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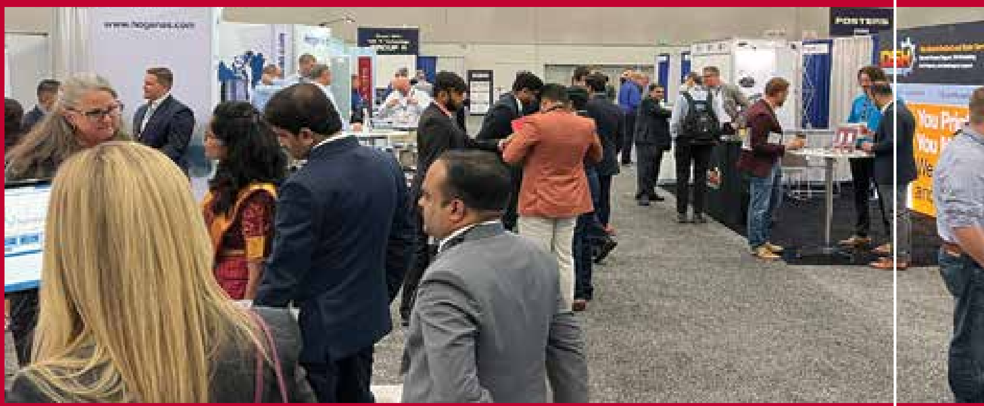

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JUNE 2023 VOLUME 12 / NUMBER 6

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Advancements in powder metallurgy and sintering

It's hard to forget about heat-treating if you have to live through a summer in the South. And although the official beginning of summer is in just a few days, in the South, summer feels like it begins around February 12.

By the time you may be reading this, many will be arriving at PowderMet 2023 — the International Conference on Powder Metallurgy & Particulate Materials — in Las Vegas, Nevada.

PowderMet 2023 is a hub for technology transfer for professionals from every part of the industry, including buyers and specifiers of metal powders, tooling and compacting presses, sintering furnaces, furnace belts, powder handling and blending equipment, quality-control and automation equipment, particle-size and powder-characterization equipment, consulting and research services, and more.

The 2023 show will boast in-person interaction for business deals, information exchange, and panel discussions on the latest innovations in the industry.

And speaking of the heat-treat industry, if you're experiencing some summer heat right now, we have a few articles in this month's issue that might keep your mind off it — at least for a while.

The June issue's cover story takes a look at a fascinating topic in the additive manufacturing industry, as well as a fairly new technology that is advancing the process known as powder DED.

Powder directed energy deposition offers a higher deposition rate than powder bed fusion, and, with the introduction of new technology from Nidec, the process is ideal for printing functionally graded materials into very large structures.

On the topic of sintering, our second focus article takes a deep dive into the effects of sintering temperature and atmosphere on stainless steel.

With our June issue also being a PowderMet 2023 preview, make sure you check out our profile and Q&A that share some important trade-show details.

In addition to our main articles, don't neglect the amazing industrial knowledge of our columnists. They're always offering up must-know expertise on a variety of important heat-treating subjects.

As we take the plunge into summer, I'd like to take this moment to remind you to let *Thermal Processing* be your eyes, ears, and, most importantly, your voice. No matter the challenges you face, we are here, first and foremost, to shine a spotlight on your valuable products, services, and know-how.

Whether it's a powerful ad or an expert article, let us share your insights with the people who are searching for it.

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

KENNETH CARTER, EDITOR
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IFHTSE

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Thierry Allirot

Tracy Dougherty

AFC-Holcroft names new executive management team

As part of a management reorganization, AFC-Holcroft has announced Tracy Dougherty and Ronald Waligora will share leadership responsibility as dual chief operating officers. Dougherty, formerly vice president of Sales, has been named chief operating officer in charge of Sales, Applications, Marketing and Aftermarket Sales, while Waligora, formerly senior engineering manager, has been named chief operating officer for Project Management, Engineering, Manufacturing, and Field Services. Both have spent many years working for the company and both are active in AFC-Holcroft's professional membership organizations such as the Metal Treating Institute and ASM International.

"I expect this to be a smooth transition as we have a talented and dedicated team of employees within AFC-Holcroft," said Dougherty. "We will continue to provide our customers with the best thermal processing equipment in the industry with a renewed focus on customer service and support."

Along with the promotion of Waligora and Dougherty, the company hired Thierry Allirot as chief financial officer for The Atmosphere Group and its subsidiaries including AFC-Holcroft. Allirot has a Master's degree in finance and a Bachelor's degree in logistics. He spent 20 years as a CFO in the United States and other countries, with his experience bridging across different industries.

MORE INFO www.afc-holcroft.com

Lindberg/MPH ships steam atmosphere pit furnace

Lindberg/MPH, a leading manufacturer of heat-treat furnaces and nonferrous melting and holding equipment, has shipped an electrically heated steam atmosphere pit furnace for steam treating parts. Manufacturers use the steam-treating process to create a uniform blue-black finish on the surface of parts, which improves wear and corrosion resistance.

This steam-treating furnace has a maximum temperature rating of 1,250°F and work chamber dimensions of 22" diameter x 36"depth. The furnace has a maximum gross workload of 1,200 pounds and is designed for a pit type installation if required. The custom lid assembly uses a pneumatically operated boom lift with electric swing. The lift is connected to the control system so both the heat and atmosphere are shut off when opened.

The pit furnace is insulated with vacuum-formed ceramic fiber modules that allow for rapid heat-up rates and fast control response. A circulation fan distributes heat evenly throughout the chamber, which ensures rapid and uniform heat transfer throughout the product load. The furnace temperature is controlled by a Eurotherm programmable controller with advanced PID control. A Eurotherm excess temperature controller provides overtemperature protection and disconnects the power to the heating elements in the event that temperature exceeds the desired set-point.

"This steam atmosphere pit furnace has the sufficient capacity to process a workload of 1,200 pounds," said Kelley Shreve, application engineering manager. "This furnace was also designed with a custom powered lid for ease of loading."

Features of this Lindberg/MPH electric pit furnace include:

» Pneumatically operated lid with pow-

Lindberg/MPH has shipped an electrically heated steam atmosphere pit furnace for steam treating parts to a tooling manufacturer. (Courtesy: Lindberg/MPH)

An electrically heated conveyor oven with forced air cooldown by Wisconsin Oven was shipped to an automotive manufacturer for use tempering automotive parts. (Courtesy: Wisconsin Oven Corporation)

ered swing feature for ease of loading.

» Vacuum-formed ceramic fiber modules with low heat storage for rapid heat-up rates.

» Atmosphere tight retort to maintain the steam atmosphere.

» Heater coils designed with low surface watt density for extended service life.

» Programmable temperature controller with adjustable alarm set-point.

» High limit controller to prevent temperature from exceeding set-point.

MORE INFO www.lindbergmph.com

Wisconsin Oven ships pin conveyor oven

Wisconsin Oven Corporation shipped one electrically heated conveyor oven with forced air cooldown to an automotive manufacturer. The oven will be used for tempering automotive parts and features a chain-style conveyor system with vertical pins.

This chain conveyor oven has a maximum temperature rating of 260°C and interior chamber dimensions of 3’6” W x 20’10” L x 9” H. The recirculation system is designed with a top-down bottom-up airflow configuration and uses a 55,000 CFM @ 50 HP blower. Guaranteed temperature uniformity of ±2.5°C at 163°C was documented with a temperature uniformity test.

The conveyor system is a continuous chain style that includes vertical pins attached to four chains to uniformly carry the parts as they are transferred through the oven. The parts are loaded onto the chain conveyor and transported through the heating and cooldown zones of the oven. The parts automatically fall off the exit end of the oven and roll into a chute, where they are removed by a robot. “Our continuous designs provide customers with innovative solutions to meet their load and process requirements,” said Mike Grande, vice president of sales. “This conveyor oven was designed with high-velocity impingement air nozzles for rapid, uniform heating and optimal part results.”

Features of this tempering oven include:

» The parts are automatically scanned while being loaded onto the conveyor, and the system validates that the correct part is being loaded. It then gives the part a pass/fail regarding heating time and temperature.

» Ambient cooldown zone.

» Top-down bottom-up airflow to optimize the heat-up and uniformity of the product load.

» Continuous chain conveyor with vertical pins.

» Programmable temperature controller and recorder with Ethernet capabilities.

» Supervised installation with start-up and training.

This conveyor oven was fully factory tested and adjusted prior to shipment from the facility. All safety interlocks were checked for proper operation and the equipment was operated at the normal and maximum operating temperatures. An extensive quality assurance check list was completed to ensure the equipment met all Wisconsin Oven quality standards. This equipment is backed by a 2-year warranty.

MORE INFO www.wisconsinoven.com

Retech adds more space as growth exceeds expectations

Retech's new facility will house the fabrication, welding, small assemblies, and other manufacturing machinery. (Courtesy: Retech)

Retech, a Seco/Warwick Group company, is set to expand into a larger space yet again.

The 60-year-old company relocated most of its operations to Buffalo, New York, just five years ago as part of parent company Seco/Warwick Group's long-term planning. Now, they have already outgrown their new home and will be taking over a second space that is more than 60 percent larger than their current building, which they will continue to occupy as well. In addition, they still maintain a modest office space for their west coast staff where they began, in Ukiah, California.

Earl Good, Retech managing director, anticipated starting the move in May, just in time to host this summer's Retech 60th anniversary celebration, including all the Seco/Warwick Group companies.

Good reports that competition for industrial space such as this has been fierce in Buffalo in recent years, so he feels particularly grateful to have landed the current deal after spending eight months looking for a suitable space.

The new building will house the fabrication, welding, small assemblies, and other manufacturing machinery, which they were able to move in right away. In contrast, the current building will continue to house the R&D operations, large assemblies, and factory acceptance testing operations.

The new 70,000-square-foot building has 5,000 square feet of office space and a huge 65,000 square feet of high-roof industrial space, including approximately 30,000 square feet under a bridge crane with 45 feet of floor-to-hook clearance, and 40,000 square feet under roughly 25 feet of floor to hook clearance. It has three ground-level bay doors and three dock-height bay doors, and even has access to railroad siding should they ever need it.

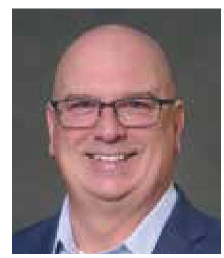
"When we moved into our new Buffalo headquarters, we anticipated an upward trajectory, but this really exceeds expectations," Good said. "This move puts us at 113,000 total square feet of R&D, manufacturing, assembly, and storage space, which allows us to stay ahead of that growth instead of catching up to it."

As they grow into the new space, they will also be staffing up accordingly. Good estimates Retech will eventually hire on 30-60 new staff at all levels, including entry-level, experienced trade technicians, and engineers.

MORE INFO www.retechsystemsllc.com

Ipsen USA hires Choate to expand customer support

Ipsen USA has hired David Choate as director of field service. Choate oversees all field service operations in North America, including repairs, installations, relocations, retrofits, and the teams supporting those activities including field service, warranty and technical support. He is also responsible for global service activities when supporting Ipsen USA exports.



David Choate

One of Ipsen's main initiatives under Choate's leadership is expanding the service team to provide more localized support to customers, resulting in quicker response times.

"Ipsen service is world class," said Choate. "I am thrilled to be a part of this team as we continue our drive for service excellence."

Choate comes to Ipsen from Cupertino Electric, Inc. in Edgerton, Wisconsin, where he served as a product line manager. Prior to that, he held various service-focused roles including market director for Bear Communications, and senior manager of field service for NetApp.

Choate has an Associate of Arts in telecommunications technology from the Community College of the Air Force, and a Bachelor of Science and Master of Business Administration from the University of Phoenix. In addition to his work experience and education, he is a veteran of the U.S. Air Force.

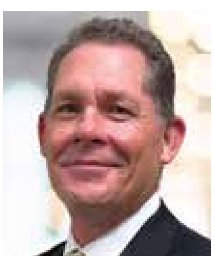
"Choate brings a solid, diversified background to Ipsen and we are excited to have him join our team," said John Dykstra, Ipsen's chief service officer.

MORE INFO www.ipsenusa.com

Jamieson named president/CEO of Allied Mineral

As part of a strategy to maintain executive continuity in the leadership of Allied, Paul Jamieson, current president of Allied Mineral Products, LLC (Allied), was named president and CEO effective May 1. This change is in conjunction with current chairman and CEO Jon R. Tabor announcing his decision to step away from his CEO duties to work exclusively as Allied's Board chairman.

Jamieson has been with Allied for 33 years. Starting in refractory sales into steel markets in Canada, he steadily rose through the organization taking on larger responsibilities within the sales organization for Canada and the United States. In 2017, he became president of Allied. Jamieson has a bachelor's degree in ceramic engineering from McMaster University in Ontario, Canada.



Paul Jamieson

Tabor has been with Allied for 32 years. He served as president and CEO for six years prior to his becoming Allied's chairman and CEO in 2018. Tabor will stay actively involved in the business but plans to step back from the day-to-day operations with a reduced schedule and will focus more on strategy and key initiatives.

"I am humbled and honored to continue with the stewardship of Allied as president and am committed to being your CEO," Jamieson told employees. "I am dedicated to ensuring the continued sustainability of the Allied ESOP and will work with our team to build on the solid foundation already set by Jon (Tabor) and the executive team. At Allied we plan, and we have a strong plan into the future."

Founded in Columbus, Ohio, in 1961, Allied is a leading global manufacturer of monolithic refractories and precast refractory shapes. Allied offers a variety of refractory system designs, products, and technical solutions for high-heat industrial applications that provide heat-containment solutions for its customers worldwide. Allied manufactures in 12 facilities located in eight countries. Headquartered in Columbus, Ohio, with a global workforce of more than 1,100 employees, Allied manufactures more than 2,500 products sold in more than 100 countries. Beginning with success in the foundry industry with coreless induction furnaces, Allied has expanded its product offerings to include all metal-related industries as well as others such as solar, silicon, waste to energy, incineration, petrochemical, and mineral processing. Allied operates state-of-the-art research and development facilities in the U.S. and China, as well as seven precast shape facilities across the globe. As an ESOP company, Allied is employee-owned.

MORE INFO www.alliedmin.com

L&L Special Furnace has shipped a QTO model quench tank with safety lid and fusible links. (Courtesy: L&L Special Furnace)

L&L Special Furnace ships heated oil quench tank

L&L Special Furnace has shipped a small model QTO1224 heated oil quench tank for quenching a variety of heat-treated tools used in the forging industry, such as nippers and ladles.

Forging is the heating of steel to a malleable state or liquid that can be formed or poured into required shapes and tools. The tools are heat-treated in a furnace to required hardness and then quenched in oil to set hardness.

The quench tank holds 65 gallons of oil and is ideal for quenching parts from 50 to 75 pounds. The quench tank oil is agitated by an impeller with 1/2 HP explosion-proof motor and is heated with a 4.5 kW immersion heater to maintain the oil at a slightly elevated temperature to help eliminate oil flashing and fire potential. There is also a safety lid with fusible links that closes automatically if the fusible links melt, dropping the lid and blocking exposure of the surface of the oil to air to prevent any potential fire.

The quench tank has a Eurotherm digital overtemperature protection. This shuts the heater off if the temperature is above a set level. The overtemp will not allow the heater to operate until the overtemp has been manually reset and the oil temperature is below the programmed setpoint.

This small, versatile quench tank is available in various sizes and can be equipped with quench coolers, baskets, and production elevators for pneumatic quenching as required. The quench tank can also be put on casters for portability.

All L&L furnaces can be configured with various options and be specifically tailored to meet customers' thermal needs. They also offer furnaces equipped with pyrometry packages to meet ASM2750 and soon-to-be-certified MedAccred guidelines.

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

MORE INFO www.llfurnace.com

Ipsen USA puts focus on hiring, development

To keep up with business growth, Ipsen USA has hired more than 50 new employees over the past year and implemented new training programs.

With continued focus on customer service, hiring initiatives include expanding the parts department and increasing the number of field service personnel.

In addition to ramping up its recruiting efforts, Ipsen has also implemented internal training and advancement programs to focus on employee retention and developing leadership roles. So far, six employees have earned their PLX (Principles of Leadership Excellence certificate) through MRA, one of the largest employer associations in the nation.

"I am extremely grateful for our senior management's commitment and investment in professional development," said Lydia Nieuwenhuis, Ipsen's HR and benefits manager, who completed the program in March.

The PLX program is comprised of 12 sessions over six months. The goal is to provide opportunities to learn the skills, behaviors, and knowledge needed for effective, successful leadership. Over the past year, eight Ipsen employees have been promoted or moved to roles with greater responsibility, including two who previously earned their PLX.

"Ipsen is committed to developing our employees' skills and promoting from within the company," said Janet Nanni, Ipsen's direc-

In addition to ramping up its recruiting efforts, Ipsen has also implemented internal training and advancement programs to focus on employee retention and developing leadership roles. (Courtesy: Ipsen USA)

tor of human resources. "We have a team of dedicated, hard-working individuals, many of whom have the potential to become valuable leaders in the organization."

