Technologies and Processes for the Advancement of Materials

Thermal processing

ISSUE FOCUS ///

THERMOCOUPLES / MEDICAL APPLICATIONS

10 TIPS TO ENSURE ACCURATE THERMOCOUPLE MEASUREMENT

COMPANY PROFILE ///

Astaras, Inc.

MAY 2023
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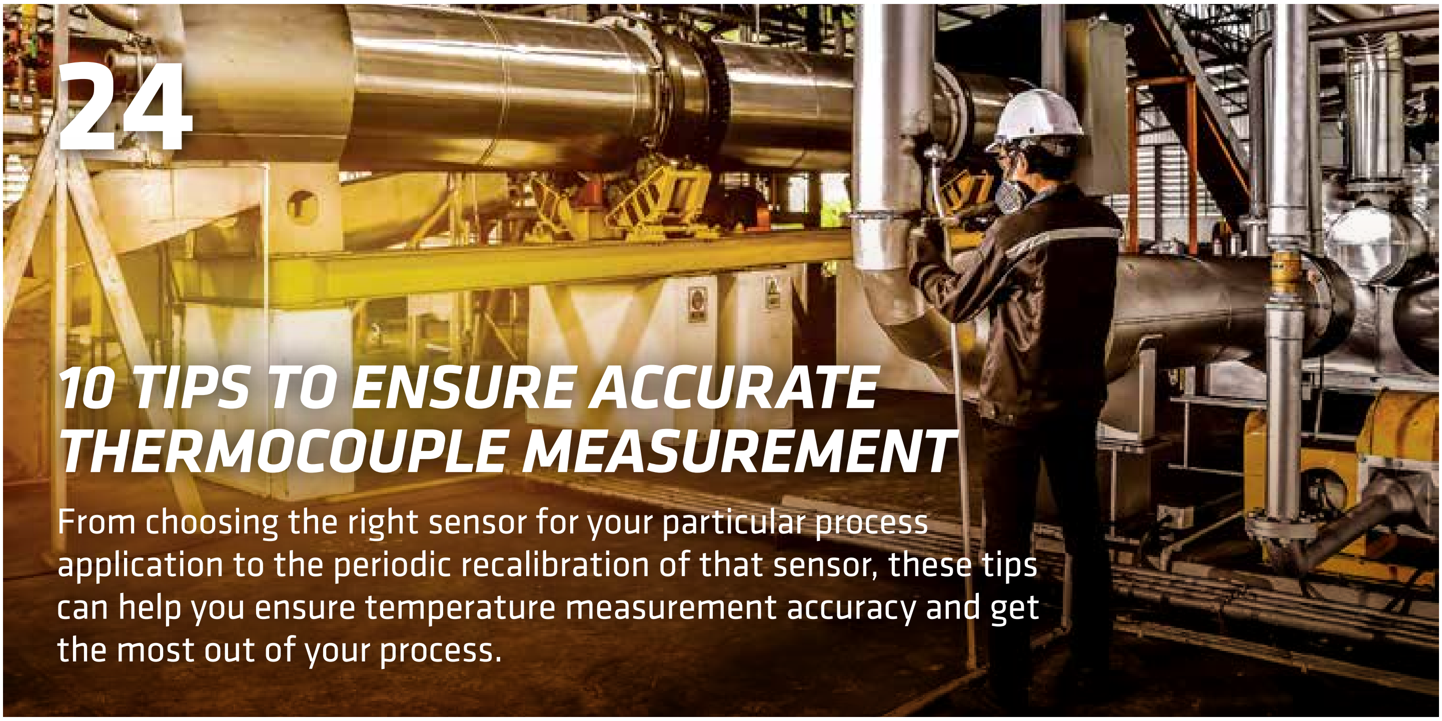

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10 TIPS TO ENSURE ACCURATE THERMOCOUPLE MEASUREMENT

From choosing the right sensor for your particular process application to the periodic recalibration of that sensor, these tips can help you ensure temperature measurement accuracy and get the most out of your process.

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Astaras offers tungsten solutions in the Americas for a host of industries including aerospace, high-temperature applications, die casting, medical, homeland security, nuclear, oil and gas, precision tooling, automotive, and high-performance racing applications.

COVER PHOTO: SHUTTERSTOCK (4) / ILLUSTRATION BY RICK FRENNEA

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Monitoring precise temps takes precise equipment

Thermocouples may seem like a routine piece of equipment for a heat-treating operation, and it might be easy to dismiss them, but not using the proper thermocouple could mean a huge dent in your company's bottom line.

But just because something isn't flashy, doesn't mean you should take it for granted.

This month's cover story from Conax Technologies breaks down how to ensure accurate thermocouple measurements with 10 tips to aid with choosing the right sensor for your particular process application as well as dealing with the periodic recalibration of that sensor. This might be something you bookmark for future reference because it's full of useful thermocouple information.

For the past few years, *Thermal Processing* has added a medical-applications Focus topic because, like aerospace, heat-treating is also a big part of products that not only keep us alive, but also help make living more comfortable.

To that end, our next story takes a technical deep dive at the effect of heat treatment on some titanium alloys used as biomaterial.

And in addition to those two articles, our third story brings to a conclusion Gregory Fett's series on carburized steel mechanical properties. It's been a pleasure sharing his insights with you over these three issues.

But the May issue's thermal-processing coverage is just getting started. Be sure to check out our monthly columnists as they tackle a variety of subjects vital to heat treating.

You'll also find our company profile and Q&A features shining a spotlight on other important aspects of heat treating.

I hope you enjoy this month's content, and if you'd like to contribute to a future issue, please don't hesitate to contact me. I'm always on the lookout for expert advice that furthers the advancement of the heat-treat industry.

Yes, May is finally here with — hopefully — a relaxing summer close on its heels.

So, grab our latest issue and take it to the deck. It may not keep you cool, but the information inside certainly is.

As always, thanks for reading!

KENNETH CARTER, EDITOR
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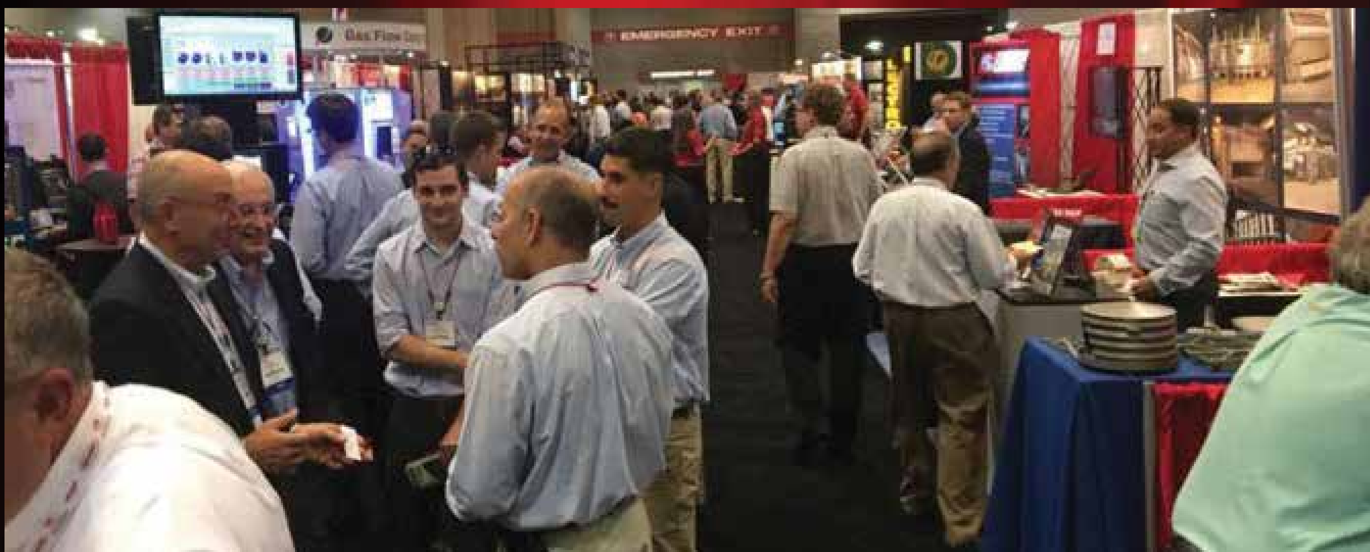
HEAT TREAT EVENTS 2023



Forge Fair 2023 › May 23–25 | Cleveland, OH

PowderMet 2023 / AMPM 2023 › June 18–21 | Las Vegas, NV

IFHTSE World Congress › Sept 30–October 3 | Cleveland, OH

FABTECH 2023 › September 11–14 | Chicago, IL

IMAT 2023 › October 16–19 | Detroit, MI

Heat Treat 2023 › October 17–19 | Detroit, MI

Global Materials Summit › December 5–7 | Naples, Florida

Thermal processing

Look for bonus distribution of *Thermal Processing* at many of these shows. And we look forward to seeing you at select events this year.

Due to the ability to handle high temperatures and submersion in liquid polymers, Graphalloy bushings are used in several plastic recycling technologies including high-temperature pyrolysis processes. (Courtesy: Graphalloy)

Graphalloy bearings aid high-temp application

The senior project manager at a company that developed a new technology to recycle plastics reached out to engineers at Graphite Metallizing to solve their bearing issues.

Graphite Metallizing manufactures Graphalloy® self-lubricating high-temperature materials.

The company is a pioneer in regenerating post-consumer and post-industrial plastics into new plastics, reclaiming these resources' full value. This includes contaminated food containers.

The project manager needed a bearing/bushing that could handle high temperatures and submersion in liquid polymers. During the engineering discussion, it was confirmed that the distance between bolt centers of Graphalloy's type 845F4 flange block did not match those of the company's IPTCI® type UCFCS206-20, four-bolt flange housing. However, Graphalloy's type 845-39 inserts would fit perfectly into these housings.

Application:

- EQP: Reactor.
- MOD: Bottom impeller drive mount.
- LOA: 50 LBS.
- SPD: 1000 RPM.
- ENV: Submerged in liquid polymer.
- TEM: 330°C.

The project manager asked for and received a sample of the Graphalloy nickel-grade material that Graphalloy's engineer recommended, based on the application. He wanted to conduct a compatibility test on their application with the polystyrene material at high temperatures.

A few weeks later, the project manager contacted Graphalloy to say, "after receiving your sample, our evaluation has been positive and I'm including our purchase order here. We want to purchase three pieces of your type 845 bushing inserts in the nickel material, and we want to use one in an assembly quickly."

Weeks later, the project manager said that Graphalloy was a success and was now part of their new reactors. The company licenses its process and sells equipment and services in connection with their unique reactors.

Due to the ability to handle high-temperatures and submersion in liquid polymers, Graphalloy bushings are used in several plastic recycling technologies including high-temperature pyrolysis processes.

Graphalloy bushings offer solutions in places where traditional bearing lubricants will not work, including high-temperature applications, clean environments, submerged operation applications, and more. The Graphalloy material is self-lubricating, non-galling, chemically resistant, and can withstand temperatures from minus-400°F (minus-240°C) to +1,000°F (+535°C).

MORE INFO www.graphalloy.com

New Vastex infrared conveyor ovens up to 78 inches wide

New EconoRed™ Series VI conveyor ovens by Vastex Industrial, available in 30-, 54-, and 78-inch (76, 137, and 198 cm) widths, are equipped with six infrared heaters in a single chamber for rapid curing, drying, or preheating of parts, laminates, and coatings.

Model ER-VI-30 offers a 30-inch (76 cm) wide conveyor belt and 15,600 watts of power; model ER-VI-54, a 54-inch (137 cm)

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

New EconoRed™ VI series high production conveyor ovens in 30-, 54-, shown, and 78-inch. (76, 137, and 198 cm) widths can cure, dry, or pre-heat at high rates. (Courtesy: Vastex Industrial)

belt and 31,200 watts. Model ER-VI-78 with 46,800 watts and a 78-inch (198 cm) wide belt can accommodate large parts, sheet, and film products in single or multiple rows.

All models include a digital PID temperature controller accurate to ±1°F (±0.5°C), and an exhaust system that removes fumes and moisture while cooling the chamber's outer skin for operator safety.

The 13.25-foot-long (404 cm) conveyor belt runs true by means of a low-friction belt aligner patented by the company, with digital belt speed controls allowing infinitely adjustable dwell times to suit process requirements.

Capacity (belt speed) can be doubled or tripled when needs increase by adding one or two modular heating chambers and extending the conveyor belt, increasing throughput in direct proportion to each additional chamber.

Heaters come with a 15-year warranty and are height adjustable from two to seven inches (5 to 17.7 cm) to accommodate parts as well as sheet products.

A Teflon®-coated fiberglass belt is standard, with optional Kevlar® and stainless-steel mesh belts available for high-heat and/or sanitary applications.

Other options include conveyor extensions at the infeed or discharge end of the oven to optimize loading and cooling/unloading of products; a conveyor air bar to speed the cooling and handling of items exiting the chamber; and an exhaust hood that can be mounted to the rear of the unit to remove fumes of adhesives, inks, and other coatings that continue to off-gas after exiting the chamber.

Also offered are conveyor models with infrared heaters up to 68,400 watts, and cabinet/batch ovens with forced, filtered air, adjustable racks, and stainless-steel finned strip heaters up to 3,100 watts.

MORE INFO www.vastexindustrial.com

Allied Mineral announces exclusive Japan distributor

Allied Mineral Products announced Shinagawa Refractories as its exclusive distributor of monolithic refractory technology for the aluminum market in Japan.

Shinagawa and Allied have a long-standing relationship. In 2005, Allied licensed its monolithic refractory technology to Shinagawa in Unanderra, Australia.

Shinagawa is a global leader in high-quality refractories, supporting vital social infrastructure for 145 years with superior values and optimal solutions for virtually every essential industry. Shinagawa values a close relationship with customers and promises the highest and most consistent performances. By doing so, Shinagawa responds to the needs of its customers in essential industries with speed and competitiveness in cost and performance.

Shinagawa believes the key to its future is "proximity" — meaning nearness in space,

time, and relation. Proximity could be translated as physical or geographical closeness and availability in the same time zone, with a secure relationship built on trust.

Since 1961, Allied Mineral Products has become a leading global producer of monolithic refractories and precast shapes. Allied's innovative product solutions are backed by world-class research and engineering teams.

With 12 manufacturing and three research and development facilities, Allied's unique product testing, design engineering capabilities, and new product development programs allow Allied to meet the unique needs of each customer. Allied's strong sales force drives the company's commitment to "being there" with product availability and service and support.

With a combined expert knowledge of the local Japanese market and world-class monolithic refractory technology for the aluminum market, Shinagawa and Allied Mineral Products have the capability to provide value-added solutions and unmatched service to the Japanese aluminum industry.

MORE INFO www.alliedmineral.com
www.Shinagawa.co.jp/en

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. Tools such as nippers and ladles are very important parts of foundry and forging equipment.

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

Optris celebrates 20 years of infrared innovation

Since 2003, Berlin-based Optris GmbH has been taking care of accurate, reliable, and non-contact temperature measurement in many different industries and research. The company has always succeeded in developing and implementing new technologies. In the meantime, customers from all over the world rely on the infrared thermometers and thermal imaging cameras known for their quality.

In 2003, managing director Dr.-Ing. Ulrich Kienitz founded Optris with the goal of enriching the range of measuring temperature sensors with innovative measuring and application principles. Since then, his company has grown to become a global leader in non-contact temperature measurement. Optris develops portable and stationary industrial thermometers as well as thermal imaging cameras that make temperature measurement easy and work safer. The applications for infrared temperature measurement are many — the systems are used in the glass, metal, and plastics industries as well as in the automotive and electronics industries. In medical technology and bioscience, Optris devices support research, and they are also used for early fire detection, e.g. in the wood processing industry, in modern battery cell production, or in recycling or waste processing.


