [10]. The bars were sintered in a 150 mm (6”) mesh belt furnace at a temperature of 1,120 °C (2,050 °F). The nitrogen level in the atmosphere was varied from a high of 95 percent nitrogen to no nitrogen. The atmospheres analyzed are shown in Table 3.

After sintering, the specimens were tested for tensile and impact properties in accordance with ASTM E8 and ASTM E23 respectively [11-12]. Apparent hardness and micro-indentation hardness were evaluated in accordance with MPIF standards [10]. The carbon, nitrogen, and oxygen contents of the specimens were determined using combustion techniques according to ASTM E1019 [13]. Microstructure evaluation was completed using light optical microscopy. In order to quantify the effect of vanadium and nitrogen content on the sintering atmosphere, the average grain size of the ferrite was determined using the planimetric method outlined in ASTM E112 [14]. Pearlite colony size and lamellar spacing analysis was conducted use SEM measurements.

RESULTS

The tensile values for the F-0000 materials are shown in Figure 1.

Small differences were observed between the mix compositions with the vanadium alloyed steels having consistently higher tensile properties compared to the pure iron powder. Once the nitrogen was present in the atmosphere, there was little change in performance as the amount increased.

When no nitrogen was present, the values of the vanadium alloyed steels was lower compared to when 25 percent nitrogen was present in the sintering atmosphere. Similar trends were observed for the materials containing carbon. The F-0008 tensile results are shown in Figure 2.

At the lower level of vanadium, only a small difference in ultimate strength was observed compared to the pure iron powder. However, there was a significant increase in the yield strength. The material with the higher vanadium level was significantly stronger than the other materials.

The vanadium materials again showed higher ultimate and yield strength compared to the pure iron powder even with no nitrogen present indicating that vanadium by itself is providing some improvement in strength. With regards to the effect of nitrogen, both of the vanadium materials showed an increase in performance once nitrogen was introduced in the atmosphere. The impact performance of the materials was the opposite of the tensile properties as expected. The vanadium materials had lower impact energy compared to the pure iron material. Nitrogen had a small improvement in impact energy at the 25 percent N_2 / 75 percent H_2 condition compared to no nitrogen; however, as the level increased, the impact energy decreased. The data are presented in Figure 3.

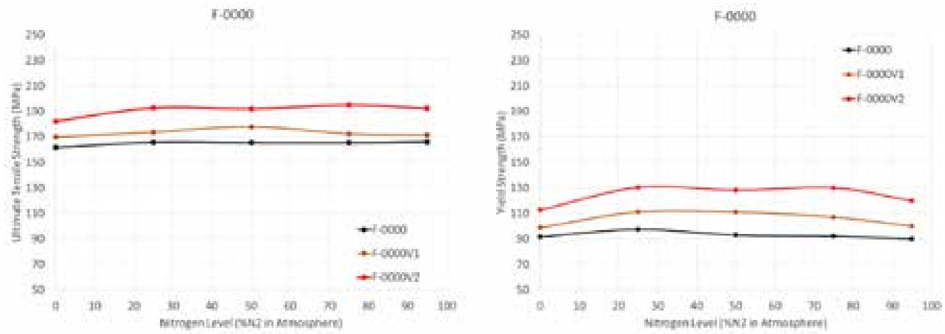


Figure 1: Tensile properties of F-0000 compositions (left: ultimate, right: yield).

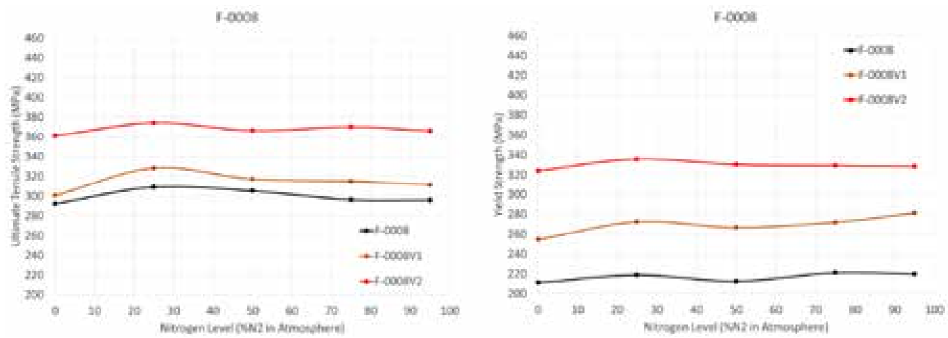


Figure 2: Tensile properties of F-0008 compositions (left: ultimate, right: yield).

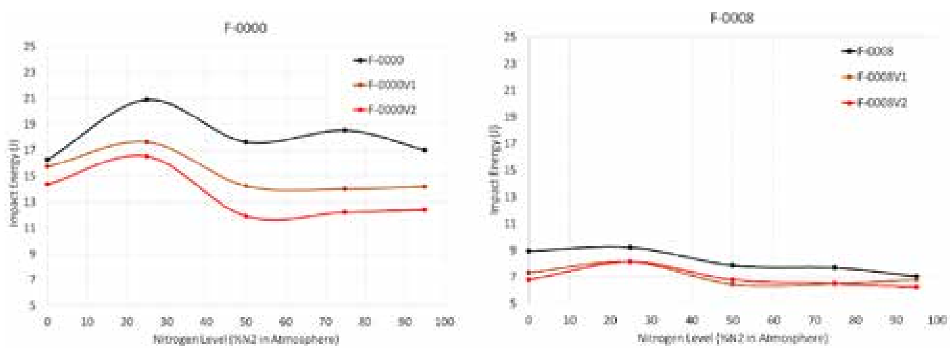


Figure 3: Impact properties of F-0000 (left) and F-0008 (right) materials.