MORE INFO www.ipsenglobal.com/careers

Seco/Warwick USA growth spurs move to new offices

Seco/Warwick USA, a Seco/Warwick Group division, has outgrown its century-old current Meadville, Pennsylvania, office after more than 60 years as tenants and has found a new home.

They are moving into the recently rehabilitated Crawford Business Park occupying the former American Viscose Corporation textile mill, just about two miles away. A combination of factors gained Seco/Warwick the entire top floor of the old plant's office building.

While it may be a new home for Seco/Warwick, it is not a new building. The sprawling plant opened in 1930 as a viscose mill, now more commonly known as rayon. At its peak it employed nearly half of Meadville. After many decades, the mill closed and significant funding was put into cleaning, remodeling, and subdividing the million-square-foot plant into more than 50 smaller commercial and industrial spaces.

"The larger space will certainly be nice, but I'm really looking forward to the expansion this will enable," said Marcus Lord, Seco/Warwick USA managing director. "I'll probably bring on three or four more employees right after the move. From there on, as sales and installations increase, I'll continue to staff up accordingly."

Prior to the move, Seco/Warwick's Meadville team of 24 employees were packed into a 2,200 square foot office space. The new space at 18360 Technology Drive is 11,000 square feet, with tall ceilings and windows on all sides offering lots of light and 360° views. Another big advantage of an in-town move is that none of the employees will need to relocate. Beyond enjoying the extra elbow room and conference calls uninterrupted by freight train whistles 15 feet away, the move is also part of a larger strategic plan for the company. In addition to the office space, there is enough room to bring in the electronics assembly operation where they build their furnace control panels. The move, expected to be complete by the end of May 2023, also puts Seco/Warwick in the same business park as their sister company, Seco/Vacuum, which will be very convenient as they often collaborate on projects that have some overlap.

Seco/Warwick has Meadville roots that go back nearly as far as this building, so the move really underscores the role Seco/Warwick has always held as a Meadville company.

MORE INFO www.secowarwick.com

Nitrex installs new exothermic generator

UPC-Marathon, a Nitrex company, recently installed an ExoFlex™ gas generator for Jomarca, a long-time customer and one of the biggest manufacturers of fasteners, bolts, nuts, and fixing elements in Brazil.

The generator will supply exothermic gas to a continuous wire annealing furnace, which is part of Jomarca's efforts to meet market demand efficiently and sustainably for baling wire in the South American construction industry.

Jomarca already owns two EndoFlex endothermic gas generators from UPC-Marathon, a Nitrex company, that supply endogas to the company's production for carburizing fasteners. In March of this year, Jomarca upgraded its wire operations with a 150 m3/h capacity ExoFlex generator to ensure consistent gas composition and prevent scale formation on the wire surface. By using exothermic gas instead of nitrogen, the company expects to reduce operating costs, increase production efficiency, and improve the wear properties and finish of its wire products.

Jomarca has been a loyal customer of UPC-Marathon along with its former busi-

Nitrex recently installed an ExoFlex exothermic generator at Jomarca in Brazil. The generator will supply exothermic gas to a continuous wire annealing furnace, which is part of Jomarca's efforts to meet market demand for baling wire efficiently and sustainably. (Courtesy: Nitrex)

ness asset Atmosphere Engineering, since 2014. The company has consistently been impressed with the quality of the products and the support received. The ExoFlex gas generator is the latest addition to Jomarca's in-house heat-treating operations and represents a significant step towards the company's long-term sustainability goals. With this generator, Jomarca now has the ability to produce exothermic gas on-demand with zero waste, while also making more efficient use of electricity and gas feedstock.

As the lead on this project, UPC-Marathon's Sales Director for Brazil, Marcio Boragini, added,

"We are grateful for the longstanding partnership with Jomarca and thank them for their continued trust in our products and services," said UPC-Marathon's sales director for Brazil, Marcio Boragini, lead on the project. "By providing them with our latest generator technology, we have helped Jomarca improve process efficiency, achieve sustainability, and exceed their customers' expectations for high-quality wire products. The ExoFlex gas generator is yet another example of our commitment to innovation and ensuring a great customer experience, and we look forward to continuing our partnership with Jomarca in the years to come."

MORE INFO www.nitrex.com

Heat Treat 2023 and other conference news

Heat Treat 2023, scheduled for October 17-19 in Detroit, Michigan, is co-located with IMAT 2023 and the Motion+Power Technology Expo in Detroit, Michigan, and will cover many topics of interest. This is the 32nd ASM Heat Treating Society Conference and Exhibition.

At press time, there were about 125 papers submitted from international heat-treating professionals.

The event is also co-located with ASM's Annual Meeting, "International Materials, Applications and Technologies (IMAT)" Conference & Expo, providing Heat Treat attendees with access to 100 materials-related exhibitors and more than 400 additional technical presentations and workshops. Additionally, the Motion + Power Technology Expo 2023 will give attendees access to another 300 exhibitors.

There are numerous student/emerging professionals initiatives, including free college student registration, Fluxtrol Student Research Competition and the new ASM Heat Treating Society Strong Bar Student Competition. This is an opportunity for young professionals and students to meet international heat-treating experts.

The technical program is available at www.asminternational.org/heat-treat/technical.

28TH IFHTSE CONGRESS

November 13-16, 2023 | Yokohama, Japan

Sponsored by the Japanese Society for Heat Treatment, this conference offers participants an opportunity to network and hear papers on a wide-ranging series of topics, including thermal processing of steel, surface hardening additive manufacturing, and modeling and simulation of industrial processes. Important dates:

- Preliminary program release: June 30, 2023.
- Deadline of extended abstract: July 25, 2023.
- Deadline of early registration: July 31, 2023.
- Deadline of full paper submission: September 22, 2023.

A special issue of JSHT will be published in March 2024 (scheduled). Applicants can submit a full paper to the special issue. Only the presenters of the 28th IFHTSE Congress can submit full papers for this special issue. For more information, go to jsht.or.jp/ifhtse2023/index.html

Plenary Lectures

- Prof. Marcel Somers of Technical University of Denmark: Nitriding and Nitrocarburizing.
- Prof. Lu Jian of City University of Hong Kong: Grain Refinement.

Keynote Lectures

- Prof. Massimo Pellizzari of University of Trento, Italy: Heat Treatment for Additive Manufacturing.
- Prof. Imre Felde of Obuda University, Hungary: Heat Treatment Simulation.
- Prof. Satohiro Tsuchiyama of Kyushu University, Japan: Alloy Design and Microstructure Control.
- Prof. Rainer Fechte-Heinen of IWT, Bremen, Germany: Quenching and Distortion Control.

A well attended event at a beautiful location.

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

This event, organized by the Chinese Heat Treatment Association

Opening speech from Prof. Xinya Li, president of CHTA.

(CHTA) and the Harbin Institute of Technology was April 24-26 in Hangzhou. This conference was a hybrid event with more than 260 attendees in person and more than 10,000 participants online.

The opening ceremony was presided over by Prof. Mufu Yan from the Harbin Institute of Technology. Prof. Xinya Li, president of CHTA; Dr. Stefan Hock, secretary general of IFHTSE; and Bin Gu, deputy district governor of Yuhang District, Hangzhou, delivered opening speeches respectively, welcoming friends from all over the world gathering in Hangzhou to exchange information about the heat-treatment industry.

NEW EXECUTIVE COMMITTEE MEMBER: JIANFENG GU

Prof. Dr. Jianfeng Gu has been appointed to the executive committee of IFHTSE at the recent governing council assembly.

He is the deputy president of IFHTSE'S member organization Chinese Heat Treatment Society (CHTS), a professor at the School of Materials Science and Engineering of Shanghai Jiao Tong University (SJTU), and the director of the Institute of Materials Modification and Modeling (IMMM) at SJTU.

He graduated and received his Ph.D. at SJTU, where he pursued his scientific career. Two extensive research and teaching periods took him abroad: One was a two-year postdoctoral fellowship at the University of Technology of Troyes (UTT), France, and the other was a one-year senior visiting scholarship at the University of Nevada — Las Vegas (UNLV).

Jianfeng Gu

His major research interests include: numerical simulation of heat-treatment processes and its engineering application and microstructure and properties of advanced alloys (high-entropy alloys, additive manufactured titanium alloys, and metamaterials, etc.).

We welcome Prof. Gu to the executive committee to strengthen and promote the interests of the Chinese HTSE community and IFHTSE.

SPOTLIGHT ON MEMBERS

Russian Society of Metal Science and Heat Treatment (ROMiT)

ROMiT unites specialists in the field of heat treatment of metals, producers of equipment for heat treatment, and researchers in the field of macro- and microstructure obtained after heat treatment.

ROMiT is tasked with uniting specialists of the Russian Federation on physical metallurgy, thermal processing equipment, and control processes of heat treatment. It is also tasked with standardizing the terminology and names processes of heat treatment in coordination with international organizations. ROMiT is a hybrid of industrial and academic participants, providing a trade group responsible for exhibitions and conferences promoting the interests of the heat-treating and surface-engineering community in Russia.

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.

IFHTSE LEADERSHIP

EXECUTIVE COMMITTEE

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INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

The IHEA calendar heats up

This year's IHEA Fall Seminars will be the Combustion Seminar and the Safety Standards and Codes Seminar offered over two days in Cincinnati.

New — Sustainability Webinar Series: IHEA's new webinar series will focus on carbon producing heating processes and provide methods to optimize their efficiency and reduce their carbon emission intensity. Additionally, these webinars will cover the various scopes of carbon emissions and the methods to determine site, or specific equipment, carbon footprint. Available DOE tools and other resources for determining and reducing carbon footprint will be presented. Overall, this webinar series offers an excellent overview of carbon emissions, how to determine them, and how to reduce them. The first webinar in the series, "Thermal Processing Carbon Footprint," was in May and is now available on IHEA's website under the "Sustainability" tab. Registration is free for this webinar series.

›› **June 15:** Defining Greenhouse Gas (GHG) Emissions to Target NET-ZERO

›› **July 20:** DOE Tools and Programs for GHG Reduction

›› **August 24:** Ongoing Sustainability: Industry Best Practices for Continual Improvement

For details and to register for the webinars, go to www.ihea.org/sustainabilitywebinars.

Webinar presenters include B.J. Bernard, Surface Combustion; and Michael Stowe, Advanced Energy.

FUNDAMENTALS OF INDUSTRIAL PROCESS HEATING

Fall Online Course – Begins August 21

IHEA's Fundamentals of Industrial Process Heating Online Course has been a successful source of high-level learning for those in the industrial heat processing industry for more than a decade. The course is taught over a six-week period and designed to give students flexibility, along with interaction from a moderator and online forums to communicate with other students. Each week, students will be assigned a chapter to read from the Fundamentals of Process Heating course book (electronic version included with course registration) and expected to participate in forum discussions and complete weekly quizzes. There is a final exam project that will be assigned during the fifth week of class. The moderator will be available by email to respond to questions and provide clarification.

The comprehensive curriculum includes the following topics: combustion fundamentals and fuels, combustion equipment for gaseous and liquid fuels, elements of heat transmission, heat balance and efficiency calculations, advanced heat transfer principles, and fundamentals of electrical heating.

This online course is a terrific value for IHEA members and nonmembers alike, considering no travel expenses are involved, and there is no time out of the office.

A former online student said, "Because of balancing an extremely busy workload and family life, I am not able to be on a regular schedule or take time in the evening to travel to a class. The advantage for me is that I can check in when time permits and still stay current on all activities. The course information is directly related to my work, and I found it to be very beneficial."

Registration for the course is open now through August 16, 2023, at www.ihea.org/event/FundamentalsFall23. Registration fee includes an electronic course handbook, weekly assignments, class forums, and the opportunity to contact the moderator throughout the course. A certificate of completion noting 18 PDHs earned will be given to each attendee who successful completes the course. Printed materials are available for an additional fee.

IHEA'S FALL SEMINARS SET FOR OCTOBER 31 AND NOVEMBER 1

Cincinnati, Ohio

The IHEA Fall Seminars will be October 31 and November 1. This year, IHEA will offer the Combustion Seminar and the Safety Standards and Codes Seminar at the Embassy Suites by Hilton – Cincinnati RiverCenter, a convenient venue for the annual training courses.

For more than half a century, the combustion division of IHEA has delivered quality education for those in the thermal heat processing industry. IHEA's Combustion Seminar continues to provide attendees with updated and relevant information from experts in combustion technologies. The seminar is designed for those responsible for the operation, design, selection and/or maintenance of fuel-fired industrial process furnaces and ovens. With more than 12 hours of instruction from manufacturing professionals, attendees will learn from the best in the industry. For complete details and registration information, go to www.ihea.org/event/Combustion23.

IHEA's popular Safety Standards and Codes Seminar will provide a comprehensive overview of NFPA 86, including the recent updates in the newly released NFPA 86 Standards for Ovens & Furnaces, 2023 Edition. The seminar covers critical safety information for those involved with a wide range of industrial thermprocess applications. Sessions will cover the required uses of the American National Standards governing the compliant design and operation of ovens and furnaces. Speakers are all involved in NFPA and serve on the technical committees, so they can bring the most updated information to attendees. For more information and registration details, go to www.ihea.org/event/Safety23.

TABLETOP EXHIBITION AND RECEPTION

There will be a combined tabletop exhibition and reception Tuesday, October 31. Attendees from both seminars will have the opportunity to speak with company representatives and learn more about the products and services discussed in the classroom. Member companies benefit by connecting with attendees from both seminars during the tabletop exhibition and reception.

Registration fees for the seminars include admission to one seminar, seminar materials, tabletop exhibition and reception on Tuesday, and lunch and refreshment breaks on Tuesday and Wednesday. Upon completion of the course, seminar attendees will be issued a certificate documenting 15 Professional Development Hours (PDHs). There is a group discount available for two or more registrants from the same company who register at the same time. The first registrant will pay the full registration fee, and each subsequent registrant will receive a $125 discount. Seminar details and registration information are at www.ihea.org/Fall23.

IHEA CALENDAR OF EVENTS

JUNE 15

Sustainability & Decarbonization Webinar Series – Defining Greenhouse Gas (GHG) Emissions

Greenhouse Gases (GHGs) come in several forms. One of the most common is carbon and this is what this webinar will focus on. Carbon emissions fall into several categories known as "scopes." This presentation will define scope 1, 2, and 3 carbon emissions.

JULY 20

Sustainability & Decarbonization Webinar Series – DOE Tools and Programs for GHG Reduction

There are many options available to help determine carbon emissions for equipment, processes, sites, and organizations. This presentation will review some of these available tools and how to apply them to different situations.

AUGUST 21

Fundamentals of Industrial Process Heating

6 week online course I $775 IHEA members / $950 non-members

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

AUGUST 24

Sustainability & Decarbonization Webinar Series – Ongoing Sustainability: Industry Best Practices

Carbon reduction is not a project, it is a process, and must be ongoing. Earlier sessions will help you determine your carbon footprint and understand ways to track and impact your carbon footprint. In this presentation, we will review methods and programs to ensure the continual improvement of your carbon reduction efforts.

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

JASON MEYER
MECHANICAL ENGINEER /// DANTE SOLUTIONS

An analysis of the bending failure of a carburized case from the HTS2021 Strong Bar competition.

Learning from failure in bending stress

A couple of years ago, as I was finishing my graduate studies, I was lucky enough to participate in the Strong Bar competition put on by the ASM Heat Treat Society at the Heat Treat Show 2021. This competition challenges university students to design and execute a heat treatment of their choice on a provided steel bar, which then will be tested in bending at the heat treat conference that year. The group with the highest combined load and deflection is deemed the winner.

This competition opened the possibility for my teammate and me to work in the university's materials lab which was otherwise closed off to non-PhD students. We were able to perform metallurgical analysis such as sectioning, polishing, performing the micro-hardness traverse, and even etching the sample to see the microstructure. As a budding mechanical engineer looking to pursue a career in a materials-dominated industry, this was an invaluable experience. Our team weighed the available options for heat treatment on the bar and assumed our fellow competitors would be going for quench and temper processes to ensure their bars would be able to handle the bending load. Wanting a more novel heat treatment, our team decided on carburization to take advantage of the higher strength from adding carbon to the steel, as well as leveraging the residual surface compressive stress induced by the process. Unfortunately, this led to a more brittle microstructure and our bar failed spectacularly in the three-point bend machine on the conference floor. Regardless, much was learned, and it was a great experience overall.

After the competition, we received the broken sample and attempted to determine the mode of failure. Classically, bending stress is given by the equation: $\sigma = \frac{Mc}{I}$ where sigma is the bending stress, M is the bending moment, c is the distance from the neutral axis, and I is the moment of inertia which handles the geometry effect on bending; shown schematically in Figure 1.

From the equation and Figure 1, we can see that the greater the distance from the neutral axis, the greater the magnitude of bending stress that point experiences. A hand calculation was performed using the data from the bend test, shear and bending moment diagrams learned from the previous coursework, and the bending stress equation previously described. The hand calculation returned a maximum tensile stress of 2333 MPa, which is more than three times the reported yield of 4140, and an FEA model was executed to view and analyze the non-linear behavior from bending.