Optris CEO Dr. Ulrich Kienitz. (Courtesy: Optris)

In the past 20 years, Optris has constantly reinvented itself and also further developed its own products. In the 2010s, the company greatly optimized the performance parameters through so-called micromachining, thus improving the price-performance ratio.

"This allows such products to be used in series in mechanical and plant engineering," said Kienitz. Modern measuring systems now reliably detect even 25 µm small objects in the temperature range from minus-50°C to 3,000°C within a few milliseconds.

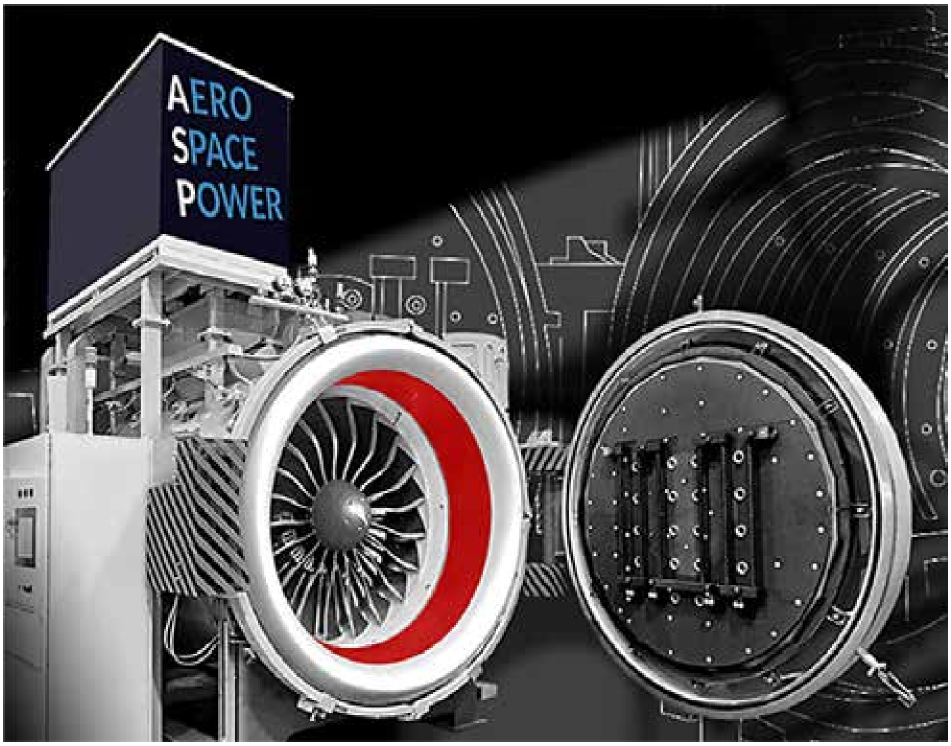
As an international company, Optris is active in many countries around the world.

"From the very beginning, Optris has focused on building a broad distribution network, including OEM sales," Kienitz said. Abroad, people trust in this competence —

the export share of the products is 75 percent. Strong growth markets for the Berlin experts are the U.S. and Asian markets. Through technological innovation and a local presence, Optris aims to further expand its international business in the future.

MORE INFO www.optris.de

Seco/Warwick to supply furnace for MRO industry



Aero Space Power has ordered a custom-made Vector® vacuum furnace from Seco/Warwick for repair solutions for both complex aircraft engines and gas turbines for the energy industry. (Courtesy: Seco/Warwick)

Aero Space Power, a modern European MRO facility with experience in the renovation and energy industry has ordered a custom-made Vector® vacuum furnace from Seco/Warwick.

The solution will be used for repair solutions for both complex aircraft engines and gas turbines for the energy industry. This is another example of an application where Vector supports the most demanding industries, this time in Hungary.

The furnace on order is a unique solution due to the effective size of the heating chamber. It has been adapted to the Aero Space Power requirements and has a working area of 1,300 x1 ,000 x 1,500 mm. Thanks to this, the furnace can accommodate large components – mainly aircraft parts, as well as gas turbines for the energy sector.

"The furnace construction is based on the standard Vector vacuum furnace design, which can be adapted to individual needs," said Maciej Korecki, vice president of the Vacuum Furnaces Segment at Seco/Warwick Group. "We create tailor-made furnaces based on proven solutions, which gives the customer confidence that their system is backed by our many years of experience and hundreds of implemented solutions.

"This approach to each order, needs, and the solution is the Seco/Warwick team trademark. Vectors are vacuum furnaces working in various industries. Their versatility combined with the personalization capability, makes it the first-choice furnace in all corners of the world," Korecki said. "I am glad that another partner from the MRO industry is associated with the Seco/Warwick brand. It is worth emphasizing that this is an industry where it is crucial to ensure efficient execution of orders for parts necessary for maintenance departments. Production, strategic planning, and appropriate maintenance enables users to reduce costs, which is a priority here. Reliable Vector is a link that expedites this process."

The featured technology on order, in addition to non-standard dimensions, is designed to process work in the presence of two gases: argon (used for partial pressure) and nitrogen, which is used mainly in the cooling process.

Additionally, the furnace will be equipped with a dew point sensor for each of the gases. It is a system which solves one of heat treatment's very critical operational requirements, which is to control the quality/purity of gas used during the process. Vector also features a partial pressure control system based on three gases (hydrogen, argon, and nitrogen) to help prevent evaporation and sublimation of alloying elements from the load surface during the vacuum heat treatment or vacuum brazing process.

The MRO market is currently experiencing growth, mainly because access to new parts is becoming more and more difficult. Knowing the exact specifications for the MRO components and having reliable equipment for their production, users can optimize not only the supply chain planning process itself, but also the expenses incurred by the company for this purpose. This custom-made Vector will solve Aero Space Power's challenge, which was the heat treatment of large components — even with a diameter up to 1,400 mm.

"We decided to acquire in-house heat treatment because we want to be independent in production. It will also give us much better control over the process and treated part quality," said Mark Peter Biro, commercial sales manager, Aero Space Power. "By purchasing a Vector furnace, we reduce the risk of delays in delivery, which is critical for our industry. The lack of parts causes very costly delays in the jet engine and turbine repair process. By installing production capacity in-house and creating our own heat treatment department, we not only become independent from external suppliers, but we also significantly reduce transportation costs. This is an important decision which will allow us to be more competitive in the MRO market."

The MRO industry has been significantly affected by the global pandemic. Before 2020, new orders for basic parts were processed within 24 hours. Deliveries lasting no longer than two days was the standard. Currently, the situation does not look good, and deliveries are prolonged due to interrupted supply chains. The unstable situation in Europe and new sanctions packages mean that many MRO companies have to revise their existing development and optimization strategies. Ownership of vacuum furnaces allows companies to fully control the production process and can be an important key to success.

MORE INFO www.secowarwick.com

Exact Metrology attends POWERGEN

From left, Dean Solberg, Rob Ellington, and Noel Brekas at POWERGEN International. (Courtesy: Exact Metrology)

Exact Metrology representatives were on hand at POWERGEN International to offer solutions for the thermal, hydro, nuclear, wind and diesel industries.

Exact Metrology: A Division of In-Place Machining Company and a comprehensive 3D metrology service provider and hardware sales company, exhibited together with In-Place Machining Company (IPM), Oasis Alignment Services: A Division of In-Place Machining Company, and East Coast Metrology: A Division of In-Place Machining Company.

The show was held at the Orange County Convention Center in Orlando, Florida. POWERGEN is the largest networking and business hub for generators and solution providers engaged in power generation. Power producers, utilities, EPCs, consultants, OEMs and large-scale energy users gather to discover education, peer-to-peer networking, and solutions from top providers.

Exact Metrology displayed its Leica RTC360. Manufactured by Leica Geosystems, these portable coordinate measuring machines are designed to measure large-scale objects. The RTC360 3D Reality capture scanner is ideal for professionals managing project complexities with accurate and reliable 3D representations. This scanner effectively combines a high-performance 3D laser scanner with Leica Cyclone Field 360, a mobile device app for edge computing that automatically registers scans in real time, and Leica Cyclone REGISTER 360, an office software that integrates the 3D model into the workflow. Additional features include capturing scans, including enriching HDR imagery, in less than two minutes, automatically recording moves from station to station, and augmenting data capture with information tags.

Measurement services displayed by OASIS Alignment Services included 26 power plant (hydro, steam, and gas) jobs performed in 2020. Most jobs involved metrology support, with two including mechanical work. In 2021, the total number was 37, most of which were metrology supported, with six jobs including mechanical work. Last year, 29 power plant jobs were performed, two including mechanical work. To date in 2023, 10 jobs have been accomplished, three involving mechanical work. Examples of mechanical jobs in the power industry typically include cooling tower fan alignment, pump alignment, replacement of turbine bearings, generator alignment, new coupling installment, gearbox alignment, circular pump alignment, repair of broken shaft, and solar generator alignment. Some metrology alignment jobs comprised inspection of turbine components, monitoring of components during a rebuild, structural movement studies, flatness inspections, and others.

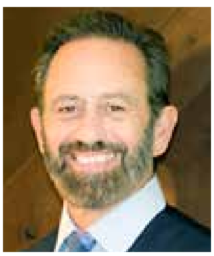
Present at the event were Dean Solberg, vice president of metrology sales and services at Exact Metrology; IPM sales managers Noel Brekas, Ronnie Onofry, and Rob Ellington; Paul Parry, director of sales-field machining; and Ulises Uscanga, head of industrial plant solutions at Leica Geosystems.

"The recent acquisition of East Coast Metrology allows IPM Measurement Group to provide nationwide coverage with metrology services to complement its field machining capabilities," said Solberg. "We are excited to continue serving our customers' needs as their one-stop shop."

MORE INFO www.inplace.com
www.exactmetrology.com

New regulatory consultant to support RadTech and PAMA

RadTech, the non-profit trade association for ultraviolet (UV) and electron beam (EB) technologies has hired Dr. Gregory Pace, an analytical scientist with broad experience in global regulatory affairs, analytical laboratory services and operations, food packaging materials testing, and product stewardship. Pace will assist with member regulatory needs and also work with members of the Photopolymer Additive Manufacturing Alliance (PAMA), a RadTech collaboration with the National Institutes of Standards and Technology.



Dr. Gregory Pace

"With the growing demands of regulatory compliance, we are pleased to welcome Greg as part of our team," said Michael Gould, president of RadTech and technical key account manager, RAHN USA. "We look forward to engaging Greg's experience with our membership as we work to better address regulations, and also educate regulators about our technologies."

During his 30+ year career in industry, the public sector, academia, and consulting, Pace has held scientific, corporate, and divisional scientific and management positions in global regulatory affairs, product stewardship, analytical chemical and polymer characterization, product quality assurance, and packaging ink R&D.

MORE INFO www.radtech.org
www.pama3d.org

Graphalloy bushings handle tough washdowns

Graphalloy® recently assisted a major food processing plant with a problem with one of its applications. The company produces name-brand sliced luncheon and deli-shaved meats which are distributed throughout the United States.

The application is in the caustic washdown area of their meat-processing conveyor. The load is 3-4 pounds, speed: 193 RPM, in ambient temperature.

The plant was having issues with grease washing out of the bearings during the washdown process, which increased maintenance time. The metal bearings also had to be replaced on a weekly basis, which increased costs.

In 2010, they worked with engineers at Graphite Metallizing, the makers of Graphalloy, who recommended Graphalloy copper-grade bushings to replace the greased bearings, since Graphalloy does not require external lubrication. They initially tested four pieces of Graphalloy and, after a few weeks, converted one entire conveyor to Graphalloy.

Graphalloy bushings are self-lubricating and maintenance-free. They are chemically resistant and can operate in submerged conditions, with hostile liquids. Graphalloy will not swell. FDA acceptable grades are available.

This plant has been using the Graphalloy copper-grade bushings in their meat processing conveyors, with caustic washdown, for more than 11 years now and the plant manager is very pleased with the performance and cost-savings.

Over the years they've converted the rest of their conveyors, and Graphalloy engineers are working with them on additional applications at this plant.

Graphalloy Bushings offer solutions in places where traditional bearing lubricants will not work, including high-temperature applications, clean environments, submerged operation applications, and more. The Graphalloy material is self-lubricating, non-galling, chemically resistant, and can withstand temperatures from -400°F (-240°C) to +1,000°F (+535°C).

MORE INFO www.graphalloy.com

Conference updates and other IFHTSE highlights

ECHT 2023 CONFERENCE

AIM is proud to announce the ECHT 2023 Conference in Genova, Italy, at Magazzini del Cotone. The conference will meet May 29-31, 2023. ECHT 2023 will cover all relevant topics for the heat-treatment and surface-engineering community. The conference will include a special focus on sustainability. Presentations will cover light alloys, heat treatment of steel, and surface engineering and coatings from industry, research centers, and universities.

Examples of papers to be presented include:

›› "Efficient modelling of quenching processes via CFD," P.E. Ramirez Lopez — Swerim AB, Sweden and KKTH Kungliga Tekniska Högskolan, Sweden; A. Sundström, S. Häglund — Swerim AB, Sweden; H. Kristoffersen, E. Troell — RISE/IVF, Sweden; A. Olofsson - Advanced Engineering Transmission Production, DXTGR Scania CV AB.

›› "Optimal shape design using response surface method to reduce heat treatment deformation," K. Nambu — Osaka Sangyo University, Japan; K. Shiraki, M. Okumiya — Toyota Technological Institute, Japan.

The ECHT 2023 Conference will be in Genova, Italy, May 29-31.

›› "Effect of two-step heat treatment on microstructure and mechanical properties of additively manufactured tool steel," L. Kučerová, K. Burdová, Š. Jeníček, I. Chena — University of West Bohemia, Czech Republic.

›› "Heat treatment from a sustainability perspective," K. Buchner — Aichelin Holding GmbH, Mödling, Austria.

›› **More info:** www.aimnet.it/echt2023.htm

HEAT TREAT 2023

Heat Treat 2023 will be co-located with IMAT 2023 in Detroit, Michigan, October 17-19, 2023.

At the present time, there are approximately 125 papers from international heat treating professionals.

The conference will be 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 event is co-located with the Motion + Power Technology Expo 2023 with 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.

›› **More info:** www.asminternational.org/web/heat-treat/event-info

28TH IFHTSE CONGRESS

The 28th IFHTSE Congress, sponsored by the Japanese Society for Heat Treatment, will be November 13-16, 2023, in Yokohama, Japan. This wide-ranging conference offers participants the opportunity to network and hear papers on a wide-ranging series of topics, including the thermal processing of steel, surface hardening additive manufacturing, and modeling and simulation of industrial processes.

Important dates

- Notification of paper acceptance: May 31, 2023.
- Preliminary program release: June 30, 2023.
- Deadline of extended abstract: July 14, 2023.
- Deadline of early registration: July 31, 2023.
- Deadline of full paper submission: September 22, 2023.

A special issue of JSHT is scheduled to be published in March 2024. .

29TH IFHTSE CONGRESS

The 29th IFHTSE Congress, held jointly with the ASM IMAT annual meeting, will be September 30-October 3, 2024, in Cleveland, Ohio. Details will be announced soon.

IFHTSE GLOSSARY ONLINE

This wonderful achievement is now online and enables the user to type in a term and obtain the language equivalent in numerous other languages, including French, German, Japanese, Italian, Arabic, Chinese, and many others. This effort, using global experts, is intended to be a living document with more terminology added, as well as eventual definitions. Check it out at: ifhtse-glossary.com

SPOTLIGHT ON MEMBERS

Bosch

In 1886, Robert Bosch founded the "Workshop for Precision Mechanics and Electrical Engineering" in Stuttgart. This was the birth of today's globally operating company. Right from the start, it was characterized by innovative strength and social commitment. With more than 100 locations, and 35,000 employees, its products span transportation, mobility, home appliances, innovative drive and control technology, as well as power tools for professionals.

