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Thermal processing

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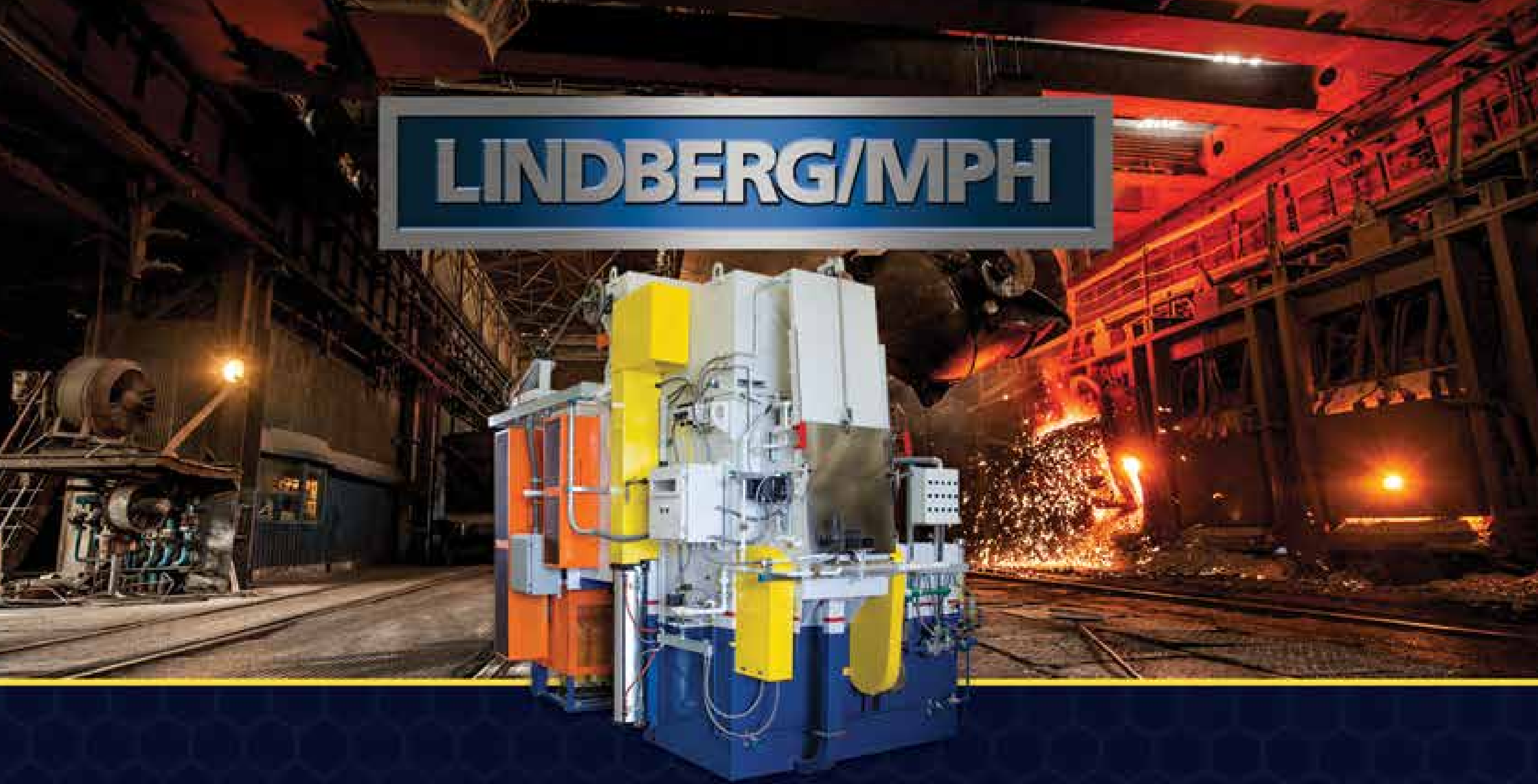
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FROM THE EDITOR ///

Heat Treat 2021 – live and in person

It's finally here.

And by "it," I mean Heat Treat 2021.

If you're reading this, odds are you may be walking the show floor at this very moment. But, if you're not, here's what you're missing out on:

» 2 1/2 days of face-to-face networking opportunities with about 200 heat-treat exhibitors/companies. All of the top companies and big names in the heat-treating industry will be represented.

» Latest research and industry insights offered during more than 100 technical presentations.

» Continued co-location with Motion + Power Technology Expo 2021 with access to additional exhibitors, in the co-located exhibit hall.

» Student/emerging professionals initiatives, including free college student registration, Fluxtrol Student Research Competition, and the new ASM Heat Treating Society Strong Bar Student Competition.

To keep things hot (hey, it's *Thermal Processing*; heat-treating puns are low-hanging fruit), our September issue sets the tone as the perfect primer for Heat Treat 2021. You might even run into some of our contributing authors right here on the show floor.

In our Focus section, an article from Quintus will introduce you to the next level of hot isostatic pressing and how it's being used for production processes that include casting, MIM, and additive manufacturing.

An article from TAV VACUUM FURNACES looks at how to properly debind parts produced by metal AM.

Our final feature article explores the use of plasma nitriding and how it can be used to improve the wear and corrosion resistance of 18Ni-300 maraging steel.

In addition to those articles, we have a wealth of information in the form of our columnists and a plethora of news updates throughout the industry.

I hope your time spent at Heat Treat 2021 is productive and profitable, and remember that *Thermal Processing* is here to boost that success.

So if you're walking the floor in St. Louis, be sure and stop by *Thermal Processing's* booth (#931) and say hey. I'd love to talk about editorial opportunities, and our advertising representatives would be happy to discuss ways to take your message to the next level.

As always, thanks for reading!

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

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The advanced features of the Tenova two state-of-the-art technology WBFs provide reduced emissions and energy savings. (Courtesy: Tenova)

Tenova starts up two new walking beam furnaces at Ternium

Tenova, a company specialized in sustainable solutions for the green transition of the metals industry, successfully started up two 400 t/h walking beam furnaces (WBF) at the new Ternium hot strip mill facility, located in Pesqueria (Mexico). Ternium is a leading company in the Americas that manufactures and processes a wide range of high-quality steel products.

The advanced features of the two state-of-the-art technology WBFs provide reduced emissions and energy savings. The furnaces are designed to heat steel slabs (up to 39 t) at 1,250°C, with a specific consumption of 1.16 MJ/Kg, while keeping NOx emissions lower than 60 ppm. This emissions level is well below the required limit.

The furnaces' features include the novel SmartBurner Monitoring System (SBMS), which enables the monitoring and optimizing of the burner's performance, operation, and maintenance. The SBMS is a network of embedded sensors connected to the Tenova Digital Infrastructure, through secure connection protocols and intrinsic system reliability. The collected data is post-processed locally on an edge computing unit as well as remotely on the Tenova Cloud. By constantly monitoring the status of the burner, the SBMS offers breakthrough approaches to inspection, maintenance and tuning, as well as reducing safety risks related to on-site operations.

"The Ternium Industrial Center started its first phase in 2013 focused on downstream products as cold rolled and galvanized for the industrial market. Now, we have started up the main production line of the second phase, a new hot rolling mill with a capacity of 4.4 million tons," said Paulo Lopez, Pesquería plant director at Ternium. "The two new WBFs are part of the plant's new lines and will produce coils to be used in the automotive market in the USMCA area, granting Ternium an increased access in this sector."

"This new Tenova equipment joins the previous walking beam furnaces built for Ternium at its plants in San Nicolas, Argentina, and in Monterrey, Mexico, confirming the fruitful collaboration between the two companies of the Techint Group for this type of application. This represents an important new reference for Tenova in the reheating furnaces market," said Nicola Cavero, senior vice president Tenova Italimpianti.

MORE INFO www.tenova.com

Thermalogic launches new website

Thermalogic Corporation has launched a new website offering a modern, streamlined, and user-friendly platform that provides a better view of its extensive control, sensor, and transmitter product lines.

The new website also features an area where customers can elaborate on specific design features and application needs with Thermologic's control and sensor configurator. Thermologic can work from customer drawings, sketches, descriptions, ideas, or obsolete products to meet their exact needs.

"When companies want something that is top notch, they come to Thermalogic," said Joe Grein, president of Thermalogic.

For 50 years, Thermalogic has provided design, engineering, and manufacturing services for temperature controls and sensors for OEM and volume users.

MORE INFO www.thermalogic.com

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

The co-located 2022 AMPM conference and PowderMet2022 will be held June 12–15, 2022, in Portland, Oregon, at the Portland Convention Center.

AMPM Conference, PowderMet2022 call for papers

The program committee for the Additive Manufacturing with Powder Metallurgy Conference (AMPM2022) has issued a call for papers and posters covering the latest developments in the fast-growing field of metal additive manufacturing (AM). The AMPM conference has grown significantly since its debut in 2014 as the only conference focused on metal AM. The 2022 conference will be held June 12–15, 2022, in Portland, Oregon, at the Portland Convention Center.

Technical program co-chairmen Animesh Bose, Desktop Metal, and James Sears, Amaero Additive Manufacturing, request abstracts covering any aspect of metal AM including:

- Modeling of metal AM materials, components and processes.
- Design of metal AM components.
- Particulate production for metal AM.
- Metal AM build processes.
- Metal AM sintering.
- Metal AM post-build operations.
- Metal AM materials.
- Metal AM materials properties.
- Metal AM testing and evaluation.
- Metal AM applications.
- Metal AM management issues.

"As the only annual metal additive manufacturing/3D printing conference, the AMPM conferences provide the latest R&D in this thriving technology," said James P. Adams, executive director/CEO, Metal Powder Industries Federation. "The continued growth of the metal AM industry relies on technology transfer of the latest research and development, a pivotal function of AMPM2022."

The abstract submission deadline is November 5, 2021.

All topics related to powder metallurgy and particulate materials should be submitted to the co-located PowderMet2022: International Conference on Powder Metallurgy & Particulate Materials at PowderMet2022.org.

Technical program co-chairmen Paul Hauck, SSI Sintered Specialties, and Tim McCabe, OptiMIM, request abstracts covering any aspect of PM and particulate materials technology.

Suggested topics include:

- Design and modeling of PM materials, components and processes.
- Particulate production.
- General compaction and forming processes.
- Powder injection molding (metals and ceramics).
- Pre-sintering and sintering.
- Secondary operations.
- Materials.
- Refractory metals, carbides and ceramics.
- Advanced particulate materials and processes.
- Material properties.
- Test and evaluation.
- Applications.

» Management issues.

"The annual PowderMet conference is the powder metallurgy (PM) industry's strategic networking event, bringing delegates face-to-face, exposing the latest research and development, celebrating industry achievements, and more," said James P. Adams, executive director/CEO, Metal Powder Industries Federation. "North America's largest exhibit, a collection of leading suppliers and service providers for PM, particulate materials, and metal additive manufacturing applications, will provide the cutting-edge advancements in the industry."

The abstract submission deadline is November 5, 2021.

The co-located conferences are sponsored by the Metal Powder Industries Federation, the North American trade association representing the powder metallurgy industry, and its affiliate APMI International.

APMI International is a non-profit professional society which promotes the advancement of powder metallurgy and particulate materials as a science. Its purpose is to disseminate and exchange information about PM and particulate materials through publications, conferences, and other activities of the society.

MORE INFO www.mpif.org
www.ampm2022.org

Epcon Industrial Systems designs and builds ovens and oxidizers for continuous web processing applications. (Courtesy: Epcon)

Epcon Industrial designs, installs high-velocity oven

Epcon Industrial Systems is a known leader in designing and building ovens and oxidizers for continuous web processing applications, where the web can be either steel or aluminum, paper, plastic, fiberglass, and/or any composite material.

The company's challenge for an automotive industry customer was designing a high-velocity oven with forced convection to process 60-inch wide steel or aluminum web. This system used Epcon's patented technology to integrate the functionality of oven(s) with the oxidizer, to increase efficiency. The system was 100 percent installed and commissioned on a turnkey basis.

MORE INFO www.epconlp.com

Vastex infrared conveyor oven boosts temperatures

A new BigRed™ 4D-54 infrared conveyor tunnel oven from Vastex Industrial boosts temperatures to over 300°F (149°C) within the first several inches of conveyor travel, and maintains at-cure temperatures of up to 900°F (482°C), satisfying high-capacity curing, drying, and baking requirements.

It is equipped with a 54-inch (137 cm) wide conveyor belt, dual heating zones, and four height-adjustable infrared heaters capable of heating film, sheet, parts, and metal products uniformly from edge to edge, at high rates.

An air flow mapping system draws 'make-up' air into the chamber's double-walled shell through filtered inlets along opposite exterior sides serving to cool the outer shell for safety, while preheating incoming air.

An exhaust fan located below the center of the conveyor belt draws the preheated air downward at rates up to 700 CFM (19.8 CMM) over and through the belt, removing heat, moisture, fumes, and contaminants from the chamber.

The six-inch (15.3 cm) diameter exhaust fan outlet can rotate 360 degrees for easy connection to ductwork, and the control box can be located on the right (standard) or left side of the chamber.

Exhaust filters located on both sides of the conveyor prevent dust, lint, or other contaminants from entering the blower or exhaust stack. Cleaning all filters before or after each shift can be accomplished in one minute according to the company, safeguarding the product, equipment, and shop environment.

Exhaust flow sensors with warning

Capacity of BigRed™ 4D-54 infrared conveyor oven can be doubled or tripled as new or when needs increase by adding one or two additional heating chambers and extending the conveyor belt. (Courtesy: Vastex)

lights alert operators to a clogged exhaust line, clogged filter, or blower failure. Other safety features include a light tower to monitor oven status, and a 'cool down mode' for powering down.

With a total of 22,800 watts, it is wired for 240V as standard, and available in three-phase, 208, 380, and 480 voltages. The heaters carry a 15-year warranty, and feature closely spaced coils that provide high-density, medium-wavelength infrared heat for maximum IR efficiency without cold spots. Dual digital PID temperature controls maintain accuracy to ±1°F (±0.5°C).

A Teflon-coated fiberglass belt with alignment tracking system is standard. Optional stainless-steel mesh belts for high-heat applications are available.

Capacity (belt speed) can be doubled as new or retrofit by adding one additional heating chamber (total 45,600 watts), or tripled by adding two additional chambers (total 68,400 watts), and extending the conveyor belt.

All BigRed 4D-54 configurations are 71.4 inches (181.4 cm) wide x 51.6 inches (131.1 cm) high. Lengths are 105 inches (266.7 cm) for single chamber units, 142 inches (360.7 cm) for two-chamber units, and 178 inches (452.2 cm) for three-chamber units.

MORE INFO www.vastex.com

Lucifer Furnaces delivers customized recirculating oven

Lucifer Furnaces' Model 42-T36 was delivered to a U.S. automotive supplier. (Courtesy: Lucifer Furnaces)

Lucifer Furnaces recently delivered a large 4000 Series oven to a leading automotive supplier in the United States.

Model 42-T36 has a chamber size of 30"H x 30"W x 36"L, heating to 1,200°F with 35 KW of power. This model is complete with a high CFM rear-mounted fan assembly to recirculate the heated air uniformly throughout the chamber. A stainless-steel liner isolates the heating elements from the work area and directs air forward over the heating elements and back through the chamber in a horizontal pattern for uniform heating.

This furnace was customized with a heavy-duty cast work tray which sits on the floor of the chamber inside the liner area to support the workload and protect the floor brick. The horizontal swing door is lined with lightweight pyroblock insulation with a ceramic fiber gasket to reduce heat loss around the chamber opening. A safety microswitch automatically shuts off power to heating elements and fan when door is opened, eliminating electric shock and heat blast hazards to the oven operator.

Controls include a Honeywell digital time proportioning temperature controller accessorized with a high limit controller for safety in the event of a high temp excursion.

MORE INFO www.luciferfurnaces.com

Metal Injection Molding Conference seeks presentations

A call for presentations has been issued for MIM2022, International Conference on Injection Molding of Metals, Ceramics and Carbides, to be held in West Palm Beach, Florida, February 21–23, 2022. Authors have until October 1 to submit presentation abstracts on manufacturing innovations and material advancements. All abstracts accepted for presentation will require a PowerPoint submission prior to the conference. Authors will be notified of acceptance or rejection by October 31, 2021.

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. Sponsored by the Metal Injection Molding Association, a trade association of Metal Powder Industries Federation and its affiliate APMI International, MIM2022 brings together product designers, engineers, end users, manufacturers, researchers, educators, and students for technology transfer.

The Metal Injection Molding Association operates as a trade association within Metal Powder Industries Federation, an incorporated trade organization. Its objectives include improving and promoting the products of the metal injection molding industry, and to promote investigation, research, and interchange of ideas among its members, among other objectives.

Metal Powder Industries Federation is the North American trade association formed by the powder metallurgy industry to advance the interests of the metal powder producing and consuming industries and provides a single point of reference for all MPIF member companies.

MORE INFO www.MIM2022.org

Maker of EV chassis components orders heat-treat equipment

Seco/Vacuum, a Seco/Warwick Group company, will provide two furnaces and auxiliaries with working zones that can accommodate loads with dimensions up to 1,000 mm x 1,000 mm x 2,400 mm (40"x40"x96") and up to 7.5 metric tons of weight.

The Vector® vacuum hardening furnace is equipped with a convection heating system to improve heat transfer at lower temperatures thus reducing internal stresses; the cooling system can quench with nitrogen at pressures up to 25 bar. The furnace will exceed NADCA 207 requirements for quenching process and class 2 temperature uniformity requirements per AMS2750F.

The nitriding furnace is a pit-type configuration, with working dimensions to match the hardening furnace. The patented ZeroFlow® nitriding process achieves optimum results by using uniform high convection heating, precision nitriding potential and ammonia control, along with vacuum purging to reduce operating costs.

"By demonstrating our expertise in high-pressure gas quenching to this customer over the past year, we built a reputation with their engineering team that we are capable of achieving the required quenching rates within such a large envelope, which will be accomplished with a powerful 500kW quenching system. The customer also appreciated the custom engineering that we put into handling such a heavy workload," said Piotr Zawistowski, managing director of Seco/Vacuum.

The tool and die market serving traditional and EV automotive markets use vacuum heat-treating technology extensively to produce bright, high-quality parts. Seco/Warwick's vacuum tempering and nitriding furnaces are highly regarded for their clean operation, precise temperature uniformity, reduction of quench distortion, automation and software, compact design, and overall reliability.

MORE INFO www.secowarwick.com

Burloak Technologies commissions DELTA H® systems

Burloak Technologies received and commissioned two DELTA H® furnace systems for use in both R&D as well as full-scale additive manufacturing production of aluminum products.

Burloak reported that parts initially being processed in the two furnace systems included items for the Canadian Space Agency and revolutionary communications satellites.