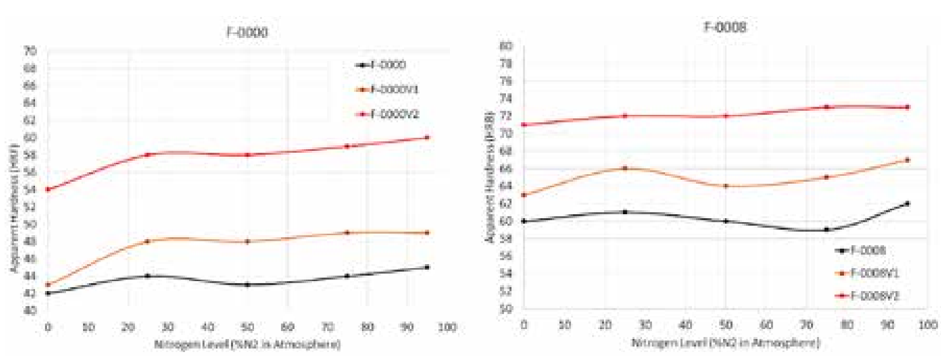


Figure 4: Apparent hardness properties of F-0000 (left) and F-0008 (right) materials.

Apparent hardness values were similar to the tensile properties. Both of the vanadium alloys resulted in higher apparent hardness values compared to the pure iron. The nitrogen increased the hardness compared to no nitrogen. Increasing the nitrogen level in the atmosphere did not make an appreciable increase in hardness. The hardness results are shown in Figure 4.

DISCUSSION

The impact of the vanadium alloying is

Mix ID	Sintering Condition				
	0N	25N	50N	75N	95N
F-0000	0.0003	0.0002	0.0007	0.0010	0.0026
F-0000V1	0.0004	0.0029	0.0034	0.0036	0.0035
F-0000V2	0.0009	0.0055	0.0066	0.0068	0.0069

Table 4: Nitrogen content of F-0000 materials (w/o).

Mix ID	Sintering Condition				
	0N	25N	50N	75N	95N
F-0008	0.0003	0.0004	0.0010	0.0015	0.0016
F-0008V1	0.0004	0.0033	0.0045	0.0053	0.0065
F-0008V2	0.0003	0.0047	0.0063	0.0070	0.0082

Table 5: Nitrogen content in F-0008 materials (w/o).

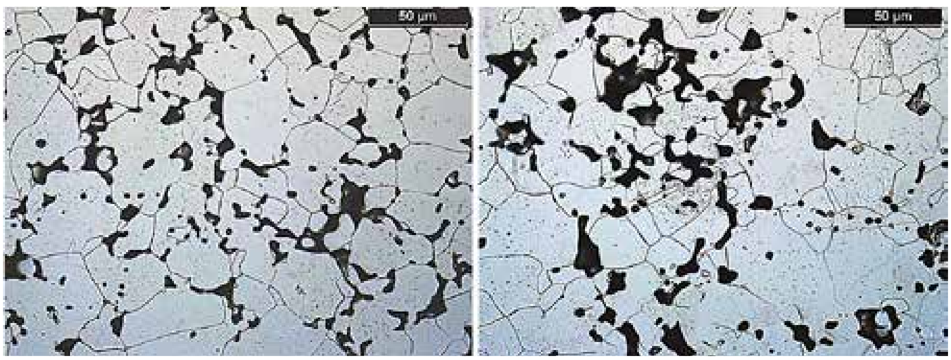


Figure 5: Microstructure of F-0000 (left) and F-0000V2 (right) in 0N sintering conditions.

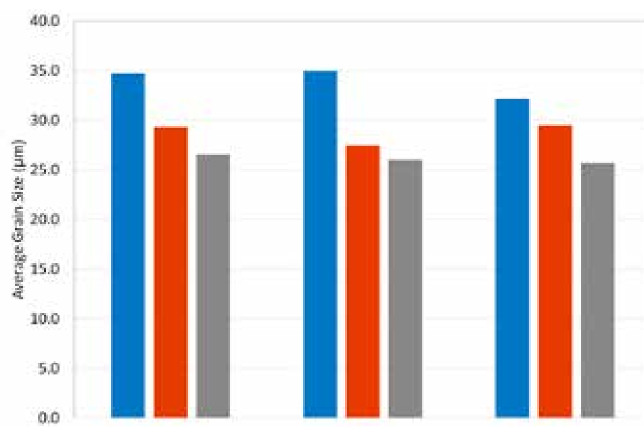


Figure 6: Average grain size measurements of F-0000 material systems.