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.

UPCOMING IFHTSE EVENTS

MAY 29–31, 2023
ECHT23
Genova, Italy I www.aimnet.it/echt2023.htm

OCTOBER 17–19, 2023
Heat Treat 2023
Detroit, Michigan I www.asminternational.org/web/heat-treat

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

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

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IFHTSE

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INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

IHEA launches sustainability and decarbonization initiatives

IHEA has been developing a variety of initiatives over the past six months relating to sustainability and decarbonization in the industrial heating equipment industry.

"We are rolling out the first initiatives we've been working on," said IHEA Executive Vice President Anne Goyer. "There's no question there is a great deal of uncertainty for many in our industry when it comes to determining how to begin addressing the issues of sustainability and decarbonization. With many years of experience and expertise from our membership, IHEA is ready to help the industry through the daunting task of lowering carbon emissions in an objective and unbiased manner."

The first initiative was to develop a Sustainability area on the IHEA website that features the foundation of information the industry needs. This section of the IHEA website will evolve as time goes by. Content and resources will be added on a regular basis, and visitors will always find something new that will be of value. To access this information, go to www.ihea.org and click the "Sustainability" tab on the navigation bar at the top of the home page.

The first three items under Sustainability on the website include:

FREQUENTLY ASKED QUESTIONS

The Frequently Asked Questions (FAQ) section on IHEA's Sustainability page will be an evolving list of answers to the most popular questions asked today. Visitors are encouraged to submit their own questions that will be answered by industry experts. If you don't see a question you would like answered, complete the FAQ submission form at the bottom of the page and the question and answer will be added to the website.

GLOSSARY OF TERMS

Hoping to alleviate much of the confusion involved in sustainability and decarbonization discussions, the glossary provides a quick review of commonly used sustainability and decarbonization terminology. This section on the IHEA website will evolve as the initiatives grow.

RESOURCE LIST

The IHEA Resource List is a growing collection of important resources to help the industry find a wide variety of information related to sustainability and decarbonization. It includes links to websites that IHEA members have found useful.

In addition to the new Sustainability section on the website, IHEA is launching a complimentary webinar series meant to walk people through many of the issues they are or will be dealing with related to decarbonization.

Three generations of Super Systems Inc.: grandson Will Thompson, CEO Steve Thompson, the son of company founder Biil Thompson.

The first four series include:

›› **May 11:** Thermal Processing Carbon Footprint.

›› **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.

More info: www.ihea.org/sustainabilitywebinars

MEMBER SPOTLIGHT: SUPER SYSTEMS INC.

SSi was established in July 1995 by Bill Thompson, father of current CEO Steve Thompson, and it has been serving the thermal-processing industry ever since. Gold probes have been a mainstay of the business for more than 25 years, and the company's probes continue to set the standard for oxygen detection and carbon calculation. As time passed, many other technologies have been introduced, such as dew point analyzers, gas analyzers, process controllers, software, and flow technology. Almost all products are the result of customers' requests for more heat-treatment-specific solutions. SSi began with the heat-treater in mind. That focus continues to guide the company in developing new products and technologies to help its customers meet industry standards of quality and repeatability.

SSi now has 110 employees and serves many major industries, including aerospace, automotive, military/defense, engines/propulsions, machine building, agriculture, and medical.

SSi will always be known for the Gold Probe, but today the company's product line includes so much more: controllers, flow meters, analyzers, software solutions, and engineered systems — all products SSi is proud to offer the thermal processing industry today.

The SSi team has extensive industry experience in addressing technological demands to help its customers be more efficient and produce better-quality products. SSi products help deliver cost-effective, precise, and reliable solutions to its customers' heat-treating processes. Today's heat treater is looking for ways to consistently run parts and eliminate scrap and rework. Industrial process controls such as the SSI Modular Matrix provide that foundation. The expandable I/O allows the system to extend to all inputs, making processes efficient and error free. In addition, SSi's SCADA package (SuperDATA) provides all stakeholders with real-time and historical information to make intelligent decisions from virtually anywhere.

SSi provides a wide array of technology specific to each application, software, or hardware. In its state-of-the-art facility, the company has the resources to design and build technology from the circuit board up. SSi employs professionals in the areas of electrical, computer, metallurgical, and mechanical engineering to deliver the latest technology to the industry.

SSi began with the Gold Probe. It has been enhanced over the years, but it is still the probe the company supplies for applications where carbon or lack of oxygen are important. SSI manufactures infrared (IR) analyzers, and they are the standard of the industry with in-house developed firmware and IR technology. SSi has a line of industrial gas and liquid flow meters that provide precise control, second to none, with many different options to address the right application. The company has been addressing the Industrial Internet of Things (IIoT) for years with its SCADA system. SSi developed SuperDATA for process data collection, and it is used globally by commercial and captive heat treaters. Customers can capture millions of data points daily to provide historical proof of process and real-time business intelligence.

SSi's eFlo 2.0 flow meter is designed for harsh environments and uses superior technology for measuring gas and liquid flow. The eFlo 2.0 can come with a keypad or touchscreen interface and is offered in a variety of sizes and motorized manual valves. SSi's technology provides temperature and pressure compensation to provide precision control of gas and liquid flow rates.

The Matrix Series Controller provides a flexible platform for meeting a large variety of control applications. The expandable I/O for analog and digital cards allows for right-sizing an application. The instrument has all the built-in features for sophisticated thermal-processing applications, includes a customizable HMI allowing the right interface to be created for the application, as well as built-in data logging. SSi's Modular Matrix is applicable in vacuum, nitriding, carburizing, annealing, solution, aging, ferritic nitrocarburizing, endothermic gas, nitrogen methanol, multi zone, and more.

SSi's SuperDATA software package is an HMI SCADA system designed specifically for the thermal-processing industry. This package allows personnel on the shop floor to use data for immediate decisions and proof of process. This software was created with the goal of giving business stakeholders the key performance data yielding quality heat-treated parts in the most efficient manner.

SSi has a dedicated R&D team that is constantly looking for ways to improve existing products or bring new technology and ideas to the industry. In the last 12 months, the company has stayed the course of continuing this practice where equipment design has been improved in order to provide more precision in atmosphere evaluation and control. A new instrument platform headed to the market provides modular I/O and enhanced features for many types of heat-treating processes. Software enhancements are continuously developed with operational efficiencies and industrial automation in mind.

Looking to the future, SSi plans to continue to lead the way. SSi is also placing an emphasis on minimizing the carbon footprint of its customers and the thermal-processing industry as a whole. Its products directly play a role in efficiency, reducing scrap and reducing rework, which ultimately allows those using SSi's products to reduce their carbon footprint as well as save time and money. SSi has offices in five countries with business partners spanning the globe.

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DR. WILLIAM MARK MCVEA, P.E.
PRESIDENT AND PRINCIPAL ENGINEER /// KBE+

Gas carburizing is a cost-effective hardening solution for gears but there are several factors to consider in making the decision.

An overview of heat treatment techniques

Editor's note ›› This is the second in a five-part series.

In this second segment of my series on heat-treating techniques, I will discuss the pros and cons of gas carburizing.

Carburizing is a thermochemical process in which carbon is diffused into the surface of low carbon steels to increase the carbon content to sufficient levels so that the surface will respond to heat treatment and produce a hard, wear-resistant layer.

The process of gas carburizing the component is held in a furnace containing an atmosphere of methane or propane with a neutral carrier gas, usually a mixture of N_2, CO, CO_2, H_2, and CH_4. At the carburizing temperature, methane (or propane) decomposes at the component surface to atomic carbon and hydrogen, with the carbon diffusing into the surface of the component to be heat treated. In most cases, the carburizing atmosphere is created from methane or propane, and is produced in a special device (the endothermic generator) by gases partially oxidated with air. The reaction for methane is: $2CH_4 + O_2 (+N_2) \Rightarrow 2CO + 4H_2 (+N_2)$ and similar for propane. The atmosphere consists mainly of: CO, H2, and N2, while the main C carrier is CO (reaction $2CO \Rightarrow C + CO_2$), while CO_2, H_2O, O_2, and CH_4 are residual gases. The carburizing atmosphere is delivered to a furnace from the endothermic generator (not directly), and methane or propane is injected directly into the furnace in small amounts to compensate for the carbon absorbed by steel.

Methanol is the only agent which can create the carburizing atmosphere directly in a furnace, which decomposes accordingly: $CH_3OH \Rightarrow CO + 2H_2$. The temperature is typically 925°C and carburizing times range from five to six hours for a 1 (mm) depth case to as much as 90 hours for a 4 (mm) case. The quenching medium is usually oil, but can be water, brine, caustic soda, or polymer, and neutral gas under high pressure.

INTENT OF CARBURIZING HEAT TREATMENT

Carburizing, or carburization, is a heat-treatment process in which iron or steel absorbs carbon while the metal is heated in the presence of a carbon-bearing material, such as charcoal or carbon monoxide. The intent is to make the metal harder and, in the case of gears, drive carbon into a surface layer (thickness and carbon density are a function of the process and process variables).

The application of force to a gear or bearing is accomplished through a same contact patch created from the theoretical point or line contact as a function of the geometry. The local deflection that causes an actual contact area to be formed is due to the local deflection of the material in the contact patch to change from a curvilinear surface profile to essentially a flat surface. The relationship in the contact patch between the two bodies in contact is complex and a function of material properties, hardness level, and sliding velocity, etc. However, the main component of the von Mises surface stress is compressive.

Thus, by inducing proper stress in the surface of a part (gear or bearing, etc.) the resultant compressive stress induced by an external applied force must first negate the induced tensile stress, go through a neutral stress, and then into compressive stress. This works well in the loaded contact region of a gear or bearing and on the root of the non-loaded side of the gear tooth. There are many similarities in terms of the effect to shot peening the root of a gear tooth (however, shot peening is a localized effect, i.e. just the root of the tooth) and the overall effect of heat treating.

To be complete, the difference between von Mises stress and principal stress is that the maximum principal stresses are the components of stresses when the basis of other stress tensors are zero (all vector representations of stress as a function of the summation of all applied forces are zero) and define the stress concentrated in a specific region. Von Mises stress, on the other hand, is a scalar quantity obtained from the stresses acting on any structure. In essence, it is the maximum non-vector point stress, if we think of a discretized representation of the loaded body. Maximum von Mises stress criterion is based on the von Mises-Hencky theory, also known as the Shear-energy theory or the maximum distortion energy theory.

METHODOLOGY OF CARBURIZING

There are three main methods of carburizing: gas carburizing, liquid carburizing, and pack carburizing. The gas carburizing process is a surface chemistry process, which improves the case depth hardness of a component by diffusing carbon into the surface layer to improve wear and fatigue resistance based on immersing the part in a gaseous carbon-rich environment at an elevated temperature. Liquid carburizing involves placing parts in a bath of a molten carbon-containing material, often a metal cyanide.

Finally, pack carburizing is a process which involves placing steel items into a furnace in close proximity to high-carbon items. These high-carbon items include everything from carbon powder to cast-iron particles, and more. After you've inserted these items, they will be heated with the use of carbon monoxide

I will focus on gas carburizing, a process that involves placing the parts in a furnace maintained with a methane-rich gaseous atmosphere, for the remainder of this article.

Gas carburizing has become the most effective and widely used method for carburizing steel parts in large quantities, even though it is a complex process (and thus potentially more expensive). Gas carburizing is conceptually the same as pack carburizing, except that carbon monoxide (CO) gas is supplied to a heated furnace and the reduction reaction of carbon deposition takes place on the surface of the part. This process overcomes most of the problems of pack carburizing.

Carburizing is carried out at a temperature where the steel is austenitic, typically in the temperature range 820 to 950 °C (1,510 to 1,740 °F), and which requires a controlled furnace atmosphere at slight overpressure that transfers carbon from the atmosphere to the steel surface. "Case hardening" is sometimes alternatively used to more clearly describe the fact that the process includes both hardening and tempering.

OUTCOME OF GAS CARBURIZING

The highest hardness of a hardened steel having a martensitic microstructure is obtained when its carbon content is high, around 0.8 percent carbon by weight. Steels with such high carbon content are hard, but also brittle, and therefore not well-suited to be used as gears or bearings. Any component that experiences dynamic bending and tensile stresses during operation are candidates for carburizing. A carbon content as high as 1 percent carbon by weight makes the steel difficult to machine as in cutting, turning, or drilling. The case with increased carbon concentration is typically 0.1–1.5 mm (0.004–0.060 inches) thick. The core of the part maintains its low carbon concentration and corresponding lower hardness.

The issue of machinability can be mitigated by using a low carbon content steel during machining the part to a form near the finished dimensional requirements. The part at this point will be a little "bigger"; it will have enough stock such that as it distorts during heat treatment, there will be enough excess material to be post-heat treatment (PHT) machined to its final required form and dimensions.

The low carbon content in the steel before heat treatment ensures good machinability and then, after carburizing, the finished part will have enhanced material performance due to the hard case caused by the high surface carbon concentration, and with a softer core, which in combination of properties will assure good wear and fatigue resistance.

Carburizing depth is defined by the requirements of the gear or bearing during service. The requirements for the case depth and hardness ratio between surface and core are also a function of the operational requirements and design parameters set by the service factors for the gear or bearing. Proper case-depth requirements are determined by the surface load, wear conditions, and static and bending fatigue stresses that the finished part will be subjected to in its service life. A limiting factor is typically the cost of the required process time, which increases in a parabolic manner as carburizing depth increases.

When it comes to carburizing depth — or case depth — this is defined as the depth from the surface to the point corresponding to a specified carbon concentration. The case depth is typically defined as the gradient where the carbon concentration is approximately 0.35 percent carbon by weight. Case depth depends on several factors and the interaction of time at temperature and carbon concentration in the atmosphere. The longer the part is at temperature and the atmosphere is stable at the defined carbon concentration, the greater the case depth. Increasing the temperature (and keeping all other parameters constant) and carbon will diffuse deeper and faster into the surface of the part.

PITFALLS OF THE GAS CARBURIZING PROCESS

It is essential that the furnace atmosphere is evenly mixed and circulated so that all part surfaces will experience the same carburizing effect with respect to final carbon content and case depth. Thus, it becomes critical to maintain an even flow, both in terms of velocity of the moving gaseous mixture and the concentration and uniformity (not homogeneity) of the various gaseous components as they move through the furnace. If either of these parameters are 'off,' then the resultant effect of the heat-treatment process will not be uniform throughout the part load or even throughout the part itself.

Beyond the issues outlined above (which are addressed by good maintenance procedures and process control, which can be monitored in real-time, and the system adjusted in real-time), there is the issue of effectiveness of the entire process. A good deal of work continues to develop new techniques (processes) that generate better parts.

Many techniques are reliant on the inherent ability of the equipment used. One technique that produces similar final parts but takes less time in the furnace is that of carbon pulsing. Details can be researched and are well described, but at a high level the carbon concentration is dynamic (not static) and varies from an over-concentration to less than the required amount that would normally be necessary to achieve the final case hardness. This technique provides a means to create a very high carbon concentration atmosphere without the adverse outcome of soot formation. Another interesting technology is to use gas jets to drive mixture into the atmosphere and create the uniformity required for good heat-treatment results, without the need for the typical fan-driven atmosphere velocity profile. Another technique is to use propane as the carbon generating agent, and to use ammonia as a cracking catalyst to separate the molecular components. Purity, consistency, and concentration all become more manageable and can be fine-tuned to provide more specific results. And there are other techniques.