The two furnace systems include a single-chamber (SCAHT®), fully-automated, horizontal quench, solution heat treating furnace capable of operating from ambient to 1,200°F followed by rapid quenching in less than seven seconds — a requirement for processing critical-application aluminum parts. This SCAHT furnace is also capable of slow quenching geometrically complex AM parts. The systems provide precise duplication of heat treat cycles. Included is a comprehensive data acquisition system in full compliance with AMS2750F — Instrumentation Types A, B, or C and can produce irrefutable, scientifically defensible batch records. As safety is paramount, the fully enclosed quench system met all the strict Canadian safety standards as well as all electrical and design safety requirements of CSA/UL/CUL and NFPA.

Burloak also commissioned a dual chamber (DCAHT®) aluminum aging oven system. Both chambers are identical and can operate from ambient to 600°F with precision control and uniformity. A unique feature is "Rapid Cooling" whereby overall cycle time for parts is minimized.

All chambers are 24 inches wide, 18 inches high, and 48 inches deep. All qualified as Class 2 and proved capable of Class 1 uniformity. In both the SCAHT and the DCAHT, operators never have to handle dangerous hot parts. With the quenching system on the SCAHT as well as Rapid Cooling on the DCAHT, all heat-treating cycles are fully automated from "cold to cold" with operators only attending to load or unload part trays.

"DELTA H builds straightforward, easy-to-use heat treatment ovens that are exceeding our internal and customer quality requirements. Training personnel from operations, maintenance, and quality is an easy and painless process. The transparency of the systems will be pleasing to customer, AS9100, and Nadcap auditors," said Peter Adams, Burloak Technologies chief innovation officer and co-founder.

DELTA H® SCAHT® and DCAHT® fully automated AM and aerospace aluminum heat treating at Burloak Technologies. (Courtesy: Delta H Technologies)

"The systems provided to Burloak represent a new chapter in our dedication to the aviation and aerospace industries as well as additive manufacturing in general. It is very humbling to be among the technology providers to such an innovative and pioneering company as Burloak Technologies," said Ellen Conway Merrill, DELTA H vice president.

MORE INFO www.delta-h.com

Tenova launches hydrogen-ready burner for furnaces

Tenova, a leading company in sustainable solutions for the green transition of the metals industry, achieved a key milestone toward a more sustainable combustion process: the development of the first burners for heat treatment furnaces using up to 100 percent hydrogen while keeping NOx emissions largely below the strictest limits.

After the recent launch of the multi-megawatt TSX SmartBurner family for reheating furnaces fueled with a mixture of natural gas and hydrogen (up to 100 percent), the company is now ready to bring onto the market a self-recuperative burner for heat-treatment furnaces.

The new 200-kilowatt TRKSX (Tenova Self-ReKuperative Flameless) SmartBurner was successfully tested with a variable fuel mixture of natural gas and hydrogen to potentially eliminate CO2 emissions during the combustion process. The system works in flame and flameless mode with the aim to keep nitrogen dioxide emissions well below the strictest future limits.

"TRKSX SmartBurners preheat the combustion air at high temperature directly into the burner body through the heat-exchanger. This makes it possible to reduce fuel consumption significantly, making this technology extremely efficient (approximately 78 percent). Moreover, it allows to maintain minimum level of NOx emissions, releasing less than 80 mg/Nm^3 @ 3 percent of oxygen even with 100 percent hydrogen," said Davide Astesiano, R&D manager at Tenova Italimpianti.

The TRKSX SmartBurner was designed in consideration of the decarbonization goals of the steel industry, and will be first installed in a heat-treatment furnace for pipes at the productive site of Tenaris (in Dalmine, Italy), a leading global manufacturer and supplier of steel pipe products and related services for the world's energy industry and other industrial applications and part of the Techint Group, to which Tenova also belongs.

Tenova's hydrogen-ready burner represents a further step toward the decarbonization of the metals industry while maintaining NOx emissions well below the strictest future limits. (Courtesy: Tenova)

"Our target is to enlarge Tenova's burner portfolio to offer our customers the best solution for the decarbonization of their plants, and we plan to adapt all our burners to be hydrogen-ready. They are also integrated with sensors to make possible dynamic control of waste gases flow, generating precious data for machine learning applications," said Nicola Cavero, senior vice president at Tenova Italimpianti.

MORE INFO www.tenova.com

Allied Mineral Products celebrates 60th anniversary

Allied Mineral Products is celebrating its 60th anniversary. In its early days, Allied began selling minerals from a home office and garage in the northwest Columbus area. The need for warehouse space led co-founders Bill Winemiller and Bob Scott to lease a downtown building off East Chestnut Street. This new facility allowed for distribution of several product lines of minerals across a five-state area. Soon after, the partners created their own line of refractory products to market.

Allied's first product sold was MINRO-AL® RAM A31-W to Ridge Tool (now Emerson), creator of the modern pipe wrench and a line of RIDGID® tools and equipment. Jon K. Tabor was instrumental in the sale of this product against strong market competition. Credited with what became known as the "Allied Way," Tabor went on to enjoy a 50-year career serving Allied and its customers before retiring from Chairman Emeritus in 2020.

Allied's headquarters and manufacturing campus spans 40 scenic acres on the west side of Columbus, Ohio. This flagship location houses a state-of-the-art research and technology center and a newly renovated monolithic and precast shapes manufacturing facility.

Key events through the years have shaped Allied into a culture of working together toward a common goal, including the introduction of the ESOP (Employee Stock Ownership Plan) in 1976. Being employee-owned means employees' actions directly affect the company's profitability.

Allied opened its first international location near Johannesburg, South Africa, in 1998. In 1999, Allied began manufacturing in a leased facility in Tianjin, China. These expansions paved the way for subsequent locations in Tianjin, the Netherlands, South China, India, Brazil, Chile, and Russia. Every product made in each facility follows the same stringent manufacturing process.

From humble beginnings to a world leader in refractories, Allied's focus is "being there worldwide" for customers with its people and products. This commitment is proven through adaptive manufacturing, timely deliveries, and on-site product installations.

"We started with the idea of being there for our customers and will continue on into the future. It's who we are to our core," said Jon R. Tabor, chairman and CEO.

MORE INFO www.alliedmin.com

Solar vacuum heat treats longest nickel alloy tubes

Solar Atmospheres of Western PA successfully vacuum heat-treated the largest and longest load of nickel alloy tubing ever in a commercial vacuum furnace.

The mission was to preserve the crucial elements of brightness and cleanliness of the 45-foot-long seamless tubing while meeting extremely stringent mechanical properties.

"We spent countless hours reviewing critical systems such as triplicate pumping systems and redundant hot zone controls for any unforeseeable event that might arise during the 100+ hour run. We are also fortunate that we can rely on our furnace manufacturing division, Solar Manufacturing, for guidance should any issue arise. This successful run will ignite a production campaign for the next five years, once again boosting confidence that this 48-foot vacuum furnace will surpass our customers' expectations," said Michael Johnson, sales director.

MORE INFO www.solaratm.com

Celebrating 50 years of IFHTSE in 2022

The special emphasis of ECHT2022, to be held in Salzburg, Austria in 2022, will be on Heat Treatment in Steel Processing.

The 27th IFHTSE Congress will be in Salzburg, Austria, September 5-8, 2022, at the Wyndham Grand Salzburg Conference Center. This is going to be a special event, as it will also commemorate the 50th anniversary of the founding of IFHTSE.

The conference co-chairmen are Masahiro Okumiya, Toyota Technological Institute (Japan), president of IFHTSE; and Reinhold Schneider, University of Applied Sciences, Upper Austria, chairman of the ASMET Heat Treatment Committee.

The special emphasis of ECHT2022 will be on Heat Treatment in Steel Processing. Topics include furnace design, thermomechanical treatments; quenching technology, additive manufacturing, and coating technologies. For more information, go to www.ifhtse-echt2022.org/

IMPORTANT DATES

›› **Abstract Submission Deadline:** January 31, 2022
›› **Notification of Acceptance:** March 31, 2022
›› **Preliminary program:** April 30, 2022
›› **Full paper Submission Deadline:** May 31, 2022

SPOTLIGHT ON MEMBERS

IFHTSE is a federation of organizations, not individuals. There are three groups of members: scientific or technical societies and associations, universities and registered research institutes, and companies.

This month we highlight the India (Mumbai) Chapter of ASM.

Established in 1979 by Dr. H.M. Mehta with a handful of dedicated volunteers, it has been continuously pursuing the mission of ASM of collecting and disseminating knowledge on materials and processes. This is being done through technical courses on subjects such as metallurgy for the non-metallurgists, failure analysis, metal forming, heat treatment, welding, non-ferrous metals, thermal spraying, and more. The Exhibition Heat Treat Show began in 1990 and has become a trademark of the chapter. The show is held biannually and is well attended by Indian industry and international exhibitors and authors. Other activities include arranging conferences, workshops, and exhibitions on recent developments in material processing, material application engineering, equipment, and more.

The next event is the 4th MET-2021, International Conference on Materials, Engineering and Technology, September 29–October 1, 2021, at the Bombay Exhibition Center in Mumbai, India.

HEAT TREAT 21
31ST HEAT TREATING SOCIETY CONFERENCE & EXPOSITION

UPCOMING EVENTS

HEAT TREAT 2021, sponsored by the Heat-Treating Society of ASM. This event will be in St. Louis, Missouri, September 14-16. This event will be held jointly with IMAT and The Thermal Spray Society. This year's conference and expo will feature:

» Latest research and industry insights offered during more than 100 technical presentations.

» Continued co-location with Motion + Power Technology Expo 2021 with access to additional exhibitors, in the co-located exhibit hall.

» Student/emerging professionals' initiatives, including free college student registration, Fluxtrol Student Research Competition, and the new ASM Heat Treating Society Strong Bar Student Competition.

MEMBERS IN THE NEWS

Sören Segerberg (1943-2021)

It is with much regret to announce the passing of Sören Segerberg. He received his M.Sc in Engineering at KTH Royal Institute of Technology and was an ASM Fellow. His citation for ASM fellow read "for sustainable development of quenching technology and leadership in the global heat-treating industry, including research leading to the understanding of quenching principles and for the development of testing equipment for gas and liquid quenchant characterization." He is the author of many papers on measuring and monitoring quenchant performance. He had been retired from IVF (now RISE) for more than 10 years. He was a true mentor and teacher.

Segerberg and his company, HEATTEC Värmebehandling AB, manufactured the ivf SmartQuench test probes and furnaces for RISE. His work will be carried on by his son, Peter Segerberg.

IFHTSE 2021 EVENTS

Due to the pandemic, many conferences planned for 2021 have either been delayed or canceled. Please watch this space for updates on current conference planning.

SEPTEMBER 8–10
4th Mediterranean Conference on HTSE
Istanbul, Turkey | mchtse2020.com

SEPTEMBER 13–16
ASM International Materials Applications & Technologies
St. Louis, MO, USA | www.asminternational.org/web/imat

SEPTEMBER 29–OCTOBER 1
14th HTS International Exhibition and Conference
Mumbai, India | www.htsindiaexpo.com

OCTOBER 26–28
HK 2021
HK is the largest materials technology industry meeting in Europe
Cologne, Germany | www.hk-awt.de

APRIL 2022
12th Tooling Conference & Exhibition (Tooling 2022)
Örebro, Sweden

SEPTEMBER 2022
27th IFHTSE Congress / European Conference on Heat Treatment
Salzburg, Austria

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

NOVEMBER 13-16, 2023
28th IFHTSE Congress
Yokohama, Japan

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

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Getting to know IHEA member Nutec Bickley

Nutec Bickley is focused on understanding its customers' thermal equipment needs and working to supply the best equipment to meet those needs at the most competitive price.

On June 14, 1990, Nutec Industrial (later to become Nutec Bickley) was established in Monterrey, Mexico, expressly for the construction of furnaces, kilns, and combustion systems.

With acquisitions along the way — Bickley, GFC, Dragon Kilns, and Olson — the company has been able to tap into a wider knowledge base and design a range of furnaces and kilns that meets the most demanding requirements of international leaders in aluminum, forging, ferrous casting, ceramics, refractories, and abrasives.

Today Nutec Bickley (with a workforce of 220) is focused on understanding its customers' thermal equipment needs and working to supply the best equipment to meet those needs at the most competitive price. By applying the latest proven technology, Nutec Bickley is able to provide innovative solutions that meet or exceed its customers' expectations in equipment quality, production efficiency, and operational economy.

For the metals industries, Nutec Bickley supplies the aluminum, forging, ferrous casting, tube, rod and wire, electrode drying, and coating drying sectors. For ceramics, the company supplies the sanitary ware, technical ceramics, refractories, insulator, tableware, clay pipe, abrasives, cores, and colors sectors.

When people hear Nutec Bickley's name, what should come to mind is that it's a trusted name for reliability, fuel efficiency, cost competitiveness, and transparent operation. Nutec Bickley's customers are always at the heart of everything it does.

NUTEC BICKLEY

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Phone: +52 (81) 8151 0800 **U.S. Phone:** +1 (855) 299 9566

Website: www.nutecbickley.com

E-mail: sales@nutec.com

Nutec Bickley has broad international experience in incorporating SCADA into furnace and kiln facilities.

SCADA is a computer-based system that monitors equipment performance in real time that can control and change settings by communicating with the equipment's control system. It is configured to store all data for years; this information can be analyzed to replicate the optimum operating conditions of the equipment.

Once installed, operators are able to have complete control of their firing process, enhancing efficiency and productivity. Nutec Bickley's latest Industry 4.0 platform integrates the latest technology to not only monitor the process, but also to keep the equipment operating at peak performance with smart maintenance technology. All the data generated during the firing process is stored in Nutec Bickley's own SCADA system.

Nutec Bickley strives to meet the most demanding requirements of international leaders in aluminum, forging, ferrous casting, ceramics, refractories, and abrasives.

This is used to generate reports, graphs, and intelligence data to help customers in their decision-making process.

Nowadays, with fuel costs constantly increasing, Nutec Bickley is seriously committed to working with its customers to improve kiln production rates and efficiencies by minimizing fuel usage and providing the latest proven technology in heat-recovery systems

According to the kiln application, Nutec Bickley's engineers review process parameters and available areas to carefully design and size the required combustion equipment, controls, heat exchanger type and size, and exhaust systems for a complete solution in order to obtain the optimum kiln operating efficiency.

The company's people lie at the heart of what makes Nutec Bickley unique, and they are certainly much, much more than the sum of their parts. They have been the key to the company's success for more than five decades and many have been with Nutec Bickley for more than 20 years, which says a good deal.

As a team — and Nutec Bickley is very much a team — the company may enjoy shared success today but always with an eye on tomorrow. Nutec Bickley makes its mission to recruit and nurture the best talent. That done, Nutec Bickley makes the best use of the wealth of experience and expertise within the company to undertake internal training in all main areas — design, combustion system knowledge, fabrication, electronics, commissioning, spares, and after sales.

Nutec (Nutec Bickley's sister company), which is part of Nutec Group, just acquired the assets of Protective Concepts Inc. from Cypress, Texas. Nutec Protective Concepts, LLC began officially operating July 1, 2021.

On April 7, 2021, a couple of executive-level changes were made to companies within the Nutec Group: Daniel Llaguno, previously CEO of Nutec Bickley, moved on that date to take control of Nutec (Ceramic Fiber Division); while Gilberto Walls, formerly CEO of Nutec Fiber Division, now heads up Nutec Bickley.

Nutec Bickley will develop many strategies to optimize its pricing by maintaining and even increasing the quality of its products and services.

The Nutec Bickley family comes together every day to demonstrate drive and dynamism, operating on the basis of trust and mutual respect.

During June 2021, the company received an order from a large company for two large furnaces for the forging industry. This project confirms its improvements in customer experience and satisfaction.

Nutec Bickley is focusing on improving the customer satisfaction and experience to the top, and the company is putting its customers first, now more than ever. It only focuses on having the best customer experience in the kilns/furnaces market, but also develops strategies to position the company as top suppliers with its technological tools (Industry 4.0, e-commerce, virtual-reality, customer experience, etc.). Nutec Bickley is going to expand its market coverage in product portfolio, and it will continue with its huge efforts in the company's culture by improving its PESQ Model (Performance + Execution + Service + Quality). Nutec Bickley is constantly re-structuring in order to meet its main goals.

IHEA 2021 CALENDAR OF EVENTS

SEPTEMBER 27–NOVEMBER 5
Fundamentals of Industrial Process Heating | Online Course

NOVEMBER 9–10
IHEA Combustion Seminar
InterContinental Hotel Cleveland | Cleveland, Ohio

NOVEMBER 9–10
IHEA Safety Standards & Codes Seminar
InterContinental Hotel Cleveland | Cleveland, Ohio

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

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

Costs, pump availability, and size consideration often affect decisions regarding the number of agitation units needed.

Estimating required flow through quench tanks

In this month's column, I will discuss a method of estimating the required flow for a quench tank.

Agitation has a significant effect on quenching speed. It reduces the duration and stability of the vapor phase and increases the maximum cooling rate. Effective agitation is essential to ensure that optimum properties are obtained, to maintain circulation of quenchant around the parts, and to obtain uniform temperature in the bath.

Agitation can be provided by load oscillation, pumps, or impellers. With pumped circulation or propeller agitation, baffle or manifold arrangements are desirable to direct the flow of quenchant upward around the components.

While impeller agitation is easy to design, install, and maintain, it is sometimes difficult to add to an existing quench tank due to space limitations. In these circumstances, the introduction of pumped circulation through manifolds may be preferable.

Impeller-type agitators are designed to move large volumes of liquids at low head pressures. This is typically encountered in quenching operations. As a rule of thumb, an impeller mixer will move about ten times the volume that a centrifugal pump with the same energy [1].

A pump is designed to move liquids against a high static head. As such, they have a smaller discharge capacity for the same energy as an impeller. Pumps can provide proper quenching conditions. However, there must be enough in number, and properly positioned to provide proper quenching.

On small, low-production items, agitation can be accomplished by moving the part or a small basket or tray of parts through the quenchant by hand. Work pieces may also be driven mechanically with respect to the quenching medium. For example, shafts are sometimes rotated in the quenching medium to produce the effect of agitation. Propeller or pump agitation is more desirable, however, because it is more controllable and less dependent on the operator.

Compressed air is not recommended since it produces a non-uniform quench, accelerates the oxidation and aging of quenching oils, is likely to introduce water contamination and increase fire hazards, and can promote foaming in water-based quenchants.

The type of agitation selected is dependent on the type of parts being quenched, and the volume of the quenchant to be agitated. Selection is often based on economics and not proper quench tank design.

Agitation is critical for quenching uniformity and proper control of distortion. It reduces surface-to-surface thermal gradients and provides for uniform heat transfer and uniform flow throughout the workload. It wipes the vapor blanket from parts to achieve proper quenching and minimizes persistent vapor that is trapped in keyways or blind corners. Racking and agitation work together to provide low distortion parts.

As agitation is increased, the vapor phase becomes less stable, and heat transfer increases. In the nucleate boiling region, there is little effect. In the convection region, heat transfer increases with increasing agitation. This effect is more pronounced with straight oils than with accelerated oils.