STUDY

A finite element model was developed to simulate the three-point bending experiment that was performed for the competition. Taking advantage of symmetry, the 100 mm long, 9.5 mm diameter bar was halved axially and meshed with 24,858 elements and 13,876 nodes. A fine layer of elements near the surface was used to capture the carbon case and thermal gradients present in the heat-treatment model. Two cylinders were used on the bottom of the sample for the simple supports of the bending rig, while a third was used on top to apply the load, as shown in Figure 2.

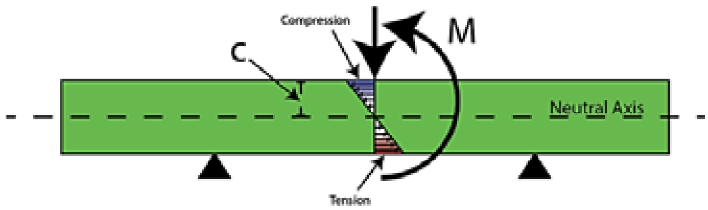

Figure 1: Schematic of bending stress in a loaded beam.

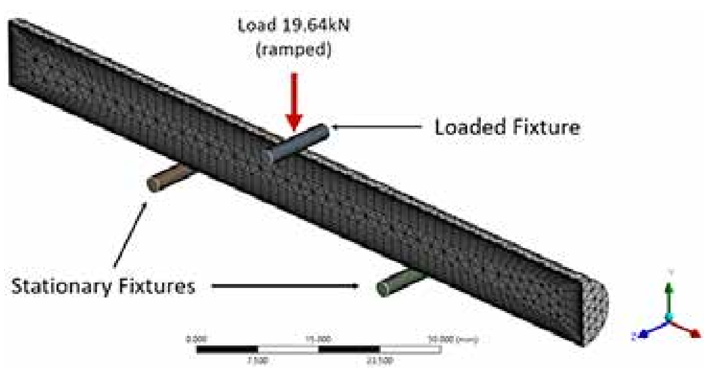

Figure 2: Schematic of mesh and loading fixtures for the FEA model.

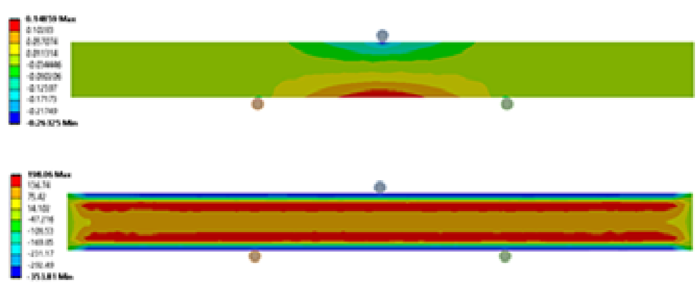

Figure 3: Initial stress contours for loading, residual stress free (top), and with residual stress from heat treatment (bottom).

Having more carbon in the case delays the martensitic transformation during quenching, causing the carburized case to transform after the core. This delayed transformation induces compression in the case from the volumetric expansion of the austenite (FCC) to martensite (BCT) solid-state phase transformation. Figure 3 shows the model setup as the load is being applied for the noncarburized (top) and carburized (bottom) bending models.

Residual stress must be balanced in a part, meaning if compression resides in the case, there must be tension to off-set the compression.

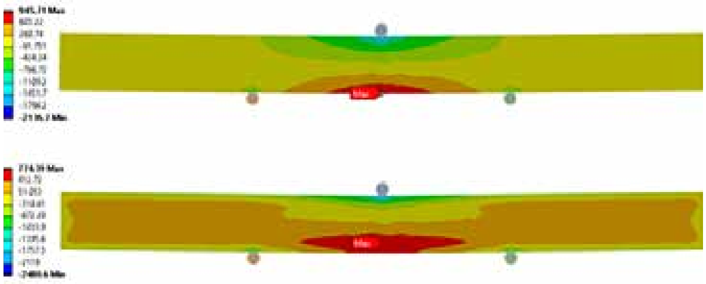

Figure 4: In-process stress contours for loading, residual stress free (top) and with residual stress from heat treatment (bottom).

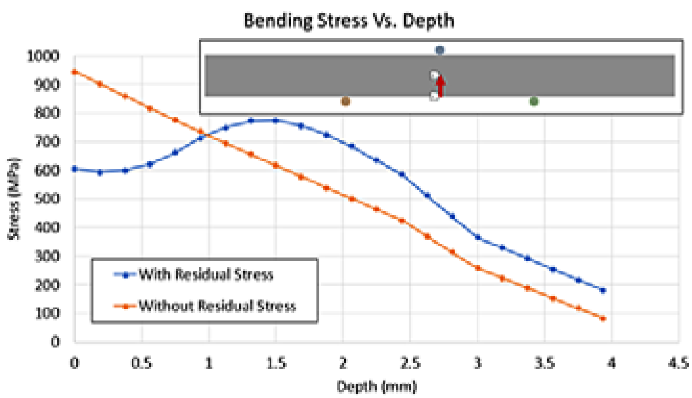

Figure 5: Bending stress vs depth from bottom surface, with and without residual stress.

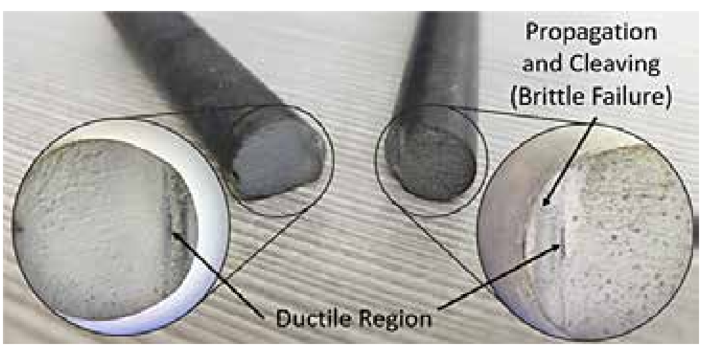

Figure 6: Tested sample, showing the fractured surface.

From Figure 3, there exists a layer of tension just under the carburized case. With a carburized sample, the magnitude of tension induced by bending is offset by the magnitude of near-surface residual compression developed during the carburization process. Likewise, the residual tension under the case increases the magnitude of tension from bending. Both factors combine to show that the maximum tension in the sample from bending is not necessarily at the surface as with the residual stress-free sample. Figure 4 shows the in-process bending stress for the residual stress free (top) and the stressed model (bottom).

Figure 5 shows the plot of a path from the bottom of the sample to the core, at the same time-step as the contours in Figure 4, showing the difference in bending stress when including residual stress from heat treatment. The residual stress-free model shows an almost linear relationship between the distance from the neutral axis and the bending stress. The model with residual stress from heat treatment shows a lower bending stress in the case compared to the residual stress-free model. The reduced bending stress persists up to 1 millimeter from the surface, at which point the tension under the case begins to add to the tension induced from bending. The peak bending stress occurs at the 1.5 mm total case depth that was achieved from the carburization process. This region, at or near the base carbon level, would be

more ductile compared to the carbon case, and at the instant shown in Figure 4 the magnitude of tension is just above the reported yield strength of AISI 4140.

When inspecting the returned sample, shown in Figure 6, it is clear that there is a more ductile region at about 1.5 mm from the surface. From the edges of this ductile patch, cracks can be seen propagating toward the surface and the cleavage along this direction is indicative of brittle failure. The rest of the sample displays these signs of catastrophic brittle failure, showing that when the cracks did form and propagate the rest of the sample quickly followed.

CONCLUSIONS

In the three-point bend test, a sample experiences a moment from the load applied that imparts compressive and tensile stresses normal to the applied load. Typically, the highest magnitude of bending stress occurs at the surface, farthest from the neutral axis, but with a carburized part this is not always the case. After a failure at the Strong Bar competition, an FEA model was executed to explore the differences between a classic bending example and one using residual stresses from heat treatment. The models show that while the surface is farther away from the neutral axis, the peak tensile stress was just under the carbon case. Comparing the results of the model to the actual sample shows an agreement to the location of peak stress and the small ductile region under the case. From this ductile region, there exists several cracks leading to the surface which are most likely the cause of the spectacular failure on the exhibit floor. This work illustrates the importance of designing a case depth that is deep enough to handle the load applied. While parts in service will not typically be bent to failure, understanding the depth and magnitude of applied stress will ensure long and safe life of components. Once the part begins to yield all bets are off, so to speak, when it comes to the beneficial residual stress from heat treatment. Overall, I would advise any student who is interested in materials and heat treatment to participate in the Strong Bar competition. It was an invaluable experience to work in the metallographic lab, design and execute the heat treatment, and learn the lessons from failure in bending.

ABOUT THE AUTHOR

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

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

Increasing the temperature of the quenchant can offer better wetting of the part and increased heat extraction as well as reducing the residual stresses and the amount of distortion.

The effect of temperature on cooling curve behavior

In this column, we will discuss the effect of temperature on the cooling curve behavior of quench oils.

DEVELOPMENT OF QUENCH OIL MAXIMUM OPERATING TEMPERATURE

The first thing to understand is the operating temperature constraint of the quench oil. This is considered the safe operating temperature of the oil.

The operating parameters of a quench oil are based on the flash point of the oil and the load size. If you consider a typical heat-treating load that follows the "one pound of parts/grids to one gallon of oil," the oil temperature will increase by approximately 70°F. According to NFPA 86 Standard for Ovens and Furnaces [1], the quench tank should be designed and sized to quench a maximum gross load such that the maximum quenchant temperature is not less than 50°F (28°C) below the flash point of the quenchant. An additional safety factor is added of 50°F (28°C) to allow for hung loads, failed heat exchangers, etc. An additional reason is to minimize oil oxidation. This is shown in Table 1.

This table doesn't provide any recommendations about the lower limit of the oil, just the recommended upper limit.

EFFECT OF TEMPERATURE

Increasing the temperature of a quench oil increases the oxidation of a quench oil, so it is a good idea to operate the oil at the lowest possible temperature that will still provide good properties and distortion control.

One of the thermophysical properties of a quench oil that changes considerably as a function of temperature is kinematic viscosity. This is the ability to properly wet the part as the part is immersed. If the viscosity is low, then the oil will readily wet the part. If the oil has a high viscosity, then wetting the part becomes more difficult. To visualize this, think of immersing a rod into a vat of water compared to a vat of molasses. Better wetting means that the oil is better able to make intimate contact with the part, and extract heat readily. The change in viscosity as a function of temperature for a medium speed quench oil is shown in Figure 1. The decrease in viscosity as the temperature is increased is typical for all oils.

Using the GM Quenchometer [2], we can look at the overall speed of a quench oil as a function of temperature. Looking at several different oils (Figure 2), we can see that as temperature is increased, the speed of the oil increases (lower number of seconds), reaches a peak, then starts to decrease in speed. Something else is also affecting the heat extraction behavior of the quenchant.

As the temperature of oil increases, the vapor phase during quenching becomes more stable, and longer (more persistent). This stable vapor phase slows down the heat extraction rate. At temperatures below the peak cooling rate, the viscosity effects are dominant.

Flash Point of Oil (typical cold oil)	350°F	177°C
NFPA Safety Factor	-50°F	-28°C
Additional Safety Factor	-50°F	-28°C
Maximum Peak Quench Temperature	250°F	121°C
Temperature Rise	-70°F	-39°C
Maximum Operating Temperature	180°F	82°C

Table 1: Illustration of the determination of safe peak temperatures and operating temperatures of quench oil.

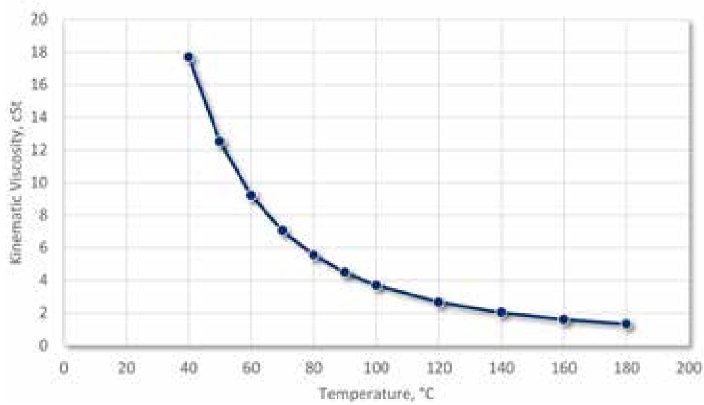

Figure 1: Viscosity changes as a function of temperature for a medium speed oil with a nominal viscosity of 18 cSt at 40°C.

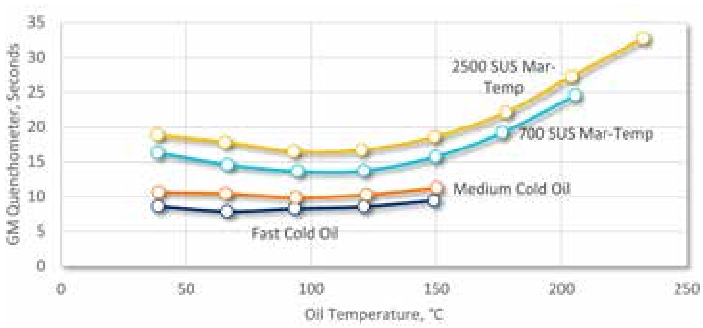

Figure 2: Change in GMQS speed of four different quench oils as a function of temperature.

At the peak temperature, neither viscosity nor vapor phase stability effects dominate. Above the peak temperature, the stability of the vapor phase dominates.

As opposed to agitation, different parts of the curve are affected. With agitation, the maximum cooling rates in all three regions are affected and increased. With temperature, only the cooling rates in the vapor phase and nucleate boiling regions are affected. The con-

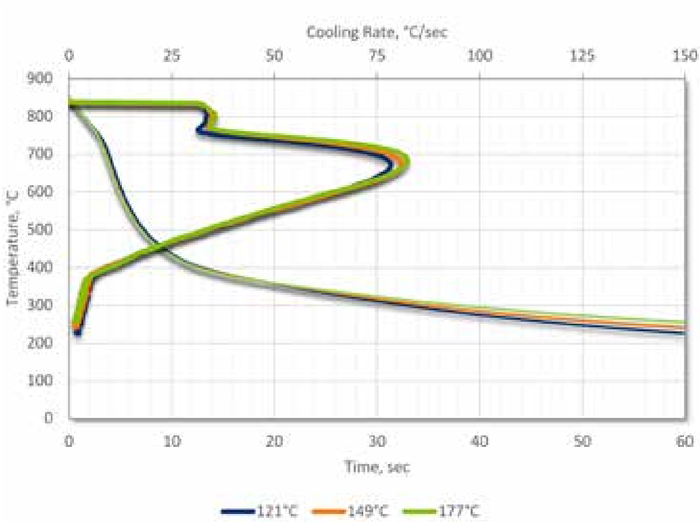

Figure 3: Effect of temperature on the cooling curve behavior of a thick mar-tempering oil as a function of temperature.

vection stage remains the same. Further, the effects of temperature are more subtle, without the large effects of agitation. The effect of temperature on a thick mar-tempering oil with a nominal kinematic viscosity of 550 cSt at 40°C is shown in Figure 3.

The benefits of increasing quenchant temperature are a slight increase in the overall quenching rate. The biggest advantage of increasing the quenchant temperature is reducing the thermal gradients in the part during quenching. This reduction of thermal gradients reduces the residual stresses formed in the part during quenching and reduces distortion. This is the primary purpose of mar-tempering oils. However, some reduction in distortion can also occur in cold oils by increasing the operating temperature to the maximum operating temperature.

CONCLUSIONS

In this article, the effect of quenchant temperature on the cooling curve behavior was shown. Increasing the temperature of the quenchant can offer better wetting of the part and increased heat extraction. This can help with achieving properties. Increasing the temperature of the quenchant can also help reduce the residual stresses and the amount of distortion occurring in a part. The effect of temperature, working in conjunction with agitation, can yield parts with excellent properties and reduced distortion.

Should you have any questions regarding this column, or suggestions for future articles, please contact the author or the editor.

REFERENCES

[1] National Fire Protection Association, "Standard for Ovens and Furnaces," Quincy, MA, 2015.

[2] ASTM, "Standard Method for Quenching Time of Heat-Treating Fluids (Magnetic Quenchometer Method)," American Society for Standards and Materials, Conshocken, PA, 88.