NEXT IN THE SERIES

The other two common case carburizing techniques — liquid and pack carburizing — can be used to provide surface hardness and case depth according to the part design requirements. However, using pack carburizing involves a process wherein steel items are loaded into a furnace in close proximity to high-carbon items. These high-carbon items include everything from carbon powder, to cast iron particles, and more. The atmosphere in the furnace is then maintained as simple carbon monoxide and without the need to maintain a constant and uniform atmosphere velocity. However, pack carburizing is dirtier than atmosphere carburizing. Shallow case depths are also not recommended, and the case depth is not consistent. Carbon potential is not as easily controlled compared to normal gas carburizing. The uniformity of carbon potential in the atmosphere is a function, and very sensitive to, the packing of the carbon material.

Finally, liquid carburizing generates the carbon potential through the use of a molten salt composed mainly of sodium cyanide (NaCN) and barium chloride ($BaCl_2$). Liquid carburizing has issues in terms of reduced ductility of the steel as a function of the process and the process requires longer heating and cooling times.

Liquid carburizing makes steel less ductile because it reduces the amount of free ferrite, which is capable of deforming without fracturing, in the final part.

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Tests show significant variation in cooling curve behavior can occur as a result of agitation.

The effect of agitation on oil quenchants

In this column, I will discuss the effect of agitation on the cooling curve of oil quenchants.

Oil has been used for many years as an industrial quenchant, with some saying that it has been used for several thousand years [1]. While oil quenchants of whale oil, vegetable oils, and mineral oils have been used industrially in the past 150 years, the effects of agitation and temperature have been less studied or documented.

Historically, agitation has always been recommended for quenching steel. However, the amount of agitation, and its effects are hard to quantify. An initial attempt as quantifying agitation was published by Grossman [2] and is shown in Table 1.

Circulation or Agitation Rate	H-Value or Quench Severity Oil	Water	Brine
None	0.25 – 0.30	0.9 – 1.0	2.0
Mild	0.30 – 0.35	1.0 – 1.1	2.0 – 2.2
Moderate	0.35 – 0.40	1.2 – 1.3	–
Good	0.40 – 0.45	1.4 – 1.5	–
Strong	0.5 – 0.8	1.6 – 2.0	–
Violent	0.8 – 1.1	4.0	5.0

Table 1: Quench severity according to Grossman [2].

The oil used by Grossman was a simple straight oil without additives, the values of H-value are conservative for modern oils. This is based on determined values of modern oils with sophisticated additive packages. For modern oils without agitation, the H-value, without agitation, can range from 0.25 to 0.85 [3].

Property	Agitation Rate, RPM No Agitation	0.5 m/s	1.0 m/s	1.5 m/s
Maximum Cooling Rate	90.5	87.5	104.2	113.1
Temperature at Maximum Cooling	630.2	619.3	635.1	647.2
Cooling Rate @ 704°C	39.3	61.1	90.7	102.0
Calculated H-Value from Cooling Rate at 705°C	0.34	0.61	0.99	1.14

Table 2: Calculated H-Value of a medium speed oil at different flow rates.

The biggest issue with the application of the Grossman H-value is the difficulty in quantifying agitation rates. The terms describing the agitation are not quantifiable and can result in errors. There is really no understanding of what is meant by "mild" or "violent" agitation. Since oils are tested without agitation per ASTM D6200 [4], this results in a narrow range of possible oil values.

EFFECT OF AGITATION ON COOLING CURVE BEHAVIOR

Agitation is critical for quenching uniformity and proper control of distortion. It reduces surface-to-surface thermal gradients and provides for uniform heat transfer and uniform flow throughout the workload. It wipes the vapor blanket from parts to achieve proper quenching and minimizes persistent vapor that is trapped in keyways or blind corners. Racking and agitation work together to provide low-distortion parts, desired properties, and microstructure. The agitation of a quenchant can be obtained in several ways. In conventional quench tanks, circulation of the quenching medium is usually provided by:

- Pumps.
- Passage of the work piece through the quenching medium.
- Manual or mechanical movement of the work piece.
- Mechanical propellers or impellers.

The selection of the agitation method is dependent on the tank design, type of quenchant, volume of quenchant, the part design, and the severity of quench required.

Traditionally, the quench severity of an oil quenchant is evaluated by quenching a heated probe into a bath of quenchant with no agitation [4]. In this test, a heated 12.5 x 60 mm cylindrical Inconel 600 probe is quenched into a 2.0 liter tall-form stainless steel beaker containing the quenchant. However, this does not show the effects of agitation on cooling curve behavior.

One apparatus to measure the effect of agitation on the cooling curve behavior is the "J-Tube." In this design, a 40-mm stainless tube is bent in the form of a "J," with the short vertical leg being 50-mm in length, and the long leg being 100-mm long. The centerlines of the legs are 75-mm apart, and the radius of the "J" is 37.5-mm (at the centerline of the tube). The J-tube is placed into a large stainless beaker and filled with oil. A standard four-blade laboratory impeller is inserted inside the tube at a depth of 25 mm from the top of the short leg (Figure 1).The ASTM D6200 Inconel 600 probe is inserted to a depth of 75-mm in the center of the longer vertical tube.

Using a medium speed quench oil, the effect of agitation was examined. In this test, the oil was heated to 60°C, and tested using the J-Tube. The results (Figure 2) show a gradual decrease in the stability of the vapor phase, and an increase in the maximum cooling rate. The cooling rate during the convection phase also increased as the RPM was increased. Table 2 shows the specific cooling curve characteristics as a function of RPM.

As can be seen from the cooling curves in Figure 2, there is a significant change in the shape of the cooling curves as a function of flow rate. As agitation is increased, the vapor phase becomes less stable, and almost disappears completely. Up to a velocity of approximately 0.5 m/s, the maximum cooling rate changes very little. However, at velocities greater than 0.5 m/s, the maximum cooling rate increases

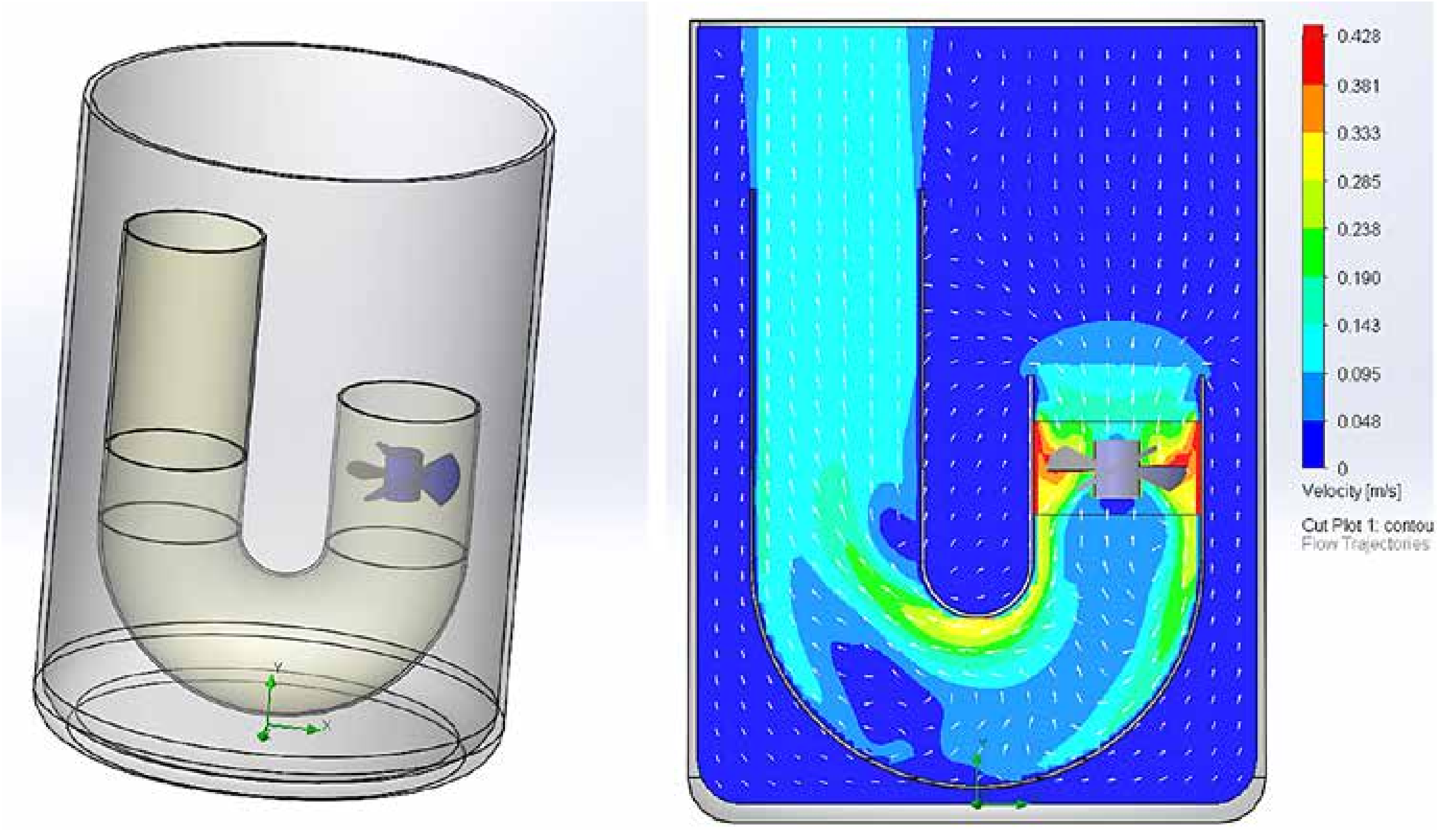

Figure 1: Schematic representation of J-Tube used at Quaker Houghton for measuring the effect of agitation with CFD analysis showing uniformity of flow.

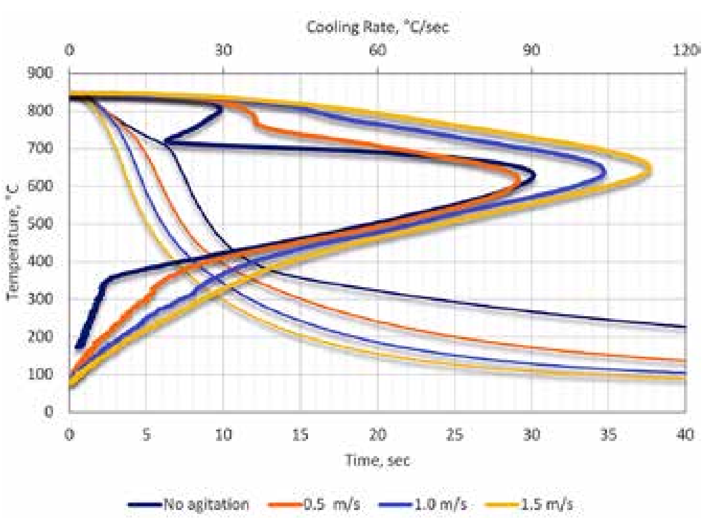

Figure 2: Cooling curves as a function of velocity in a J-Tube. Oil is a medium speed oil, at 60°C. Apparatus is shown in Figure 1.

to nearly double of the non-agitated sample. Lastly, the convection stage shows a large change in the cooling rate. As the agitation rate is increased, the cooling rate and effective heat transfer rate also increase. This is doubly significant because this region is in the temperature range of the martensite transformation temperature, and distortion control.

This also assumes that the agitation is uniform. Just increasing agitation works for increasing properties, but if the agitation is non-uniform, increased distortion — and potentially cracking — can occur. For thick sections, one way of controlling distortion is to use high agitation rates at the beginning of quenching, to ensure that parts avoid forming non-martensitic transformations (bainite and pearlite), and then slow the agitation rate as the parts approach the martensite start temperature to reduce distortion.

CONCLUSION

In this article, we have illustrated the effect of agitation on the cooling curve behavior of oils and showed that significant variation in cooling curve behavior can occur as a result of agitation. As agitation is increased, the vapor phase is destabilized, and the cooling rate increases. The maximum cooling rate occurs earlier and increases. The convection stage increases because of increased agitation.

Should there be any questions regarding this column, or have any suggestions for additional columns, please contact the write or editor.

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ABOUT THE AUTHOR

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10 TIPS TO ENSURE ACCURATE THERMOCOUPLE MEASUREMENT

From choosing the right sensor for your particular process application to the periodic recalibration of that sensor, these tips can help you ensure temperature measurement accuracy and get the most out of your process.

By CONAX TECHNOLOGIES

Careful selection and installation of temperature sensors can ensure accurate sensor performance, which in turn improves product quality and production efficiency.

1: SELECT THE CORRECT SENSOR ASSEMBLY FOR THE APPLICATION

This may seem self-evident, but it is surprising how often process efficiency is hampered by using the wrong thermocouple type. Factors such as time at temperature, degree of accuracy, thermal cycling rate, and environment may affect the selection of the best thermocouple type to produce accurate, reliable, long-term performance.

For most applications with operating temperatures of 1,400°F (760°C) or less, any of the base metal calibrations (J, E, T, and K) will function, but all are not created equal.

Type J offers the widest range of environments, including vacuum, oxidizing, reducing, and inert atmospheres over the temperature range of 32°F to 1,400°F (0°C to760°C). Above 1,000°F (538°C), however, the iron leg is susceptible to rapid oxidation, and below 32°F, the iron experiences rusting and embrittlement.

Type T is preferred for lower temperatures, including subzero (-330°F [minus-201°C]), and is resistant to corrosion in moist atmospheres. In air or oxidizing atmospheres, however, oxidation of the copper thermoelement occurs at temperatures above 700°F (370°C).

Type K is a good choice for oxidizing and inert atmospheres up to 2,300°F (1,260°C). With better oxidation resistance than Type E, J, and T, Type K thermocouples often are used at temperatures above 1,000°F, although they are subject to green rot corrosion at temperatures above 1,500°F (815°C) in low-oxygen environments. Type K thermocouples are not recommended for use in reducing atmospheres or atmospheres that alternate between oxidizing and reducing, in sulfurous atmospheres, or under vacuum conditions.

Type N is becoming more popular over time as a replacement for Type K. Type N has the same temperature range, is comparable in price, but does not suffer from the order-disorder temperature drift or green rot that can affect Type K thermocouples.

Type E exhibits the highest sensitivity of the base metal thermocouples and often is selected for this feature. These thermocouples function well in a broad temperature range from minus-330°F to 1,600°F (minus-201°C to 870°C) in oxidizing or inert atmospheres. They also successfully resist corrosion in high moisture environments. Type E thermocouples are not recommended for reducing or vacuum atmospheres.

The noble metal thermocouples (S, R, and B) and Type C are the best choice for very high temperatures or to increase long term accuracy and repeatability, though they are more expensive.