Kavskii and Zhelokhovtseva [2] showed that non-uniform cooling, particularly in the martensitic transformation range, would result in quench cracking and high residual stresses.

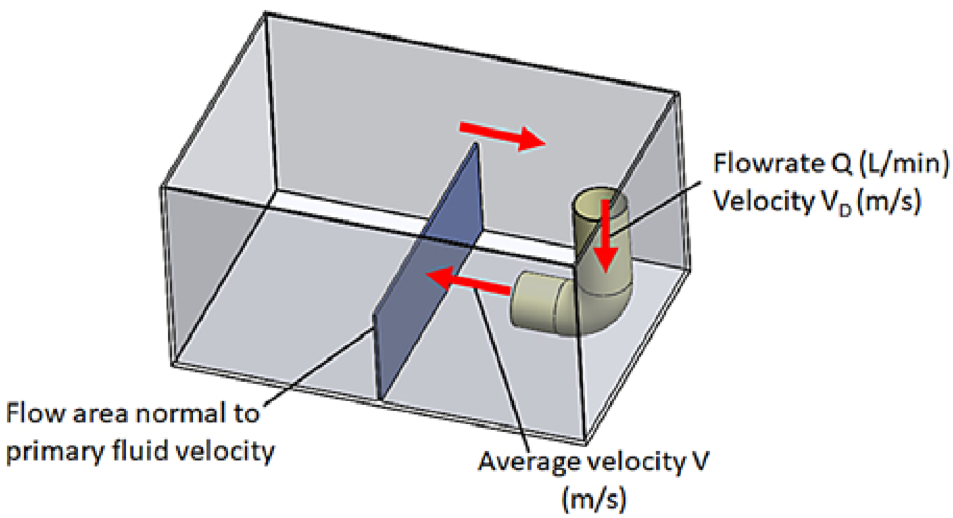

Figure 1: Schematic of a simple quench tank showing method of determining average flowrate required.

The problem of achieving quench uniformity is that the flow through the quench tank and through the workload is non-uniform. It is the purpose of the designer to intelligently design the quench tank to achieve proper uniform agitation. First, it is necessary to determine the actual flow required through the quench tank, then determine how the flow is to be achieved, whether with pump or agitator. Finally, the placement of agitators and pump outlets and inlets needs to be determined, so that proper uniform flow around parts is achieved.

ESTIMATING REQUIRED FLOW

Typical velocities, not exceeding 0.5 m/s, are encountered in immersion by gravity. Intermediate velocities, ranging from 1.1 to 1.8 m/s are achieved in hand quenching. Spray quench rings are usually oper-

The type of agitation selected is dependent on the type of parts being quenched, and the volume of the quenchant to be agitated. Selection is often based on economics and not proper quench tank design.

ated between 4.6 and 30 m/s but special applications sometimes use velocities as high as 150 m/s. In most applications, the typical agitation rates observed in commercial quench tanks are 0.25-1.5 m/s. This wide range of available fluid velocities in even similar type of quench tanks makes comparison of results in different operations, or even in the same plant difficult.

For most applications, a velocity of 0.5-1.5 m/s average flow velocity past the part is necessary for proper quenching. Generally, low density loads will require velocities of 0.5-0.75 m/s, whereas densely packed loads may require velocities greater than 1.0-1.5 m/s.

Determining the proper flow rate is one of the more difficult operations required for a quench tank. One method of calculating the necessary flow rate is by first determining the necessary velocity required for proper quenching. While this may require detailed quenching studies for precise calculation, simple approximations can be made.

The average desired velocity past the part is then multiplied across either a horizontal or vertical cross section of the quench tank (Figure 1), depending on what makes sense and whether a convenient plane of symmetry exists. In the case of Figure 1, only half the cross section of the quench tank was used, to provide for return flow to the agitator.

For integral quench furnaces, or sealed quench furnaces, it is usually convenient to take a horizontal cross section through the entire quench zone. This method is appropriate for determining the necessary flow rate for either pumps or impeller-type agitation. This average velocity value then translates into the necessary flow rate, Q up through the workload. Slight tank geometry changes can be tolerated provided the average fluid velocity past the part is maintained.

Once the necessary flow rate (m3/s or ft3/m) is determined, and an estimate of the number of pumps (or impellers) required is made, the flow rate per agitation unit (pumps or impellers) is determined. The number of agitation units is often based on economic reasons, pump availability, or size considerations.

CONCLUSIONS

In this short column, a method was described for calculating the necessary flow through a quench tank. In the next installments, we will discuss choosing pumps or impellers, and placement of the agitators.

Should you have any comments on this article, or suggestions for further columns, please contact the editor or myself.

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[1] United States Steel, "Improved Quenching of Steel by Propeller Agitation," United States Steel, Inc., Pittsburgh, PA, 1957.

[2] N. N. Kavskii and R. K. Zhelokhovtseva, "Optimum Cooling During the Quenching of Steel," Izv. VUZ Chernaya Metall., vol. 3, pp. 111-113, 1982.

ABOUT THE AUTHOR

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TONY TENAGLIER
HEAT TREAT PROCESS ENGINEER ///
HITCHINER MANUFACTURING

Employees may not go through the grueling training of a pro athlete, but the end result is still to serve the team and deliver a winning product.

It's time to recognize 'fitness' at work

Almost every child who grows up playing sports dreams of being a professional one day and playing on the big stage (instead of going to school to get a degree and then a job in that field). I remember the NCAA commercials when I was in college encouraging athletes to "go professional in something other than sports" because — let's be honest — not everyone who plays is going to be the next Tiger Woods in golf or Mia Hamm in soccer. Therefore, the sport most of us play each day is that of the industrial athlete. The playing field consists of resumes, interviews, meetings, and reports. The rules concern business, economics, profitability margins, and products that meet quality and consumer expectations. Typically, the game goes on Monday through Friday, with a weekend halftime, and scoring a paycheck every other week, instilling the habit of building a successful team to work and play with every day.

It is a sport that requires a different sort of peak performance, not in terms of pushing human capabilities with a soccer ball or golf club, but more of using a different set of skills carefully and successfully — but often without enough commendation. We tend to envy the yogi who does a split or the professional golfer who wins a major tournament, but overlook the factory worker who splits components with extreme skill and deft use of tools to produce a final part and bring the company successful business for days to come. Desiring recognition of a job well done is not limited to the sports athlete; industrial athletes hone their own skills and also take pride in tasks well done.

In order for a company to succeed, it needs a quality product produced by workers who know their job and take pride in doing it well. The saying, "Just showing up is half the battle," can be applied to the work environment. Obviously, nothing will get done without employees. So, it's important to show up to work on time and make the meetings, else you could get fired and the manufacturing process is affected. Of course, physical performance at work goes beyond just showing up. Sure, there is no need to do a certain number of pushups or sit-ups or some sort of somersault before being allowed into the office, but there is a demand physically on the employees and an expectation beyond just the ability to walk around the facility and sit in and get out of your chair.

What is expected physically is the continual awareness of and endurance for the seemingly simple tasks that make up most jobs.

This isn't to suggest you need to write a report to your boss on how well you sat at your desk prepared for work. No, physical performance at the workplace is more in the awareness of posture, for example, or using proper technique. Work is not a gym. You are not trying to build muscle or working on shaping your body. However, certain factory movements require the human body to move efficiently and quickly and capably to process parts. Awareness of the precision and importance of these movements is key to creating longevity in the sport of showing up every day and participating at work.

Work is a place to build a team, to follow the rules, and excel at reaching company and personal goals. This similarity to sports is often not recognized enough in work cultures, and it's certainly not played out on big time broadcasts each week.

It's an awareness that avoids slouching at your desk after writing a long report or preparing a presentation. It's the awareness of taking each step walking around the floor, not just for safety of where you could trip, but in presenting confidence of movement.

Today's top athletes each seem to have his or her own "mental process" for succeeding. I've been told company goals are much the same for every employee, and the points of disagreement often lie in the approach to achieving those goals. Disagreements are not typically in the vein of "let's not ship more product on time" but rather on "let's get this done" decisions such as running lot A before lot B or changing a temperature or parameter for a trial to dial in the requirements to get something done right. Finding the correct approach to achieve the goal is the area in which employees typically disagree.

Every golfer knows the goal is to get the ball into the hole with the fewest number of shots. Each one will have a different approach to making that happen. They might hit the golf ball left-handed or right-handed. Maybe their shot is a draw or a fade. The technique is up to the athlete — or, in manufacturing, the employee.

I often think back to meetings where I disagreed with someone on my team on how best to get product shipped out the door. I know what they are trying to do is right in their mind, and I am also thinking that my idea is the right way as well. Realizing there are different ways to solve a problem requires a sense of willingness to see the other perspective and be open to criticizing my own. The challenge is to continually work at better understanding myself and others in the context of working together in the constructs of the company.

The point of exercise each day is the test of habit for anything that we do, including our job performance. If we want to get good at a sport, we know we have to practice, study, practice, adapt, etc. At work, we have that same opportunity each day to work on our skills, to make habits that are healthy for the long-term game being played at the company and for our role in achieving good results.

Companies don't want employees who resemble a wave of New Year's resolution makers heading to the gym for three months to work out and then giving up. Manufacturers want employees who set realistic goals and who are willing to work consistently toward them. Job performance goes beyond simple objectives to be attained and goals to strive toward. It is the discipline of physical and mental performance every minute of every day, striving to provide products that consistently pass tough specifications. It is the pride industrial athletes take in their work, just as sports stars do with their work.

Work is a place to build a team, to follow the rules, and excel at reaching company and personal goals. This similarity to sports is often not recognized enough in work cultures, and it's certainly not played out on big time broadcasts each week. The physical and mental performance of employees is as commendable as the efforts of those winning tournaments on TV. Their awareness of solid physical (and mental) posture throughout the day shows confidence and an openness for the idea that goals can have several approaches to success. These are good habits for employees and employers to win at being a good company.

ABOUT THE AUTHOR

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

THE NEXT LEVEL OF HOT ISOSTATIC PRESSING

Hot isostatic pressing has been used widely for many years and is a well-known and trusted process to guarantee materials for demanding environments, and it is being used as a central technology for upstream production processes such as casting, MIM, and additive manufacturing.

By JIM SHIPLEY

Over recent years, the development of in-HIP heat treatment (High Pressure Heat Treatment) has led to some interesting developments, which are now changing the heat-treatment industry. Hot Isostatic Pressing (HIP), which is an essential process to remove defects and improve the mechanical properties of materials for critical components, has previously been followed by heat treatment in another piece of equipment; however, new possibilities to conduct heat treatment in the HIP vessel have seen many end users developing new procedures for critical applications.

Modern HIP machinery is an extremely good fit with the traditional heat-treatment market, offering thermal treatment that further improves material properties with the opportunity to steer HIP cycles and ultimately material microstructures. This technology has already been adopted by many OEMs who have insourced the HIP process to gain flexibility in their production. The service market has also seen an increased growth predominantly through existing heat-treatment companies adding capacity to service end-user demand and broaden their supply portfolio.

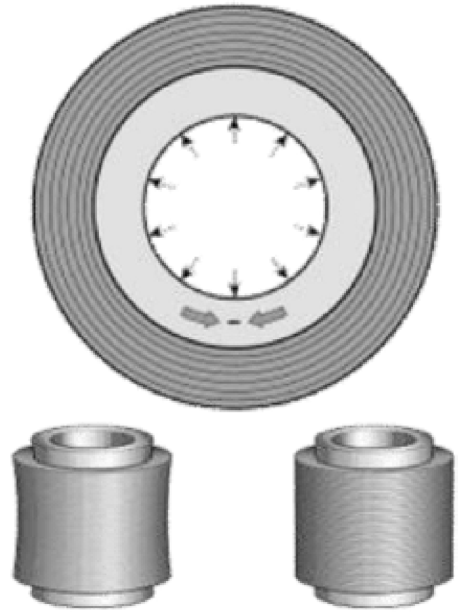

Figure 1: Wire wound forging. ©Quintus Technologies

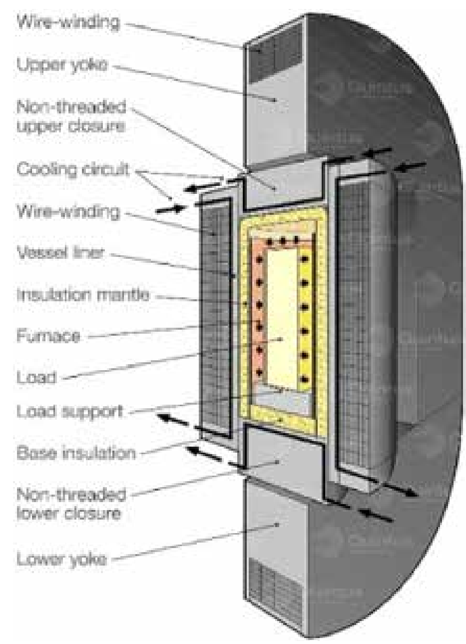

Figure 2: Schematic of a HIP pressure vessel. ©Quintus Technologies

QUINTUS TECHNOLOGIES – THE HIP PIONEER

Quintus Technologies has been the pioneer in the HIP market since the first patents back in the 1950s. Modern hot isostatic pressing equipment is typically operated at working temperatures up to 2,000°C (3,632°F) and pressures up to 207MPa (30,000 psi) as standard.

Pressure containment in the Quintus equipment uses wire-winding of forgings to induce compressive stresses in thin-walled forgings, which adds immense strength while preventing any possible crack propagation in the forging itself. A wire-wound frame is used to keep the end closures in place during the HIP cycle (see Figures 1 and 2). The design fulfils the demands of ASME Boiler & Pressure Vessel Code, Section VIII, Division 3, Pressure Vessel Directive 2014/68/EU, TSG 21-2016 (for A1-classed pressure vessels in P.R. China), the High-Pressure Gas Safety Act checked by the High-Pressure Gas Safety Institute of Japan (KHK), and The High Pressure Gas Safety Control Act checked by Korea Gas & Safety (KGS).

Usually, the payload is treated at 80 to 90 percent of the melting point, to induce creep, diffusion, and homogenization of the microstructure. In this extreme environment, porosity and other internal defects are healed, leading to improved mechanical properties with significantly reduced scatter. There are some exceptions to this rule of thumb, including ceramics and some metals such as titanium, which are processed at temperatures well below melting point for other reasons. Most metals are treated in molybdenum furnaces, which are designed for temperatures up to 1,400°C (2,552°F).

The largest application area for traditional hot isostatic pressing has been the densification of castings for industries with very high demands on fatigue resistance, such as the aerospace industry and industrial gas turbine industry. The advent of additive manufacturing is leading to an ever-increasing demand for HIP to ensure material performance in all manner of demanding application areas from orthopedic implants to racing cars and rocket engines.

Hot isostatic pressing is a batch process where parts are loaded into the chamber using load baskets or a load base, depending on size and customer requirements. Quite often, operators prefer two load bases to be able to unload/load while another cycle is running for productivity reasons. Each batch, as with other batch type furnaces, is subjected to a specific environment based on the material, the gas used, the cleanliness of the load, furnace furniture, and is dependent on operational procedures. Once the load is sealed and pressurized, purging and vacuum cycles are used to remove moisture and contaminants prior to pressurization to ensure a correct environment. Typically, 4.8 argon gas is used, although nitrogen gas is commonly used for some materials.

THE QUINTUS FURNACE DESIGN

There are a few basic material options for the furnace construction. Usually graphite is the material of choice for furnace temperatures above 1,400°C (2,552°F) while molybdenum is the predominant choice below this.

Quintus Technologies is focused on fan driven convection to ensure temperature uniformity during heating, sustain, and cooling. Not only is the gas forced around and through the payload to uniformly heat the payload, but it also can be directed over cooler surfaces to uniformly cool the load and increase cooling speeds (see Figure 3).

MODERN FEATURES THAT ENABLE LEAN MANUFACTURING

The wire-wound design of Quintus HIP vessels facilitates the addition of cooling channels close to the pressure vessel forging. Coolant is then used to ensure the wire-winding remains below design temperatures to maintain its strength. This same coolant loop can be used as a heat exchanger to remove heat from the cylindrical vessel and, consequently, the payload. The removal of heat is increased by improving the heat transfer through faster convection and more efficient heat transfer. Hence, the fan is key to the improvement of heat treatment capability. The first use of the fan in this way was developed by Quintus Technologies and has been around since the 1980s. It is known as Uniform Rapid Cooling or URC®.

SO HOW FAST CAN A MODERN HIP COOL THE PAYLOAD?

Today, larger Quintus production HIPs are able to cool the payload material itself at rates well in excess of 200°C/min (360°F/min), and smaller equipment focused on additive manufacturing and nickel-base super alloys can reach cooling rates in excess of 8,000°C/min

Hot Isostatic Pressing has been used widely for many years and is a well-known and trusted process to guarantee materials for demanding environments.

(14,432°F/min). Production equipment from Quintus Technologies is therefore on par with oil quenching or faster for the cooling part of the HIP cycle. This gives rise to significant opportunities to quench material while under pressure in the HIP. Each HIP cycle consists of a number of steps, which are programmed into one sequence comprising: loading; vacuum cycle (to remove contaminants such as oxygen); heating, including pressurization, holding, cooling, de-pressurization, and release.