ABOUT THE AUTHOR

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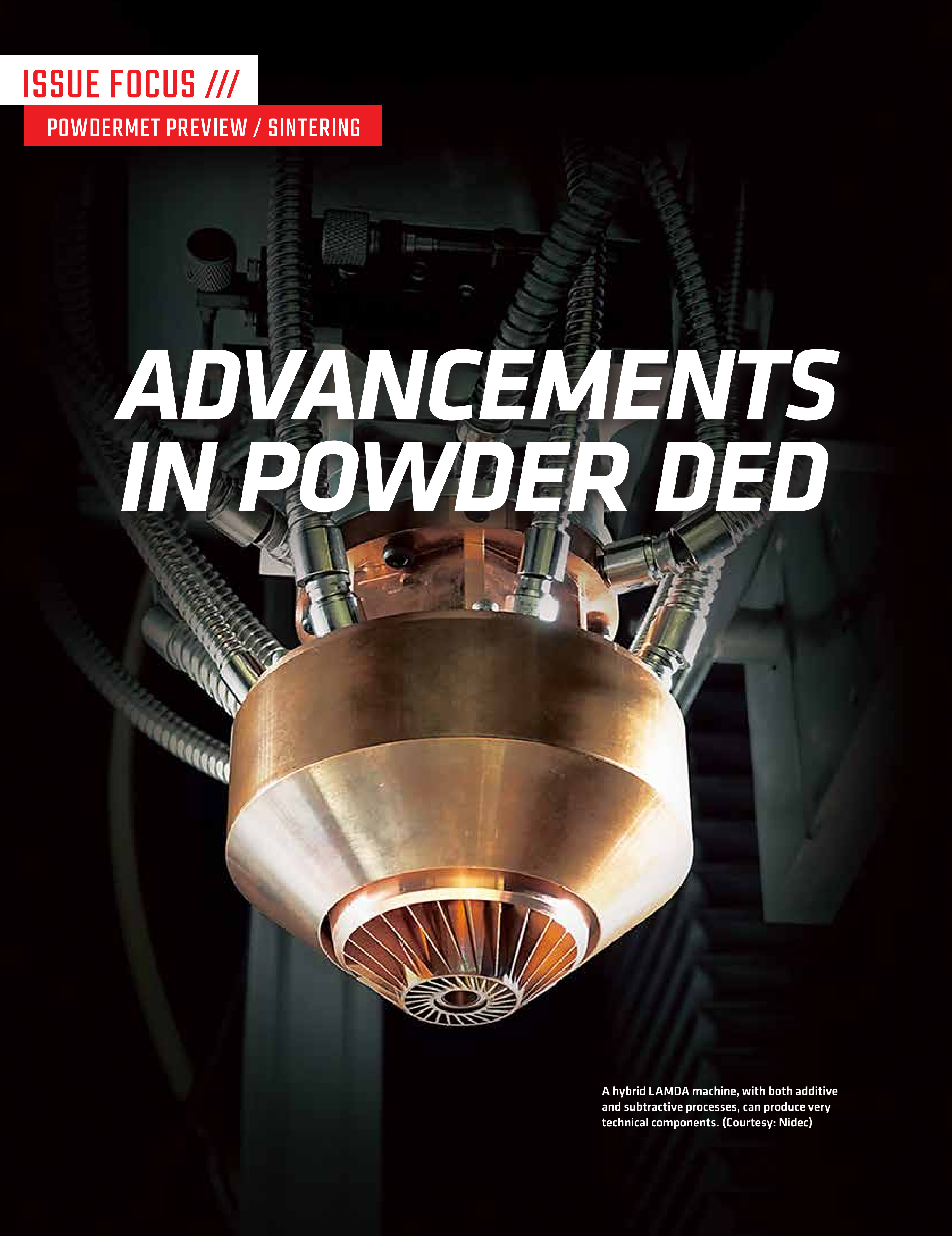
ADVANCEMENTS IN POWDER DED



A hybrid LAMDA machine, with both additive and subtractive processes, can produce very technical components. (Courtesy: Nidec)

Powder directed energy deposition offers a higher deposition rate than powder bed fusion, and, with the introduction of new technology, the process is ideal for printing functionally graded materials into very large structures.

By KENNETH CARTER, Thermal Processing editor

Powder DED, or directed energy deposition, has become a useful and economical tool within the world of metal-based additive manufacturing. Advancements within the process over the last few years have made it an even more impressive innovation now being used in a variety of industries, including aerospace, defense and military, oil and gas, mining, shipbuilding, die mold and automotive, as well as in general machine shops.

Powder DED is a process that uses a laser as a heat source to melt and solidify locally-fed metal powder together with a substrate to manufacture a three-dimensional shape by overlay welding. (See Figure 1)

Because of its higher deposition rate over traditional powder bed fusion, as well as its ability to print functionally graded materials, powder DED can be used to print very large objects. It can also be used to reduce the part weight and integrate parts with shapes beyond conventional manufacturing. This gives the process the ability to improve design, enhance functionality, and reduce parts inventory.

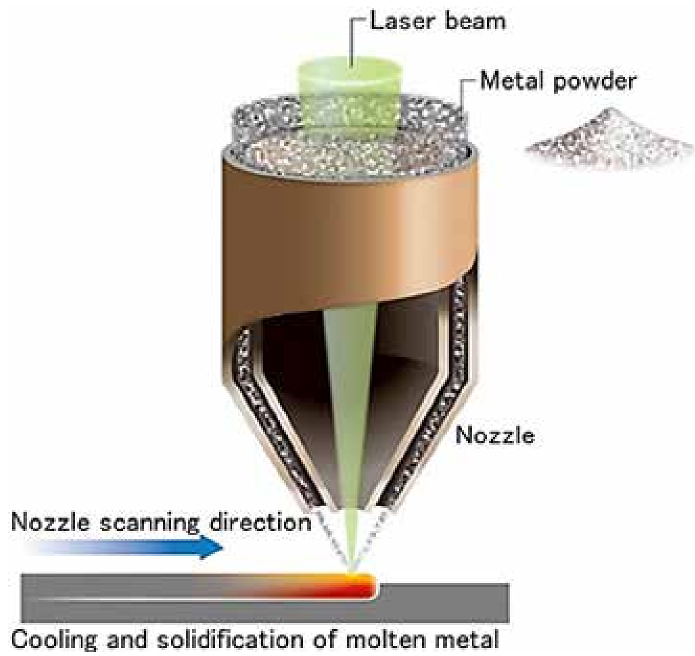


Figure 1: Powder DED metal-based additive manufacturing method.

LAMDA SERIES

As part of this push to use powder DED within a myriad of industries, engineers with Nidec Machine Tool America have developed a series of DED machines that have taken the process to the next level. The LAMDA series, originally created when Nidec was known as Mitsubishi Heavy Industries Machine Tool, is a powder DED 3D metal-based additive manufacturing machine with a local shield to manufacture parts with the ability to suppress the oxidation of reactive metals, such as titanium and aluminum. It also has the ability to keep shapes from collapsing during manufacturing by controlling the heat input using a monitoring function system.

"With powder DED, it becomes possible to produce things that are not possible with conventional machining," said Dwight Smith, vice president at Nidec Machine Tool America. "A hybrid LAMDA machine, with both additive and subtractive processes, can produce very technical components, for example, with internal cooling channels that perhaps could not be manufactured conventionally or require very expensive fabrication."

One of powder DED's greatest advantages is its speed, according to Smith. In many cases, by the time a billet is obtained for a component, the DED process can already be finished.

"Multiple different materials can be applied to the component, and even functional gradients can be produced — both of which are not possible with conventional manufacturing," he said. "Features can even be added to existing components. For example, an Inconel feature can be added to a steel part at one location and a stainless-steel feature to another."

The LAMDA500. (Courtesy: Nidec)

SYSTEM ADVANTAGES

Nidec's LAMDA series has a few advantages over other DED systems, according to Smith, the first of which is the system's monitoring and feedback system.

Figure 2 shows a system configuration diagram of the monitoring feedback function. A camera installed coaxially with the laser beam enables the user to see directly above the melt pool during the manufacturing process. This is based on the idea that a change in the state of the substrate appears as a change in the melt pool. The melt pool image is analyzed by a dedicated PC in real time, so changes can be detected immediately. Based on the detected amount of change, the manufacturing position and laser output command can be feedback-controlled. By detecting abnormalities, such as sputter, at the same time, the equipment can be safely stopped in order to prevent damage.

"Nidec has patented portions of the technology, which analyzes over 300 video frames per second to provide near real-time control of laser power and other parameters," he said. "This controls the melt pool, provides a complete production map and quality documentation. Our testing illustrates that this highly-advanced feedback methodology provides superior metallurgical results in 3D printing as well as high accuracy. Many features can be used as printed or with minimal post process machining."

High-precision additive manufacturing means manufacturing a metal into an accurate shape with the proper mechanical properties. For the LAMDA series, two types of nozzles are possible so the shape of the part, the needed accuracy, and the manufacturing speed dictate which nozzle is selected.

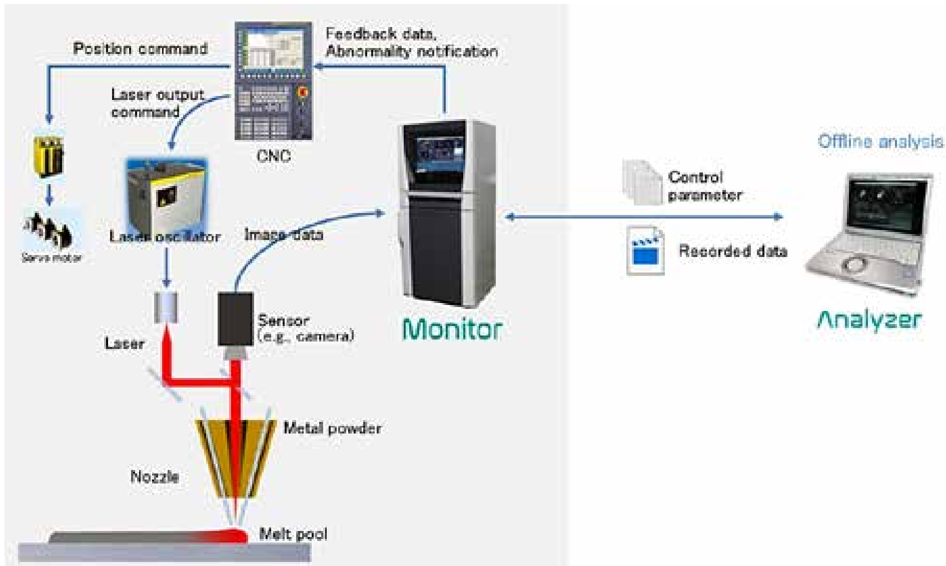


Figure 2: Monitoring function system configuration.

Powder DED technology coupled with Nidec's LAMDA series is filled with numerous applications all across multiple industrial sectors. (Courtesy: Nidec)

NOT A PBF REPLACEMENT

This is not to say that DED process is necessarily preferred to more traditional PBF. Both processes are quite different and both also fill a valuable role in the AM world, according to Smith.

"They're not really in competition with each other, but the PBF (powder bed fusion) is typically higher accuracy," he said. "Many of the parts are net finished when they come out of a PBF machine, whereas DED typically is a near net process. It really depends on the application. Some of the features on our machine are near enough to the final requirements that they don't have to be machined, but, of course, that depends on the requirements."

The second advantage of the LAMDA series is its in-house designed nozzle technology. Because of the importance of maintaining material integrity of reactive materials, combined with the need for near net accuracy, material delivery and shielding of the melt pool are essential.

High-precision additive manufacturing means manufacturing a metal into an accurate shape with the proper mechanical properties. For the LAMDA series, two types of nozzles are possible — a multi-port feeding type and an all-around feeding type — so the shape of the part, the needed accuracy, and the manufacturing speed dictate which nozzle is selected.

During the manufacturing process, the metal powder converges at the nozzle standoff setting position. The convergence diameter is about the same as the focusing spot diameter of the additive manufacturing head optical system. By accurately converging the metal powder, it becomes possible to perform manufacturing with the desired shape and dimensions.

High-precision additive manufacturing means manufacturing a metal into an accurate shape with the proper mechanical properties. (Courtesy: Nidec)

PERFECTING THE INERT GAS SHIELDING

Smith said extensive development was undertaken with these goals in mind. In particular, the use of computational fluid dynamics was employed to perfect the inert gas shielding to provide up to two times the shielded area compared to other units on the market.

"This provides the ability to focus and control the delivery of the powder, which is essential for accurate and consistent production," he said. "This advanced design can apply two different materials individually and combined. The local shield system, designed with the use of CFD, provides the largest inert gas shield to keep oxygen out of the material being melted."

This shield of inert gas — usually argon — shields the melt pool and the surrounding area during the build.

Metals such as titanium and aluminum react with oxygen when they are melted, which can adversely affect the integrity of a material. The LAMDA machine implements a shield of inert gas that completely engulfs the melt pool, excluding the oxygen and allowing the material to melt in the pool sufficiently to avoid any degradation, according to Smith.

NO SPECIALIZED CHAMBER REQUIRED

By deploying a localized shield, the process avoids the need for a specialized chamber where oxygen is replaced with argon. This also avoids the possibility of losing large quantities of the inert gas, which could affect a company's bottom line.

Needing a chamber also can affect the size of the parts being manufactured, according to Smith.

"The big advantage is for big parts," he said. "Standard LAMDA systems have been delivered and are available up to 2,500 x 900 x 1,000 mm, but there is really no limit on size. As a machine tool manufacturer, Nidec has built machines much larger, and LAMDA modular technology can be integrated into nearly any CNC machine or robot. Because LAMDA does not require an enclosure, size is no longer a limitation."

This adaptability and practically limitless size restrictions makes the powder DED process in general and the LAMDA series in particular ideal for large and unusual jobs often required in highly demanding industries.

AEROSPACE APPLICATIONS

For example, a large aluminum structure for a satellite or other aerostructure is an application well suited to the LAMDA series, especially the LAMDA500, according to Smith. A suitable build plate is located within the 5-axis printing area. A CAD file of the component can be prepared using the full range of motions of the machine. During the building process, the LAMDA AI anomaly detection system will monitor and detect any abnormal situations and stop the build.

"This allows the situation to be corrected, usually allowing the build to be successful," he said.

Powder DED implemented with the LAMDA series is also ideal for larger repair jobs where it would be impractical and cost heavy to move or replace a failed component, according to Smith. Multiple materials can be applied selectively to specific locations making it possible to repair large and expensive components cost efficiently.

"Beyond making new components from zero, this technology can be applied to add material to existing components," he said. "Imagine an expensive ship's engine crankshaft. If it needs to be repaired and it takes three years to make a new one, the LAMDA system can deposit the material where it's needed."

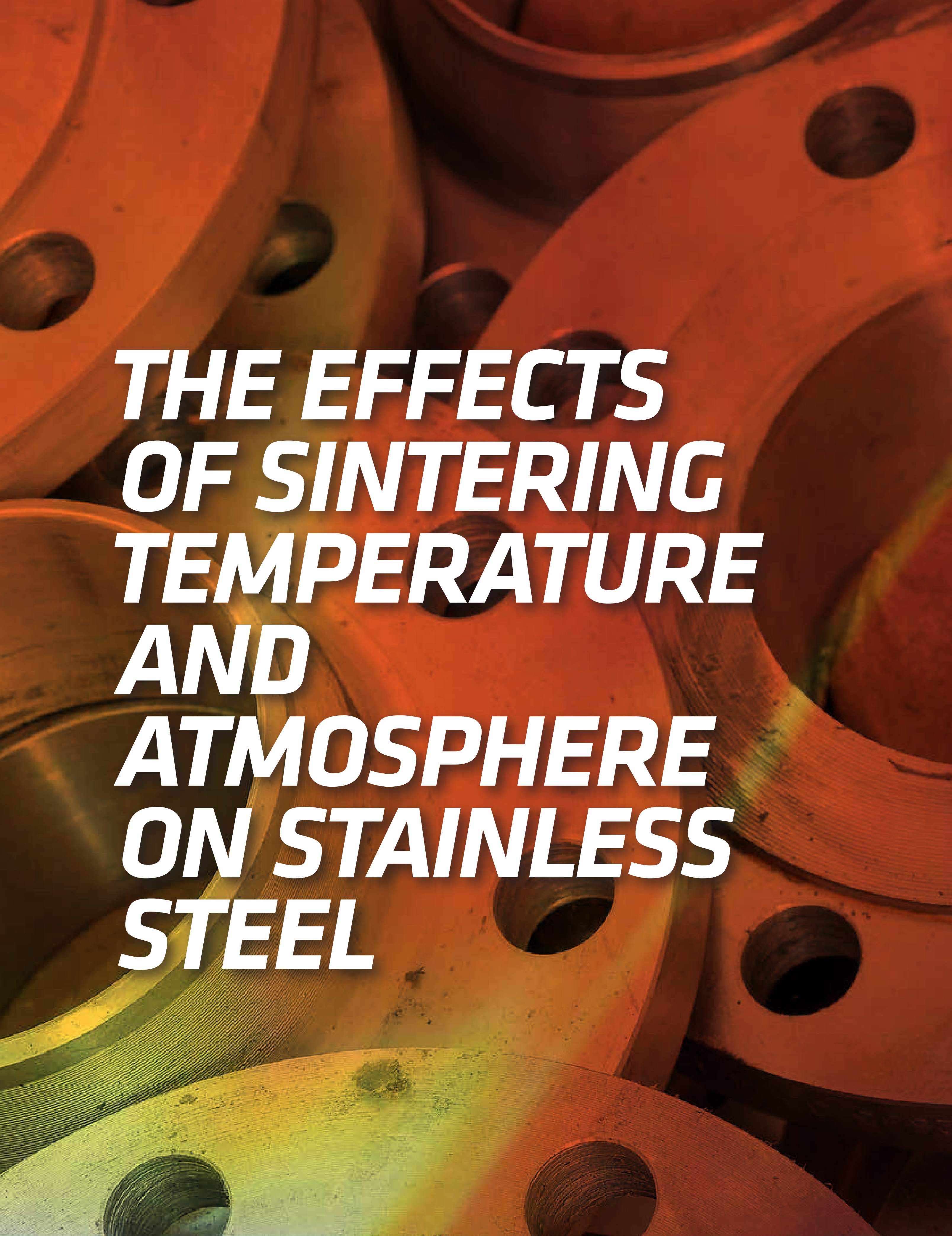
Powder DED has been well established in the aviation world for the repair of jet engine turbine blades for some time now, so by using the same concept, Smith said virtually any type of component could be added to or repaired in much the same way. This could even include adding extra features to an existing component.