Selecting the thermal element is not the only consideration. Careful selection of insulation materials and sheath materials and being certain of how these materials may interact with each other is also critical. Consult with your sensor manufacturer, providing all the details about your application environment, to ensure you select the best assembly for your needs. (Figure 1)

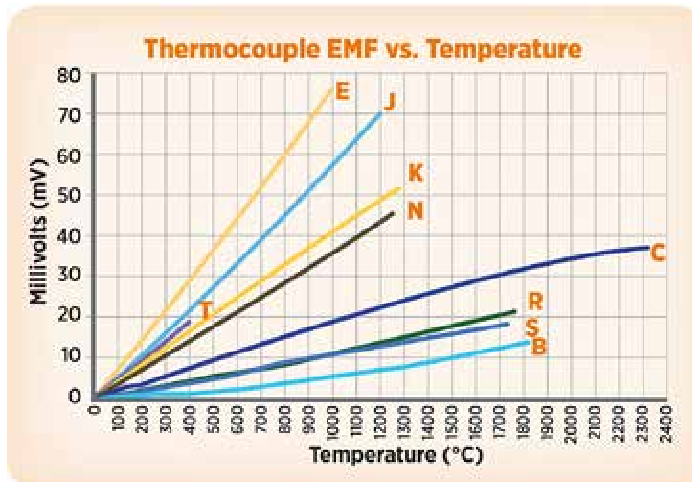


Figure 1: This schematic depicts EMF curves for various thermocouple types. Selecting the right sensor assembly for your application is the first step in ensuring accurate temperature measurement. (Source: Manual in the Use of Thermocouples in Temperature Measurement, 4th Edition, ASTM, 1993, Philadelphia)

2: ENSURE ADEQUATE IMMERSION LENGTH

One of the most common errors made in configuring a temperature sensor is not providing adequate immersion length. In a process pipe application, the sensor should extend into the process a minimum length equal to one-third the inside diameter of the pipe, with the optimum location at the center of the pipe diameter. When calculating this distance, be sure to add enough length to account for pipe and mounting flange thicknesses.

Another consideration is stem conduction. This refers to unwanted heat transfer up the metallic sheath of the thermocouple. To compensate for this, use a minimum immersion length of seven to 10 times the diameter of the probe. Keep in mind that use of a thermowell will magnify the stem conduction effect.

3: MAXIMIZE SENSOR RESPONSE TIME BY REDUCING MASS

Sensor material mass equates to sensor speed of response. Lower mass yields faster sensor response. Most oven and furnace applications do not require meaty-sized sensor elements as the environments generally are benign and sensor sheathing is not needed. Use of thermowells and pipewells offers physical strength but increase mass, slowing sensor reaction time. In addition, bare junction thermoelements respond faster than closed-sheath elements of equal size. This is particularly important to consider during thermal ramp and cool time, as excessive material mass will hamper the sensor's ability to keep track of the rapidly changing temperature.

4: LOWER-THAN-EXPECTED READOUTS MAY INDICATE POOR CONSTRUCTION

Another common problem in sensor performance is seeing a lower-than-expected output from the sensor. At low temperatures (less than 250°F [121°C]), this may indicate thermal shunting due to degradation of the cold-end seal. To check for this, measure the insulation resistance of the ungrounded thermocouple between the lead wires and the metallic sheath. The insulation resistance should be greater than 1 x 109 Ω at 500 VDC. Thermal shunting at lower temperatures also may be caused by moisture penetration of the cold-end seal.

Poor termination practices are another source of low readings. Stripping the lead wire too far or improperly applying insulation can permit moisture and contaminants to shunt the thermoelements, creating low insulation resistance. This can be corrected easily by cleaning the terminal blocks and ensuring the insulation material covers all exposed wires except the portion immediately under the terminal screw heads. (Figure 2)

5: USE THE PROPER LEAD WIRE

Extension-grade wire offers a more restricted temperature range than thermocouple-grade wire. The extension wire generally follows the EMF/temperature curve as the thermocouple wire to a certain temperature, then veers significantly. If you use extension-grade wire beyond its limitations, you may introduce a significantly large error into your readings.

For reliable readings, the thermocouple wire in the terminal head must be connected to the same thermocouple type wire all the way to the instrumentation that performs the cold junction compensation (readout, PLC, transmitter, etc.). Simply twisting signal wires together in the terminal head should be avoided, and use of a proper screw-type terminal block will provide long-term interconnection and avoid signal degradation over time due to poor connection and corrosion issues. For Types C, R, S, and B, running thermocouple-grade wires would be prohibitively expensive, so proprietary alloy wires have been developed for use with these materials.

A common cost-saving scenario is to use copper wire rather than extension wire, but copper does not follow the EMF/temperature curve of thermocouples at all and, therefore, introduces a significant degree of error. The exception to this is Type B thermocouples, which may use copper/copper wire up to 212°F (100°C). (Figure 3)

6: PROTECT AGAINST RADIO FREQUENCY INTERFERENCE

Thermocouple conductors with extension wire are sensitive to external electrical "noise" produced by handheld radios, circuit breakers and electrical relays, welding machines, variable speed motors, fluorescent lights, and other magnetic field generators. If running lead wires near power lines or other noisy signals, the lead wires should cross perpendicular and not run parallel to these lines. Numerous methods eliminate the detrimental effects of noise interference. One of the simplest is to use an ungrounded, rather than grounded, thermocouple in conjunction with twisted shielded lead wire. If the lead wire has a conductive over-braid or is run inside of conduit, the braid or conduit should be grounded on one end. Grounding at both ends will cause a ground loop and further compromise the signal.

Another is to properly secure all enclosure covers and run the cable through a metal conduit. Finally, a 4 to 20 mA signal conditioner can be located at — or as close as possible to — the thermal element. The milliamp signal is much less susceptible to interference than the extremely low voltage from the sensor.

Figure 2: Decreasing sensor sheath mass increases response time.

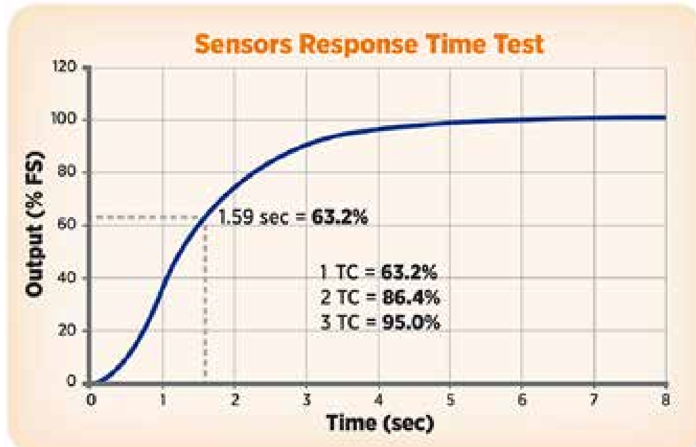


Figure 3: A typical speed of response curve demonstrates how quickly a particular sensor responds to changes in temperature.

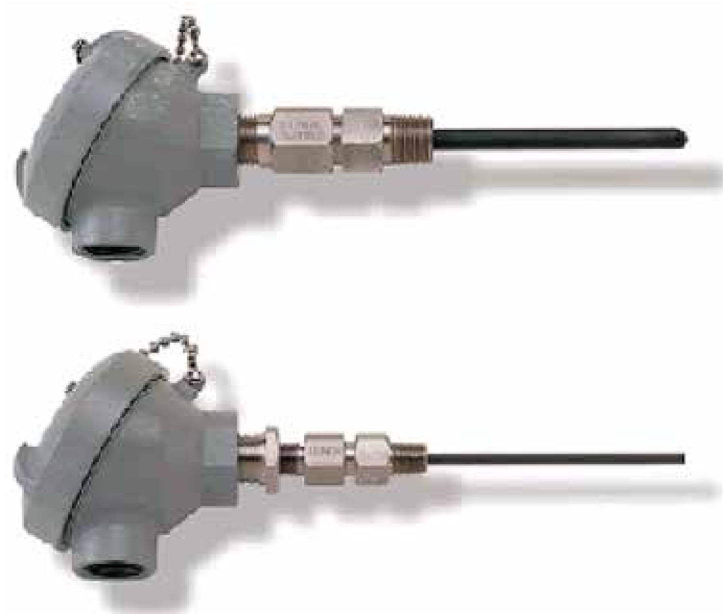


Figure 4: Selecting the right temperature sensor and knowing what to do with it can help increase product quality and production efficiency.

7: PROPERLY INSTALL SURFACE MOUNT SENSORS TO IMPROVE ACCURACY

Surface mounting is an easy and inexpensive method to monitor temperature of a process without penetrating the pressure boundary, keeping in mind that the surface temperature on uninsulated

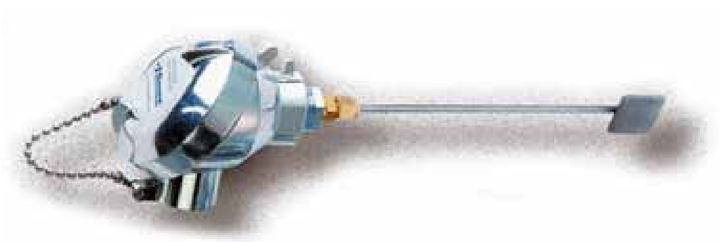


Figure 5: Weld pads maximize surface contact between the sensor and the surface to improve accuracy in surface mounting.

Figure 6: Temperature measurement accuracy is a function of all the elements in the system, not just the sensor. Transmitters and readouts also have an effect on total system accuracy.

pipe is affected by radiation and external cooling effects. To get a more accurate measurement, thermally insulate the area around the sensor, minimize sensor mass to reduce heat loss through the sensor, or maximize surface contact between the sensor and the surface to be mounted. This can be achieved with the use of weld pads or by clamping a length of the sensor sheath in continuous contact with the surface to which it will be mounted.

8: RECALIBRATE PERIODICALLY TO ZERO OUT THERMOCOUPLE DRIFT

Thermocouples used in process environments at elevated temperatures can change calibration due to contamination of the wires, loss of wire alloying constituents, or as a result of interactions between the components of the assembly (thermoelements, insulator, and sheath material). The degree of drift depends on the process environment and the purity of the materials used to construct the thermocouple. It is not uncommon for the thermocouples to be stable for long periods at 1,000°F in benign conditions. To minimize system inaccuracy, periodically recalibrate the sensor. (Figure 4)

9: NOTE THAT MEASUREMENT ACCURACY IS A FUNCTION OF THE ENTIRE SYSTEM

Often, attempts to achieve a desired measurement accuracy focus predominantly on the temperature sensor itself and do not take into consideration all the elements of the temperature measurement system. These elements may account for a significant portion of the total system accuracy. For example, extension wire tolerances can be as much as two times the limits of error of the actual thermocouple. Reference junctions, whether ice baths or electrical reference junction compensation, can introduce errors of as much as 0.09°F to 1.8°F (0.05°C to 1°C). Readouts of 4 to 20 mA transmitter components are another source of system error. Two-wire, 4 to 20 mA transmitters, for example, may introduce a basic error of 0.9°F (0.5°C). One technique to compensate for this error is to perform a calibration on the sensor/transmitter system. This allows the actual sensor offset to be programmed into the signal conditioner. (Figure 5)

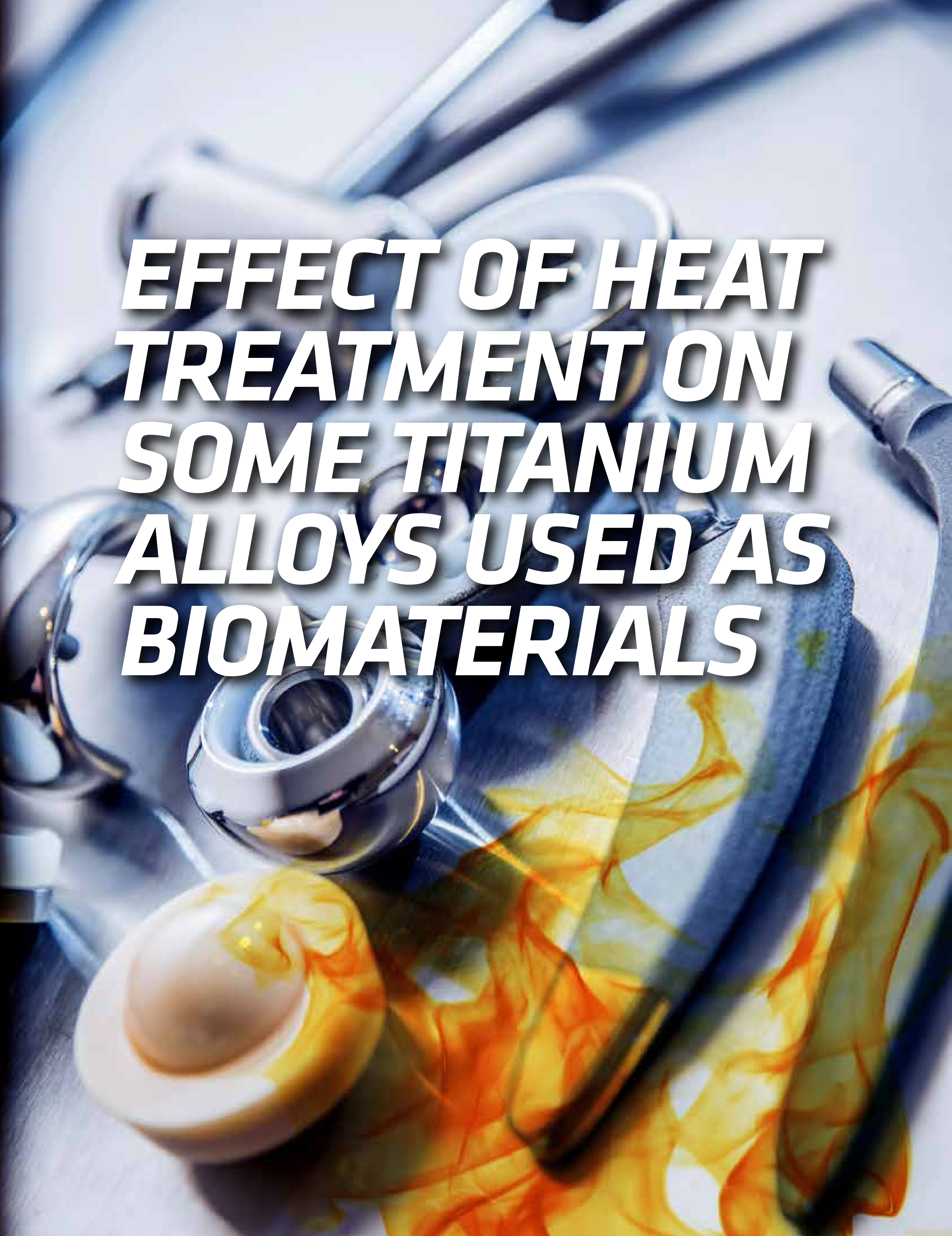
10: CONSIDER CALIBRATION UNCERTAINTY WHEN EVALUATING ACCURACY

Often, sensors are purchased with calibration data to define the actual offset within the acceptable limits of error. It is important to understand this calibration data reflects an inherent uncertainty. Calibration uncertainty should be at least four to 10 times less than the sensor accuracy you desire. Laboratory-performed calibrations approach uncertainties of ±1.8°F at temperatures of 1,832°F (1,000°C). Typically, this information is supplied on the calibration data certificate supplied with the equipment. After thermocouples have been in use for some time and recalibration is needed, the unit can be calibrated in place or returned for calibration in laboratory conditions. While calibration in laboratory conditions theoretically will provide much less uncertainty, calibration in situ can be useful because it tests the thermocouple in the same conditions and installation configuration in which it is used. In critical temperature measurement applications, knowing the uncertainty of the sensor provides a greater degree of confidence in your own measurements. (Figure 6)

ABOUT THE COMPANY

Conax is a leading designer and manufacturer of temperature sensors, compression seal fittings, and cable and harness assemblies for a broad range of industries and applications. More info: ConaxTechnologies.com.

EFFECT OF HEAT TREATMENT ON SOME TITANIUM ALLOYS USED AS BIOMATERIALS



The influence of heat treatment on the microstructure characteristics and mechanical properties of Ti-Mo-Zr-Ta alloys are investigated, in which thermal treatments are mainly used with a focus on superficial hardening to ensure proper contact wear behavior, thus improving fatigue and corrosion resistance.