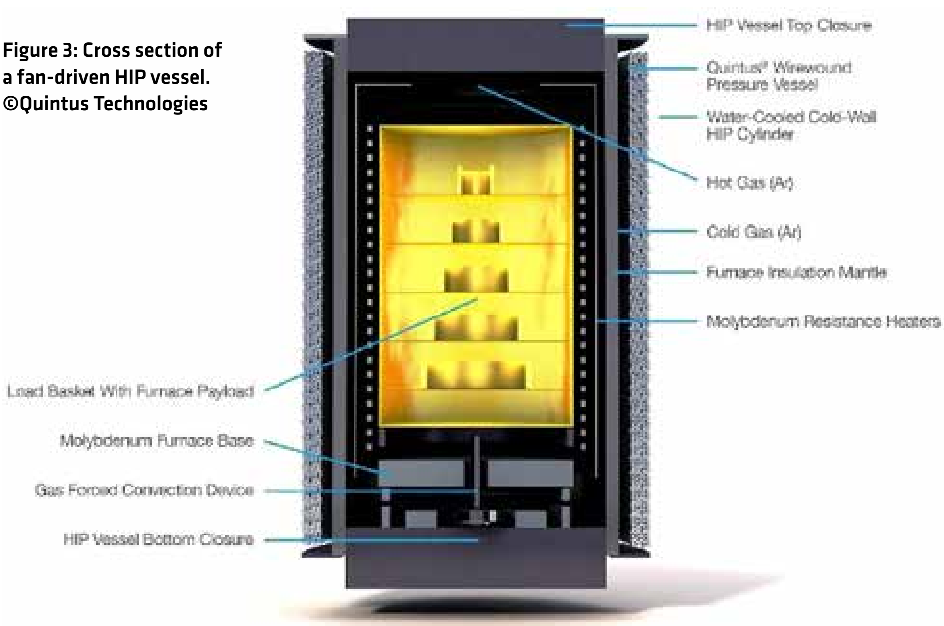

Figure 3: Cross section of a fan-driven HIP vessel. ©Quintus Technologies

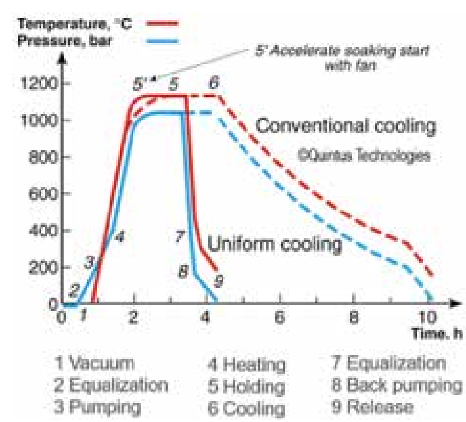

Figure 4: Uniform cooling vs. conventional cooling. ©Quintus Technologies

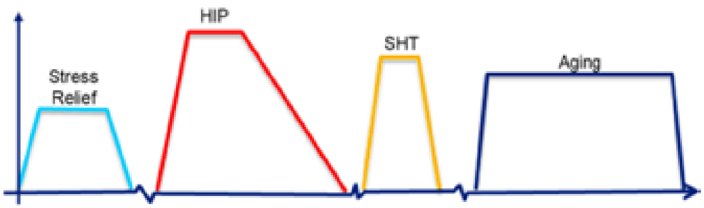

Figure 5: Typical thermal processes for additively manufactured parts.

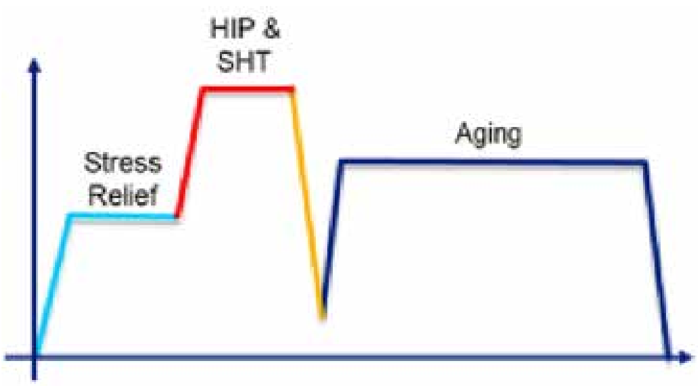

Figure 6: High pressure heat treatment process for the same parts, using an integrated heat treatment approach.

Initially, high-speed cooling was developed to increase productivity by shortening the HIP cycle through reduction of the cooling step. This typically shows quite dramatic reductions compared to conventional cooling (or turning off heaters and allowing the vessel to cool naturally). Times vary depending on alloy and starting temperature, the size of vessel, and the payload. This can be seen in Figure 4, where Uniform Rapid Cooling, URC® is illustrated.

HIGH PRESSURE HEAT TREATMENT, HPHT

The ability to cool really fast and control the cooling rate after the soaking time during a HIP densification cycle is a significant and key development for the heat-treatment industry. This leads to the possibility to combine several thermal processing steps into one

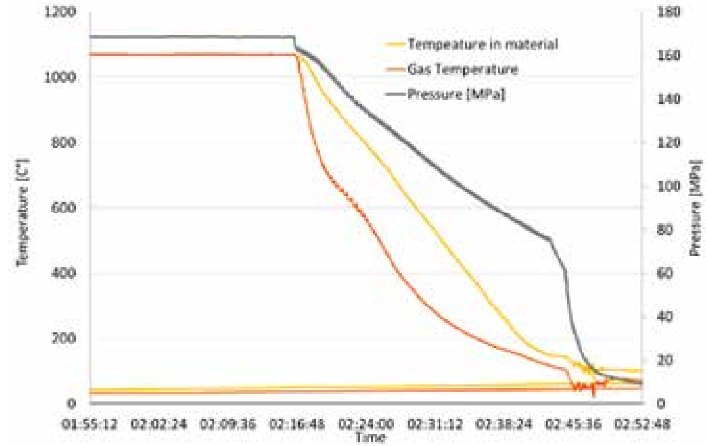

Figure 7: Example of steered cooling for a nickel-base superalloy. Material core cooling rate set at 30°C/min controlled by a load thermocouple, LTC.

cycle, conducted at the same time, under pressure. This technology has become especially of interest for additive manufacturing (AM), but also for the tailoring of microstructures for nickel-base superalloys and other cast materials. During the heating of the payload in the HIP, stress relief occurs, and this has allowed some companies to process material while on the build plate to avoid an operation and to avoid cracking or warping of parts during part removal. HIP directly on the AM build plate is especially of interest for crack sensitive alloys. The HIP soak temperature is usually equal to, or slightly above, the solution heat treatment (SHT) temperature, and as such, the load can either be cooled to the desired SHT temperature prior to starting cooling or can be cooled directly from the HIP soak temperature. This depends on the alloy, as well as the desired properties of the material.

Cooling the material from the SHT temperature at a chosen cooling rate is fully possible in modern HIP equipment using fan control, and cooling can also be stopped at a chosen temperature prior to subsequent aging if needed. The combined or integrated heat treatment approach inside the HIP vessel is known as High Pressure Heat Treatment (HPHT). See Figures 5 and 6.

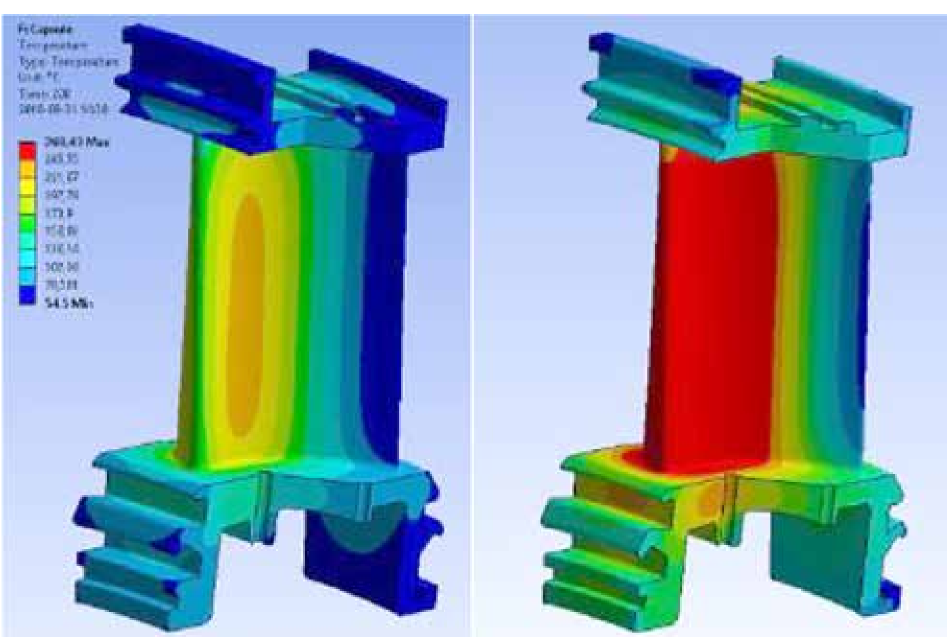

Figure 8: Finite element modeling at 150MPa (left) and 50 MPa (right) showing the effect of pressure on the heat transfer coefficient, HTCα. [1]

RECENT DEVELOPMENTS

Steered Cooling

There are several interesting and important developments in terms of the controllability of the HIP process that have now become central to many HPHT discussions. Especially important is the applicability of HPHT as a process to adjust and tailor microstructure. The heating and cooling rate of the HIP can be steered using load thermocouples (LTC) to set the cooling rate of the equipment based on the actual material temperature. This is especially interesting when considering different thicknesses of parts in the HIP load. The machine can therefore be programmed to steer the material core cooling rate in a closed control loop with the LTC, based on the thickest component (see Figure 7).

Higher pressures give higher cooling rates

The effect of the HIP pressure on the heat-transfer coefficient, HTC , has been demonstrated in recent studies. The use of this knowledge makes it possible to model the cooling rate for a specific machine, specific part geometry, and HIP parameter set (pressure, temperature, cooling rate). The modeling can then be verified using steered cooling in actual cycles. The heat transfer is improved with the use of pressure, and the cooling rate seen in the HIP is increased with the HIP pressure, so various scenarios can be simulated. This is demonstrated in the finite element simulations (FEM) shown in Figure 8 where the cooling rate of the same turbine blade has been modeled at 150 MPa and 50 MPa. So, in short, parts can be cooled more quickly by using higher pressures.

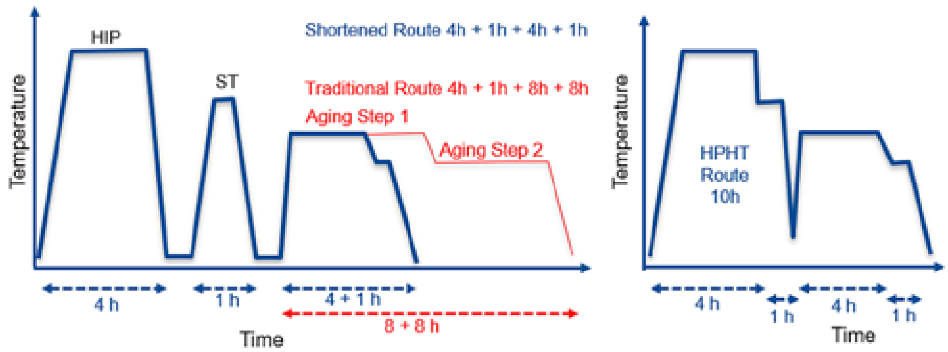

Figure 9: Illustration of a traditional production route (red solid line) and shortened (blue solid line) post-treatments for EBM Alloy 718 compared with a full HPHT cycle, reducing cycle time by 50 percent. [2]

Tailored HIP cycles

The tailoring of HIP cycles to improve properties is a new area with great interest for many companies. Due to the excellent controllability of modern HIP and HPHT processes, tailored heating, sustain, and cooling cycles can be programmed for specific material properties. This is an area of extensive research and is especially of interest for materials needing high cooling rates or having an extremely tight cooling corridor. An excellent example of tailored HIP cycles can be seen in recent work by Goel et.al. at the University West in Sweden showing the possibility to reduce the standard 24-hour thermal treatment cycle for EBM produced IN718 by 11 hours with improved properties. See Figure 9.

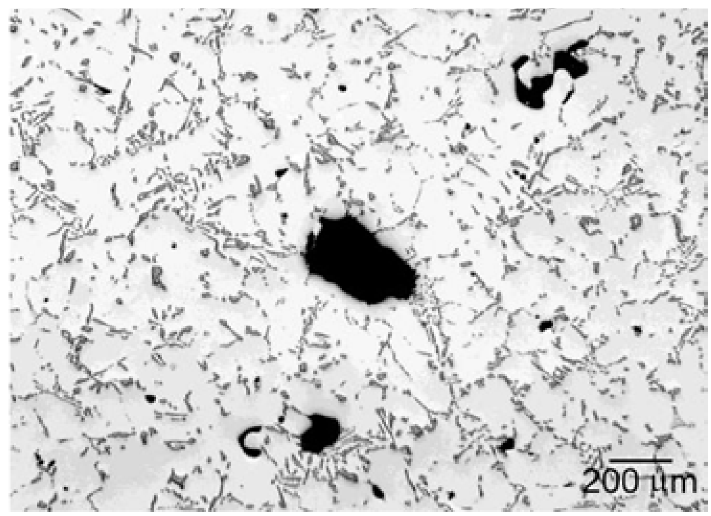

Figure 10: Porosity in cast material. [3]

WHERE IS HIP USED?

All modern-day metallurgical processes have well established histories using HIP. Cast material has been HIPed since the introduction of HIP as an industrial process in the mid-1960s predominantly to remove porosity and to improve fatigue resistance. See Figures 10 and 11.

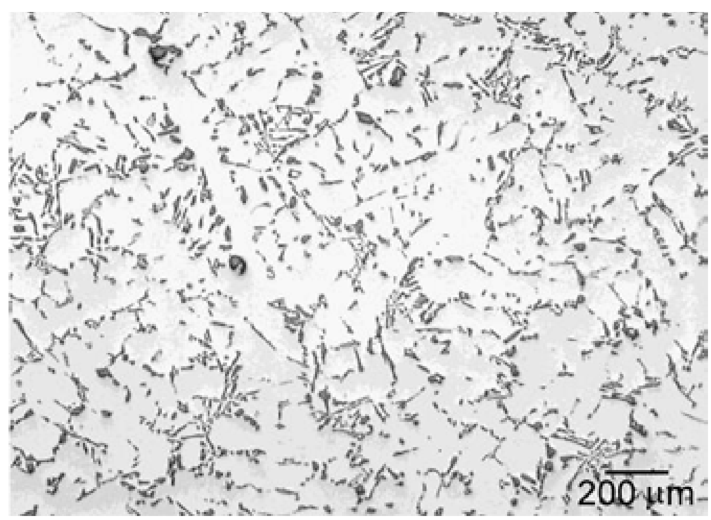

Figure 11: Post HIP micrograph of the casting. [3]

INDUSTRIAL ROBUSTNESS

Hot Isostatic Pressing has been used widely for many years and is a well-known and trusted process to guarantee materials for demanding environments. The introduction of the next level of technology, including heat-treatment steps, is a way to further tailor production processes and reduce product lead time. This is increasingly being used as a central technology to ensure product quality and removes uncertainty in product quality from upstream production processes such as casting, MIM, and additive manufacturing.

As for all production processes, lean manufacturing is key to improve product quality, reduce costs, and maximize productivity. Reducing waste and increasing throughput should always be in focus, but simply adding upstream capacity may not be the way forward. The addition of HIP with heat-treatment capability as part of the production chain can facilitate robust and lean processes through reduction of yield losses, logistics, and quality related costs.

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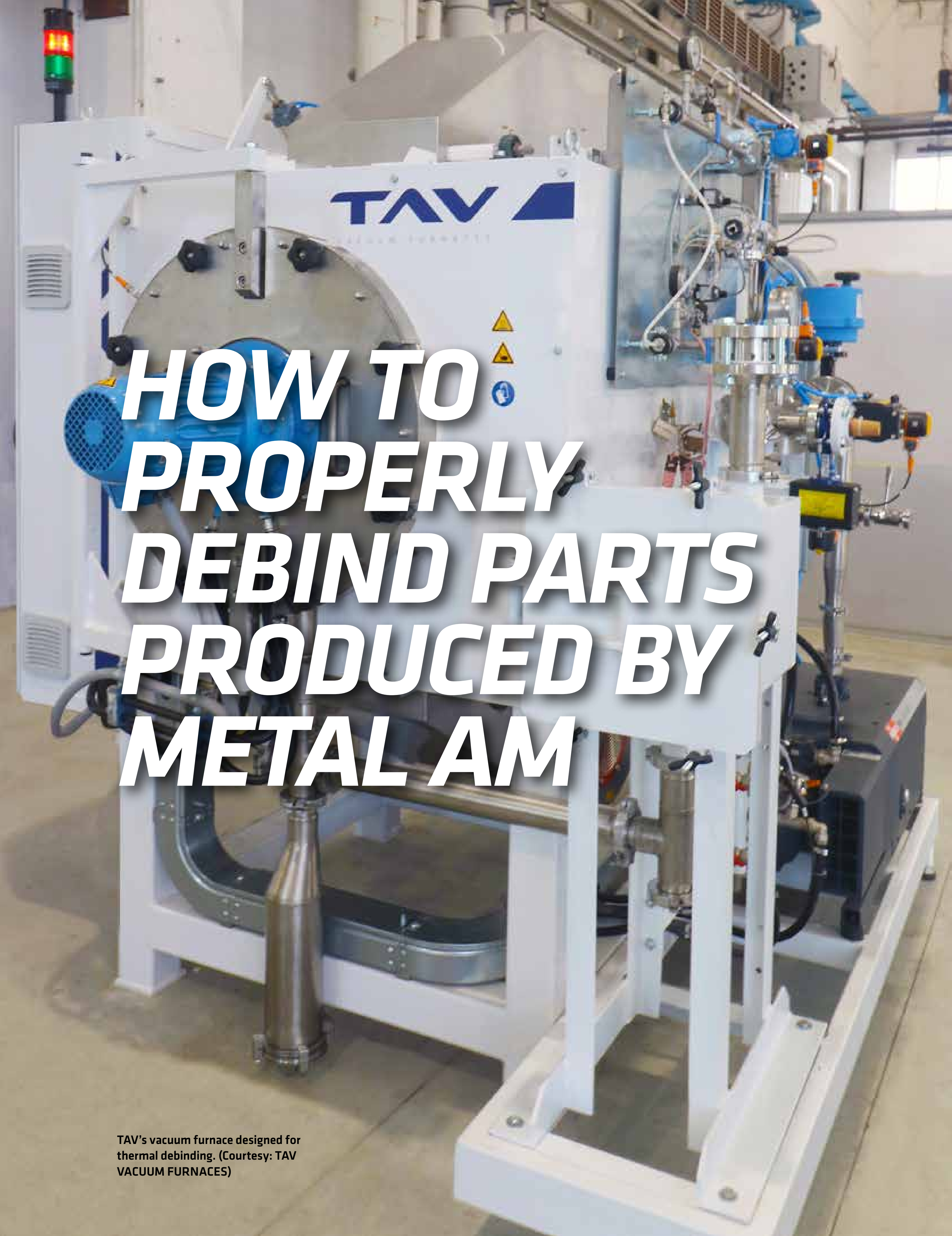
HOW TO PROPERLY DEBIND PARTS PRODUCED BY METAL AM



TAV's vacuum furnace designed for thermal debinding. (Courtesy: TAV VACUUM FURNACES)

Additive manufacturing cannot ignore the process of post printing thermal debinding, which has the purpose of separating the polymers from the metal powder, thus obtaining a sample to be sintered.

By ANDREA GIONDA

Additive manufacturing is a manufacturing technology that is gaining more and more ground among metallurgists. The process involves all the techniques used to create 3D-metal objects from a digital design.

The production of three-dimensional solid objects using AM technology is different from traditional subtractive manufacturing, which uses a block of solid material from which excess pieces are removed to produce the desired shapes.

Metal additive manufacturing, on the other hand, adds material, step-by-step, until the required object is obtained.

Some reasons to approach these new technologies include:

» The costs of 3D printers are falling, thanks to the remarkable advances made in technology.

» The geometric limits imposed by subtractive manufacturing no longer exist.

» It is possible to create multiple versions of the same product, without varying the cost of production.

» A drastic reduction of processing waste is obtained.