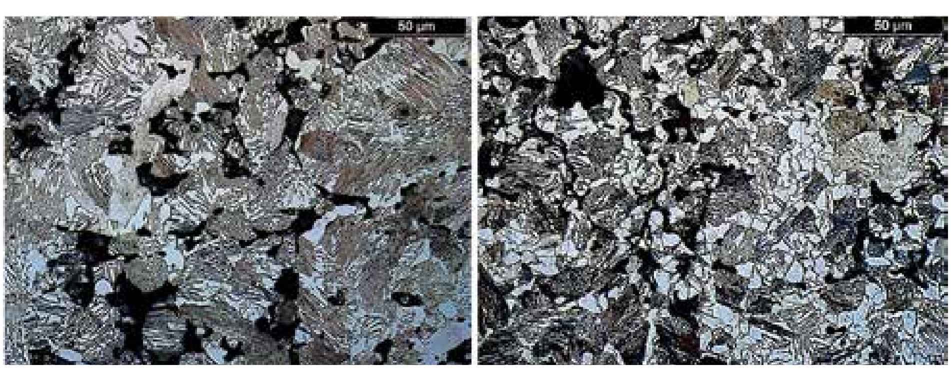


Figure 7: Microstructure of the F-0008 (left) and F-0008V2 (right) materials in the N95 condition.

clearly shown in the increase in tensile and a decrease in impact properties. Vanadium is known to combine with nitrogen and carbon to form V(C,N).

This formation leads to an increase in the mechanical properties through strengthening and refinement of the microstructure. In this study, the vanadium alloyed materials had increased strength properties without the addition of nitrogen. However, further improvement was observed when nitrogen was introduced into the sintering atmosphere for both the F-0000 and F-0008 materials. Increasing levels of nitrogen did not translate into increases in properties. To understand the amount of nitrogen absorption, the nitrogen content at each sintering condition was evaluated. The results are presented in Table 4.

While the tensile and impact properties were very similar once nitrogen was introduced into the sintering atmosphere, the chemistry data indicates that additional nitrogen was absorbed by the vanadium containing materials. The materials with the high level of vanadium alloying absorbed, on average, almost double the amount of nitrogen. It should be noted the vanadium level in this base powder was double of the lower vanadium containing material. The F-0008 based materials were also evaluated for vanadium content. The data are presented in Table 5.

Again, a similar trend was observed. The vanadium-containing materials continued to absorb more nitrogen from the atmosphere as the nitrogen level was increased. The amount of nitrogen absorbed was also elevated slightly compared to when no carbon was present in the material. The effect of the vanadium and nitrogen alloying is identifiable in the microstructure. The microstructures of the F-0000 materials are shown in Figure 5.

While both materials were ferritic, the size of the ferrite is noticeably smaller in the F-0000V2 material. This decrease in grain size results in improved strength values. Grain-size measurements were completed to quantify the decrease in average grain size between the materials. The grain size measurements are shown in Figure 6. A decrease of between 5 to 10 µm was observed for the vanadium containing materials compared to the standard pure iron material. Only very minor differences were observed when the nitrogen content in the sintering atmosphere was varied.

The ferrite size in the F-0008 material systems was also noticeably smaller for the vanadium containing materials. Photo micrographs of the F-0008 and F-0008V2 material are shown in Figure 7.

While the carbon contents of the sintered materials were similar, the spacing of the pearlite was also much closer compared to the standard F-0008 material. An analysis was conducted using an SEM to evaluate the spacing of the pearlite lamellae. The measured spacing is shown in Figure 8.

There was a measured decrease in the

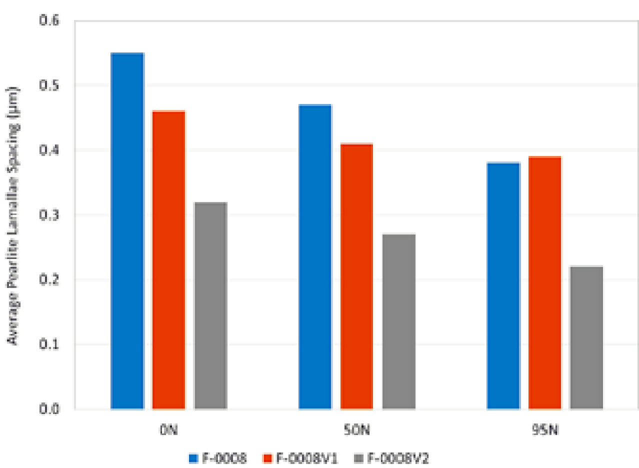


Figure 8: Average pearlite spacing of F-0008 materials.