By MADALINA SIMONA BALTATU, CRISTIANA CHIRIAC-MORUZZI, PETRICA VIZUREANU, LÁSZLÓ TÓTH, and JÁNOS NOVÁK

Titanium-based alloys are constantly improved to obtain properties suitable for their use. Improving titanium alloys is very important for performing alloys without side effects. In this article, effects of structure, microhardness, and indentation tests of eight titanium alloys were investigated after aging. The heat treatment consisted of a high-temperature quenching accomplished in three steps (650°C for 25 minutes, 850°C for 20 minutes, and 950°C for 20 minutes). The cooling process was accomplished using N_2 gas, introduced in the chamber at a 9-bar pressure for 37 minutes. Then, followed by heating to a constant temperature tempering (550°C) at 1.5 bar pressure and kept for 2 hours and 10 minutes at 2 bar pressure. Optical microscopy images were obtained of Ti-Mo-Zr-Ta alloys with grain-specific aspects of titanium alloys; acicular and coarse structures are specific to β alloys. Microhardness results showed significantly influenced by the heat treatment, increased by approximately 5% for Ti15Mo7Zr15Ta1Si and Ti20Mo7Zr15Ta0.5Si, while for Ti15Mo7Zr15Ta0.5Si and Ti20Mo7Zr15Ta an approximately 9% decrease has been noted. The modulus of elasticity results obtained by the indentation method for the experimental alloys were between 36.25–66.24 GPa. The heat treatments applied to the alloys had a pronounced effect, improving both the structure of the alloys and the results of the indentation test.

1. INTRODUCTION

Biomaterials play an essential role in medicine today by restoring function and facilitating the healing of people after various accidents or diseases. These materials used for medical applications ensure appropriate treatment from a medical point of view and improve the quality of life through performance devices [1].

Due to their excellent properties, titanium and its alloys are still the most used materials in medical applications. They are mainly used in hard tissue replacement, and the fields of use are orthopedics, dentistry, and cardiovascular medicine [2,3,4].

In recent years, the use of titanium and titanium-based alloys with applications in biology and medicine has made tremendous progress promoting innovative technologies and new materials [5]. Titanium-based alloys are distributed in three categories: α, $\alpha + \beta$ and β alloys [6]. Reduced modulus of elasticity, greater corrosion resistance, and improved biocompatibility are all advantages of adding benign elements like Mo, Si, Zr, and Ta [7]. This is due to their superior mechanical, physical, and biological properties. New titanium alloys with harmless elements, long-term performance, and no rejection by the human body are being promoted in the present era. Other benefits include high specific strength, low density, and almost non-magnetic properties [8].

Titanium makes up roughly 0.5 percent of the Earth's crust. Titanium is a lightweight, high-strength, low-corrosion structural metal used in biocompatible materials as an alloy [9]. Pure titanium is ductile, electrically and thermally inert, and paramagnetic. Due to the production of a passive oxide surface coating, titanium has good corrosion resistance in a variety of conditions. It is biocompatible because of its great strength, low density, and exceptional corrosion resistance [10].

Element	Benefits	Toxicity Level
Ti– Titanium	- is not rejected by the human body - maintains good physical connections with the bone	Non-toxic
Mo– Molybdenum	- is important for enzymes in the cellular metabolism - low concentrations in the vertebrae	Low toxicity (compared to Co, Cr and Ni)
Zr– Zirconium	- no biological role - strong resistance to corrosion - highest biocompatibility of all metals	Low toxicity
Ta– Tantalum	- no biological role - strong resistance to corrosion - used for most biocompatible implants	Non-toxic
Si– Silicon	- found in natural bone - is important for growth and bone calcification	Low toxicity

Table 1: Benefits of the elements in the human body from Ti-Mo-Zr-Ta-Si system.

Titanium castings exhibit common casting defects such as shrinkage, gas porosity, cold shuts, and misruns. The surface defects, such as surface-connected porosity or cold shuts, can be improved with heat treatments [11].

Thermal and thermochemical treatments play an important role in achieving quality characteristics to obtain a certain complex of technological and/or use properties. Over time, various improvements of biocompatible materials have been opted for in order to obtain suitable properties for the human body [12,13,14].

Numerous types of research have confirmed that thermal treatments are beneficial for improving the properties of titanium alloys, Mo element significantly affects the α microtexture of α + β titanium alloys; strong prior α colony microtexture exists before thermal deformation; the smaller α colony will hinder the formation of a large-size microtexture [15,16].

The term "biocompatibility" refers to the interaction of a medical device's tissues and physiological systems with the tissues and physiological systems of the patient. Any device's overall safety evaluation includes a biocompatibility examination [17,18,19]. When choosing alloys for medical implants, in addition to the mechanical properties, biocompatibility is also an important aspect to consider, specifically the biocompatibility of the elements that make up the alloy. The alloys from the Ti-Mo-Zr-Ta system contain biocompatible elements, the cytotoxicity of the elements being demonstrated by other researchers [2,5,13]; the overall benefits of each element are highlighted in Table 1, both in the human body and in the sampled alloys [20].

In the literature research, many articles were found on titanium alloys being used in orthopedic and aerospace applications in which the microstructure, hardness, and biocompatibility properties in the cast form of the alloys were studied [2,3]. However, a proper study investigating the heat-treatment process, microstructure, and mechanical properties relationship for this Ti-Mo-Zr-Ta system has not been found [15,16]. For this reason, tests were performed on the thermally treated Ti-Mo-Zr-Ta system, and the microstructure and some mechanical properties that were modified due to the thermal treatment were examined.

Eight alloys based on Ti-Mo-Zr-Ta, six with Si, were thermally treated and investigated to improve the properties of titanium alloys. This study highlights the microstructural and mechanical characteristics of experimental titanium alloys that have been heat treated. After the heat treatment, the samples were analyzed using optical microscopy, microhardness testing, and an indentation test.

Alloy	Average Chemical Composition (wt.%)				
	Ti	Mo	Zr	Ta	Si
Ti15Mo7Zr15Ta	73.85 ± 0.3	9.00 ± 0.1	7.15 ± 0.2	10.00 ± 0.2	–
Ti15Mo7Zr15Ta0.5Si	66.50 ± 0.1	11.00 ± 0.2	7.00 ± 0.3	15.00 ± 0.1	0.50 ± 0.3
Ti15Mo7Zr15Ta0.75Si	66.20 ± 0.1	9.00 ± 0.3	7.00 ± 0.1	17.00 ± 0.3	0.80 ± 0.3
Ti15Mo7Zr15Ta1Si	73.00 ± 0.1	10.00 ± 0.2	8.00 ± 0.1	8.00 ± 0.2	1.00 ± 0.3
Ti20Mo7Zr15Ta	58.35 ± 0.1	19.00 ± 0.2	8.15 ± 0.1	14.50 ± 0.3	–
Ti20Mo7Zr15Ta0.5Si	59.25 ± 0.2	18.50 ± 0.3	7.00 ± 0.1	14.80 ± 0.1	0.45 ± 0.1
Ti20Mo7Zr15Ta0.75Si	57.86 ± 0.1	19.50 ± 0.1	6.85 ± 0.1	15.04 ± 0.3	0.75 ± 0.1
Ti20Mo7Zr15Ta1Si	57.23 ± 0.1	19.83 ± 0.3	6.93 ± 0.1	14.98 ± 0.2	1.03 ± 0.1

Table 2: Chemical composition for Ti-Mo-Zr-Ta alloys obtained.

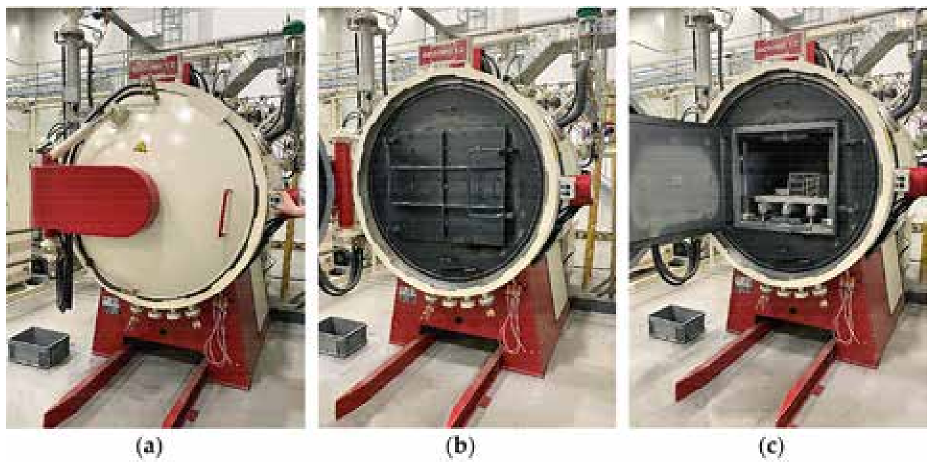


Figure 1: Horizontal high-temperature vacuum chamber furnace: (a) furnace front-view, (b) furnace set-up, (c) furnace chamber and sample holder.

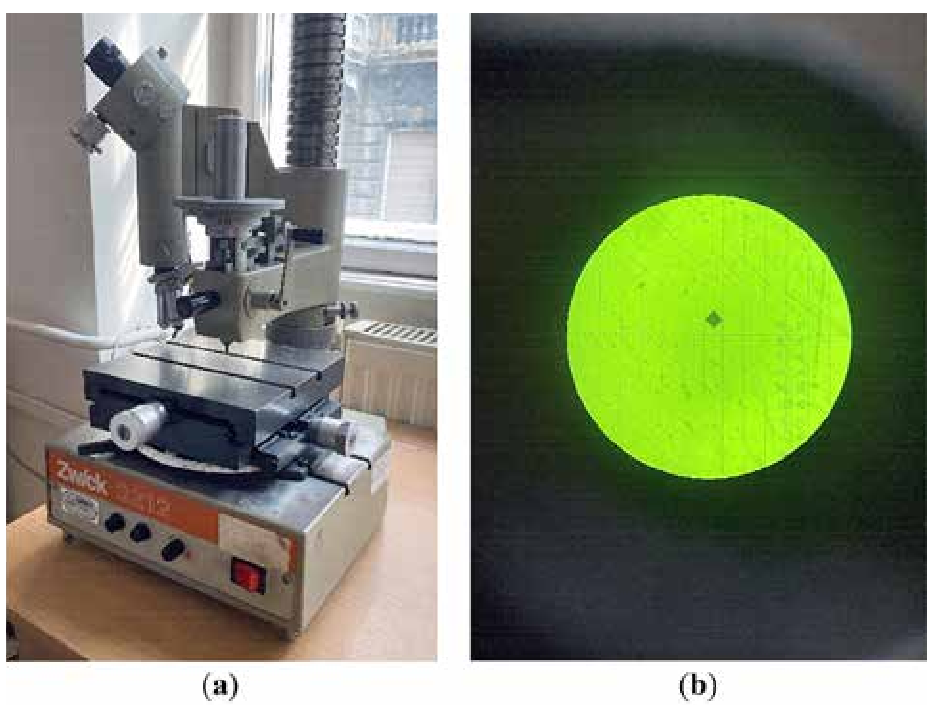


Figure 2: Hardness tester (a) front view (b) indented trace measurement.

2 MATERIALS AND METHODS

2.1 Material Preparation

Materials analyzed are from the Ti-Mo-Zr-Ta system, eight alloys developed in a vacuum arc remelting installation [20,21,22]; six contain Si. In this article, for obtaining the biocompatible Ti-Mo-Ta-Zr-Si alloys, high-purity chemical elements were used, raw materials such as Ti (99%), Mo (99%), Zr (99%), Ta (99%), and Si (99%) from Sigma-Aldrich. Table 2 shows the experimental alloys investigated in this article.

2.2 Heat Treatment

Some characteristics can be achieved with the help of thermal treatments known under the generic name of annealing. They are applied to semi-finished products obtained by casting, hot or cold plastic defor-

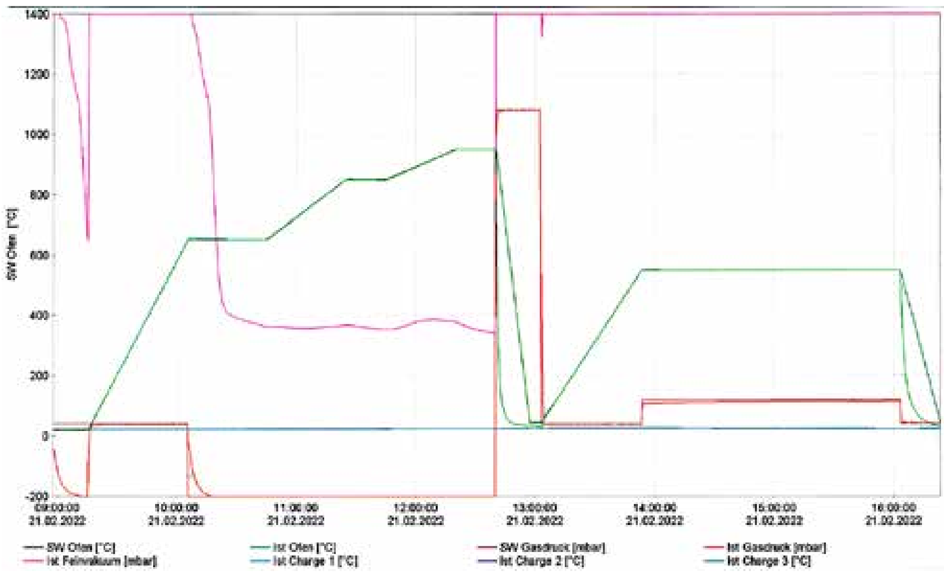


Figure 3: Heating diagram of the heat-treatment process (green – programmed and measured temperature, purple – vacuum, red – nitrogen pressure).

Charge Diagram					
No.	**Segment Name**	**Time**	**No.**	**Segment Name**	**Time**
1	Vacuum	0:16	7	Dwell on heating at 950 C	0:20
2	Heating on 650 C	0:50	8	Cooling to 45 C	0:17
3	Dwell on heating at 650 C	0:25	9	Dwell on cooling at 45 C	0:20
4	Heating on 850 C	0:40	10	Heating on 550 C	0:50
5	Dwell on heating at 850 C	0:20	11	Dwell on heating at 550 C	2:10
6	Heating on 950 C	0:35	12	Cooling to room temperature	0:50

Table 3: Data input for the furnace charge diagram.

mation (free forging or in a mold, lamination, extruding, drawing), or welded (metal constructions, machine parts, complex tools). The heat treatment for the Ti-Mo-Zr-Ta alloys has been realized using the IU 72/1F 2RV 60 × 60 × 40 10 bar CP type I vacuum furnace (IVA Schmetz GmbH, Menden, Germany) [23]. The hot zone, heat exchanger, high-capacity radial fan with an electric motor, and gas conduits are all included within the casing. The furnace's loading and unloading are done from the front using a rail-guided loading car to precisely place the cargo into the hot zone, as presented in Figure 1.

After loading, the swiveling furnace door will be hydraulically fastened to the furnace casing to prevent overpressure. After that, the treatment cycle runs completely on its own [14]. The furnace has an operating system that allows the user to program each treatment step, considering factors such as temperature, cooling rate, gas pressure, ventilation, etc.

2.3 Microstructural Characterization Methods

Optical Microscopy analyses on Ti-Mo-Zr-Ta alloys were performed with a DSX1000 digital microscope (Olympus Corporation, Tokyo, Japan). For microscopic examination, obtaining a suitable sample surface involves a series of operations: embedding with CITOPRESS–1 (Struers ApS, Ballerup, Denmark), sanding, polishing with Forcipol 2V (Metkon, Bucharest, Romania), and attacking with chemical re-agents. To work with this microscope, the prepared sample is placed on the table support plate, with the study surface facing up, ensuring the parallelism between the sample and the microscope table. The metallographic attack with chemical re-agents highlights the crystalline structure by dissolving or selectively staining the various constituents present.