"Which has some interesting options," he said. "In a prototype situation, you may decide you need a new feature here on an already-made piece. This could be used to add that feature."

Powder DED technology coupled with Nidec's LAMDA series is filled with numerous applications all across multiple industrial sectors. Its ability to create large structures and repair and enhance existing components makes it an ideal tool in the metal powder AM market, especially when factoring in convenience and the overall cost to manufacture can be lower than either traditional manufacturing or powder bed fusion.

EDITOR'S NOTE

Some information and figures for this article were adapted from "Manufacturing Technology of LAMDA Three-Dimensional Metal-based Additive Manufacturing System Using Powder DED Method," Mitsubishi Heavy Industries Technical Review, Vol. 57, No. 3 (September 2020). www.mhi.co.jp/technology/review/pdf/e573/e573070.pdf



THE EFFECTS OF SINTERING TEMPERATURE AND ATMOSPHERE ON STAINLESS STEEL

Sintering atmosphere, temperature, and solution-annealing treatment play a significant influence on the properties of precipitation-hardening sintered 17-4 PH stainless steel.

By JAN KAZIOR

So far, unlike metal injection molding (MIM), conventional powder metallurgy technology (PM) has not been regarded as a method for producing structural elements from 17-4 PH powders, due to the problems of obtaining almost fully compacted shapes after sintering. Nevertheless, recent research demonstrates it is possible to manufacture sintered parts with high strength by pressing and sintering. The purpose of the study was to determine the degree of densification of 17-4 PH sintered stainless steel during sintering at different temperatures and atmospheres. As a result of the study, it was pointed out that both the temperature and the sintering atmosphere play an essential role in the process of densification of the studied powders during sintering. The formation of delta ferrite and a more pronounced degree of spheroidization of the pores is activated by a higher sintering temperature. Furthermore, after solution-annealed and age-hardened treatment, sintered 17-4 PH stainless steel exhibits high strength with moderate ductility at a level that is difficult to achieve for other sintered stainless-steel grades, such as austenitic, ferritic, and martensitic. In turn, the largest improvement in the pitting corrosion resistance in 0.5 M NaCl solution is reached by sintering at 1,340°C in hydrogen and after solid solution treatment.

1 INTRODUCTION

Stainless steels can be classified into several groups. These include: austenitic, ferritic, martensitic, precipitation hardening, dual-phase, and duplex stainless steels. There are a lot of commercially available stainless-steel powder grades. A wide range of them can be produced by the water atomization process and then pressed and sintered. Precipitation-hardening stainless-steel powder is a relatively new family of alloys. These are designated to provide high strength and toughness by the submicroscopic precipitates in the matrix [1]. Most of the published research papers on the manufacture of sintered 17-4 stainless steel preferred injection molding technology, while there are few publications devoted to the fabrication of parts by cost-effective energy and material-saving powder metallurgy technology. However, recent published research works most clearly indicate it is possible to develop high-strength sintered parts by the traditional pressing and sintering technique [2,3,4,5,6,7]. The addition of such elements as copper and niobium, which form intermetallic precipitates during aging, cause the strengthening of 17-4 PH stainless steels. The presence of copper promotes the precipitation-hardening process, while niobium contributes to reductions in hardness after solution annealing, thus, making machining possible and hindering over aging.

To make it easier to complete phase transformation, the nickel and molybdenum contents are limited. Water-atomized 17-4 PH stainless powders have martensitic structures. During solution annealing, the matrix forms with precipitates, forming elements of supersaturated austenite solid solution, which is transformed into martensite during cooling. Upon aging, second-phase precipitates nucleate uniformly throughout the matrix. Aging treatment is designed to ensure the

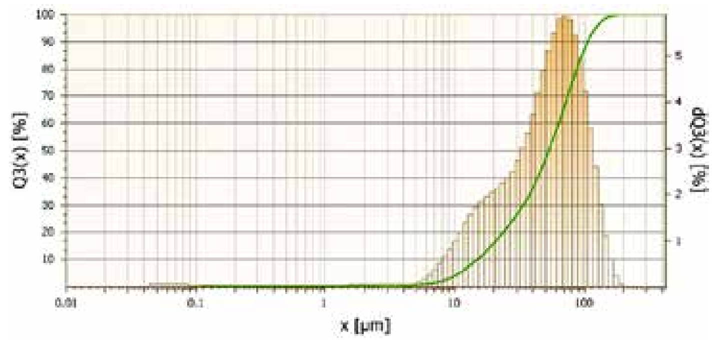


Figure 1: Laser measurements of particle size distribution of water-atomized 17-4 PH stainless-steel powder.

precipitates nucleate uniformly throughout the matrix, limiting the displacement of dislocations and, thus, causing an increase in the hardness and strength of sintered steel.

In the last study, it was confirmed that high-strength sintered stainless steels, such as 17-4 PH, achieving full or near-full density, are essential to realize the full benefit of their superior mechanical properties. It has been shown in injection molding technology, a properly conducted de-binding process and appropriate selection of other technological parameters, such as sintering temperature and sintering atmosphere, make it possible to obtain a high sintered density that will ensure high tensile strength in sintered steels. Further, the carbon remaining in the structure is crucial for the corrosion resistance and strength properties of the sintered steel. From the literature review, it is clear that only a few efforts have been undertaken to understand the densification and shrinkage mechanism during the sintering of pre-alloyed 17-4 PH stainless-steel powder [8,9].

The conducted research aimed to study the impact of technological parameters in the traditional process of pressing in rigid dies and sintering on the densification, mechanical properties, and pitting corrosion resistance in 0.5 NaCl solution of the 17-4 PH sintered stainless steel, either in the as-sintered or heat-treated conditions.

2 MATERIALS AND METHODS

Water-atomized 17-4 PH stainless-steel powder with the following chemical composition in % wt. (C-0.027; Si-0.73; Cr-16.28; Ni-4.28; Cu-4.04; Nb-0.32; Mn-0.05; P-0.015; Fe-balance) provided by Ametek (Berwyn, Pensylvania) was used. The average particle size of the powders was 55 µm. The particle size distribution of the powder is shown in Figure 1; its apparent density is 2.54 g/cm^3, and the flow rate is 31s/50g.

The compressibility of 17-4 PH powder was studied at 400-700 MPa compacting pressures for 20 × 5 mm3 cylindrical specimens. As reference materials, AISI 316 L and AISI 410 L powders were also investigated. The dilatometer bar specimens 5 × 5 × 15 mm^3, tensile specimens for mechanical features and cylindrical specimens of size ∅20 × 5 (mm^3) for precipitation-hardening treatment and for corrosion behavior were uniaxially compacted in rigid die at 600 MPa. All

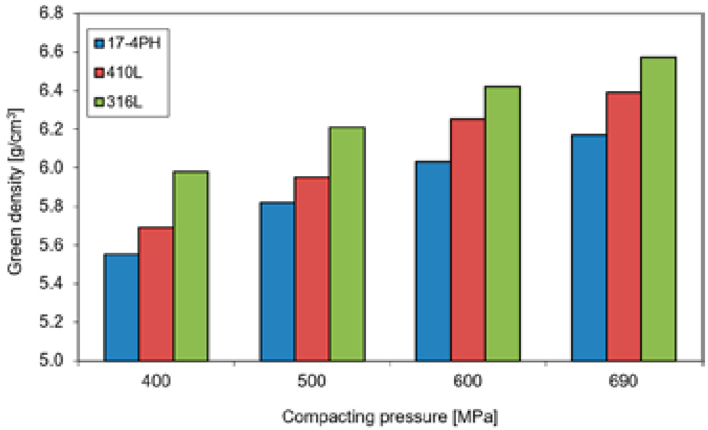


Figure 2: The green density of 17-4 PH, AISI 410 L and AISI 316 L stainless-steel compacts as a function of compacting pressure.

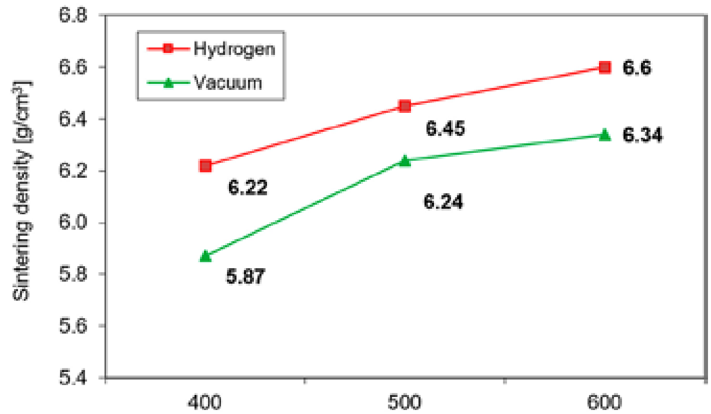


Figure 4: The effect of compacting pressure on the sintered density of 17-4 PH stainless steel after sintering at 1,240°C in hydrogen and vacuum.

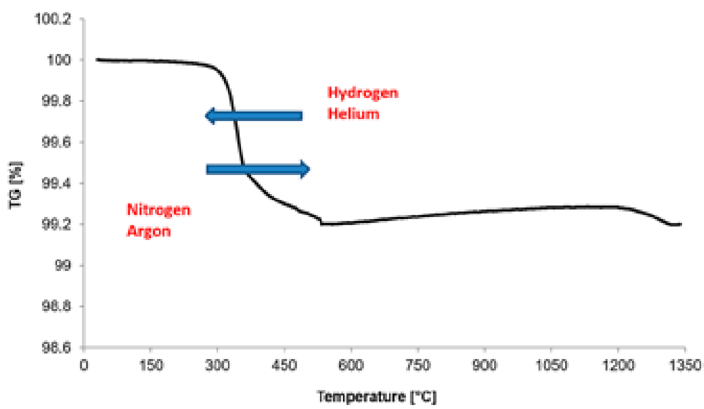


Figure 3: TG curve of 17-4 PH powders during heating to isothermal sintering temperature at 1,340°C.

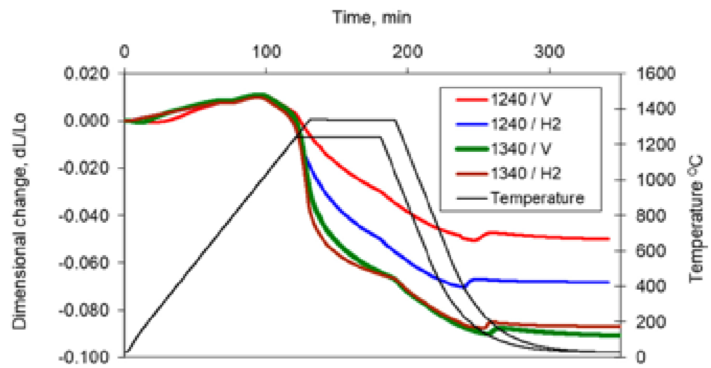


Figure 5: Dimensional changes in 17-4 PH stainless-steel compact during heating to sintering at 1,240°C and 1,340°C for 60 minutes in hydrogen and a vacuum.

compacts were thermally de-bound at 450°C for 40 minutes in pure dry hydrogen before sintering.

Dilatometric analysis was carried out in a horizontal NETZSCH 402 PC dilatometer (Selb, Germany) under pure dry hydrogen, vacuum and nitrogen/hydrogen atmosphere at two isothermal sintering temperatures of 1,240°C and 1,340°C for 60 minutes and 120 minutes isothermal holding. The thermal cycle was heating to isothermal sintering temperatures at rates of: 1, 5, 10 and 20°C/min, followed by cooling at a rate of 20°C/min.

Sintering for tensile bar specimens and cylindrical specimens were carried out in Nabertherm® P 330 (Lilienthal, Germany) tube furnace at 1,340°C for 60 minutes. Then, some specimens were subjected to a solution-annealing treatment at 1,040°C for 60 minutes in a hydrogen atmosphere. Then, some of the tested samples after solution-annealing treatment were subjected to an aging treatment at 480, 490 and 500°C in a nitrogen atmosphere.

The Archimedes method was adopted to measure sintered density in the samples. Metallographic characterization was carried out via light optical microscope (LOM) on specimens polished and etched employing standard metallographic procedures. The hardness (HV) was determined.

Tensile tests were carried out on a standard tensile machine at a crosshead speed of 1 mm/min, in accordance with the ISO 3928 test method.

The corrosion distinctive of the sintered stainless steels was tested using ATLAS 0531 EU&IA (ATLAS-SOLLICH) (Rębiechowo k/Gdańska, Poland) including reference electrode, a counter electrode, and a working electrode. The reference electrode was a saturated calomel electrode (SCE) and counter electrode was a platinum electrode. The specimen was a working electrode. The testing environment was a 0.5 M NaCl solution at ambient temperature. The potentio-dynamic polarization and open-circuit potential (OCP) measurement tests were performed. Before the corrosion test, the samples were degreased, cleaned in distilled water and, next, in acetone, and dried. The corrosion check began with the OCP and the potential of the samples was registered and tracked as a function of time until it obtained a steady value. After the OCP measurement, the potentio-dynamic test was performed at a rate of 1 mV/s, beginning from 200 mV below the OCP up to 1 V.

3 RESULTS

The compressibility of 17-4 PH powder concerning conventional stainless-steel powders AISI 316 L and AISI 410 L is shown in Figure 2. In principle, the green density of 17-4 PH stainless steel is lower regarding other highly alloyed stainless steels; however, the investigated powders exhibit reasonable compressibility to process them by conventional compaction and sintering.

For powder metallurgy technology and, in particular, in the case of stainless steels, the most important parameters in the lubricant-removal process are the heating rate, the temperature of the isothermal sintering, and the time of isothermal holding. These conditions are intended to ensure gradual, rather than rapid, decomposition of the lubricant and its complete removal. Figure 3 provides an example of the TG curve for 17-4 PH powder with a heating rate of 10 K/min in an argon atmosphere. At the same time, as a result of tests in other atmospheres, it was further noted, in addition to the previously mentioned parameters, that the type of gas used also affects the removal

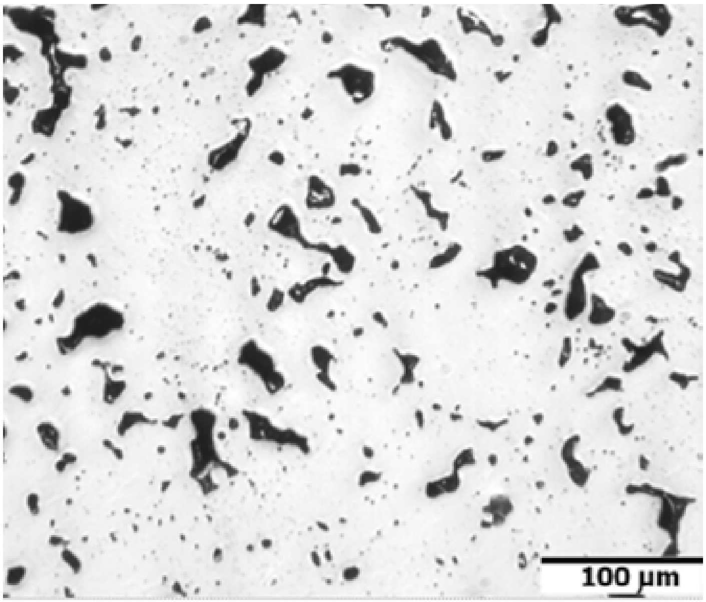


Figure 6: Microstructure of sintered 17-4 PH stainless steel after sintering at 1,240°C for 60 minutes in pure dry hydrogen, no etched.