The notable increase in the world of metal additive manufacturing of the use of methods such as the Metal Injection Molding (MIM), the Binder Jetting (BJ) and the Fused Deposition Modeling (FDM), prompted TAV VACUUM FURNACES to design and install a vacuum furnace for thermal debinding in its Research and Development laboratory in order to experiment the best solutions for this delicate post-production phase.

WHAT IS THERMAL DEBINDING IN METAL ADDITIVE MANUFACTURING?

Additive manufacturing cannot ignore the process of post-printing thermal debinding.

The printing of the samples is carried out thanks to the extrusion of a mixture of metal powder and polymer until the desired shape and size is obtained.

Polymers, also called the binder, consist of a mixture of organic compounds of different types and quantities, with different melting points.

Thermal debinding has the purpose of separating the polymers from the metal powder, thus obtaining a sample to be sintered.

Simply put, the treatment of debinding consists of the complete evaporation of the binder to deprive the metal sample of any organic compound, leaving it intact for the next vacuum sintering.

HOW TO DEBIND AFTER METAL 3D PRINTING

The debinding plant of the TAV VACUUM FURNACES R&D laboratory is able to remove the polymer and condense it into specific traps, avoiding contamination of the thermal chamber and samples in the subsequent processing stages.

The laboratory debinding furnace is therefore equipped with different technical features capable of satisfying the requirements of the additive manufacturing world.

The storage tank. (Courtesy: TAV VACUUM FURNACES)

THE HEATING SYSTEM

The heating system, which plays a fundamental role in the debinding process, is based on the following components:

» **Armored resistors:** They constitute the heating system, interposing in the insulation between the furnace and the thermal chamber.

» **Control thermocouples:** They regulate the process and are placed both in the furnace and in the thermal chamber in order to reach the specified temperature with a high degree of precision.

The working temperatures in the debinding phase are in the range between 70°C and 450°C, corresponding to the melting temperatures of the various organic compounds.

THE GAS

An essential role in debinding is the presence of inert gas.

Gases act as a carrier of the degrading components, avoiding oxidation and reduction phenomena on the metal surface of the sample.

The furnace is designed for debinding of different materials with different gases. They include:

» For stainless steels and Inconel, nitrogen is used.

» For titanium alloys (like Ti-6Al-4V), the use of argon is possible.

During the thermal cycle, it is essential to ensure a homogeneous distribution of the gas carrier in the thermal chamber in order to ensure the homogeneous removal of polymers from the sample.

In particular, TAV VACUUM FURNACES has installed a convection impeller able to make the gas flow inside its vacuum furnace uniform.

HOW TO AVOID CONTAMINATION DURING DEBINDING

In the polymer degradation step, the evaporated binder can condense as a liquid or as a powder.

For this reason, TAV VACUUM FURNACES designed and installed containers able to collect the degradation products of the debinding.

The collection, located in specific storage systems, allows a specific removal of the stearate, excluding contamination of the thermal chamber and the samples themselves.

The ideal solution is to install a storage tank and a trap in series, all supported by an efficient cooling system:

» The storage tank is used for the collection of stearate, which condenses on the cold walls in the liquid phase. In case of excessive accumulation of post process binder in the tank, the tank can be disassembled and cleaned.

» The degradation products in solid form are instead concentrated in one special trap. The trap consists of water-cooled copper coils surrounded by metal straw. In addition, there are steel grids with gradually finer meshes from bottom to top able to filter the decomposed binder with increasing efficiency.

» The cooling system of the furnace is equipped with an impeller present in the area below the system. The cooling impeller has the purpose of sucking air from the outside and transferring it to the furnace, avoiding contact with the thermal chamber.

The growing pervasiveness of additive manufacturing both at a technological and commercial level, has led TAV VACUUM FURNACES to face and support this technology with increasingly specific systems for debinding and sintering.

The trap. (Courtesy: TAV VACUUM FURNACES)

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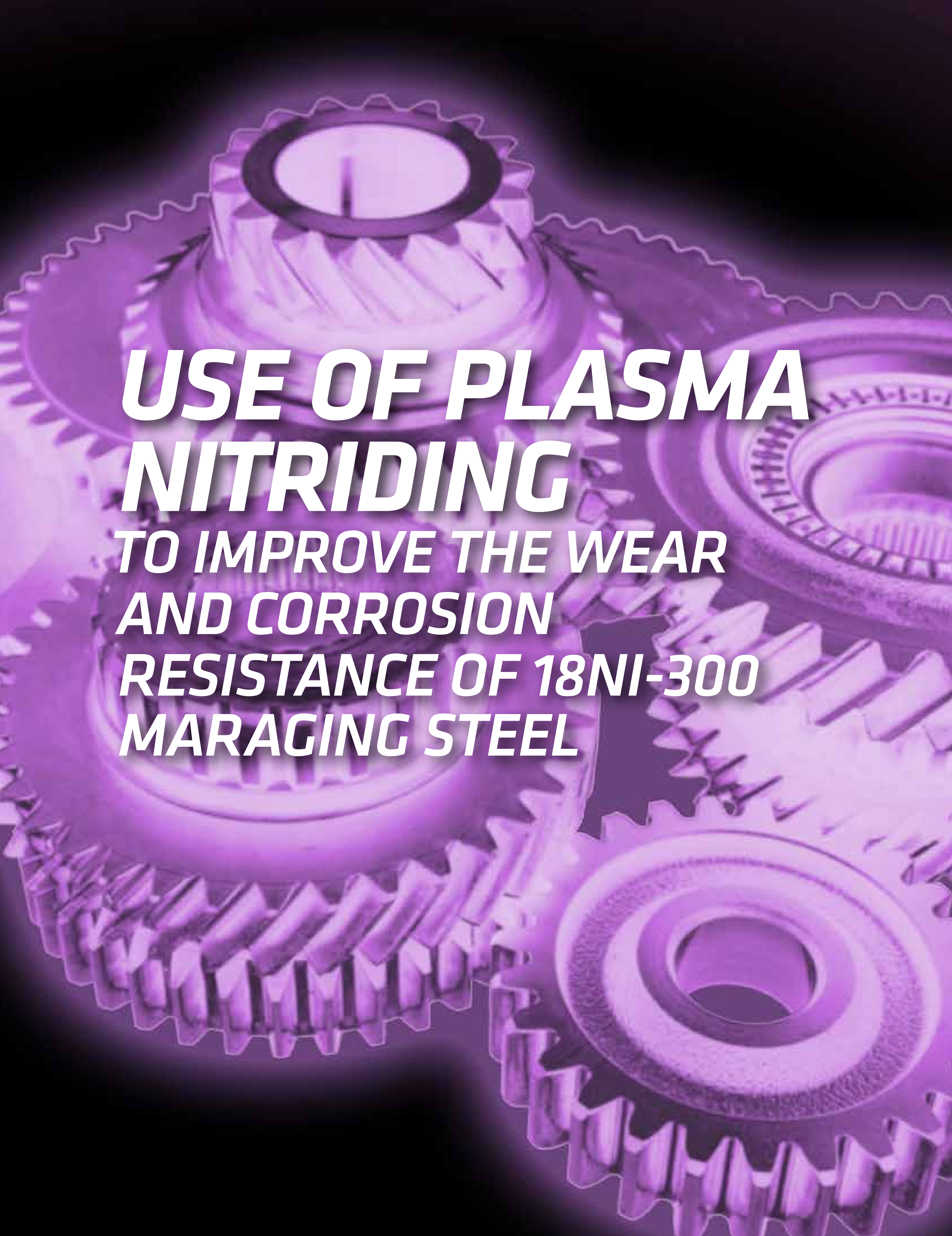
The cooling system of the furnace is equipped with an impeller present in the area below the system. The cooling impeller has the purpose of sucking air from the outside and transferring it to the furnace, avoiding contact with the thermal chamber.

The cooling impeller. (Courtesy: TAV VACUUM FURNACES)



USE OF PLASMA NITRIDING

TO IMPROVE THE WEAR AND CORROSION RESISTANCE OF 18NI-300 MARAGING STEEL

18Ni-300 maraging steel manufactured by selective laser melting was plasma nitrided to improve its wear and corrosion resistance; the effects of a prior solution treatment, aging, and the combination of both on the microstructure and the properties after nitriding were investigated.

By M. GODEC, B. PODGORNIK, A. KOCIJAN, Č. DONIK, and D. A. SKOBIR BALANTIČ

Selective laser melting (SLM) is one of the most promising additive-manufacturing (AM) technologies [1-3]. It is a powder-bed fusion process, where a high-power laser beam is used to selectively melt the powder feedstock in a layer-by-layer fashion [4]. A variety of metallic powders has been successfully employed, including pure metals (Ti, Al) [5-8], alloys (steels, Ni-based alloys) [9,10] and metal-matrix composites (MMCs) [11]. Compared with conventional manufacturing procedures, SLM offers several advantages, such as near-net-shape fabrication, the rapid production of components with complex geometries, little material waste, and all this at an acceptable cost. For these reasons, it has been widely applied in several strategic industries, including aerospace, automotive, biomedical, and electronics as well as in tool manufacturing for the production of inserts with conformal cooling channels and components with high geometrical complexity [12,13], i.e., the primary application fields of maraging steels [14,15]. Maraging steels, which belong to the group of tool steels, can be, due to their low carbon content, easily welded and also selective laser melted, and are therefore among the most used and researched in the field of AM technologies. The most investigated maraging steel for AM is the US classification 18Ni-300 (European, 1.2709; German X3NiCoMoTi 18-9-5) [4,13,16-18].

In general, 18Ni-300 maraging steels belong to the class of low-carbon iron-nickel alloys with an exceptional strength-to-toughness ratio, good ductility, machinability, and weldability, making them appropriate for use in aircraft, aerospace, molds, and tooling [12,19,20]. The ultra-high strength is the result of the hardening mechanism during the aging treatment, where the precipitation of nanometer-sized intermetallic particles (Ni3(Mo, Ti), Fe2Mo) takes place [21]. These particles are homogenously distributed in the low-carbon martensitic microstructure, where they inhibit the mobility of the dislocations and, therefore, enhance the microhardness and the strength. The high toughness and ductility originate from the ductile and machinable martensitic matrix [22,23]. However, compared to other tool steels or stainless steels, maraging steels exhibit some disadvantages, mainly related to their poor wear and corrosion resistance [20,24]. Surface-hardening processes such as plasma nitriding have been shown to be beneficial for improving the surface properties of conventionally produced maraging steel. The modified surface is provided by an insignificant reduction in the properties of the base material and with no dimensional change of the component [19,20,25]. Due to the very similar processing parameters (temperatures between 450 and 520°C and times of 1-4 hours) of the plasma nitriding process and the ageing cycle, it is possible to combine both processes into a single unique step. From the industrial point of view, this represents a significant advantage in terms of reducing the costs and times required [26].

SLM is a very complex manufacturing technology that can produce microstructures and properties that can be substantially different to those obtained using conventional techniques. Therefore, the SLM process parameters need to be accurately set and controlled in order to obtain the appropriate microstructure and properties of the manufactured parts. Many investigations of additive-manufactured 18Ni-300 maraging steels dealing with the optimization of the process parameters [27,28] and their influence on the mechanical properties and microstructure can be found in the literature [15,29-34]. There are only a few reports comparing AM with conventional maraging steel [31] because it is difficult to compare those materials without considering the heat treatments. On the other hand, maraging steel still needs to be heat treated after the SLM process to achieve the desired properties. Further, it is to be expected that additional improvements for some applications in harsh environments can be achieved by plasma nitriding, as it is already well known for conventional maraging steel. The AM process leads to a cellular martensitic microstructure with nano-segregations and a small amount of retained austenite [31,35]. After the heat treatment, the process of austenite reversion was reported [14]. Furthermore, the heat treatment for SLM maraging steel can also differ from traditional routes and needs to be optimized [36,37]. Therefore, a lot of attention has recently been devoted to post-process heat treatments, such as solution and aging treatments.

Kempen et al. [29] and Casati et al. [38] studied the effects of different aging temperatures and times on the mechanical behavior of SLM 18Ni- 300 maraging steel. They found that a significant increase in the strength and a decrease in the ductility can be obtained after aging. Casati et al. [38] also concluded the solution treatment is not necessary, and the as-built 18-Ni 300 maraging steel can be directly aged. Tan et al. [13], on the other hand, showed that a combination of solution treatment and aging was crucial for an improvement of the mechanical performance. Yin et al. [39] investigated the influence of aging temperature and aging time on the microstructure, mechanical properties (hardness, strength, ductility), and wear resistance. The maximum strength and wear resistance were obtained after aging at 490°C for 3 hours. Bai et al. [40] performed a series of heat-treatment experiments, including solution treatment (ST), direct aging treatment (DAT) and a combined solution and aging treatment (SAT) on SLM maraging steel for the systematic investigation of their influence on the microstructure evolution, microhardness, tensile properties and toughness. The results show similar mechanical properties can be achieved either by DAT or SAT. However, in terms of the practical application of SLM-processed maraging-steel parts, especially in the tooling industry, the lack of wear and the corrosion resistance still represent a significant challenge.

It is well known that nitriding can substantially increase the life span of conventionally processed tool inserts from maraging steel [41,42]. The positive effect of nitriding has also been reported for AM stainless steel 316L [43]. However, to the best of our knowledge, there are no reports in the literature on the plasma nitriding of AM maraging steel and its influence on the wear and corrosion properties. Therefore, the aim of this study was to investigate the effect of plasma nitriding combined with prior DAT and SAT conditions on the wear and corrosion resistance of SLM 18Ni-300 maraging steel. Based on a literature review, optimal SLM processing as well as post-heat-treatment conditions were applied. The results were compared to the conventional counterparts subjected to the same heat-treatment and nitriding process parameters. Although it would be of great interest to explain the influence of nitriding on the formation of the precipitates, the focus of this work was on an investigation of the influence of the heat-treatment conditions on the nitriding efficiency, the effect of nitriding on the wear and corrosion resistance, as well as a comparison of additive-manufactured and conventional maraging steel when subjected to nitriding. One of the important targets of the investigation was a comparison of the properties (microstructure, hardness, wear, and corrosion resistance) of the AM as-built material with the conventionally manufactured material. The investigation of the precipitation behavior and its correlation with the nitriding will be the subject of a separate publication.

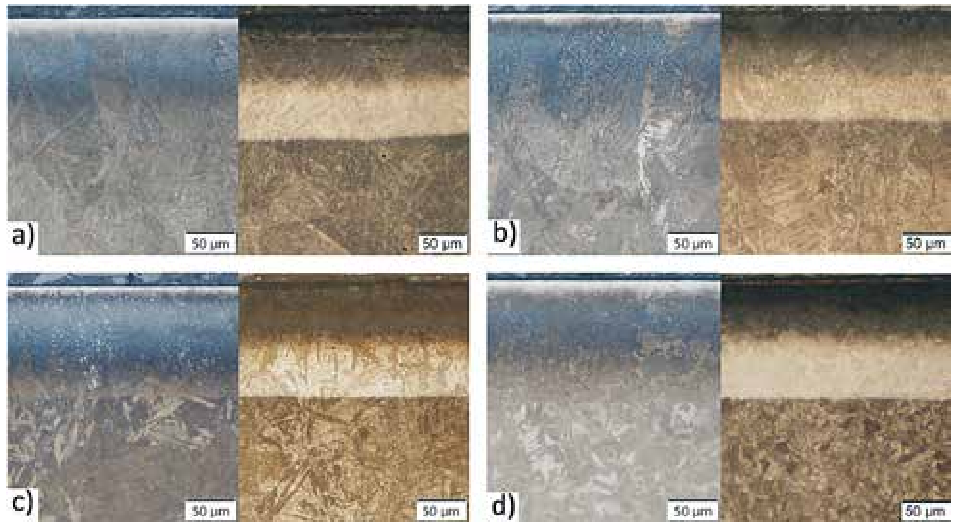


Figure 1: Light micrographs of a nitride layer etched by Nital (left part of the images) and ferric chloride (right part of the images) for maraging samples: (a) AM + N, (b) AM + DAT + N, (c) AM + SAT + N, (d) CM + SAT + N.

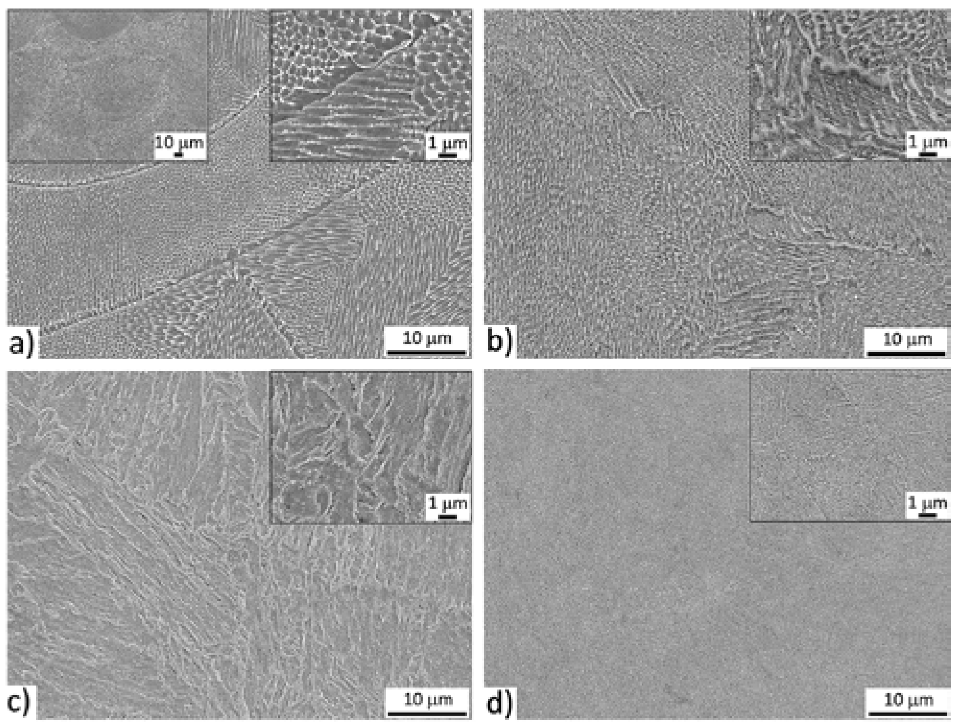


Figure 2: SE images of bulk microstructures of: (a) AM, (b) AM + DAT, (c) AM + SAT and (d) CM + SAT samples with insets of higher magnification; etched in Nital.