For polishing using the Forcipol 2V sanding/polishing machine, a time of 4 minutes was allocated on each metallographic paper (300, 500, 1,000, 1,500, 2,000, 2,500), with an application force: 20 N, using an emulsion with particles of diamond and a rotation speed of the platen of 200 rpm and the vector head of 60 rpm. The chemical etching fluid has the following composition: 10 mL HF, 5 mL HNO_3 and 85 mL H_2O [24]. Due to the fact the samples have undergone thermal treatment, the submersion time in the solution is approximately 5 seconds instead of 30 seconds (for non-treated titanium alloys).

2.4 Microhardness Test

The Vickers hardness tester is a Zwick 3212 microhardness (ZwickRoell GmbH, Ulm, Germany), presented in Figure 2. For the investigation of the alloys, the loading force will be from 0.2 to 1 kgf (small charge loads), which is why we are talking about the Vickers microhardness. The Vickers method consists in pressing a diamond penetrator on the surface of the test material, having the shape of a pyramid with a square base, with an angle between two opposite sides of 136°, with a reduced speed and a certain predetermined force. After indenting the sample, the device brings the objective of the measuring microscope over the remaining trace. The measurement of the trace diagonals (d1 and d2) is done with the help of the measuring eyepiece, with the measuring accuracy at 0.5 µm. The diagonal of the trace is established as the arithmetic mean of the two measured diagonals. The Vickers hardness, symbolized by HV, is expressed by the ratio between the pressing force and the area of the lateral surface of the mark left by the penetrator on the part.

2.5 Indentation Test

Indentation is a common method for testing the mechanical characteristics of solid-state materials, such as their hardness and elastic stiffness, by observing how their surface interacts with the penetration of a probe with a defined geometry and applied stress.

To study the behavior of Ti-Mo-Zr-Ta alloys through the indentation test, the CETR UMT-2 tribometer (Center for Tribology, Campell, California) was used. Samples with dimensions of 17 mm × 5 mm × 5 mm were used for the test. The samples were properly prepared by cutting, grinding, and polishing. The investigated samples were clamped on a flat surface of the testing apparatus with the help of screws and clamps. The tests were carried out in dry conditions. A Rockwell-type diamond indenter with a 120° indenter tip angle and 200 µm radius spherical tip was used, to which a force of 5 N was applied.

3 RESULTS AND DISCUSSIONS

3.1 Heat Treatment Process

The heat treatment has been made following the diagram from Figure 3, which has been generated by the furnace operating system, based on the input values from Table 3.

The heat treatment for the experiment has been conducted as follows:

» After locking the door to the furnace, a vacuum was achieved and maintained for 16 minutes in order to make sure no residues or other chemicals were on the materials.

» A high-temperature quenching accomplished in three steps (650 °C — kept for 25 minutes, 850°C — kept for 20 minutes, and 950°C — kept for 20 minutes) and conducted in a vacuum in order to equalize the temperature between the middle and the core of the samples.

» The cooling process was achieved using N_2 gas, which was introduced in the chamber at a 9-bar pressure for 37 minutes.

» This was followed by heating to a constant temperature tempering (550 °C) at 1.5 bar pressure and kept for 2 hours and 10 minutes at 2 bar pressure, as presented in Figure 4.

» After that, it was cooled at room temperature at a 1.5 bar pressure.

The purpose of such heat treatment can decrease the level of internal tension induced in the metal mass of the products (stress relief annealing); recrystallization of the cross grain after cold plastic deformation or of the structure resulting from casting; finishing of overheated structures; reducing the hardness of the metallic material in order to improve workability.

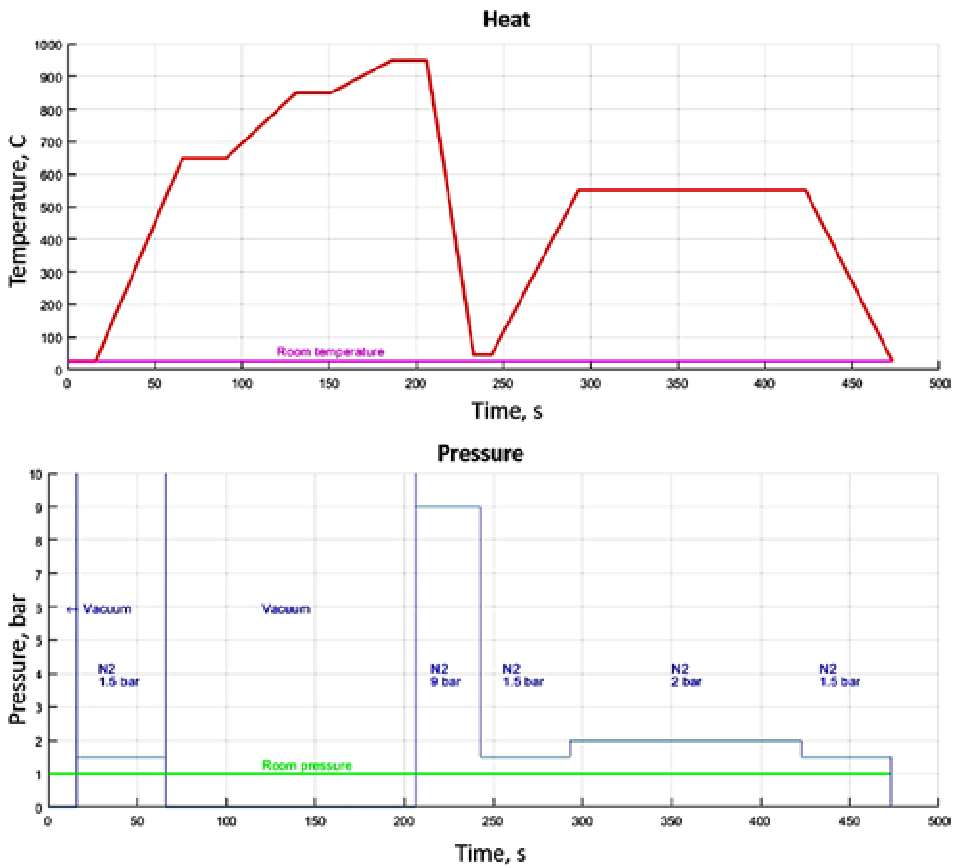


Figure 4: Extended heat and pressure diagrams generated in MATLAB.

3.2 Optical Microscopy Analysis

Figure 5 and Figure 6 show the structure of Ti-Mo-Zr-Ta alloys with grain-specific aspects of titanium alloys. Optical microscopy images for Ti15Mo7Zr5Ta, Ti15Mo7Zr10Ta, and Ti15Mo7Zr15Ta highlight the lamellar dendrites inside the β-type grains. Ti20Mo7Zr5Ta, Ti20Mo7Zr10Ta, and Ti20Mo7Zr15Ta alloys show a dendritic structure with irregular grain boundaries. These acicular and coarse structures are specific to β alloys [24,25].

At 882°C, titanium undergoes an allotropic transformation, which allows the metal to transit from an α-phase hexagonal close-packed structure to a β-phase body-centered cubic structure [26]. Due to molybdenum and tantalum stabilizers, studies have shown β-phase alloys have the advantage of increased mechanical strength and an elastic modulus similar to human bone, both of which are important aspects of the long-term use of biomaterials in the medical field [27].

Thermal treatments are a sequence of stages that consist of the heating, maintenance, and cooling of some metal alloys to obtain certain structures that ensure the desired set of physio-chemical characteristics without changing the state of aggregation of the material [28,29,30].

Compared to other conventional biomaterials, Ti-Mo alloys containing various biocompatible components such as zirconium and tantalum have superior mechanical qualities such as high tensile strength and a significantly lower modulus of elasticity close to that of human bone. When the α alloying elements are introduced into the titanium, the temperature at which the phase transition occurs changes [31,32]. The temperature range in which an α phase rises when pure titanium is alloyed with β stabilizing elements (Mo, Ta, Si), whereas the alloy with elements expands the β phase domain. Other elements, such as zirconium, have a neutral effect on the temperature domains where the two phases coexist [33,34,35].

The images obtained by optical microscopy highlight a biphasic structure consisting of a high proportion of β solid solution, in which intergranular lamellar structures specific to α″ orthorhombic martensite appear (Figure 5 and Figure 6).

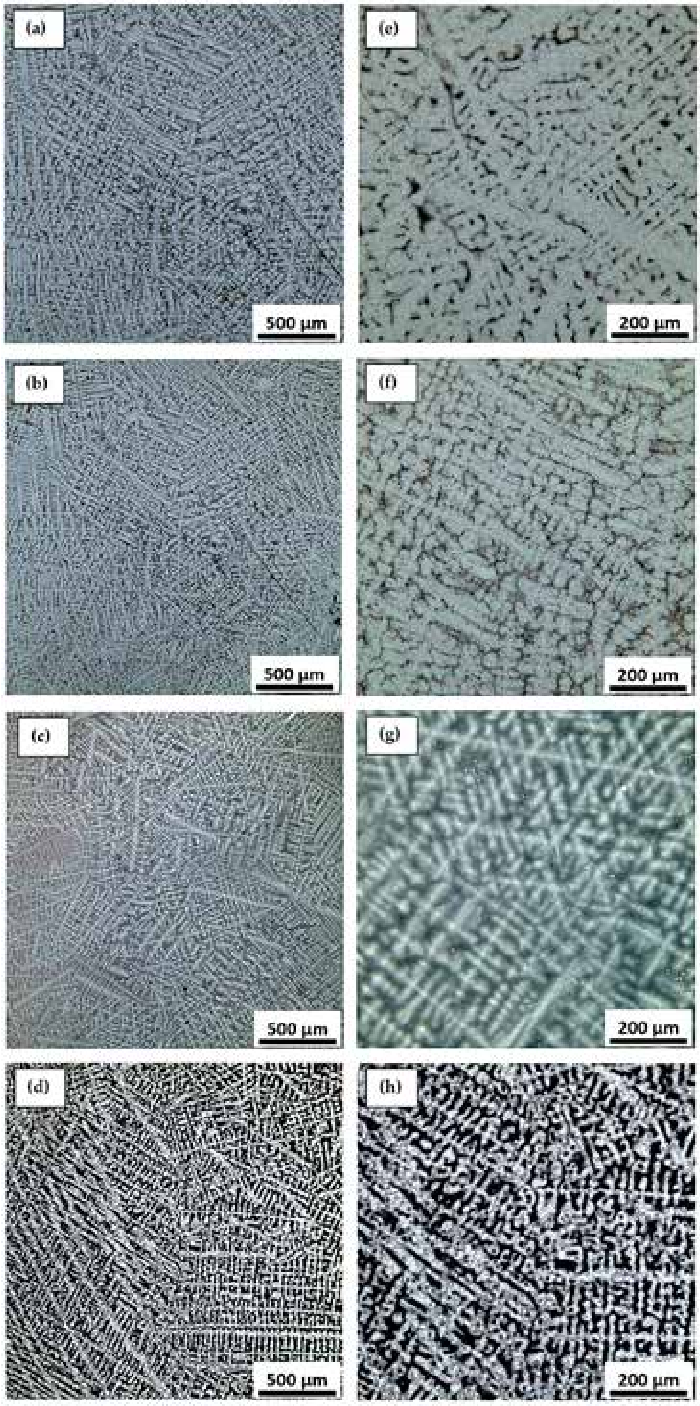


Figure 5: Microstructure analysis of Ti15Mo7Zr15Ta alloys with different percentage of Si added at a magnifying power of 70x: (a) Ti15Mo7Zr15Ta, (b) Ti15Mo7Zr15Ta0.5Si, (c) Ti15Mo7Zr15Ta0.75Si, (d) Ti15Mo7Zr15Ta1Si and of 280x: (e) Ti15Mo7Zr15Ta, (f) Ti15Mo7Zr15Ta0.5Si, (g) Ti15Mo7Zr15Ta0.75Si, (h) Ti15Mo7Zr15Ta1Si.

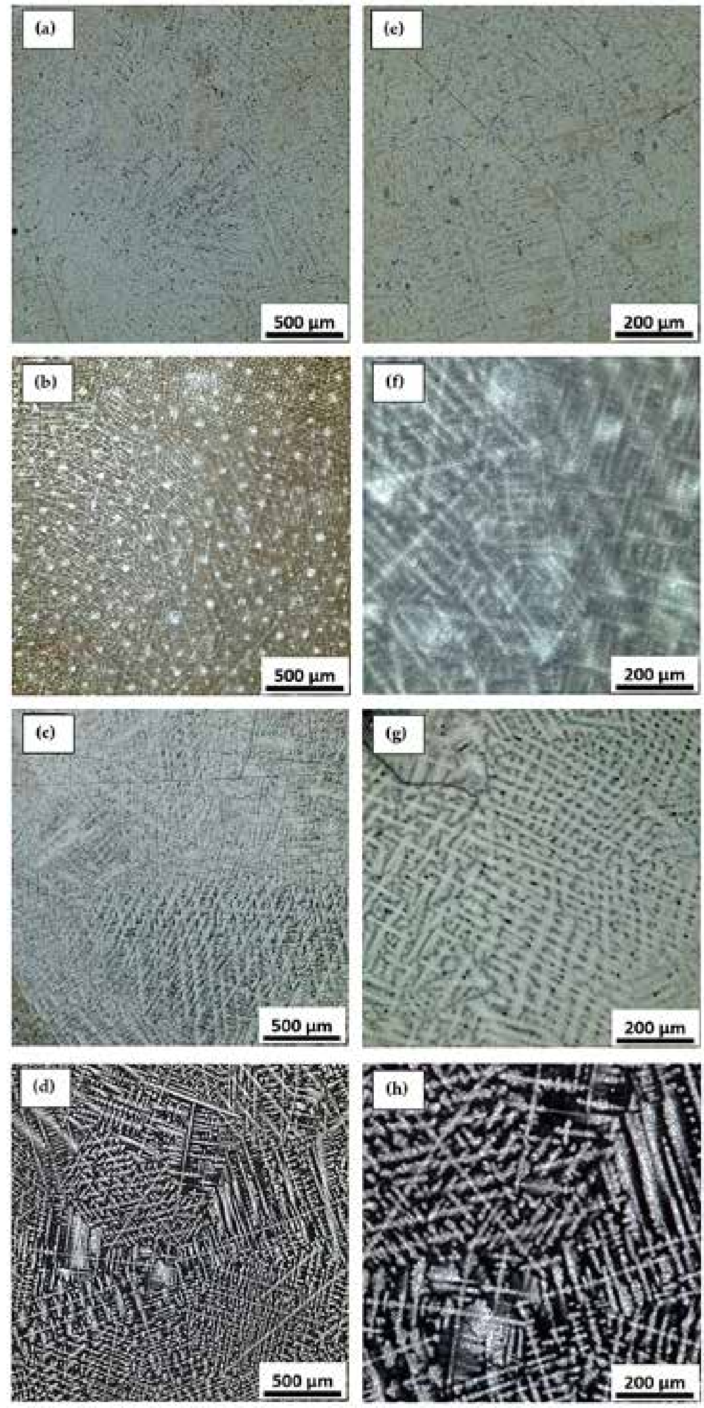


Figure 6: Microstructure analysis of Ti20Mo7Zr15Ta alloys with different percentages of Si added at a magnifying power of 70x: (a) Ti20Mo7Zr15Ta, (b) Ti20Mo7Zr15Ta0.5Si, (c) Ti20Mo7Zr15Ta0.75Si, (d) Ti20Mo7Zr15Ta1Si and of 280x: (e) Ti20Mo7Zr15Ta, (f) Ti20Mo7Zr15Ta0.5Si, (g) Ti20Mo7Zr15Ta0.75Si, (h) Ti20Mo7Zr15Ta1Si.