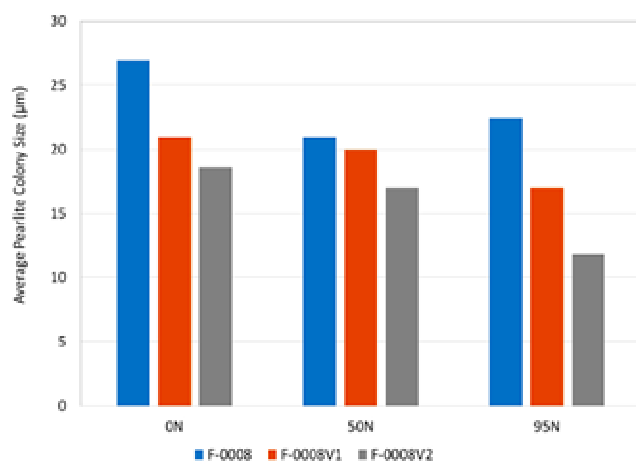


Figure 9: Average pearlite colony size of F-0008 materials.

lamellae spacing when vanadium was introduced into the powder. At the higher vanadium alloying level, the spacing of the lamellae was about one half of the spacing found in the pure base iron powder. It is well established that decreasing the spacing of the pearlite lamellae results in an increase in the tensile properties of a material. The ferrite present was also noticeably smaller compared to the standard F-0008 material. Measurement of the pearlite colony size was also conducted using SEM and point count techniques for selection of the colonies. The measured pearlite colony size is shown in Figure 9.

As observed through light microscopy, the pearlite colony size decreased noticeably with the addition of vanadium. The higher vanadium content in the F-0008V2 material also resulted in further decrease compared to the lower level found in F-0008V1.

CONCLUSIONS

Based on this study, the following conclusions can be drawn:

1. Vanadium provides an increase in the mechanical properties. Compared to a F-0000 material based on a plain iron powder, the vanadium alloys provided up to a 19 percent increase in ultimate tensile strength and a 31 percent increase in yield strength. In the F-0008 materials, the vanadium alloys provided up to a 19 percent increase in tensile strength and a 50 percent increase in yield strength. While the tensile properties were significantly increased, the impact energy was decreased by 60 percent in the F-0000 materials and by 33 percent in the F-0008 materials.

2. The addition of nitrogen in the sintering atmosphere, whether carbon was present or not, increased the mechanical properties compared to sintering in 100 percent hydrogen. However, increasing the amount of nitrogen did not have an appreciable effect on the strength and impact properties. The only property that showed an increase with increasing nitrogen levels in the sintering atmosphere was the apparent hardness.

3. Evaluation of the microstructure found the vanadium materials exhibited a smaller grain size. Measurement of the ferrite grain size found decreased average grain size when vanadium was present. Increasing the amount of vanadium in the powder resulted in a finer grain structure. The addition of nitrogen to the sintering atmosphere had little effect on the average grain size in the absence of carbon.

4. In the F-0008 materials, a decrease in the pearlite lamellae spacing was found for the vanadium alloyed materials. The use of vanadium decreased the lamellae spacing by almost 50 percent. In this case, increasing amounts of nitrogen in the sintering atmosphere resulted in a slight decrease in spacing. A decrease of up to 50 percent in the average pearlite colony size was also observed with the vanadium alloyed materials. Increasing nitrogen content resulted in further reduction of the average pearlite colony size.

REFERENCES

1. U. Engström, M. Schmidt, S. Berg, "Performance Characteristics of High Performance Diffusion Bonded Materials", Advances in Powder Metallurgy & Particulate Materials, com-

piled by W.B. James & R. Chernenkoff, Metal Powder Industries Federation, Princeton, NJ, 2004, part 7, pp. 125 – 136.
2. Höganäs AB, Höganäs Handbook for Sintered Components – Material and Powder Properties, 2004, Höganäs AB, Höganäs Sweden
3. P. Sokolowski, K. McQuaide, and B. Lindsley, "Axial Fatigue Properties of Lean Fe-Mo- Ni Alloys, Advances in Powder Metallurgy & Particulate Materials, compiled by D. Christopherson and R. M. Glasior, Metal Powders Industries Federation, Princeton, NJ, 2013
4. MPIF Standard 35, Material Standard for PM Structural Parts, 2016 Edition, Metal Powder Industries Federation, Princeton, NJ.
5. R. Glodowski, "An Updated Prediction Model for Vanadium Precipitation Strengthening of Ferritic Steels", Vanadium Microalloyed Steels Symposium, MS&T, 2014 Pittsburgh, PA.
6. A. Lawley and X. Du, "P/M Niobium/ Vanadium Steels via High Temperature Sintering", Advances in Powder Metallurgy and Particulate Materials, compiled by T. Cadle and K.S. Narasimhan, Metal Powder Industries Federation, Princeton, NJ, 1996, Part. 11, pp. 343 – 354.
7. R. Oberacker and F. Thummler, "Microalloying: A Suitable Method for the Production of Low Alloyed High Strength PM Steels?", Metal Powder Report, February 1989, pp. 120- 124.
8. C. Shade, T. Murphy, A. Lawley, and R. Doherty, "Microstructure and Mechanical Properties of Microalloyed PM Steels", Int. J. Powder Metall., 2012, vol. 48, no. 3, pp. 51-59.
9. R. Warzel III, B. Hu, A. Neilan, "Vanadium as an Alloying Element in Powder Metallurgy Steels", Advances in Powder Metallurgy and Particulate Materials, compiled by J. Strauss and R. Goto, Metal Powder Industries Federation, Princeton, NJ, 2017, Part. 7, pp. 1 – 11.
10. Standard Test Methods for Metal Powders and Powder Metallurgy Products, 2016 Edition, Metal Powder Industries Federation, Princeton, NJ
11. ASTM International Standard E 8-16, Standard Test Method of Tension Testing of Metallic Materials.
12. ASTM International Standard E 23-16, Standard Test Methods for Notched Bar Impact Testing of Metallic Materials.
13. ASTM International Standard E 1019-11, Standard Test Method for Determination of Carbon, Sulfur, Nitrogen, and Oxygen in Steel, Iron, Nickel, and Cobalt Alloys by Various Combustion and Fusion Techniques.
14. ASTM International Standard E112-96, Standard Test Methods for Determining Average Grain Size