RESULTS AND DISCUSSION

18Ni-300 maraging steel manufactured using an industrial SLM device was plasma nitrided in combination with and without a prior heat treatment to investigate their interacting influence on the wear and corrosion resistance. For a better understanding of the microstructure evolution and the formation of the nitride layer, the conventionally produced counterparts were thermochemically treated under the same conditions and compared with the AM samples. Due to the rapid solidification, the microstructure of the SLM as-built maraging steel differed significantly from the conventional steel and has a cellular/dendritic solidification microstructure [4,17]. Light micrographs (Figure 1) present microstructures of the nitride layer on the as-built sample AM + N, differently thermochemically treated samples AM + DAT + N, AM + SAT + N and a conventional sample treated under the same conditions CM + SAT + N. The conventional maraging steel in the as-delivered state was solution treated; therefore, it does not make sense to study CM + DAT because it is identical to CM + SAT. The samples were etched in two different etchants (Nital left part of images, ferric chloride right part of images) to reveal all the details in the microstructure. The microstructure observed in the nitride layer as well as in the bulk is martensitic in all the samples, although in the CM sample the prior austenite grains that transform to martensite are significantly different. The prior austenite grains of the CM sample are polygonal, while in the AM samples the prior austenite grains have a more irregular shape due to the rapid solidification, which results in the different martensitic microstructure. Etching with Nital shows the melt pools and the morphology inside them, especially the cellular structure, which is better seen at higher magnifications and in detail with the SEM micrographs (Figure 2). Melt pools can be observed in the as-built AM sample (Figure 1a) as well as in the aged AM sample (Figure 1b), with the melt-pool boundary running across the grains and having a slightly different chemical composition [44].

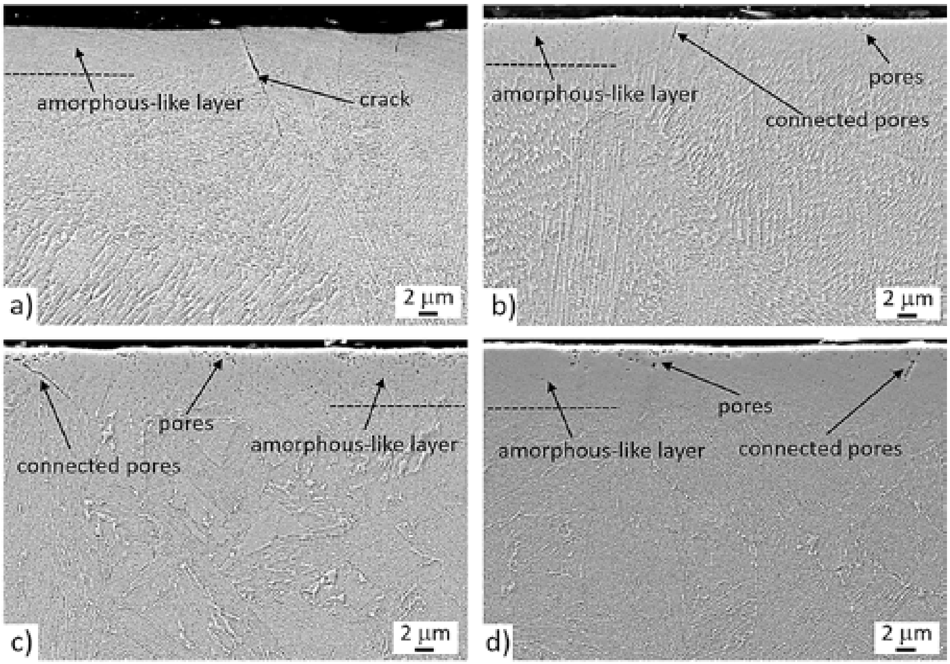


Figure 3: SE images of nitride layer for the investigated samples: (a) AM + N, (b) AM + DAT + N, (c) AM + SAT + N, (d) CM + SAT + N; etched in Nital.

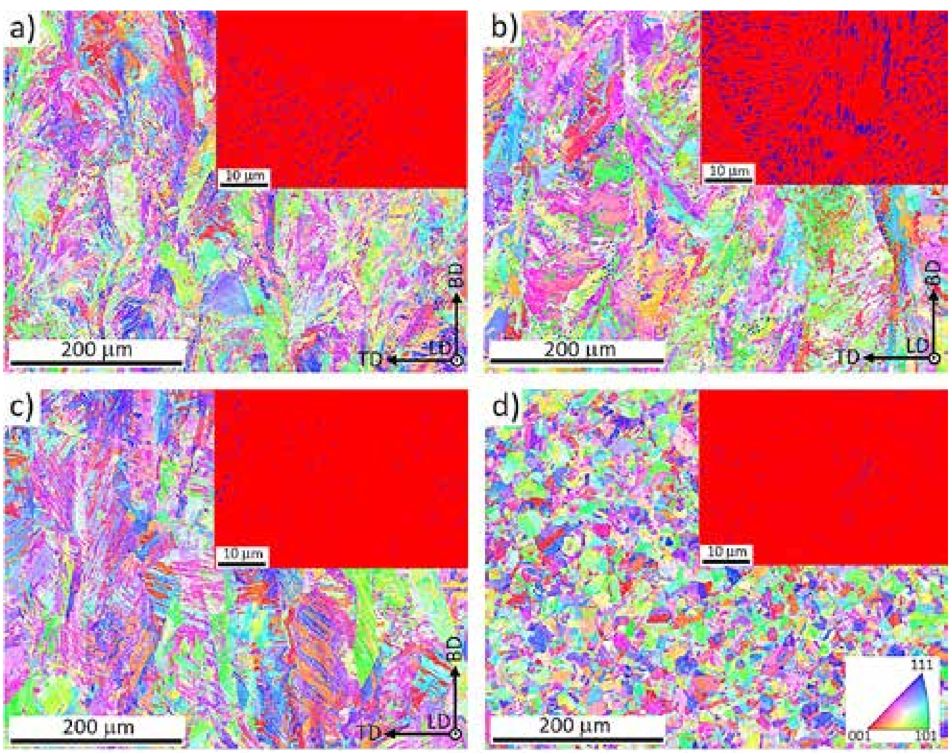


Figure 4: EBSD IPF maps in the BD direction with insets of EBSD phase analysis obtained at higher magnification of: (a) AM, (b) AM + DAT, (c) AM + SAT and (d) CM + SAT samples. LD, TD and BD stand for longitudinal, transverse and building direction, respectively.

However, after the solution treatment, the melt pools and boundaries disappear due to the diffusion process. The 8–10-µm-thick upper layer is not sensitive to the Nital etchant and most probably corresponds to the Fe_4N compound layer [45]. The ferric chloride clearly reveals the nitride-layer thickness and also the grain structure in this layer, but only in the solution-treated AM sample (Figure 1c) and the conventional reference sample (Figure 1d). The depth of the nitride zone is very similar for all the samples and is between 115 and 130 µm. Visually, the nitride zone resembles the diffusion-layer structure with two regions of approximately equal thickness, with a different sensitivity to the ferric chloride etching (upper dark and bottom light), most probably due to the edge effect of the etching and the maximum residual stresses in the surface. The transition from the nitride layer to the bulk is smooth and visually restricted to a narrow range.

The bulk microstructure was investigated by SEM, where the melt pools are clearly visible and are 100–150-µm wide and 50–90-µm high (left inset in Figure 2a). In Figure 2a, the cellular microstructure is visible and present in the whole volume. The dendrite cellular structure is a consequence of the rapid solidification and nano-segregation and is well described in the literature [31,46]. A higher-magnification image (right inset in Figure 2a) shows very small (~100 nm) precipitates forming at the triple-cell junction during the AM process. The precipitates after aging (DAT) form within the whole volume; however, the growth is faster at the prior cell boundaries with a higher density of dislocations [47]. These features give the impression that the cell structure is still present after aging (Figure 2b). After the solution treatment and aging (SAT), the cellular structure completely disappears, revealing the morphology of a martensite structure with fine precipitates (Figure 2c). As the AM + SAT and CM + SAT undergo identical heat treatments, an identical microstructure is also expected. However, from the micrographs shown in Figure 2c,d, coarser martensite laths can be seen for the AM sample. Furthermore, no precipitates are formed along the grain boundaries of the prior austenite grains and therefore these boundaries are almost invisible. On the other hand, in the CM sample the prior austenite grains are clearly visible with very fine precipitates located along the boundaries. The main reason for the coarser microstructure in the AM sample is the nature of the AM process, where elongated columnar grains are created. Therefore, the size of the grains defines the size of the martensite laths, which form as martensite packages inside those grains. The finer the grains, the finer are the packages.

Figure 3 presents the SEM image of the upper part of the nitrided zone (~30 µm). The thickness of the top, amorphous-like layer is approximately 5–10 µm, although it seems to be slightly thicker in the CM + DAT + N sample and most probably corresponding to the compound layer, which is very hard and prone to cracks. Higher magnification images of top most nitride layer can be found in the Supplementary Information with the appropriate Figure S1. In the sample AM + N (Figure 3a) small cracks are present in the compound layer, which can be assigned to the high concentration of internal stresses in the as-built AM material [48,49]. After aging, no cracks are visible in the

AM + DAT + N sample due to the stress release. However, some small pores (100–200 nm) can be observed in the surface and near-surface zones (up to a depth of 5 µm). Among the pores, some connected pores along the grain boundaries are also observed (Figure 3b).

The previously explained cellular morphology in the AM + N and AM + DAT + N samples is still visible. The solution treatment (SAT) removes the internal stresses and chemically homogenizes the AM sample. The result is a disappearing of the cellular structure and the absence of cracks in the compound layer (Figure 3c). The samples AM + SAT + N and CM + SAT + N have similar porosities in the top nitride layer, as well as connected pores (Figures 3c and d). The transformation of the ε ($Fe_{2\text{-}3}N$) phase to γ' (Fe_4N) causes an excess of nitrogen gas and forms the trapped pores beneath the surface [50,51]. The most reliable explanation for the absence of pores in the AM sample is the high dislocation density [44,46], which allows a faster diffusion of the nitrogen.

The EBSD performed on the AM, AM + DAT, AM + SAT, and CM + SAT samples indexed martensite with a small amount of austenite (retained/reverted) (Figure 4), also reported by other authors [29,31,38]. The difference in the bulk microstructure between the AM and CM samples is the result of typical conditions during the SLM process, characterized by rapid solidification and multiple reheatings, which cause elongated grain growth in the building direction. The microstructure consists of lath martensite inside columnar grains (Figure 4a–c). The heat-treated CM sample (CM + SAT) contains 1–2% of retained austenite and has small, polygonal prior austenite grains without an isotropic structure, which is typical for AM samples. The as-built AM sample, on the other hand, contains 3% of retained austenite. Aging increases the amount of austenite in the microstructure, since a larger amount of austenite is in equilibrium at the aging temperature, which remains in the microstructure after quenching and is known as reverted austenite [31]. Accordingly, the amount of austenite in the AM + DAT sample increased up to 11% (Figure 4b). To avoid the austenite after aging, a slower cooling rate should be used. However, when the AM sample is solution treated and aged (AM + SAT), again no more than 1–2% of austenite was detected (Figure 4c). The significant difference in the amount of austenite between AM + DAT and AM + SAT can be explained by nano-segregations during the AM process, which cannot be eliminated only by aging. Therefore, a larger amount of Ni in certain areas, known as a γ-stabilizing alloying element, increases the formation of austenite. The absence of nano-segregations in the conventional sample is attributed to its chemically homogeneous structure. The selected SLM process parameters did not lead to any texture formation, as shown in Figure 4. The previously described difference in the grain morphology, especially between the AM + SAT and CM + SAT, is even better seen in the EBSD IPF maps. The packages of martensite formed inside the large columnar grains in the AM material are much larger than the packages of martensite inside small polygonal grains in the CM material (Figure 4d).

The nitride layers were characterized using an EDS line-scan analysis to explain the elemental distribution, especially the depth of the nitrogen penetration. The EDS line analyses performed on the cross-section samples are shown in Fig. 5.

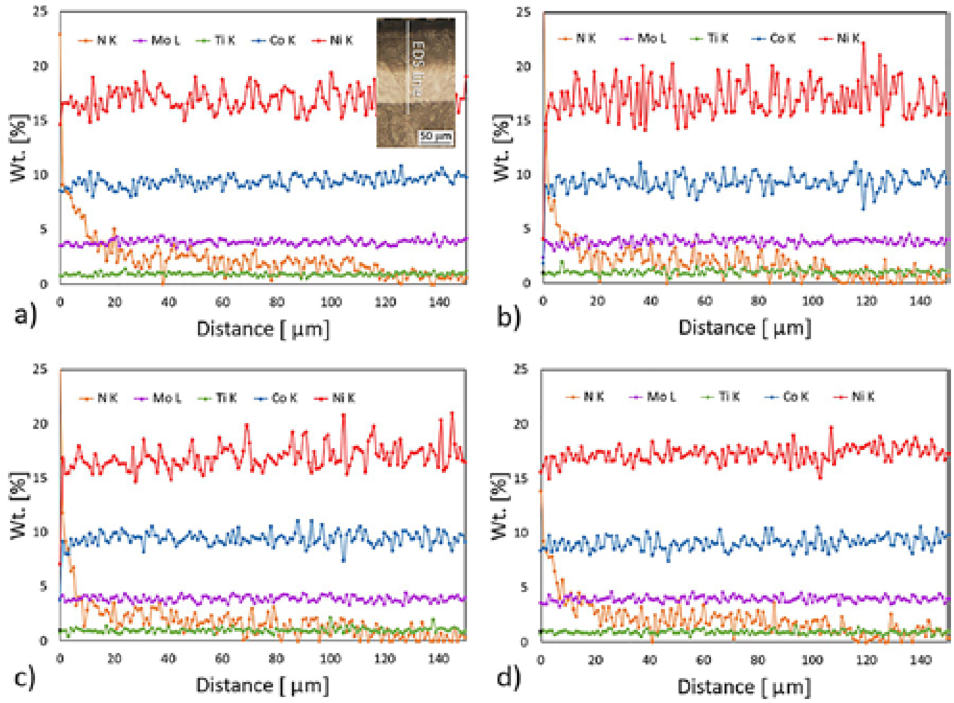


Figure 5: EDS line-scan analyses of: (a) AM, (b) AM + DAT, (c) AM + SAT and (d) CM + SAT samples.

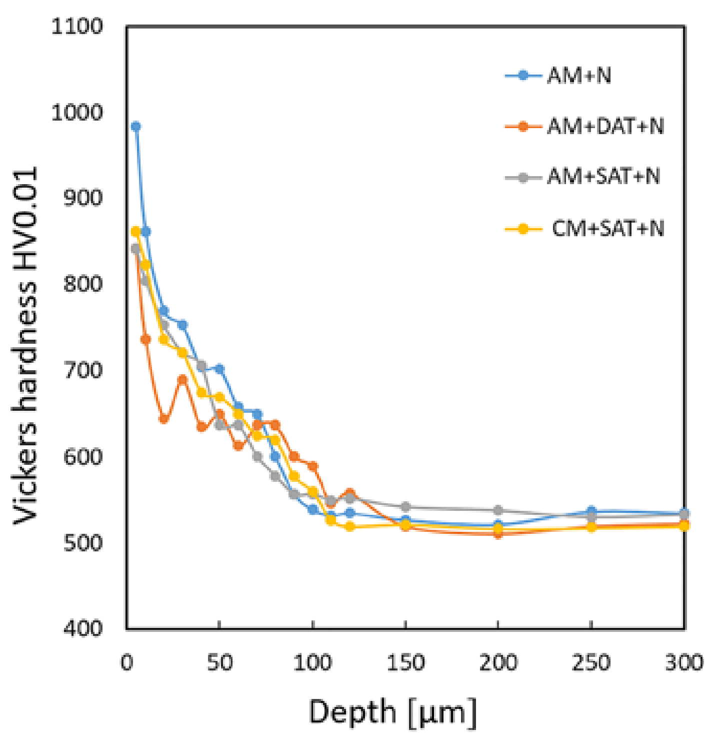


Figure 6: Microhardness depth profiles of: (a) AM + N, (b) AM + DAT + N, (c) AM + SAT + N and (d) CM + SAT + N samples.

The inset in Figure 5a schematically shows the EDS line path through the nitride layer, which was similar for all four samples. In all the samples, the nitrogen signal correlates well with the depth of the nitride layer, which is 115–130 µm, as seen from the LM micrographs. The content of nitrogen starts to increase in the top 20 µm, which corresponds well with the compound layer visible in the SEM images (Figure 3) and the hardness depth profile (Figure 6). The Ti, Mo, and Co values are similar and almost constant in all the samples. The signals for nickel show a high scatter, assigned to the redistribution of the nickel due to the higher solubility of the nickel

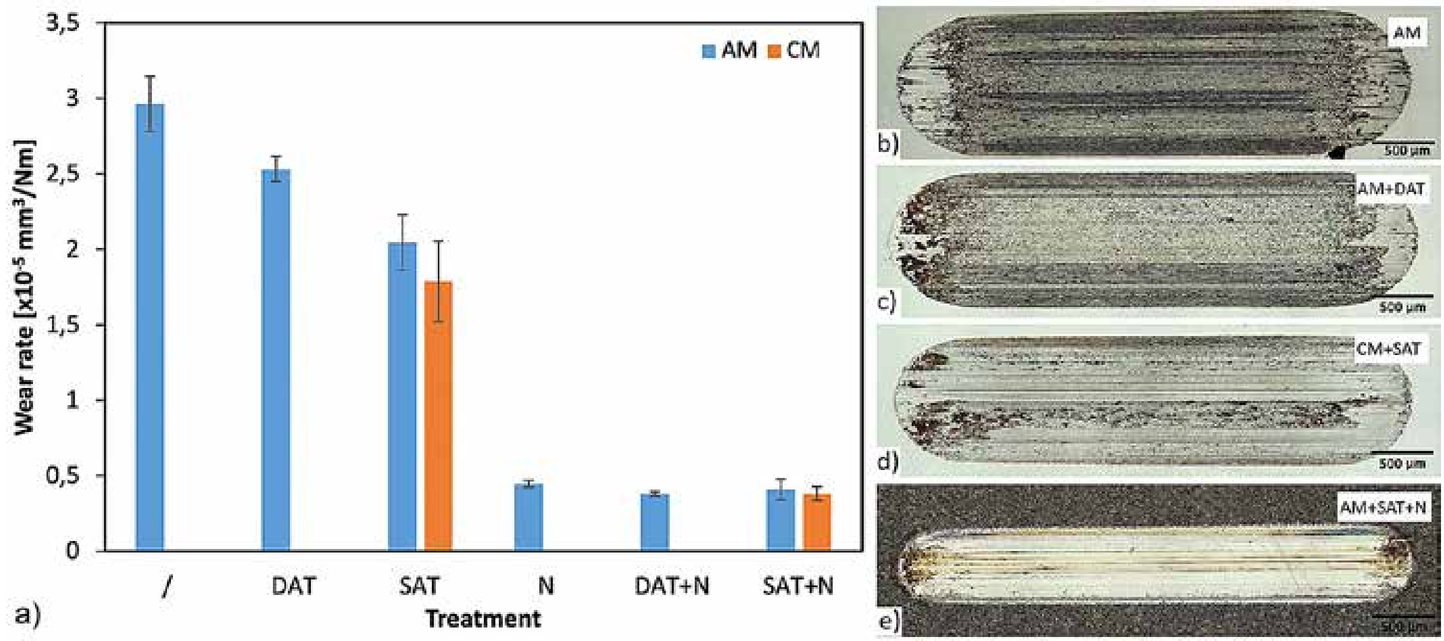


Figure 7: (a) Wear rates for the investigated AM and CM maraging-steel specimens and micrographs of the wear tracks of: (b) AM, (c) AM + DAT, (d) CM + SAT and (e) AM + SAT + N samples.