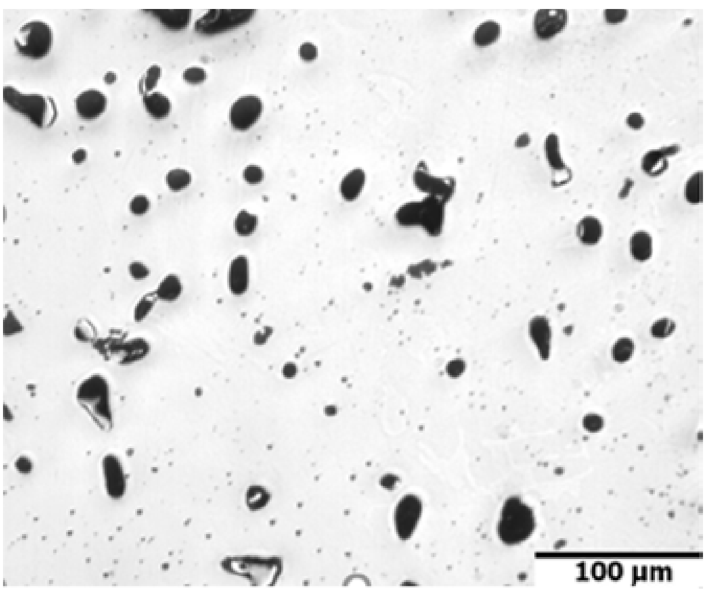


Figure 7: Microstructure of sintered 17-4 PH stainless steel after sintering at 1,340°C for 60 minutes in pure dry hydrogen atmosphere, no etched.

temperature of the lubricant. The decrease in the removal temperature of a lubricant when helium or hydrogen is used is related to the higher thermal conductivity of these gases compared to argon or nitrogen, for example, which results in faster heating of the green compacts. In addition, helium atoms or hydrogen molecules, due to their size, are much smaller compared to argon atoms or nitrogen molecules, which causes them to enter the structures of the porous material more quickly and transfer heat more quickly to the lubricant as well as the green compacts. For manufacturers of sintered products made from stainless-steel powders, this phenomenon is very important to ensure the gradual and total removal of a lubricant.

Furthermore, as expected, the lower green density of 17-4 PH compacts transforms into lower sintered density. As can be seen from Figure 4, the density of compacts sintered at 1,240°C is influenced not only by the green density but also by the sintering environment — in a hydrogen atmosphere, higher densification occurs than in a vacuum [10].

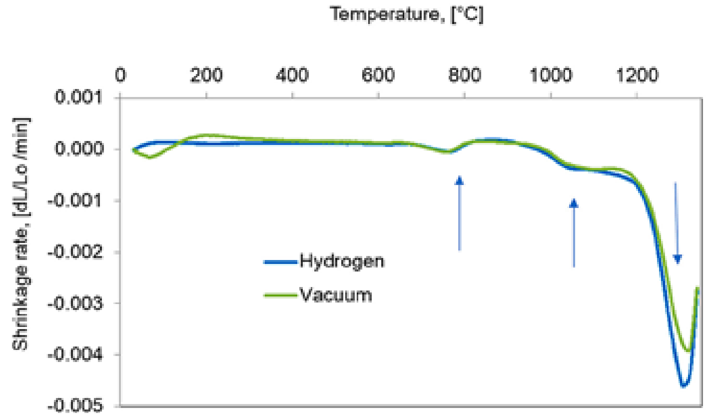


Figure 8: Shrinkage rate of 17-4 PH stainless-steel compact during heating to 1,340°C with the heating rate at 10°C/min in hydrogen and a vacuum.

Precipitation-hardened stainless steels are subjected to heat treatments consisting of solution annealing and aging to improve mechanical properties.

In Figure 5, the dilatometric dimensional changes during the sintering of 17-4 PH stainless steel compacts at 1,240°C and 1,340°C for 60 minutes in hydrogen and a vacuum are presented. As can be observed from the course of dimensional changes up to 900°C, thermal expansion prevails and then above 900°C, contraction begins, which indicates the beginning of mass transport phenomena. From the evaluation of dilatometric curves, it can be deduced that shrinkage is influenced both by the sintering temperature and the sintering atmosphere. With increasing sintering temperature, shrinkage increased for both sintering atmospheres; however, the higher shrinkage is observed for hydrogen as compared with a vacuum, in particular, for lower sintering temperatures. Further, metallographic studies of sintered 17-4 PH stainless steels in the as-unetched state indicate that as the sintering temperature increases, both in hydrogen and vacuum, a clear increase in the degree of the spheroidization of pores can be observed, as seen in Figure 6 and Figure 7.

Detailed analysis of dimensional changes indicates the shrinkage rate for sintering at lower temperatures is roughly stable during heating above 900°C and isothermal holding. On the contrary, for higher sintering temperatures, linear shrinkage is significantly higher, but the shrinkage rate starts to decrease during isothermal holding. During cooling from the sintering temperature, both in hydrogen and vacuum, at temperatures near to 200°C, expansion can be observed, which is the result of the transformation of austenite into martensite.

For a better understanding of the dimensional behavior of the study material, the shrinkage rate vs. temperature during heating up to 1,340°C for hydrogen and in vacuum are presented in Figure 8. During heating, three distinct peaks of the shrinkage rate can be observed. At a temperature near 750°C, the first peak of shrinkage rate is associated with the bct martensite transformation to γ austenite. In a temperature range 1,050-1,200°C, a second peak can be observed and can be attributed to the offset of thermal expansion by initial sintering shrinkage. The third-most visible is the result of activated sintering, initiated by a sudden shrinkage beginning near

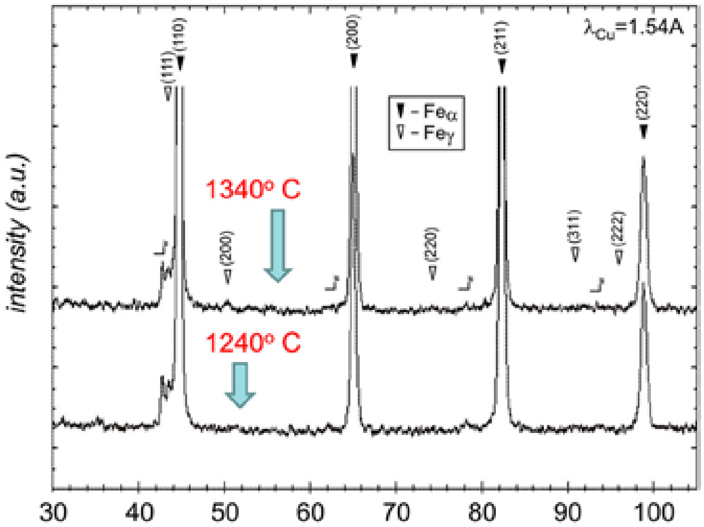


Figure 9: XRD analysis of sintered 17-4 PH stainless steel.

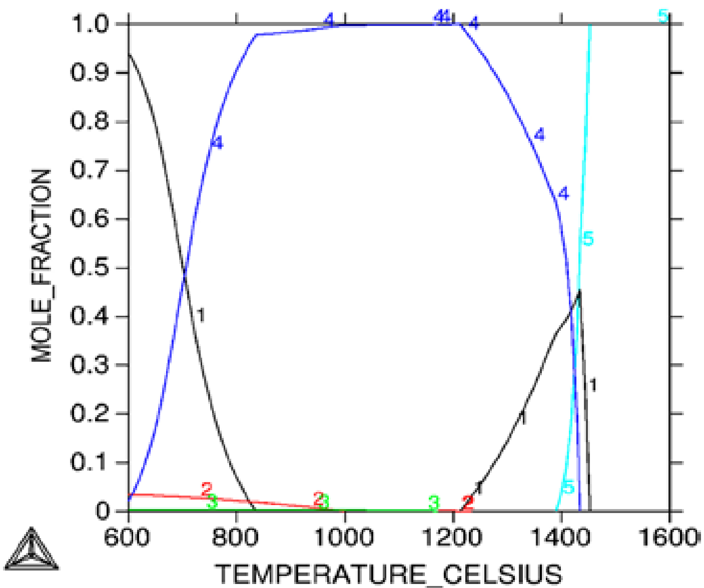


Figure 10: Thermocalc diagram for 17-4 PH powder, 1. ferrite (δ), 2. copper FCC precipitation, 3. niobium Fcc precipitation, 4. austenite (γ), 5. liquid (5).

1,250°C and may be related to the fracture of silica [11], which covers the powder particles and, thereby, causes activated sintering in the solid state associated with probable initial particle rearrangement.

Analysis of the microstructure indicates that, during cooling, the transformation of austenite into a martensitic structure takes place. Thus, after sintering in vacuum and hydrogen, δ ferrite and martensite can be distinguished in the structure. Since the files from martensite and δ ferrite overlap in XRD studies, it was decided to carry out additional sintering in a nitrogen-hydrogen atmosphere to confirm the δ ferrite affects the densification of the compact during sintering. The analysis of the test results from the thermal analysis correlates well with the XRD results shown in Figure 9. On the other hand, in Figure 10, thermodynamic calculations for the 17-4 PH sintered stainless steel are presented, as a result of which a pseudo-double plot was developed.

To better understand the role of the atmosphere, an additional sintering in a 95%N_2/5%H_2 gas mixture was performed. The respective dimensional changes in comparison with hydrogen- and vacuum-sintered compacts are presented in Figure 11. It is evident that sintering in a N_2/H_2 atmosphere gives incomplete densifications due to the stabilization of austenite by diffusion of nitrogen and, in consequence,

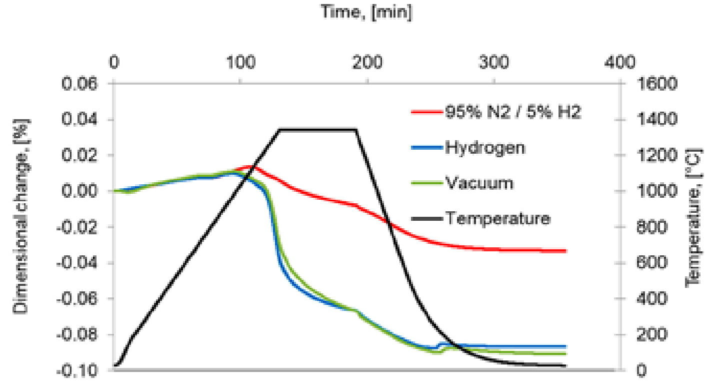


Figure 11: Dilatometric curves of 17-4 PH sintered stainless-steel compacts in hydrogen, vacuum, 95%N_2-5%H_2 in temperature 1,340°C with 10°C/min heating rate and for 60 minutes isothermal holding.

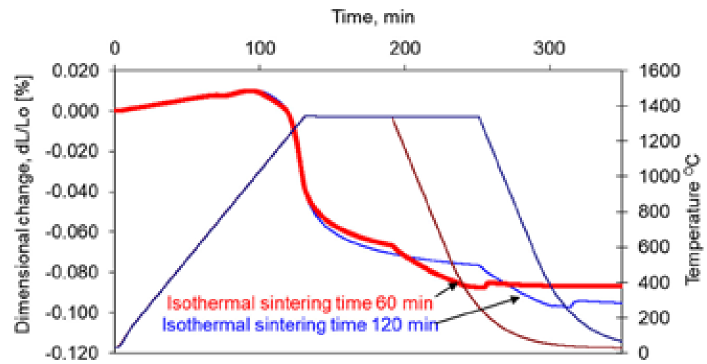


Figure 12: Influence of isothermal holding time for shrinkage of 17-4 PH stainless-steel compacts when sintering at 1,340°C with the heating rate at 10°C/min in hydrogen for 60 minutes and 120 minutes isothermal holding.

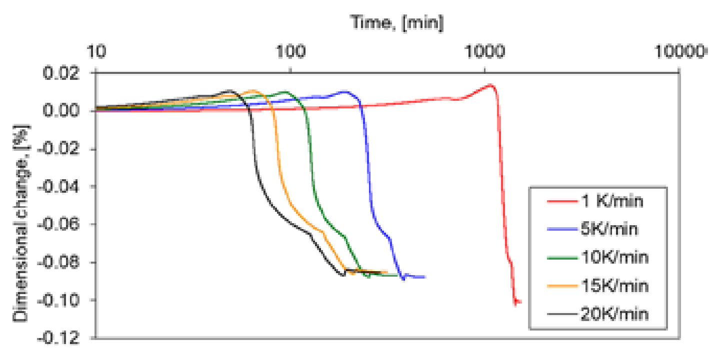


Figure 13: Dilatometric curves of 17-4 PH stainless-steel powders sintered in hydrogen, at 1, 5, 10, 15, and 20°C/min heating rate for isothermal sintering at a temperature of 1,340°C.

the transformation of austenite to δ ferrite does not occur.

In addition, the longer isothermal sintering time and different heating rate were examined to study the densification behavior of the 17-4 PH stainless-steel compact. From Figure 12, it is seen that prolonged isothermal sintering time from 60 to 120 minutes gives slightly higher densification, and the density of dilatometric samples increased from 6.95 g/cm^3 to 7.12 g/cm^3, respectively. As can be seen in Figure 13 and Figure 14, the increasing heating rate gives lower shrinkage and, for example, for heating rates 1°C/min and 20°C/min, the sintered density of dilatometric samples is 7.16 g/cm^3 to 7.09 g/cm^3, respectively.

Precipitation-hardened stainless steels are subjected to heat treatments consisting of solution annealing and aging to improve mechanical properties. Sintered 17-4 PH stainless steels were subjected to solution-annealing treatments at temperatures of 1,020-1,040°C and

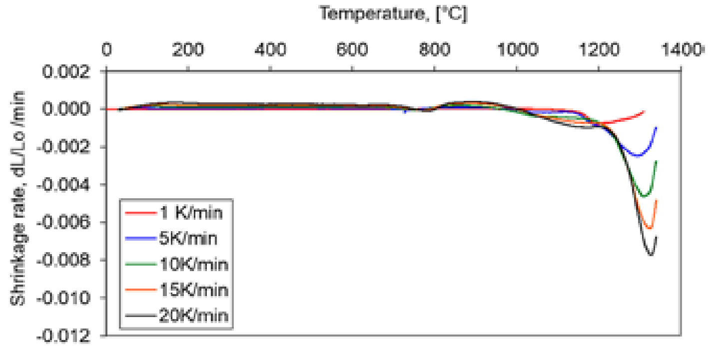


Figure 14: Shrinkage rate of 17-4 PH stainless-steel compacts sintered in hydrogen at 1, 5,10, 15, and 20°C/min heating rate for isothermal sintering at a temperature of 1,340°C.

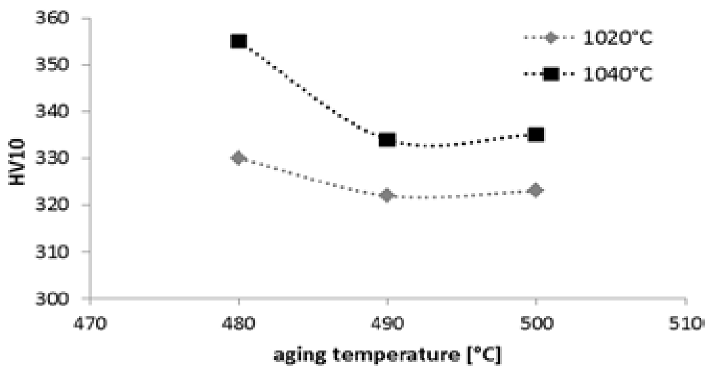


Figure 15: Hardness HV10 of sintered 17-4 PH stainless steel at 1,340°C for 60 minutes in hydrogen and then subjected to solution-annealed treatment at 1,020-1,040°C and finally aged at 480-500°C.

Treatment	UTS {MPa]	Elongation [%]
Sintering	883	2.1
Sintering and solution annealing	743	1
Sintering, solution annealing and aging	1147	2.4

Table 1: Mechanical properties of sintered 17-4 PH stainless steel at 1,340°C and subsequent solution annealing at 1,040°C and aging at 480°C.

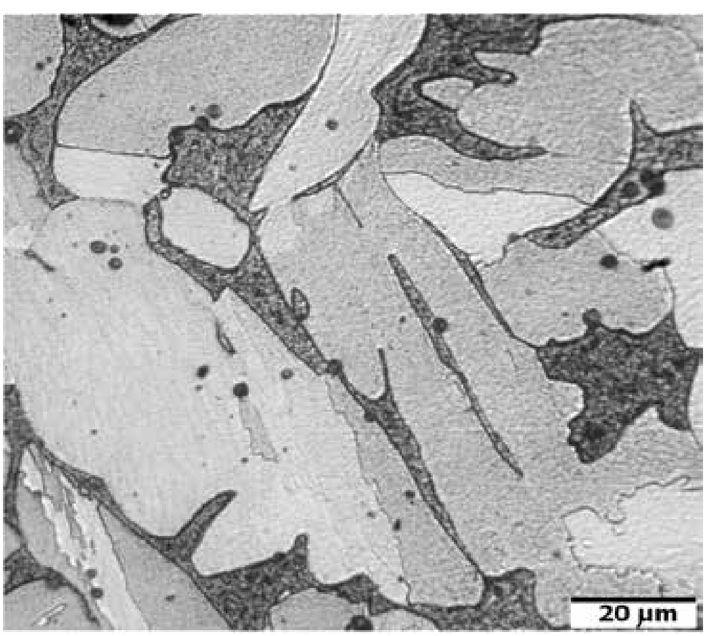


Figure 16: Microstructure of sintered 17-4 PH stainless steel at 1,340°C for 60 minutes in a pure dry hydrogen atmosphere.