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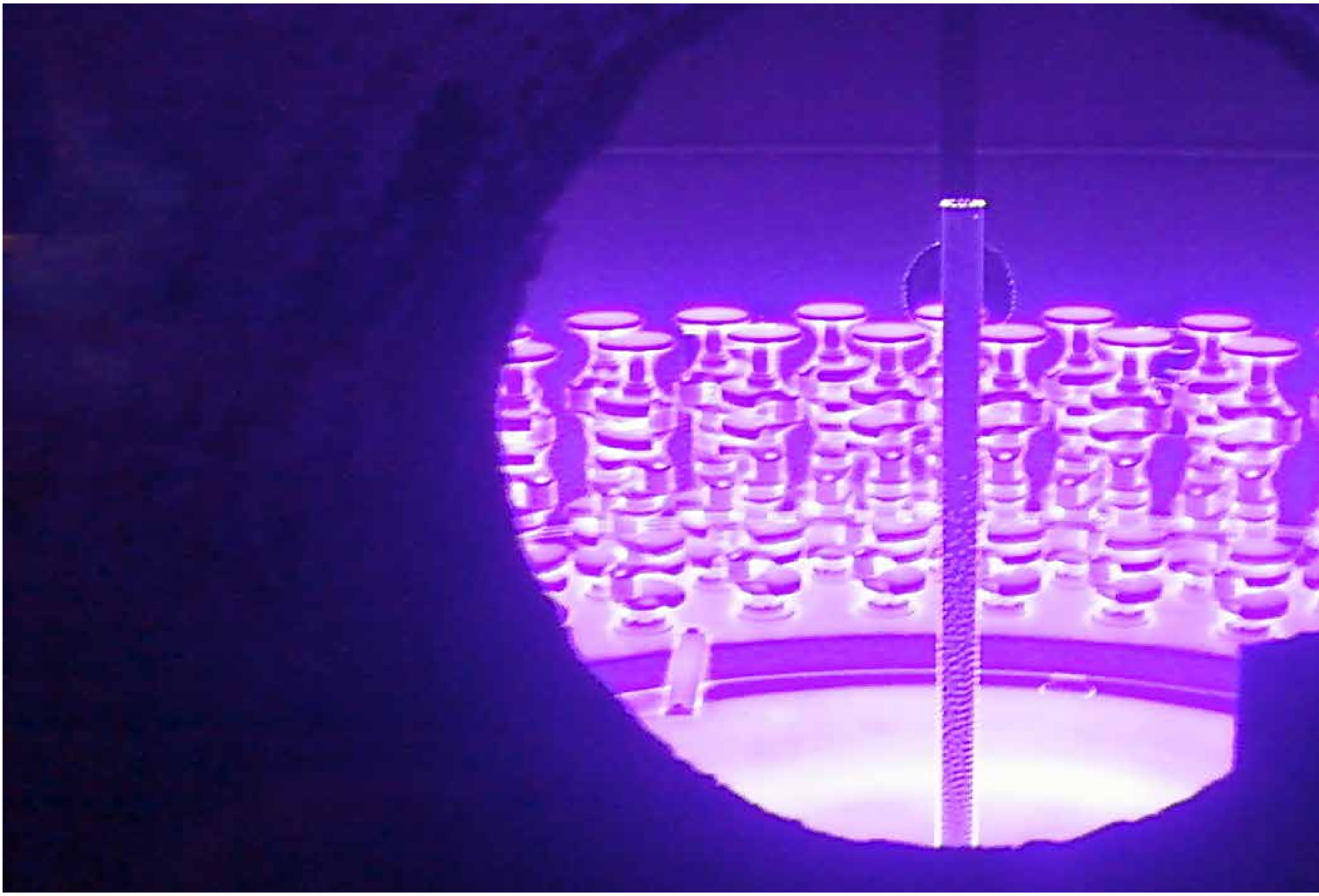

Plasma/ion nitriding for enhancing component properties

Plasma/ion nitriding and nitrocarburizing have the ability to form desired layers in alloys that cannot be easily hardened by other methods.

By E. Rolinski, R. Johnson, and M. Woods

Thermochemical surface treatments, such as plasma/ion nitriding, are effective ways of enhancing the mechanical properties of ferrous and titanium alloy parts [1, 2]. Through the thermochemical treatment, compound zone and/or diffusion layers are formed that reduce wear, friction, bending, and rolling contact fatigue (RCF). Additionally, with the sufficiently thick compound zone, corrosion resistance properties can be enhanced. (Corrosion resistance can be further improved by the introduction of a post-nitriding oxidation layer.) The nitriding process is carried out at a low temperature of about 400-590°C (750-1,100°F). The benefit of this low-temperature processing is that parts experience little to no distortion during nitriding, meaning parts can be in their finished condition and dimensions prior to nitriding.