Material	E_{corr} (mV)	i_{corr} (μA/cm2)	v_{corr} (μm/year)
AM	- 319 ± 4	1.30 ± 0.05	15.0 ± 0.5
AM + DAT	- 327 ± 4	1.35 ± 0.03	15.5 ± 0.5
AM + SAT	- 231 ± 2	1.65 ± 0.04	18.9 ± 0.5
CM + SAT	- 349 ± 4	0.87 ± 0.01	10.0 ± 0.2
AM + N	- 314 ± 3	0.88 ± 0.02	10.0 ± 0.3
AM + DAT + N	- 271 ± 2	1.06 ± 0.03 1	2.2 ± 0.4
AM + SAT + N	- 307 ± 3	0.87 ± 0.02	9.9 ± 0.2
CM + SAT + N	- 256 ± 2	0.93 ± 0.03	10.7 ± 0.3

Table 1: Electrochemical parameters determined from the potentiodynamic curves.

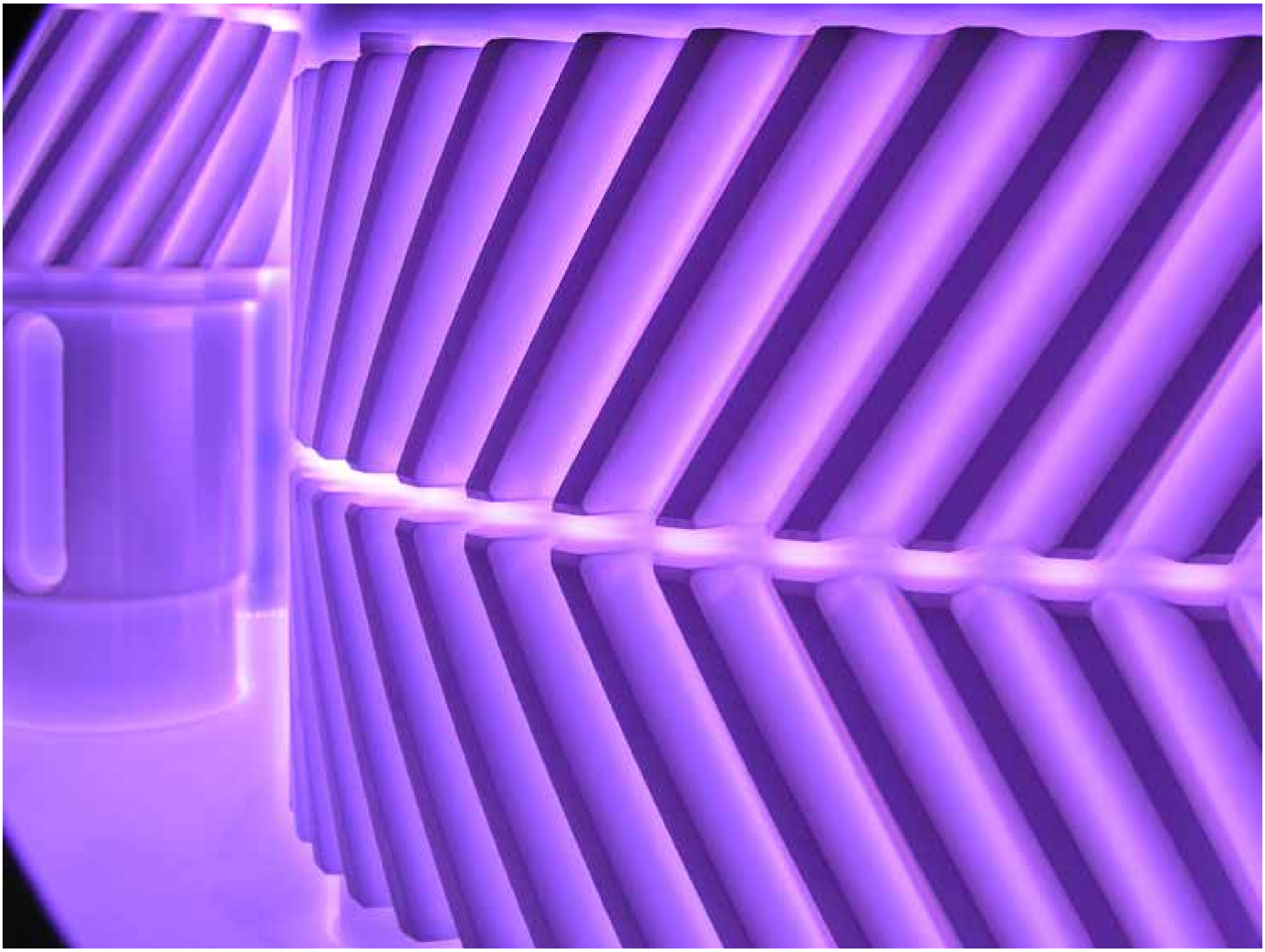
in austenite. It is well known that Ni stabilizes the austenite phase. The highest scatter is observed for the AM + DAT sample (Figure 5b), which contains the largest amount of austenite. Although the AM samples contain more dislocations and other crystal-lattice defects [44], no significant increase in the thickness of the diffusion layer is evident (Figure 1), while the amount of nitrogen in the nitride layer is almost the same for all samples (Figure 5). Based on EDS line analysis no significant effect of the heterogeneous structure on the nitriding kinetics is observed.

Bulk hardness measurements of the samples before nitriding show that the as-built sample (AM) has a lower hardness of 39 HRC (387 equivalent HV), compared to the heat-treated ones (AM + DAT, AM + SAT and CM + SAT) with a hardness of 49–50 HRC (500–515 equivalent HV). The AM sample shows the lowest hardness value because the precipitates do not form (or at least not completely) during the SLM process [14]. The sample AM + DAT contains the largest amount of austenite; therefore, a lower hardness value would be expected. However, the dislocation cellular structure is not completely removed during aging, and this contributes to the higher hardness value, which, in the end, gives similar hardness values to all the heat-treated samples. The Vickers micro- hardness depth profiles of the nitrided layer for the AM + N, AM + DAT + N, AM + SAT + N, and CM + SAT + N samples are shown in Figure 6. The bulk hardness for all the nitrided samples is very similar, i.e., in the range of 520 HV0.01. However, slightly lower values as well as a larger scatter within the nitride layer can be observed for the AM + DAT sample, which is attributed to the largest amount of austenite phase in the microstructure. It also shows a more pronounced drop in the surface hardness, which agrees with the higher austenite content and the slightly thinner compound layer, as visible from the SEM cross-section micrographs (Figure 3). In terms of the surface hardness of the nitride layer, the AM + N sample shows the highest hardness of the compound layer, around 1,150 ± 35 HV0.01, while the hardness of the other three samples is about 850 ± 40 HV0.01. The as-built sample has no precipitates, which corresponds to the lowest bulk hardness value. However, during nitriding, both processes (the formation of precipitates and nitrides) take place and increases the hardness to the highest value for all the studied samples. The higher hardness is also due to the cellular structure, with its high dislocation density and the nano-oxide particles pinning the dislocations [46]. On the other hand, in all the samples, the hardness decreases with the depth, reaching the value of the base material at a depth of approximately 120 μm, correlating well with the LM images (Figure 1).

In terms of wear resistance (Figure 7a), the highest wear rate (wear volume divided by normal load and total sliding distance) in the range of 3.0×10^{-5} mm^3/Nm was obtained for the AM sample. This is due to the high internal stresses, nano-segregations, and the small number of precipitates, resulting in a lower bulk hardness (40 HRC) and combined abrasive/adhesive wear, as shown in Figure 7b.

Although the sample is thermally exposed several times during the laser melting of its upper layers, it is just for very short periods of time, which cannot replace the post-aging procedure, which gives the maraging steel its final properties (i.e., high bulk hardness of 48-50 HRC) due to the precipitates' formation (Ni_3(Ti,Al). Interestingly, the aging treatment itself does not significantly improve the wear resistance of the AM sample (AM + DAT). The wear rate is reduced by less than 15%, with the adhesive wear component still being very strong (Figure 7c). The main reason lies in the high retained-austenite content. A further improvement in the wear resistance of the AM samples, on the other hand, is obtained by a combination of solution and aging treatment (AM + SAT), providing a high hardness

Plasma nitriding was shown to be a beneficial thermo-chemical treatment for the AM maraging steel (18Ni- 300) in terms of improving the wear and corrosion resistance.



and a more homogeneous microstructure. This results in a reduced abrasive-wear component and an about 40% improvement in the wear resistance, as compared to the as-built AM sample. However, regardless of the heat-treatment conditions, the AM samples with a reduced microstructure homogeneity show an approximately 15% lower wear resistance than the conventional samples treated under the same conditions and showing the same bulk hardness.

Although the conventional maraging steel is delivered in the soft-annealed condition, the solution treatment additionally eliminates the macro-segregations, thus providing a further improvement in the wear resistance (Figure 7d). An even more drastic increase in the wear resistance, obtained for all the samples, was provided by plasma nitriding, as shown in Figure 7a. The wear rates were reduced by 4–7 times. The high hardness of the nitride layer eliminated the adhesive-wear component, at the same time providing a superior abrasive wear resistance (Figure 7e). The formation of the hard nitride layer more-or-less eliminates the negative SLM effects as well as the heat-treatment history, with all the samples showing very similar wear rates of about $0.4 \times \cdot 10^{-5}$ mm^3/Nm and the wear being concentrated within the top 10 μm of the nitride layer. However, for the AM material, the presence of microcracks in the nitride layer of the as-built sample (AM + N) and the significant number of pores in the near-surface area of the AM + SAT + N sample result in somewhat higher wear rates and more scatter (Figure 7a). A detailed examination of the friction behavior of the tested samples is explained in the Supplementary text with the appropriate Figure S2 and Figure S3.

Potentiodynamic polarization curves for all the AM and CM samples measured in 3.5% NaCl are presented as Supplementary Figure S4. The corrosion potentials (E_{corr}), corrosion current densities (i_{corr}), and corrosion rates (v_{corr}) are listed in Table 1. Based on the results of the corrosion measurements, the as-built AM sample has a similar corrosion resistance to the AM + DAT and AM + SAT samples. The as-built AM sample has a high dislocation density, internal stresses

[49] and chemical nano-segregations [31]. The internal stresses and chemical nano-segregations make a negative contribution to the corrosion properties, while the absence of precipitates has the opposite effect. The slightly increased corrosion of the AM + DAT and AM + SAT samples is probably the result of precipitate formation during the aging. The nitriding improves the corrosion resistance, due to the formation of a compound layer, which is known to be corrosion-resistant [52]. Our results show the nitrided samples exhibit a passive region in the potentiodynamic curves, compared to the samples prior to nitriding, where this region was not observed (see Supplementary Figure S4). In fact, nitriding without a prior heat treatment achieves more-or-less the same corrosion rate. However, without the prior heat treatment, due to the high internal stresses some cracking of the nitride layer is observed (Figure 3a). In general, the corrosion rates for AM are higher than for the CM samples due to the appearance of local stresses caused by the multiple melt cavities, the dendritic cellular structure, and the increased roughness, which results in increased corrosion in these areas [53]. A comparison between the AM + SAT and CM + SAT samples shows the improved corrosion resistance of the conventionally produced material due to its better chemical homogeneity, particularly since pores are not present in such material. In the SLM-produced materials, the number of pores is small, but they cannot be completely avoided, which results in a slightly lower corrosion resistance. The sample CM + SAT shows a similar corrosion resistance to the nitrided samples, which can be attributed to the fine-grained structure with fine martensite laths. This is also an explanation for the better corrosion properties of the CM + SAT sample compared to the AM + SAT sample, although in both cases the same heat treatment was performed.

CONCLUSIONS

In this study the influence of plasma nitriding in combination with different prior-heat-treatment processes on the wear and corrosion resistance of AM maraging steel was investigated. The results were compared with conventional maraging steel subjected to the same heat and thermo-chemical processes. The following conclusions can be drawn:

» As-built AM material contains a small amount of retained austenite because of nano-segregations caused by rapid solidification during the AM process. The aging treatment leads to more reverted austenite, while after the solution treatment and aging, a larger amount of austenite is not obtained. After aging, the samples still have a lot of chemical inhomogeneity, which causes the formation of austenite. Therefore, a slow cooling rate is essential for a smaller amount of austenite. The microstructure of the AM material is similar in all the investigated conditions (as-built, directly aged, solution treated, and aged) and consists of elongated columnar grains with martensite laths inside them. On the other hand, the microstructure of the conventional material is much finer in terms of the grains and martensite laths.

» Plasma nitriding was shown to be a beneficial thermo-chemical treatment for the AM maraging steel (18Ni- 300) in terms of improving the wear and corrosion resistance. The nitride layer consists of the compound and diffusion layers with thicknesses of 5–10 µm and 100–120 µm, respectively. The thicknesses of the layers correlate very well with the nitrogen concentration in the surface. Plasma nitriding without prior heat treatment results in a small crack within the compound layer due to the high internal stresses, which diminish the surface resistance to wear. On the other hand, for the plasma nitriding on the heat-treated samples, very small pores of up to 200 nm were formed in the compound layer. Despite this, the AM and conventional samples, heat treated prior to nitriding, had the best and very similar wear resistances.

» Plasma nitriding has a positive effect on the corrosion resistance, which can be observed in the formation of a passive region. However, in general, AM-produced samples have higher corrosion rates than their conventional counterparts due to the greater inhomogeneity, some porosity, and the appearance of local stresses caused by multiple melt cavities, a dendritic cellular structure and an increased roughness.

» For the conventional maraging steel, it was already shown it is possible to combine the aging and nitriding into a single step. One of the aims of the present research was to confirm the same for AM materials. However, the results show this is not the optimal solution for the AM material, due to crack formation in the compound layer. The nitriding with the prior heat treatment (i.e., aging or solution treatment and aging) leads to the formation of a crack-free nitride layer, required in the case of tool inserts subjected to heavy loads and severe contact conditions. On the other hand, the short annealing time for stress release might be sufficient to prevent cracking during the nitriding while maintaining a high dislocation density, which enables a pore-free compound layer.

MATERIALS AND METHODS

Gas-atomized powder feedstock (MS1) supplied by EOS, corresponding to maraging steel grade 18Ni-300 (C ≤ 0.003, Si ≤ 0.10, Mn 0.04, S ≤ 0.001, Co 8.8, Cr ≤ 0.1, Mo 5.0, Ni 17.8, Ti 0.80 wt%), was used for the SLM built parts. The size of the powder particles was less than 63 µm, with the majority in the range from 15 to 45 µm. SLM samples of 30 × 30 × 30 mm^3 were built in an industrial AM machine (EOS EOSINT M280) with 400-W fiber laser, using commercial process parameters: laser power of 285 W, laser speed 960 mm/s, distance between the laser paths 0.11 mm, hatching in x and y, alternating and rotating.

Commercial 18Ni-300 maraging (C ≤ 0.002, Si ≤ 0.10, Mn ≤ 0.1, S ≤ 0.001, Co 8.5, Cr ≤ 0.1, Mo 4.9, Ni 17.8, Ti 0.68 wt%) steel in the as-delivered (soft-annealed) state was used as a conventionally manufactured counterpart. Chemical compositions were determined with an X-ray fluorescence spectrometer XRF (Thermo Scientific Niton XL3t GOLDD+) and ELTRA Elemental Analyzer CS800 (for carbon and sulphur).

Heat and thermochemical treatment (plasma nitriding). A post-process heat treatment is essential for both SLM and conventionally manufactured maraging steel in order to improve the mechanical properties. The heat treatment was performed in two different stages, with the parameters (temperature and time) chosen on the basis of the literature data [40]:

» Direct aging at 520 °C for 6 h (DAT).

» Solution treatment at 840°C for 30 minutes + aging treatment at 520°C for 6 hours (SAT).

For the enhancement of the surface properties, such as wear and corrosion resistance, the samples were thermochemically treated by plasma nitriding. Plasma nitriding (N) was performed on the prior heat-treated samples (DAT or SAT) at the nitriding temperature of 520°C. Due to the identical aging and nitriding temperature, the SLM sample was also nitrided in the as-built state (without any prior heat treatment) in order to investigate the possibility and effectiveness of joining the two processes in a single step.

A Metaplas Ionon HZIW 600/1000 cold wall reactor, equipped with an internal convection-heating system and an internal gas/water heat exchanger for rapid cooling, was used for the plasma nitriding. The convection and plasma heating of the specimens to the sputtering temperature of 450°C and processing temperature took approximately 3.5 hours. The soaking time at the nitriding temperature was 6 hours in a gas mixture of 75 vol% H_2: 25 vol% N_2.

Microstructure characterization: The microstructures were characterized on cross-sectioned metallographic samples [mounted in conductive Bakelite resin, grinded, finally polished using 1-μm diamond suspension and etched in Nital (2% Nitric Acid, Ethyl Alcohol) and ferric chloride ($FeCl_3$)] using a light microscope (Nikon Microphot FXA) equipped with a digital camera (Olympus DP73).

A field-emission scanning electron microscope (ZEISS Cross Beam 550 FIBSEM) was used for the energy- dispersive spectroscopy (EDS) at 15 kV and 5 nA for mapping and 2 nA for line scanning analyses, as well as for secondary-electron (SE) imaging. Electron-backscatter diffraction (EBSD) was employed with a Hikari Super EBSD Camera at 70° with an accelerating voltage of 15 kV and a probe current of 10 nA to observe the microstructure with the included TEAM EDAX software, and for the data post processing, OIM software was employed.

Wear testing and hardness measurements: A reciprocating sliding-wear test machine with the ball- on-disc contact geometry was employed to determine the wear behavior (wear volume and coefficient of friction) of the samples. A 20-mm-diameter Al_2O_3 ball was used as the oscillating counter-body to simulate the abrasive wear mechanism and concentrate the wear on the steel-disc samples. Dry sliding-wear tests were performed at a normal load of 20 N, corresponding to a nominal contact pressure of 900 MPa, and an average sliding speed of 0.12 m/s (amplitude 4 mm and frequency 15 Hz). The overall testing time was 1,000 seconds, resulting in a total sliding distance of 120 meters. Three parallel tests at room temperature were performed on all the samples, which were mirror polished before the nitriding. After the test, the wear volume was measured directly by analyzing the wear track with a high-resolution 3D optical microscope (Alicona InfiniteFocus G4 3D) based on a variation of the focus, intended for topography and form measurements. On the other hand, the coefficient of friction was measured continuously as a function of the testing time and sliding distance, with the average values obtained during the steady-state conditions that were calculated.