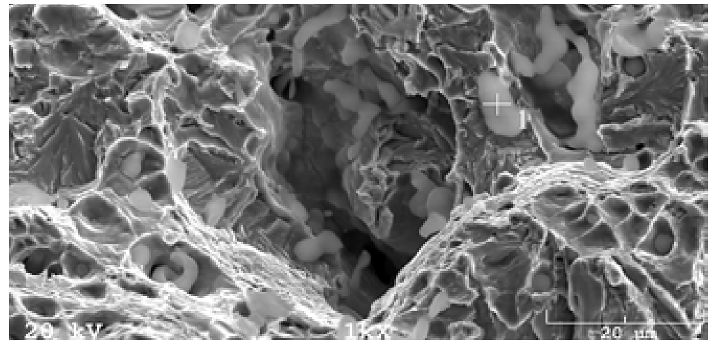


Figure 17: SEM fracture of sintered 17-4 PH stainless steel at 1,340°C for 60 minutes in hydrogen.

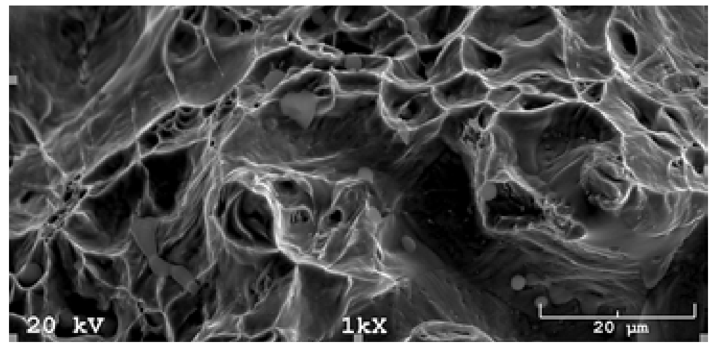


Figure 18: SEM fracture of sintered 17-4 PH stainless steel at 1,340°C for 60 minutes in hydrogen and subsequent solution annealing at 1,040°C.

then aged in a temperature range of 480-500°C. The results of HV hardness measurements are shown in Figure 15, while the mechanical properties of the tensile test are shown in Table 1.

As a result of the study of the strength properties of sintered 17-4 PH stainless steels, the results obtained show it is possible to attain a tensile strength after solution annealing (1,040°C) and aging of 1,147 MPa and an elongation of 2.4%. If it is necessary to increase plastic properties, the aging temperature should be increased to 550°C, obtaining an elongation of 3-4%. Increasing the plastic property results in decreasing the strength properties to a level of 800-1,000MPa.

An example of the microstructure of the sintered 17-4 PH stainless steels in the non-etched state is shown in Figure 16. The matrix of the sintered steel is martensite with a small amount of delta ferrite and visible rounded pores. The presence of delta ferrite during high-temperature sintering certainly promotes the spheroidization of pores and extensive densification of the sintered material. In addition, the dispersive precipitates, as a result of the heat treatment, significantly improve the mechanical properties. However, the fine dispersive precipitates are not visible under an optical microscope.

In addition, fracture findings on the SEM well correlated with the results of tensile tests. After sintering (Figure 17) and solution-annealed treatment (Figure 18), the fracture surface is ductile. In contrast, after aging (Figure 19), the fracture surface indicates some brittle areas.

Stainless steels are significantly resistant to general corrosion, but in aggressive environments (in particular, those containing chlorides), they are prone to various forms of localized corrosion (pitting, crevice, intergranular, stress corrosion cracking). Pitting is recognized as the most dangerous type of corrosion because it is very difficult to detect and also to ensure adequate protection. Pitting is the most common type of corrosion in stainless steel. It is manifested in the form of small pits on passive metal surfaces.

Open-circuit potential (OCP) changes were measured for all test steels immersed in 0.5 m NaCl solution, and the results are shown

Designation of Sample	A	B	C	D	E
Condition of treatment sintering	Sintering	Sintering, Solution-annealing	Sintering, Solution-annealing aging (480° C)	Sintering, Solution-annealing aging (490° C)	Sintering, Solution-annealing aging (500° C)

Table 2: Description of investigated samples.

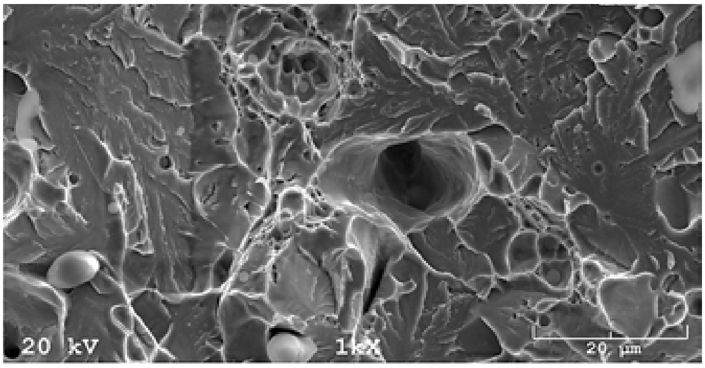


Figure 19: SEM fracture of sintered 17-4 PH stainless steel at 1,340°C for 60 minutes in hydrogen and subsequent solution annealing at 1,040°C and aging at 480°C.

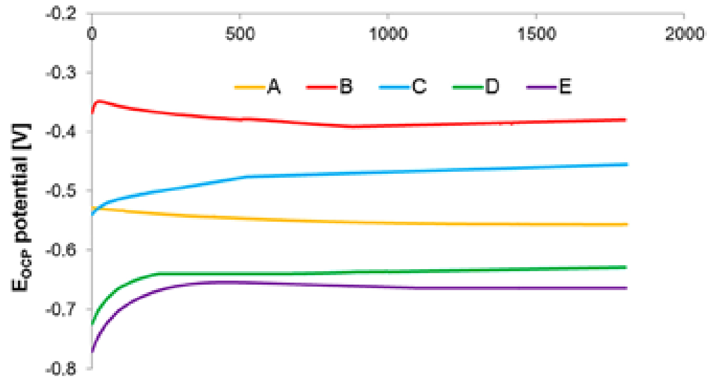


Figure 20: OCP changes after being immersed for 30 minutes in 0.5 M NaCl solution for 17-5 PH sintered stainless steel.

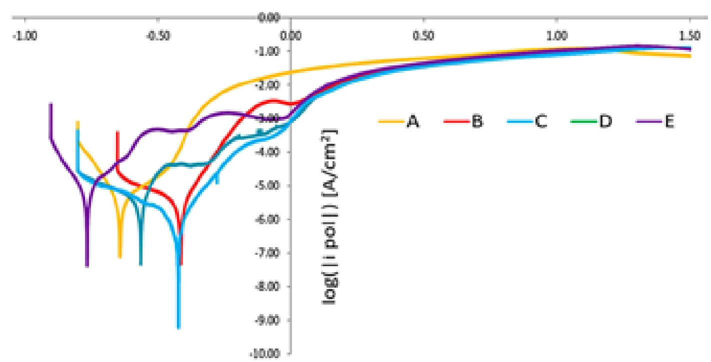


Figure 21: Potentio-dynamic polarization curves of 17-4 PH sintered steels in 0.5 M NaCl solution.

in Figure 20. The description of a sample designation applied in the following part of this article is given in Table 2.

The potential of sintered steel shows the tendency to slightly reduce with time. After 30 minutes of exposure in 0.5 M NaCl solution, the sample almost reaches a steady state and OCP potential is about minus-556 mV. The potential of solution-annealed steel is more positive and equals minus-380 mV. From the analysis of the presented characteristic, it can be concluded that solution-annealing treatment leads to a potential increase (shift to more positive values) in comparison to the sintering process while, after aging, the treatment potential of 17-4 PH sintered steels is reduced.

Figure 21 shows the polarization curves of the tested sintered 17-4 PH stainless steels. As expected, sintered 17-4 PH stainless steel does not show typical anodic polarization curves consisting of an active, passive, and trans-passive region. The typical maximum of the active-passive transition does not appear. There is a rapid increase in current density and destruction of the passive layer and transition to the pitting corrosion area.

In the case of the sample after solution-annealed treatment, the polarization curve is different. An active-passive transition maximum and an active, passive, and trans-passive region may be observed. Similar polarization curves were obtained for steel aging at a temperature higher than 480°C.

Results of the performed electrochemical test indicate that, by applying a solution-annealing treatment after the sintering process, resistance to pitting corrosion slightly increases. Furthermore, the potentio-dynamic polarization measurements reveal that solution-annealing and aging treatment at 480°C leads to optimum corrosion resistance in a 0.5 M NaCl solution, including higher OCP, polarization resistance, and pitting potential. On the other hand, aging at 500°C results in the deterioration of corrosion resistance.

4 CONCLUSIONS

Sintering temperature and atmosphere play a significant role in the densification during the sintering of 17-4 PH stainless-steel compact. The increase in sintering temperature results in an increase in density, which is related to the fact that a higher sintering temperature promotes the formation of delta ferrite, which affects the degree of pore spheroidization and an increase in the degree of densification. In contrast, a longer isothermal sintering time and higher heating rate slightly increased the sintered density of samples. Furthermore, as expected, higher densification occurs in hydrogen than in a vacuum. Moreover, the sintering in a N_2/H_2 atmosphere gives incomplete densifications since the nitrogen in the solid solution prevents the formation of delta ferrite, which enhances the sintering and densification.

After the solution-annealing and aging treatment, the precipitating hardening sintered 17-4 PH stainless steel shows high strength with reasonable ductility levels that are hardly achievable for austenitic, ferritic, and martensitic sintered stainless-steel grades.

The largest improvement in corrosion resistance of sintered 17-4 PH stainless steel is achieved by sintering at 1,340°C in hydrogen after a solid solution-annealing treatment. On the other hand, after solution annealing at 480°C, the resistance to pitting corrosion in a 0.5 NaCl solution (higher OCP, polarization resistance, and pitting potential) is the highest, as compared to solution annealing at 500°C, where the corrosion resistance decreases significantly.

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DATA AVAILABILITY STATEMENT

Data presented in this article are available at request from the author.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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POWDERMET2023 VIVA LAS VEGAS

PowderMet2023, home to the largest annual exhibit in the Americas featuring the leading suppliers of powder metallurgy, particulate materials, metal injection molding, and metal additive manufacturing processing equipment, powders, and products, will showcase a massive display of PM innovations and technology sessions.

By THERMAL PROCESSING STAFF

Powder metallurgy can be an important part of the thermal-processing world, so it's important that companies who offer this process, as well as companies who need it, can come together in one place to share and discover the latest innovations the powder metallurgy world has to offer.

For years, now, the Metal Powders Industries Federation (MPIF) has sponsored PowderMet, the leading technical conference on powder metallurgy and particulate materials in the America.

PowderMet2023 is a hub for technology transfer for professionals from every part of the industry, including buyers and specifiers of metal powders, tooling and compacting presses, sintering furnaces, furnace belts, powder handling and blending equipment, quality-control and automation equipment, particle-size and powder-characterization equipment, consulting and research services, and much more.

This year's trade show is in the heart of Las Vegas, Nevada, at Caesars Palace.

PowderMet2023 is home to the largest annual exhibit in the Americas showcasing the leading suppliers of powder metallurgy, particulate materials, metal injection molding, and metal additive manufacturing processing equipment, powders, and products. This massive display of PM innovations is a must-see opportunity to review the latest technology.

In addition to PowderMet, the event will be co-located with AMPM2023, additive manufacturing with powder metallurgy.

Along with multiple exhibits, attendees will also have access to more than 200 technical presentations from experts from all over the world on the latest research and development.

The conference will open with welcome remarks from MPIF Executive Director/CEO James P. Adams. MPIF President Rodney Brennen will share the State of the Industry report as well.

PowderMet2023 will offer a variety of networking opportunities along with carefully planned technical programs that will allow attendees to explore the exhibit hall, catch up on the latest R&D, and celebrate industry achievements.

Some of the technical programs that may be of interest to industrial heat treaters include (check the PowderMet2023 app for times):

PREPARATION OF RE-W POWDER FEEDSTOCKS USING LIQUID PRECURSOR IMPREGNATION

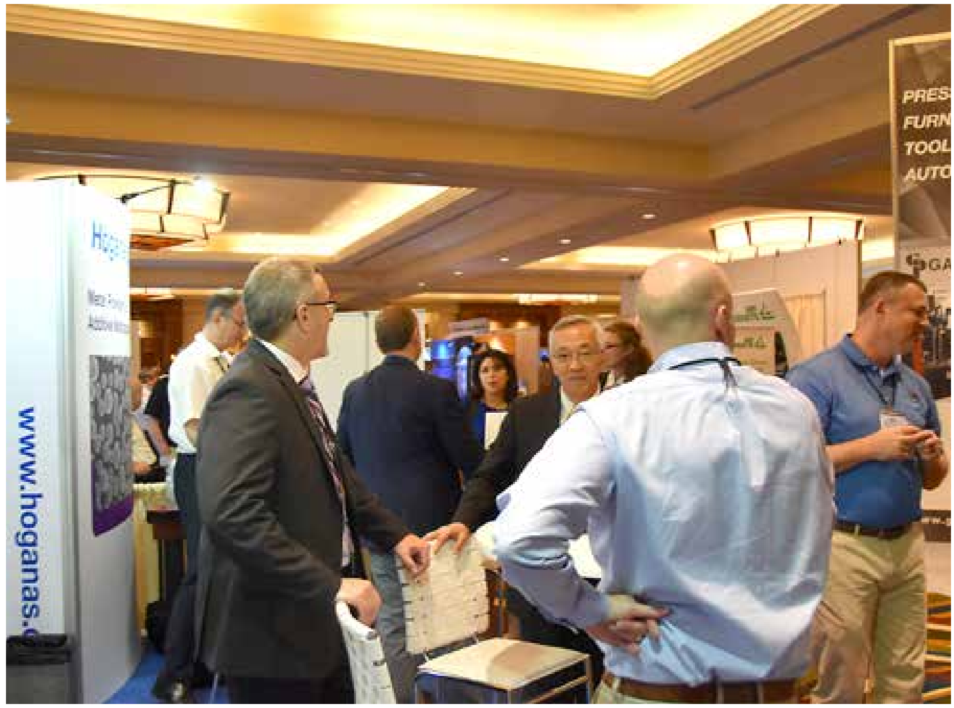
Rhenium-tungsten alloys are useful refractory metals due to their high-temperature mechanical strength, high density, and thermal conductivity. To produce a Re-W powder feedstock, pure metal or oxide powder precursors are typically blended or mechanically alloyed. Although this technique can be sufficient for conventional powder metallurgy, it is not suitable for additive manufacturing or other applications that require strict control over powder properties. This work applies a liquid precursor impregnation method to prepare Re-W powder feedstocks without altering the properties of the underlying W powder. The ability to produce various rhenium compositions on both fine 1-5 micron and spherical 15-micron W powders is demonstrated, and the powders are consolidated in a dilatometer to assess how this powder preparation influences densification behavior. The microstructure and compositional homogeneity of the consolidated alloys are investigated as well. Overall, this work evaluates a novel, facile power feedstock preparation method for refractory metal alloys.

FURNACE ADVANCEMENTS FOR THE REMOVAL OF LUBRICANT, CURING OF SOFT MAGNETICS, AND THE CONTINUOUS SINTERING OF BINDER JETTED MATERIALS

Lubricant removal has been one of the most difficult problems in the sintering of conventional powder metal components; however, following more than 10 years of research, a paradigm shift has been presented to the industry that allows the complete removal of lubricants in compacts that are 92 percent dense and under. This has resulted in significant gains in uniformity and component properties. As the powder metal industry struggles to find new applications and join the movement to electric vehicles, soft magnetics have shown a great deal of promise for the future. Conventional thermal process techniques are not optimized for the manufacturing of these products. This session will investigate a new approach to curing soft magnetics that provides flexibility to the producer, along with significant gains in efficiency. As additive manufacturing, specifically binder jetting, becomes more widely accepted, there is a rising need for continuous de-binding and sintering of these products. Using a minimalist approach to the optimized design of a continuous push furnace has provided an approach that has lower capital cost, less maintenance cost, and better quality. This session will discuss this new approach and how it compares to conventional vacuum processing that is commonly used.

NEW INTEGRAL SINTER-QUENCH FURNACE DESIGN FOR PM FERROUS PARTS

Powder metallurgy sintering furnaces for ferrous parts have been optimized for production of plain and carbon parts. The sinter hardening process has been developed by rapidly cooling parts coming out of the sintering section using a fan and heat exchanger to get the desired cooling rates for modified alloys. However, for conventional sintering and through hardening, two different processes are used. This can be in-house continuous or batch sealed quench furnaces for post-sintering operations. Alternatively, sintered materials are sent to a dedicated heat treater's plant for carburizing or carbo-nitriding process using integral oil quenching system. Good results have been observed in a metallic muffle continuous-hardening furnaces. It is worth exploring design features of a sintering-cum-hardening furnace using oil quenching. Combining the sintering basic primary process and secondary heat treatment process in a PM plant will have many advantages. A stable sinter quench process will reduce raw material powder cost as compared to a sinter hardening process. This new process will reduce multiple handling of sintered parts. This continuous process will enhance PM reach in meeting industry demands with shorter delivery time and consistent quality.