Plasma/ion nitriding and nitrocarburizing methods are very clean and environmentally friendly processes that cannot be matched by other methods. Additionally, plasma/ion nitriding uses less processing gases (nitrogen and hydrogen) than gas nitriding (ammonia). Therefore, the uniqueness of the plasma nitriding method deserves more attention that will be briefly reviewed here.

THE PLASMA NITRIDING PROCESS AND EXAMPLES OF APPLICATIONS

Plasma/ion nitriding's vacuum process relies on the electrical glow discharge generated between the cathode (treated object) and the anode (the wall of vacuum furnace). The plasma's high intensity in near-surface regions generate active nitrogen species and the heat needed for achieving proper temperature. The process can be observed through a port window, Figure 1.

Figure 1: High performance 4340 steel crankshafts during plasma/ion nitriding (left) and after the treatment (above). Note combination of mechanical (plates) and chemical (red paint) methods of masking/protection from the treatment. (Courtesy of Advanced Heat Treat Corp. Monroe, Michigan).

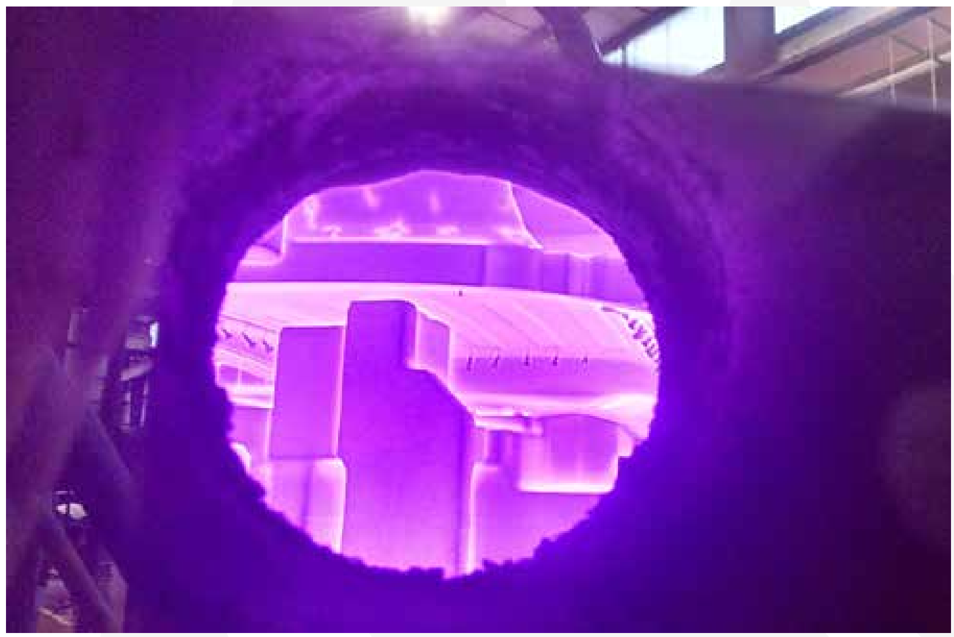

Figure 2: Large stamping dies during plasma nitriding. Note small pins and bolts masking holes inside of the die. (Courtesy of Advanced Heat Treat Corp. Monroe, Michigan).

Additional energy can also be supplemented by applying resistance heaters installed in the wall of the furnace.

The process is widely used for many applications, specifically those involving stainless steels, low-density sintered/powdered metal products, and parts requiring area-selective treatment. Protection of certain areas such as threads, sharp edges, and other critical areas can be easily met by applying mechanical masking, eliminating contact of the plasma with the surface in question.

This can be seen in Figure 1 where the plates on top of each crankshaft protect internal threads from hardening.

WELL-SUITED FOR LARGE PARTS

Large parts, such as stamping dies, are excellent candidates for plasma nitriding. Figure 2 shows the large stamping dies during the treatment. Such dies are typically made of cast irons. Applying plasma nitriding to gray cast iron products allows for effective hardening without roughening their surface, which can occur when processed via gas nitriding [1].

Plasma nitriding is very well-suited for hardening long objects that require uniform treatment and contain sections requiring local protection from the treatment such as threads. Figure 3 shows a very long shaft (> 30') being loaded into the vessel through an opening in the roof of the shop building. Excellent uniformity of plasma along the entire shaft resulted in the formation of a very consistent layer and superior hardness.

As mentioned before, the surface properties of nitrided components and tools are superior to unprocessed conditions and offer distinct advantages over comparative surface hardening processes such as chromium plating. Hardness values depend on the treated material. For example, nitrided H-13 steel can achieve more than 1,000 HV (>70 HRc equivalent), see Figure 4. This is extremely important for many applications and those of modern tools used for forming Ultra High Strength Steels.

Frictional properties of nitrided steels are also excellent [2]. Numerous tribological tests have proven plasma nitriding's wear endurance as seen in Figure 5. The average nitrided layer can endure friction at contact stresses up to 300 MPa, and deeper layers formed in harder materials, like those in bearing steels, can work even at higher levels.