Depth profiles HV0.01 of the nitride layers were measured using an Instron Tukon 2100 B Vickers hardness tester. Bulk hardness before nitriding was measured using an Instron B2000 Rockwell hardness tester (HRC).

Electrochemical measurements: The electrochemical evaluation was performed in a 3.5% NaCl solution at room temperature using a three-electrode system with the test specimen as the working electrode, a saturated calomel electrode (SCE, 0.242 V vs. SHE) as the reference electrode and a platinum mesh as the counter electrode. All the samples were stabilized at the open-circuit potential (OCP) for 1 hour prior to the measurement. The potentiodynamic curves were measured at a scan rate of 1 mV/s on a Potentiostat/Galvanostat/FRA instrument (BioLogic SP-300 with EC-Lab V11.27 software). All the measurements were repeated three times to obtain statistically relevant results.

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AUTHOR CONTRIBUTIONS

M.G.: Conceptualization, investigation, supervision, writing — original draft preparation, B.P.: Investigation, writing — review and editing, A.K.: Investigation, writing — review and editing, Ä.Œ.D.: Investigation, D.A.S.B: Investigation, writing — original draft preparation, writing — review and editing.

COMPETING INTERESTS

The authors declare no competing interests.

ADDITIONAL INFORMATION

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A TRUSTED SOURCE FOR REFRACTORY SOLUTIONS

Plibrico is able to offer its high-quality product line with the help of an in-house research and technical development team. (Courtesy: Plibrico)

Plibrico has pioneered the research and development of refractory technology essential for the most demanding thermal conditions for more than a century.

By KENNETH CARTER, Thermal Processing editor

Plibrico's name may sound a bit unusual, but what the company offers the thermal-processing industry is anything but.

That innovative commitment to heat-treating comes in the form of designing, manufacturing, and installing refractory solutions that safely improve productivity, temperature control, and service longevity, according to Brad Taylor, Plibrico's president and CEO.

"Plibrico's products and services enable our clients — the heat-treat and thermal-processing industries — to safely and efficiently create quality products for *their* customers," he said.

CONCEPT-TO-COMPLETION REFRACTORY NEEDS

Plibrico maintains an integrated supply chain that allows for turnkey concept-to-completion refractory products and services needed to stop mechanical stresses, abrasion, and corrosion brought on by high temperatures and the daily wear and tear caused by production, according to Taylor.

"We have refractory product development and manufacturing that includes advanced castables with low cement, ultra-low cement, or no cement; along with gun mixes; plastics; and shotcrete," he said. "And then, to help reduce client downtime, we manufacture precast shapes and have our fast-track line of products that offer an accelerated bake-out."

Plibrico is able to offer its high-quality product line with the help of an in-house research and technical development team that truly understands industry applications and clients' needs, according to Taylor.

"To fully service our clients, Plibrico has a network of refractory installation offices and partners that help to provide a complete solution for our clients. Everything from new construction installations, to complete rebuilds and repair of refractory linings, including the demolition and tear-out as well as bake-out services," he said.

That means "being there" for each and every client when they most need help, 24/7, and making sure the company is a trusted source for refractory solutions, according to Taylor.

"We are driven by a customer-first philosophy," he said. "Over the years, refractory technology has developed from a simple idea into a complex, ever-evolving solution. Plibrico provides advanced, proven technologies and unparalleled service to thermal processors. Refractory solutions are engineered by application specialists who form close partnerships with clients. We like to focus on client outcomes, not just products, to successfully develop the correct solution for clients. Through the lens of our clients, we work to understand the problem and then drive to define a solution, that gets the client's key processes online as safely and fast as possible to help minimize lost production time. We've been focused on solutions that help the heat industry reduce downtime and extend refractory life."

PLIBRICO REDI-SHAPES

One product Taylor said the company offers in particular that has helped clients minimize their downtime is Plibrico Redi-Shapes®.

"That's our trade name for our custom-engineered line of precast shapes, which we design and manufacture internally to exacting specifications — any size or intricate configuration — depending on client needs," he said. "Custom firing options help combat specific application challenges such as abrasion, erosion, thermal shock, or metal and slag penetration. Redi-Shapes enable fast refractory lining replacement, especially in recurring high-wear zones, from weeks to days. Our Redi-Shape solution is really built upon the knowledge and genuine expertise that our team has in both refractories and installation services."

The Plibrico Company was founded in 1914 by the Schaeffer family when it opened its doors as the Pliable Brick Company. (Courtesy: Plibrico)

Downtime compression becomes a huge factor in whether a client is able to meet its company production and financial goals, according to Taylor.

"Our team continually demonstrates time and again its customer-driven core values combined with a swift response flexibility where we can really enable our customers to get their critical heat-

Plibrico is known for its plastic refractories, the first product that came out from the company. (Courtesy: Plibrico)

ing systems back online and operating quickly," he said.

PANDEMIC CHALLENGES

With COVID-19 affecting a large part of the world over the last year, Taylor noted that, as the industry snaps back, it's caused an increase in demand for Plibrico's clients' products.

"As the economy recovers from COVID, the heat-treat industry, like other thermal-processing industries, is running its equipment full-out," he said. "Production demand is there. Thermal processors are struggling to keep up with their customers' demands. And if you combine the increased demand with the upstream supply chain challenges the industry as a whole is facing, thermal processors are depending on companies like Plibrico more and more to provide critical components and services that are all geared toward minimizing unexpected interruptions and downtime."

Many refractory companies during 2020 took the approach of reducing their working capital by limiting inventory or relying on their raw material suppliers to have product readily available, but Taylor emphasized that Plibrico took a different approach.

"We didn't do that," he said. "With the uncertainty of COVID, we managed the working capital of the business, but we did so by right-sizing our inventory — making sure we had the right products and raw material on the shelf, at the right time, so that we were ready to satisfy our clients. We anticipated the pent-up demand. And while I'll admit our timing was a bit lucky, our strategy was intentional."

OUTCOME PROBLEM SOLVING

Focusing on outcomes happens to be Plibrico's problem-solving philosophy, according to Taylor.

"We are preparing for a much more sophisticated thermal-processing industry."

"Our technical team and project managers listen to the client to truly understand what the pain-point is or the problem the client's trying to solve," he said. "And, sometimes, that's a real challenge. Clients know what the symptoms are; they know what they're trying to take care of, but they really look to us to identify the root cause and then develop that full solution that fixes their issue."

"More often than not, what we find is clients will come through our application or technical side, not necessarily looking for a product, but wanting to have someone to talk through an issue or a problem they're having," he said. "We look to really understand what the root cause is — whether it's a corundum issue, a thermal expansion and contraction problem, abrasion difficulty, or other challenges — and from there, we're able to develop a full solution that includes both products and services, so clients have a complete solution vs. just part of the answer."

WHAT'S IN A NAME?

But just where did the name Plibrico come from?

The Plibrico Company was founded in 1914 by the Schaeffer family when it opened its doors as the Pliable Brick Company, according to Taylor.

Far left: Plibrico maintains an integrated supply chain that allows for turnkey concept-to-completion refractory products and services. (Courtesy: Plibrico)

Left: Plibrico Redi-Shapes® is the company's trade name for its custom-engineered line of precast shapes, which can minimize customers' downtime. (Courtesy: Plibrico)

"Through the years, it eventually came to be known as the Plibrico Company (PLI-able BRI-ck CO-mpany)," he said. "The founding was based upon the realization that ordinary refractory linings of fire-brick or tile of the day have problems. Contraction and expansion from heating and cooling cycles open up the joints between bricks. Corners and edges fuse and spall as they are exposed to the fire, walls bulge, and arches collapse as the individual brick loosens. Schaeffer knew that an ordinary fire brick lining construction would be no stronger than its joints, and if you can eliminate the joints, you can lengthen the life of the refractory. His ideas led to the development of today's monolithic construction and plastic refractories. Plibrico is known for its plastic refractories, the first product that came out from the company. Since then, we've had several firsts throughout the industry and continue to lead the way innovating."

A CENTURY OF SUCCESSES

Plibrico has had many breakthroughs over the years, including the first commercially available successful plastic refractory — the industry's first true flexo anchoring system — or being one of the first companies to develop a complete line of non-wetting monolithics for the aluminum industry, according to Taylor.

"What I'm personally proudest of is our clients' successes, as well as the length of time a lot of our clients have been with us," he said. "We've built a business over more than a century, based on trust, knowledge, and experience — qualities that create close, lasting relationships. I am also very proud of Plibrico's resiliency and our ability to respond to industry changes ahead of clients' needs. And I'll tell you, it's because of our team of dedicated industry professionals. They drive the company each and every day, listening to our customers and making sure that we're providing the best solution for them and exceeding their expectations."

As Plibrico looks to the future, Taylor said the company will continue to drive its investment in innovation.

"Products, services, manufacturing techniques, and processes — all of this will be aimed at delivering cost-effective refractory solutions for clients that are easier to install, can increase service-life, and improve the mechanical properties of the product itself," he said. "This will also be combined to support a greater dependency on organizations like ours with the knowledge and genuine technical expertise in the field of refractory."

INDUSTRY CHANGES

Taylor pointed out that an especially difficult challenge that faces the refractory industry is that many experts in the field are aging out, resulting in the loss of valuable knowledge, so he emphasized that it is incumbent upon his company to continue to make investments in their employees to retain and grow that knowledge within the organization, and that also involves the increase in automation that all industries continue to implement.

"We are preparing for a much more sophisticated thermal-processing industry," he said. "Plibrico, as well as its clients, is impacted by the accelerated use of data, automation, alternate fuel sources, and artificial intelligence. Plibrico as an organization understands these changes, and the need for different products and services as a result of these — whether it's processing temperature decreases or materials that are off-gassing as a result of alternative fuels — and is aligned with that evolution to be able to support our clients and remain the trusted source for refractory solutions."

MORE INFO plibrico.com

HEAT TREAT 2021

"Why attend HEAT TREAT 2021? Three reasons: networking, technical sessions, and camaraderie."

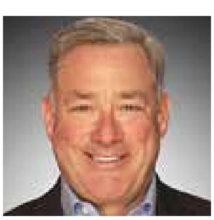
HEAT TREAT 2021 is scheduled to hit St. Louis, Missouri, September 14-16. The show will bring thousands of industry experts and insiders to the Gateway to the West, where they will be on hand with knowledge to take heat-treating into 2022 and beyond. *Thermal Processing* reached out to several exhibitors and asked them to share their plans for HEAT TREAT 2021. If you're going to be at the show, be sure and stop by their booths for more information.

(Courtesy: ASM International)

AFC-HOLCROFT

Booth # 1827

Mike Coburn, Technical Sales



Why attend HEAT TREAT 2021? Three reasons: networking, technical sessions, and camaraderie. Networking allows multiple customers to visit us in one spot. It's an opportunity to mingle with different disciplines such as engineering, purchasing, maintenance, and operations. Technical sessions are worth attending. Short and succinct, they speak to technical areas that are new to me. I not only want to be an expert on my own material, but I also want to understand other processes a customer might be engaged in. You can't beat the camaraderie, whether it's an opening night party or taking guests out to dinner. It builds strong relationships.

ALD VACUUM TECHNOLOGIES NORTH AMERICA INC.

Booth #1231

Andrew Chan, Sales & Applications Engineer

ALD Vacuum Technologies is excited to exhibit in person again at the Heat Treat Expo. This year, we are joining booths with ALD Thermal Treatment to showcase our combined capabilities as an all-around heat-treatment solutions provider. Whether it is new in-house capacity, toll heat-treatment services, or anything in between, we provide a seamless customer-service experience and generate the results you require. We are also excited to discuss our ALD Expert™ Industry 4.0 solutions, which are gaining interest and momentum in North America. If you are a new or existing user of ALD equipment, we can discuss how our I4.0 modules will benefit your operations in the long term.

ECM USA, INC.

Booth #1413

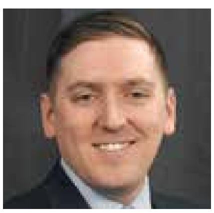
Dennis Beauchesne, General Manager

As a trusted global vacuum furnace manufacturer in a wide range of heat-treat industries — automotive (ask us about heat treating in EV transmissions), aerospace, 3D additive, crystal growth, photovoltaic, VIM/VAR & more — ECM USA is excited to showcase our newest and proven innovations at Booth #1413. We are ready to solve your heat-treat challenges — from upgrading your production line to include partial/full advanced automation to achieving your eco-friendly initiatives with our newest innovative Eco Vacuum Furnace. Stop by our booth #1413 during the Exhibitor Reception for a Bourbon 3-ways tasting. Visit us online to learn more at www.ecm-usa.com.

GASBARRE THERMAL PROCESSING SYSTEMS

Booth #1119

Benjamin T. Gasbarre, President — Industrial Furnace Systems

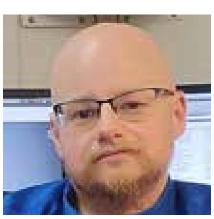


Gasbarre Thermal Processing Systems offers a full line of atmosphere and vacuum furnace equipment configured for both batch and continuous applications. Gasbarre takes a 360-degree approach to servicing our customers. From sales and applications engineering to equipment design, manufacturing, commissioning, and never-ending aftermarket support, our team of engineers, metallurgists, and technicians understand your process from all angles. Gasbarre's technical capability and commitment to service will ensure your success today and into the future. Come visit us at Booth 1119 to see how Gasbarre can provide solutions to your thermal processing needs.

L&L SPECIAL FURNACE CO., INC.

Booth #923

Dave Cunningham, General Manager



L&L Special Furnace Co., Inc., is the leader in high-uniformity batch furnaces, ovens, kilns, quench tanks, and heat-treating systems. All manufacturing and engineering are done in-house from one location just south of Philadelphia, Pennsylvania. L&L sells and services worldwide. Visit Booth 923 to meet company representatives who can explain how L&L Furnaces can make a difference in your heat-treating applications. Also visit www.LLFurnace.com and download PDF product bulletins and more.

LINDBERG/MPH

Booth #1622

Kelley Shreve, Applications Engineer

Lindberg/MPH is exhibiting at Heat Treat 2021 to provide attendees with information on our industrial heat-treat furnaces, including pit, box, integral quench, and hot-stamp designs for the ferrous and non-ferrous markets. Lindberg/MPH manufactures custom and standard heat-treat furnaces for many different industries, including

aerospace, automotive, energy, electronics, foundry, and more. While at Lindberg/MPH's booth (#1622), attendees should look forward to meeting and speaking with our experienced, knowledgeable staff who are able to answer any and all of your heat-treat furnace, industry, and process-related questions.

NOBLE INDUSTRIAL FURNACE

Booth #818

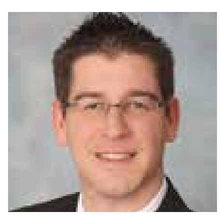
Eric Landry, Accounts Manager

Noble Industrial Furnace will be exhibiting at HEAT TREAT 2021. We look forward to networking with fellow thermal-processing equipment manufacturers, suppliers, and attendees. This show will provide us the opportunity to exhibit some of our newest custom-designed heat-treat furnaces, plus the chance to reconnect with key players in the industry alongside existing and new customers. It will also be our official trade show kickoff of our Noble 1-Stop program we initiated in 2020. Answering a critical need of our customers to provide repairs, maintenance, and inventory, this program offers decades of heat-treat knowledge and experience with service and repairs on all brands of heat-treat equipment. Stop in to see Eric and Jen in Booth #818.

SECO/VACUUM

Booth #1607

Tom Hart, Product Manager

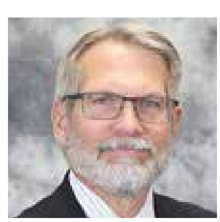


At SECO/VACUUM's booth 1607, we invite you to look into the future of heat treatment. SECO/VACUUM is introducing more new innovations than any other equipment manufacturer to improve the productivity, efficiency, and cost effectiveness of your heat-treatment department. SECO/VACUUM leads with such advanced technologies as single-piece flow UniCase Master low pressure carburizing, a 4D Quench vacuum heat-treatment solution, ZeroFlow precision gas nitriding, CaseMaster Evolution vacuum oil quench, Super IQ vacuum carburizing, Vector high pressure gas quench vacuum furnaces, and Pit LPC, our latest innovation for large parts or parts requiring thick case depths.

SOLAR MANUFACTURING

Booth #1313

Jim Nagy, President



Solar Manufacturing will be showcasing our Mentor® and Mentor® Pro compact furnace series. The Mentor® Pro is destined to be as popular as its predecessor. Like the Mentor®, the Mentor® Pro is well-equipped with high-performance features such as a graphite insulated hot zone, a 1,000-pound workload capacity, SolarVac® Essentials controls, and 50 HP internal quench. Both allow heat treaters the convenience of running smaller workloads more economically. To learn more, stop by booth #1313 at Heat Treat 2021.

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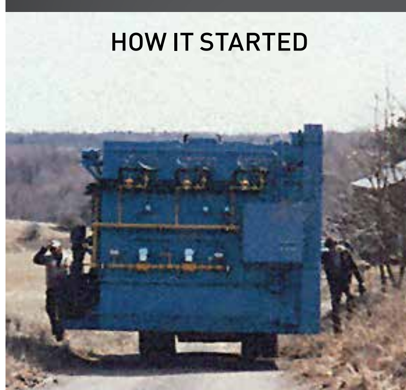
Lunaire


HOW IT STARTED


HOW IT IS NOW

ADVERTISER INDEX ///

(Courtesy: AGMA)

SUPER SYSTEMS INC.

Booth #1021

Bob Fincken, VP Sales

Visit SSi and discover how our plant-wide SCADA system works for you with new features for improved process management and data acquisition. SuperDATA PRO and LE3 include a Pyrometry app for managing historical and future scheduling of surveys, SATs, calibrations, and more. The software's scheduling app organizes work orders using an intuitive schedule to assign orders to specific assets. Let us show you the latest in flow meter technology and see our complete line of meters from in-line totalizers to standard meters with touchscreens or keypads to high pressure gas and liquid meters. See you at the show.

WISCONSIN OVEN CORPORATION

Booth #1620

Doug Christiansen, Application Engineer

Wisconsin Oven Corporation is exhibiting at Heat Treat 2021 to provide attendees with information on our standard and custom industrial ovens. Our heat-treat ovens serve a multitude of industries, including aerospace, automotive, composites, energy, finishing, and more. During the show, we will be highlighting our Horizontal Quench System that is designed for Solution Heat Treating aluminum. This system is a cost-effective alternative to a drop bottom furnace that optimizes floorspace, with quench times as low as five seconds and load ratings up to 8,000 pounds or more. Attendees who visit Wisconsin Oven's Booth #1620 will be greeted by our knowledgeable personnel.

VISIT US AT HEAT TREAT 2021

Thermal Processing will be at ASM International's biannual heat-treat show. We hope you'll stop by our booth (#931) to chat with our staff and share your Expo experiences. We look forward to seeing you there.

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