The premier event of the Americas on powder metallurgy and metal additive manufacturing conferences will be held in Las Vegas, Nevada on June 18–21.

OPERATING ECONOMICS OF ROLLER HEARTH FURNACES COMPARED TO MESH BELT FURNACES

The workhorse of the press and sinter industry, the mesh belt furnace (MBF) cannot be used for sintering above 1,150°C (~2,100°F) due to low belt life at higher temperatures. One alternative is the roller hearth furnace (RHF) that uses graphite trays for parts transport instead of a belt, compared to the MBF in which parts are either placed directly on the belt or on graphite/ceramic trays over the belt. An earlier investigation of 600mm (~24 inches) furnaces of both types that was previously published showed lower energy consumption to the extent of 20 percent by the RHF, a consequent reduction of the total sintering cost and the added possibility of higher temperature sintering. Furthermore, the RHF design concept allows the construction of wider and longer sintering furnaces for higher throughput and lower unit cost than is possible with the MBF. In this investigation, a similar comparison of operating cost is presented for the RHF and MBF but with a larger width of 900mm (~36 inches), both operating at the same sintering temperature.

OPTIMIZING THE SINTERING PROCESS OF HIGH-PERFORMANCE CARBIDES

The demand for carbide tools and components with highest quality, as well as the constantly rising costs for energy and raw materials, make optimization of the sintering process of high-performance carbides indispensable. The coating of the carrier plates with graphite- and ceramic-dispersions plays a decisive role, ensuring separation between component and plate as well as optimized grain growth. Graphit Kropfmühl GmbH (GK), a manufacturer of graphite-containing dispersions, has been providing high-performance results in Europe for this sintering application with its Grap Aqua series. Due to its own mines in Europe, Africa, and Asia, GK has direct access to various raw materials, with the right one being selected depending on process requirements. Customized dispersions, characterized by a low level of impurities and/or already containing various ceramic components, have been targeted to improve the sintering processes and product quality. The range of coating performances in the carbide sintering application is presented, including a case study from GK's experience in Europe using its graphite-based dispersions.

MACHINING RESPONSES OF PM STAINLESS STEEL COMPONENTS MANUFACTURED UNDER DIFFERENT SINTERING CONDITIONS

Powder metallurgy (PM) stainless steels offer exceptional corrosion resistance but present a very different machinability behavior compared to common carbon and low-alloyed PM steels. Since they contain a high-alloy content with no carbon addition, stainless steels consist of either an austenitic or ferritic microstructure after sintering. Such types of metallurgical matrixes are soft and form long chips during machining. In addition, work-hardening occurs on the machined surface due to the high alloyed matrix. Generally, the stainless steel (SS) components are preferred to be sintered at high temperature in a vacuum or 100 percent reducing atmosphere to achieve high sintered density, prevent oxidation, and limit metallurgical defects. When they are sintered in a nitrogen-containing atmosphere, nitride formation with chromium occurs in the matrix resulting in a different behavior in machining. In this study, the machining response of a PM 316 stainless steel is evaluated after being sintered at conventional and high temperatures in atmospheres containing different percentages of nitrogen. At the same time, methods to improve the machinability are investigated to provide machining solutions for the related stainless steels.

PROPERTIES OF GREEN AND SINTERED FC-0208 USING HGS 2.0

The lubricant in powdered metal plays an important role in the powdered metal process. It allows parts to be ejected from the die during molding, as well as hold the part together before sintering. With the use of better lubricants, time and money can be saved in the powdered metal industry due to the improved properties. Improved green strength and lower ejection forces means less broken green parts as well as the ability to machine green parts, reducing the wear on tooling. With the use of High Green Strength Second Edition (HGS 2.0) lubricant these desired properties could be achieved. A new proprietary lubricant, HGS 2.0, is being tested to determine its properties when used in the powdered metal process. This research is presenting the properties of HGS 2.0 lubricant as well as green and sintered parts of FC-0208 blended with this new lubricant.

PROGRESS IN GAS ATOMIZATION REACTION SYNTHESIS OF POWDERS FOR ADVANCED CONSOLIDATION OF OXIDE DISPERSION STRENGTHENED FERRITIC STEELS

To replace mechanical alloying that needs days of milling and suffers from contamination and inhomogeneity, oxide dispersion strengthened (ODS) ferritic steels, e.g., "14YWT," were made with powders from gas atomization reaction synthesis (GARS). The Fe-Cr alloys contained Y, W, Ti, and Zr and are atomized with Ar+O2 to produce Cr-enriched surface oxide. TEM analysis of GARS powders revealed that the surface oxide layer characteristics are controlled by oxygen concentration and size-dependent droplet cooling during rapid solidification. During solid state consolidation, trapped powder surfaces become oxygen reservoirs that are released on heating above ~900°C for reaction with Y-containing intermetallic compounds within each particle, forming highly stable oxide dispersoids. In this work, alloy composition and O_2 levels were varied to produce desirable precursor powders for consolidation either by solid-state friction/stir shearing with indirect extrusion or by laser-powder bed fusion to enhance oxide dispersion strengthening.

METAL INJECTION MOLDED STAINLESS STEELS EXHIBITING EXEMPLARY PROPERTIES AND VERY LOW SHRINKAGE PRODUCED USING HOMOGENEOUS MULTIMODAL POWDER MIXTURES

The achievable tolerances of parts made by metal injection molding are determined by sintering shrinkage and uniformity of sintering shrinkage, which are determined largely by powder loading and uniformity of powder loading in the molded green part. The current state-of-the-art somewhat limits the maximum size of metal injection molded parts. Here, multimodal mixtures of high purity spherical 316L and 17-4PH stainless steel powders having high tapped density and high spatial uniformity have been produced using a very high fraction of an atomizer distribution to produce highly loaded feedstock and molded into parts showing sintering shrinkage of about 12 percent. In addition, these high-density powders retain manageable flowability when compounded into MIM feedstock, and can provide 1,000x more contact points hereby facilitating the sintering process. The current work showcases the ability of homogeneous multimodal mixtures to exhibit reduced sintering shrinkage without compromising sintered density or material properties. The performance of these multimodal mixtures has the potential to open metal injection molding to a broader range of potential applications with notable benefits, such as the production of larger parts or more precise smaller parts and the potential reduction or elimination of secondary operations. Furthermore, the powders discussed here use a larger portion of an atomization curve resulting in less material waste and a more efficient supply chain.

CHARACTERIZATION OF PHASE TRANSFORMATION IN SINTER HARDENED STEELS

Sinter-hardening is a thermal process in which a ferrous product (material) is sintered and then cooled at a rate sufficient to produce a predominately martensitic microstructure. Density (porosity) and volume (weight) of the components also play a crucial role in martensitic phase formation during sinter-hardening. Understanding the thermal responses of PM materials made at different densities and dimensions is vital to the selection of a suitable sinter-hardening steel with desired mechanical properties.

Previous work characterized the sinter-hardened microstructures of a FL-4608 based material prepared at different density levels with different copper and graphite additions. It has demonstrated that the density has significant effect on the martensite formation when it is above certain density levels. Adjusting the copper and graphite levels can reduce or eliminate the effect of density. In this study, the effect of density and dimensions is further investigated on the phase transformation of material with the same alloying compositions through analysis of thermal responses in the sinter-hardened steels.

SPARK PLASMA SINTERING AND HOT PRESSING AL-SC SPUTTERING TARGETS

One of the most successful piezoelectric materials in electro-acoustic applications is aluminum scandium nitride thin films produced by reactive sputtering from AlSc alloy targets. The AlScN films are used in the manufacture of the bulk acoustic wave (BAW) filters enabling the current 5G communication revolution. The AlSc alloy system is very challenging for the manufacturing of sputter targets due to the presence of multiple brittle intermetallics and a propensity for segregation. Powder processing can overcome many of these issues. In this study, we utilize powder processing to investigate three alloy compositions with Sc contents of 5at%, 30at% and 50at%, representing a phase structure of Al+Al3Sc, Al3Sc+Al2Sc, and Al2Sc+AlSc. The alloys were gas atomized, followed by conventional hot pressing (HP) or spark plasma sintering (SPS) to provide a high-density target. Characterization of the atomized powders, including morphology, microstructure, and chemistry will be discussed. In addition, microstructure, density, hardness, fracture toughness, and predominant fracture mechanism as a function of process conditions will be compared for the two consolidation methods. Sputtering performance will also be summarized.

ACCELERATING TTM OF HIGH-PERFORMANCE METAL PARTS: FROM PROTOTYPING TO MANUFACTURING ON ONE AM PLATFORM

When it comes to producing high-performance metal parts of relatively small dimensions, manufacturers today can choose among various traditional and additive manufacturing (AM) technologies. While traditional technologies (e.g., CNC machining, metal injection molding (MIM), and investment casting) provide high quality and competitive costs in large runs, they typically require costly and lengthy product development processes. While varying metal AM technologies (e.g., metal binder jetting (MBJ) and direct metal laser sintering (DMLS)) each has their advantages/disadvantages, most involve powder-based processes that raise safety and other operational challenges. One relatively new metal manufacturing technology – metal material jetting – today delivers an automated production process that enables cost-effective prototyping and manufacturing using the same metal AM system. As a result, the time to market (TTM) of performance parts can be accelerated rapidly. In this presentation, representatives of XJet and Azoth, a metal service bureau, will highlight the experience of a metal service provider in using XJet's AM system (and underlying material jetting technology) from prototyping to production.

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"PowderMet provides networking at every corner. From the time you arrive, you will meet with old friends and make new acquaintances."

What makes PowderMet2023 and AMPM2023 important events within the industry?

As the premier powder metallurgy (PM) events in the Americas, the annual PowderMet (International Conference on Powder Metallurgy and Particulate Materials) and co-located AMPM (Additive Manufacturing with Powder Metallurgy Conference) are a hub for technology transfer for professionals from every part of the industry. The combined conferences bring together the industry to network and learn from each other. It provides an opportunity for those who are veterans in the industry, as well as those who are just breaking into the industry to collaborate, view the latest R&D, and find solutions to similar issues. It is also the perfect location for those that are interested in using this exciting technology, and it is their chance to have an opportunity to discuss their options while learning about several manufacturing technologies, such as press and sinter, metal additive manufacturing (AM), metal injection molding (MIM), and isostatic pressing.

What can attendees expect in the way of programs?

The technical program was developed and organized by industry peers. Over 150 professionals in both PM and AM joined forces to collaborate and compile the individual sessions. With nearly 200 papers being presented by industry experts from around the world, topics will cover all aspects of the technology. Additionally, conference proceedings will capture the technology transfer for future reference.

Programming is aligned to provide an excellent experience for first timers and seasoned attendees alike. Numerous networking opportunities are intentionally designed for interaction with other attendees, speakers, and exhibitors. For 2023, we have over 60 future engineers from 25 universities with us courtesy of student conference grants from the National Science Foundation (NSF), Center for Powder Metallurgy Technology (CPMT), and the Metal Powder Industries Federation (MPIF).

Throughout the PowderMet2023 and AMPM2023 conferences, we will build momentum as we "Find Our Way" back to Pittsburgh, Pennsylvania, in June 2024. We will be gearing up with the latest R&D and hottest topics to present in western Pennsylvania. If you are interested in being part of the program in Pittsburgh, submit your abstract today at PowderMet2024.org or AMPM2024.org.

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

As an exhibitor, you have direct access to the decision makers in the industry. We offer over seven hours of non-compete time, where attendees will be able to walk and meet with companies that can offer unique solutions to their everyday needs. We are also utilizing lead retrievals to assist in the exhibitor/attendee follow-up.

In addition to a Networking Luncheon that is held in the exhibit hall, we also offer a 90-minute networking reception, the PM Evening Alehouse, in the exhibit hall. The energy and excitement during the cocktail reception can't be found anywhere else. The connections you make, the opportunities that await your company will provide the ROI you need to come back year after year.

How will PowderMet2023 allow for networking?

PowderMet provides networking at every corner. From the time you arrive, you will meet with old friends and make new acquaintances at the opening reception. Once the conference kicks off, there are a plethora of opportunities to network and make those meaningful connections. From the exhibit hall to the luncheons, to the closing event and everything in between, the contacts you make will become lifelong friends.

Will there be any special events that take advantage of the Las Vegas setting?

Will there be events? Yes! We are excited to have world class rock and roll drummer Sandy Gennaro provide his keynote presentation "Beat the Odds, How to Achieve Rockstar Status in Business and Life." As manufacturing continues to evolve, we must adapt to change, just like the members of a rock band. Sandy's message should resonate well with our attendees. He should have great insight as throughout his 50-year career, Sandy has toured with world renowned artists including Cyndi Lauper, Joan Jett, Bo Didley, The Monkees, and many more.

Our closing event will include dinner in an intimate setting where country music singer/songwriter, Rodney Atkins, who will perform an acoustic set, where he will give us the stories behind the songs. With six No. 1 hits and eight top-5 singles, it should be an exciting show.

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

As always, I look forward to meeting face-to-face with the industry and having the group together under one roof. The energy that you can get from meeting with your colleagues and peers in the same room is unmatched.

As we continue to be impacted by the current economy, inflation, transportation delays, and other challenges, Las Vegas will be a great springboard as we bridge from 2023 to 2024 and head to the "City of Bridges," Pittsburgh, Pennsylavnia, in 2024. Learn more about speaking, exhibiting, and attending these exciting conferences at PowderMet2024.org or AMPM2024.org.

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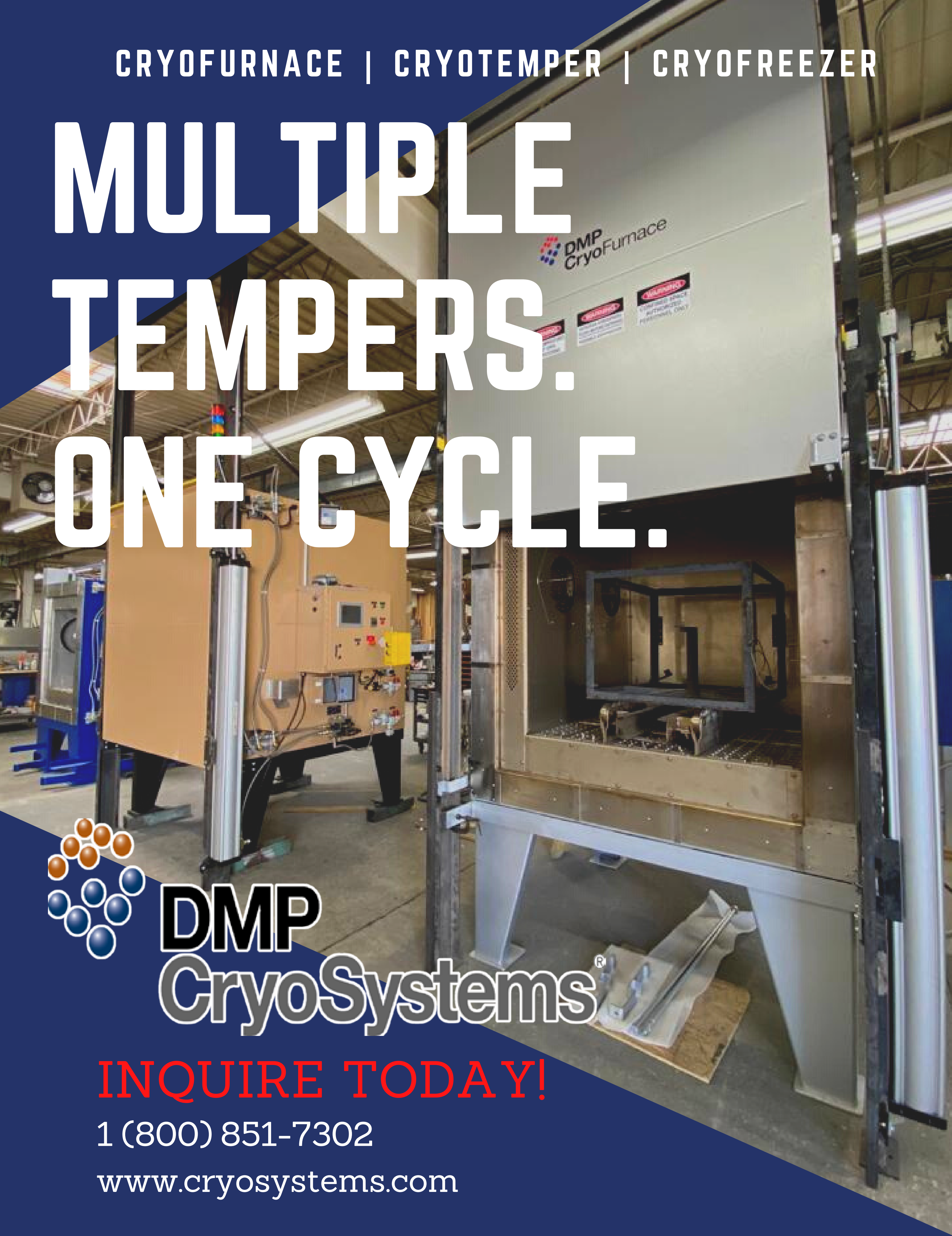
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