Plasma/ion nitriding and nitrocarburizing have a promising future, in part from the environmental benefits, but also from its unique ability to form desired layers in alloys that cannot be easily hardened by other methods. As highlighted, plasma/ion nitriding can be applied to a variety of materials, part dimensions, and selectively controlled through proper masking. In addition, the low processing temperatures,

Figure 3: Loading of a 10-meter-long shaft into the nitriding vessel and the vessel itself (Courtesy: Advanced Heat Treat Corp., Monroe, Michigan)

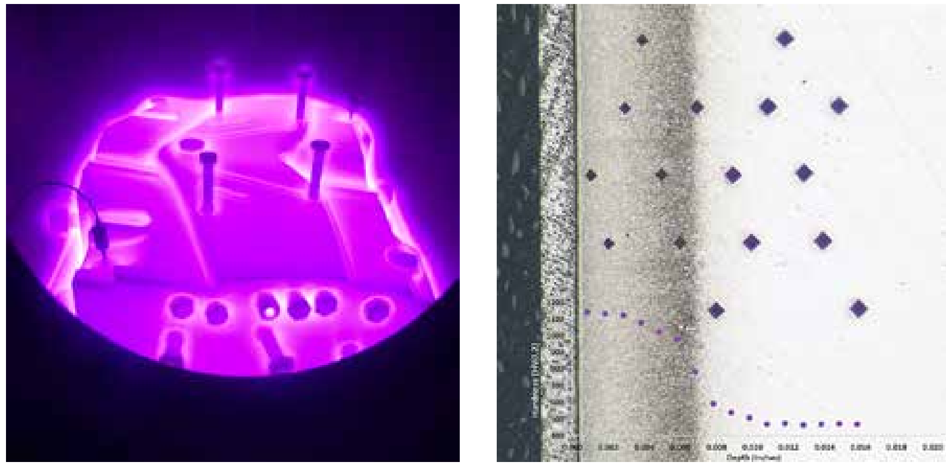

Figure 4: Photograph of the plasma treated H-13 small hot stamping die and photo micrograph of the layer structure and microhardness profile. Etched with 3 percent Nital.

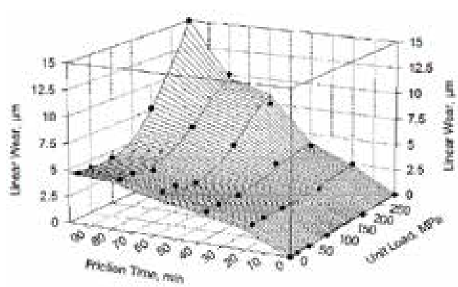

Figure 5: Linear wear depth vs. time of friction at different unit loads of nitrided layer produced in Nit135M steel. Adopted from [2]

which prevent part distortion, allows finished materials to be hardened and re-hardened again to provide long-lasting lifetimes of critical components. Plasma/ion nitriding will also be increasingly used through many industries (aerospace, automotive, agriculture, etc.) because of the excellent tribological, fatigue, and corrosion properties in finished products.

REFERENCES

1. E. Rolinski, G. Sharp, "Controlling Plasma Nitriding," ASTM International, Materials Performance and Characterization, Vol. 6, No 4, 2017, pp.698-716, https://doi.org/10.1520/MPC20160051. ISSN 2370-1365.
2. J. Senatorski, J. Tacikowski, E. Rolinski and S. Lampman, Tribology of Nitrided and Nitrocarburized Steels, ASM Handbook Vol 18, Friction, Lubrication and Wear Technology, ed. G. Totten ASM International, 2017, pp.638-652.
3. E. Rolinski, Thermochemical Surface technologies Applicable to Gears, Gear Solution, HOT SEAT December, 2016, pp 17.
4. E. Rolinski, T. Damirgi and M. Woods, "Ion nitriding of Ferrous and Titanium Alloys for Gear Application", Thermal Processing for Gear Solutions, Fall/Winter 2015, pp. 36-40.
5. E. Rolinski," Plasma Assisted Nitriding and Nitrocarburizing of Steel and other Ferrous Alloys", Chapter 11 in Thermochemical Surface Engineering of Steels, Ed. E. J. Mittemeijer and M. A. J. Somers, Pub. Woodhead Publishing, 2014, pp 413-449.

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Dr. Edward Rolinski received his M.S. in manufacturing technology in Warsaw, Poland, and received his doctorate for his research in phenomenon in the ion nitriding process. He has taught physical metallurgy and surface engineering and received his ScD (habilitation) for studying plasma nitriding of titanium. Rolinski is a senior scientist at Advanced Heat Treat Corp. in Monroe, Michigan, solving technical problems and developing technologies.

Mikel Woods is the president of Advanced Heat Treat Corp. (AHT) and has been with the company for more than 13 years. Woods obtained his bachelor's degree in accounting at University of Iowa and received his executive masters of business administration from the University of Wisconsin. To contact Woods or learn more about Advanced Heat Treat, please visit www.ahtcorp.com.

Rich Johnson started with Advanced Heat Treat Corp. (AHT) in 2017 as a Process Metallurgist, and in 2018, he was promoted to Materials and Process Manager at AHT's Monroe, Michigan, location, where he manages the metallurgy and quality departments. Johnson has a master's degree in materials science and engineering from Stanford University.

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MARKETPLACE

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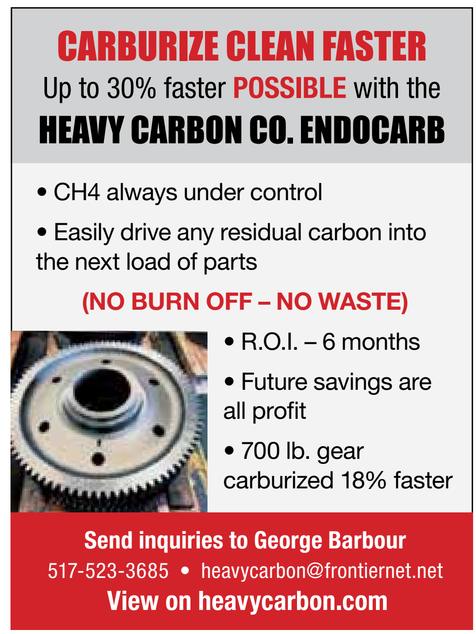

AD INDEX

COMPANY NAME — PAGE NO.

"There are very few things we have not seen"

What are your duties with Noble Industrial Furnace? What is your typical day?

My duties include, but are not limited to, oversight of design and construction of our new builds along with leading contracting crews on the road. We are a leading manufacturing company that continues to have roots in the field servicing all types of heat treat furnaces and equipment.

My typical day begins with coffee and emails then helping the crews get loaded up and out the door. With a steady flow of simultaneous projects in the shop, there is always something to do from ordering parts, double checking prints to helping weld pipe or lay brick. When not in the shop, you'll find me in the front office working with our design team, writing equipment proposals, and taking time to connect with our customers and vendors.

What products and services does Noble Industrial Furnace offer?

Noble provides industries worldwide with a full range of customized industrial thermal processing equipment. We build, repair, and maintain all typical batch furnace designs along with belt and tube furnaces.

After consulting with each customer, Noble provides customized furnace designs that incorporate the needs of the customer. Once the furnace concept and drawings have been accepted, work begins, and Noble takes over the project until its completion. All aspects of the construction, installation, testing, and training of the furnace are handled by Noble Industrial Furnace. Only when our customer's end users are up and running does Noble consider the job complete.

Noble also specializes in furnace refurbishment. When acquiring a new furnace or system is not budget friendly, customers choose Noble to refurbish a furnace. Refurbishing a furnace transforms a worn and outdated piece of equipment into a high-performance furnace meeting all updated safety and control regulations.

We also offer on-site emergency and scheduled repairs of all types of thermal processing equipment with minimal downtime to get our clients back up and running as soon as possible.

Noble has also responded to our customers' needs by providing preventative maintenance programs. These annual or semi-annual services include completion of all necessary maintenance, a thorough inspection of the equipment, and a detailed inspection report of our findings and maintenance performed.

What is Noble doing to advance the heat-treat industry?

We have been perfecting our design for gas and electric coating furnaces for the aerospace and ground-based turbine industries. Our close partnership with Lachance Controls for the past 35 years has helped bring us into the position where we can produce state-of-the-art equipment. Such systems have been sought out and purchased by the top turbine and engine builders in the world.

What are some of Noble Industrial Furnace's proudest moments?

Much of what we build is built to design, and nothing makes us prouder than when we deliver a quality product that meets or exceeds our customers' expectations. Most times, after a furnace is put in production, we visit our customer's facilities and have the opportunity to engage with the people who use our equipment each day. It's the feedback we get from those visits that makes us truly proud and committed to what we do.

We have built some great furnaces and these furnaces have lasted. And in many cases these furnaces have continued in production with changes in supervision, process, and location. Knowing we have designed, fabricated, and installed furnace systems both domestically and internationally along with meeting the many challenges of furnace design, including performance, size, uniformity, and process, makes us proud of our accomplishments.

What sets Noble Industrial Furnace apart when it comes to what you can offer a customer?

We know our furnaces. Every cut and weld, each component from brick to bolt, every burner and element, each valve, switch, and regulator is set in place by a skilled member of our team.

We know our customers. Having close relationships with our customers is an integral part of ensuring the equipment delivers. We have worked with many of our customers for multiple decades.

We know the industry. With over 175 years of combined experience in designing, building, and installing industrial thermal-processing equipment, there are very few things we have not seen. We provide our customers with products specifically designed to perform at or beyond their requirements.

Where do you see Noble Industrial Furnace in 10 years? In 2038?

Over the next 10 years we are focused on expanding our business to compete with a wider market, both domestically and internationally. We plan to open a satellite office to improve our abilities to serve our current customers and to expand our customer base as well. Working one-on-one with our customers, we will also strengthen our relationships and be the go-to source for thermal processing methods and equipment as our customers seek to improve their production methods, capabilities, and efficiencies.

By the time 2038 rolls around, we hope to be the standard bearer for coating furnaces. We are committed to leading the industry and providing customers with equipment that maximizes their production opportunities and overall business growth, with the broader benefit of strengthening the manufacturing industry in our country.

MORE INFORMATION noblefurnace.com