The structure of the Ti-Mo-Zr-Ta alloys is similar to the microstructure of the commercial Ti-6Al-4V alloys. Typically, the Ti-6Al-4V microstructure contains α-type very fine acicular needles, α + β lamellar structures, and β-type grains [36,37]. In general, the microstructure of titanium alloys consists of a lamellar structure of α and β. However, the α morphology could change with heat treatment or depending on the amount of β elements added.

The lamellar microstructure, produced on cooling from the phase field, and the equiaxial microstructure, resulting from the recrystallization process, are the two extreme situations of phase arrangements, and they both affect the microstructure of titanium alloys. Much investigation has gone into how phase size and arrangement affect mechanical properties. With the increase of the volume fraction of the β phase, the strength of the alloy will increase, and the properties will be close to the human body [38].

The alloys presented a structure composed of dendrites that are typical of the phase structures α″ and grains characteristic of β-type alloys. α″ orthorhombic martensite frequently occurs in titanium-based alloys in which β-stabilizers from the transition metal category are found, including Mo, Nb, and Si. For our alloys, the presence of the

α″ phase is due to the decomposition of the β phase during cooling.

3.3 Microhardness Results

For the Vickers microhardness method, at least 10 tests are carried out on the material under test. For each trace, the average value of the diagonal is calculated based on the sizes of the two measured diagonals. The difference between the dimensions of the diagonals is allowed to be within a maximum margin of error of 2%. The samples were evaluated before and after the thermal treatment. The results are presented in Table 4 and Figure 7.

The results showed the microhardness is significantly influenced by the heat treatment, with the exception of the Ti15Mo7Zr15Ta0.5Si and Ti20Mo7Zr15Ta alloys.

It can be observed that, with the increase of the percentage of silicon and molybdenum by 20%, the hardness value after heat treatment is significantly increased, visible in the Ti20Mo7Zr15Ta0.75Si and Ti20Mo7Zr15Ta1Si alloys.

Microhardness studies on the surface show the depth of work hardening of the machined surface. The heating and cooling phenomena are the main cause of the microhardness growth on the surface and subsurface. The environment and cutting conditions affect the heating and cooling phenomenon. Due to grain refinement, the microhardness of machined surfaces rises. Since titanium alloys and nickel-based superalloys have a greater range of applications in the aerospace and biomedical areas, they have received a great deal of attention from researchers over the past 10 years. Many of these articles have focused on the surface hardness of machined surfaces [11,16,17].

3.4 Indentation Results

The indentation test is a method to characterize the behavior of a

	Microhardness (HV)	
	Before Treatment	After Treatment
Ti15Mo7Zr15Ta	237.27±5.3	375.75±2.5
Ti15Mo7Zr15Ta0.5Si	343.98±2.2	310.44±3.6
Ti15Mo7Zr15Ta0.75Si	370.07±1.5	373.63±2.3
Ti15Mo7Zr15Ta1Si	364.24±3.3	383.00±3.1
Ti20Mo7Zr15Ta	305.34±4.1	278.00±5.2
Ti20Mo7Zr15Ta0.5Si	341.10±2.8	360.38±2.4
Ti20Mo7Zr15Ta0.75Si	318.20±9.2	483.50±6.7
Ti20Mo7Zr15Ta1Si	274.64±1.8	391.13±0.9

Table 4: Measured microhardness before and after the thermal treatment.

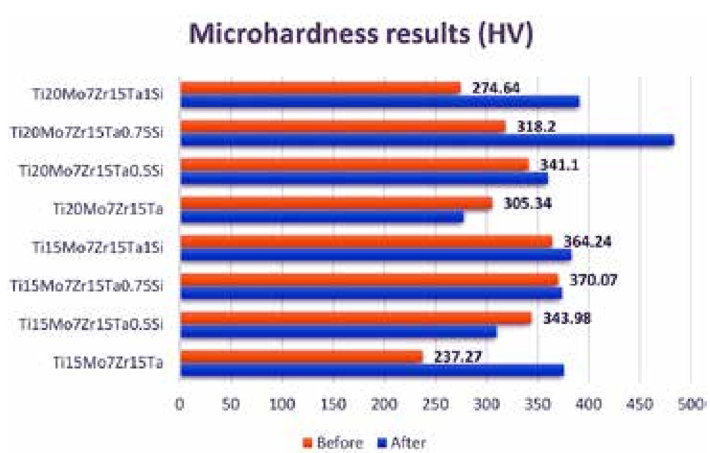


Figure 7: Hardness comparison (before and after the thermal treatment).

Alloy	Loading Deformation [N]	Release Deformation [m]	Young Modulus [GPa]	Stiffness [N/m]	Specimen Poisson Ration
Ti15Mo7Zr15Ta	13.52±0.2	10.39±0.1	41.89±0.3	2.03±0.1	0.23
Ti15Mo7Zr15Ta0.5Si	13.54±0.1	6.07±0.3	47.34±0.1	3.23±0.2	0.23
Ti15Mo7Zr15Ta0.75Si	13.54±0.2	6.73±0.4	66.24±0.1	4.26±0.1	0.23
Ti15Mo7Zr15Ta1Si	13.52±0.4	7.57±0.2	60.25±0.4	4.95±0.1	0.23
Ti20Mo7Zr15Ta	13.52±0.2	6.62±0.2	50.43±0.3	4.25±0.3	0.23
Ti20Mo7Zr15Ta0.5Si	13.53±0.3	6.79±0.3	54.65±0.2	4.56±0.1	0.23
Ti20Mo7Zr15Ta0.75Si	13.52±0.1	5.89±0.4	54.25±0.3	4.65±0.2	0.23
Ti20Mo7Zr15Ta1Si	13.54±0.2	6.72±0.4	36.25±0.4	4.35±0.1	0.23

Table 5: Indentation results.

material under a complex load. The applied load and displacement are measured during the test, while the residual footprint can be measured after the test has been completed. The results of this test are commonly used for material testing to determine the deformation resistance of a material.

Three determinations were made for each alloy for a more precise determination. The results of the modulus of elasticity of the Ti-Mo-Zr-Ta alloys are highlighted in Table 5.

The modulus of elasticity obtained by the indentation method for the experimental alloys from the Ti-Mo-Zr-Ta system is between 36.25–66.24 GPa. The lowest value is presented by the Ti20Mo7Zr15Ta1Si alloy (38.57 GPa), and the highest value is presented by the Ti15Mo7Zr15Ta0.75Si alloy (66.24 GPa). The low values of the elastic modulus of the investigated alloys are due to the presence of β-stabilizing elements, such as Mo, Nb, and Si. According to the results in Table 5, as the Si content increases with a high content of 20% Mo, the modulus of elasticity decreases by about 30 GPa.

However, for medical applications aimed at replacing hard tissues, it is known that too much hardness leads to high wear, and too little modulus of elasticity prevents the uniform distribution of mechanical stresses, thus favoring bone resorption [2].

Great efforts are being made to produce implantable medical devices newly generated from Ti alloys that present a modulus of elasticity closer to that of bone and do not release ions with cytotoxic potential [3].

4 CONCLUSIONS

In this article, the influence of heat treatment on the microstructure characteristics and mechanical properties of Ti-Mo-Zr-Ta alloys has been investigated. Thermal treatments are mainly used, focusing on superficial hardening, thus ensuring proper contact wear behavior; improving fatigue and corrosion resistance. The main results are as follows:

Regarding the microstructural analyses, the variation of the α, α + β, and β type phases consists of differences in the chemical composition of the constituent elements. β-type structure formation is highlighted in Ti-Mo-Zr-Ta alloys, which contain a high percentage of stabilizing elements (Mo, Ta, Si). Zirconium in concentrations below 7% also contributes to the refinement of the microstructure, thus allowing the formation of a homogeneous and evenly distributed structure. Therefore, elements such as tantalum (5-15%), molybdenum (15-20%) and silicon in different concentrations (0.5, 0.75, and 1%), contribute to the formation of the β phase at titanium alloys.

Based on the microhardness testing, it was observed the hardness of some alloys has increased by approximately 5% for Ti15Mo7Zr15Ta1Si and Ti20Mo7Zr15Ta0.5Si, while for Ti15Mo7Zr15Ta0.5Si and Ti20Mo7Zr15Ta an approximately 9% decrease has been noted. At the same time, a slight increase of 0.9% has been observed for Ti15Mo7Zr15Ta0.75Si. An influence of the heat treatment is highlighted in Ti15Mo7Zr15Ta, Ti20Mo7Zr15Ta0.75Si, and Ti20Mo7Zr15Ta1Si; these changes come from the concentration of each beta stabilizer on the alloys.

The results of the indentation test on the Ti-Mo-Zr-Ta alloys highlighted a reduced modulus of elasticity compared to the classic alloys, identifying the Ti20Mo7Zr15Ta1Si alloy (38.57 GPa) with the lowest value close to the human bone (15–30 GPa).

In conclusion, the application of thermal treatments aims to achieve the proper properties of the metallic product in efficient economic and technical conditions. An improvement in hardness was seen in the alloys and a low modulus of elasticity, recommending them as alloys for orthopedic implants.

AUTHOR CONTRIBUTIONS

M.S.B.: conceptualization, management; C.C.-M.: writing — original draft preparation, investigation; P.V.: methodology, financing, data curation; L.T.: investigation, writing — review and editing; J.N.: validation, investigation. All authors have read and agreed to the published version of the manuscript.

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Not applicable.

DATA AVAILABILITY STATEMENT

All data provided in the present manuscript are available to whom it may concern.

CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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CARBURIZED STEEL MECHANICAL PROPERTIES
BENDING ULTIMATE AND IMPACT STRENGTH

Case depth, core hardness, and steel composition all play an important role in determining part performance.

Editor's note » This is part three of a three-part series on carburized steel mechanical properties.

By GREGORY FETT

In Part 2, it was determined that a test bar must have a radius or stress concentration in order to predict what will happen with a carburized gear loaded in bending. It was also determined a new test bar was needed that could more accurately represent a differential gear that was unable to pass a vehicle impact test. The test bar must have the capability to be easily tested under slow bend, bending impact, and bending fatigue conditions. The decision was to use an oversized Charpy bar with a simulated gear root radius rather than a V-Notch [1]. The oversized Charpy bar was called a U-Notch Bar and was 12.7 mm square by 63.5 mm in length with 50.80 mm between supports (Figure 1). The radius was 2.29 mm and the cross section at the bottom of the radius was 10.80 mm.

The cross section was designed to duplicate the core hardness on the subject differential gear, and it was approximately the same cross section as the bottom of the actual gear tooth where the fracture occurred. The U-Notch bar could also be readily run on a Charpy tester by making a new set of slightly oversized fixtures.

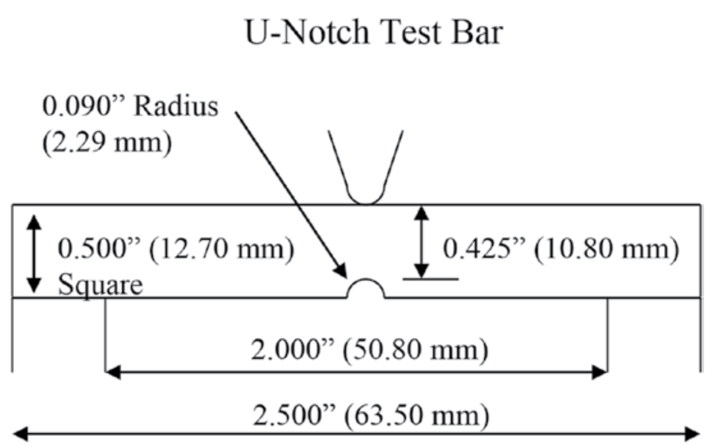

Figure 1

CARBURIZED STEEL TESTS

Figure 2 shows a series of carburized steels tested under slow bend using the U-Notch test bar [1]. Similar to the one-inch diameter shouldered test bar in Part 2, 8615, 8620, and 8625 low nickel steels were used as well as medium nickel 4320 and high nickel 9310. PS55, which is a medium nickel high molybdenum steel, was also evaluated. In addition, carbonitrided 8625 and 4320 with a light case depth were tested as well as 8615 with no temper and an elevated temperature temper. The results appear to be similar to the shouldered bar results.

Bending yield (JEL) and ultimate strength initially increase with increasing core hardness. It is typical for the standard depth carburized case to initially crack in the vicinity of or below the yield. This appears as a small blip on the load vs. deflection curve and is audible. The maximum bending yield and ultimate strength of the low nickel steels occurred at 33 HRC, and then the ultimate strength decreased and met the yield at 40 HRC. The medium nickel 4320 steel appears to follow the same trend except the yield is a little higher than with the low nickel steels. The 9310 steel continues to increase in bending strength with increasing core hardness and still maintains a separate yield and ultimate strength. The PS55 steel is similar to the 9310, except the strength level is lower. The light case carbonitrided 8625 and 4320 samples also continue to increase in bending strength beyond 40 HRC and maintain a separate yield and ultimate strength. The highest strength bars were the 4320 light case carbonitrided sample and the 8615 carburized sample tempered at 750°F.

The 8615 carburized sample with a standard 350°F temper had a core hardness of 31 HRC, and the 4320 carburized sample with a temper had a core hardness of 45 HRC. This is similar to the actual gears from the vehicle impact test. The 8615 had a higher bending strength than the 4320. Tempering 8615 carburized steel at 350°F provides only a small increase in bending strength over the untempered condition. Tempering 8615 carburized steel at 750°F provides a very large increase in bending strength.

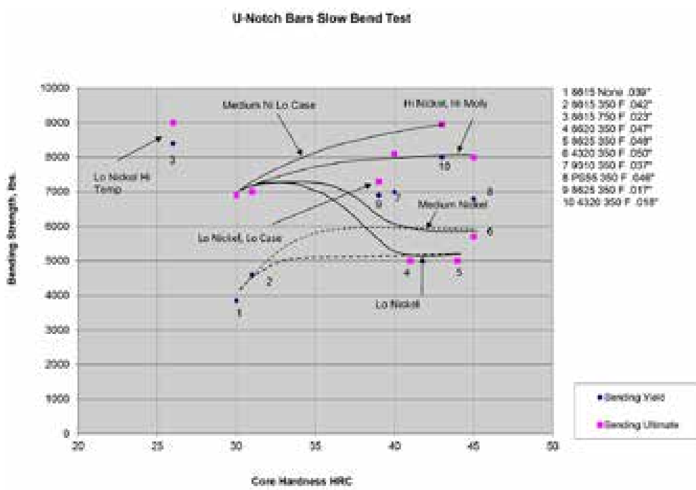

Figure 2

QUENCH EMBRITTLEMENT, CASE DEPTH, AND ALLOY CONTENT

This is additional confirmation the carburized case does suffer from quench embrittlement. High core hardness above 40 HRC can be detrimental or beneficial depending on the steel grade and the case depth. A medium nickel steel such as 4320 can provide a modest increase in bending strength over a low nickel steel such as 8620 when the core hardness of both is 40-45 HRC. However, the yield and ultimate will be the same, and the failure will be elastic only. Higher alloy steels such as PS55 and 9310 continue to increase in bending strength as the core hardness increases to 40 HRC and above, and they remain ductile with a separate yield and ultimate. A medium nickel steel such as 4320 with a light case depth can provide bending properties similar to or better than 9310. Since the carburized case suffers from quench embrittlement [2] less case is better for bending strength.

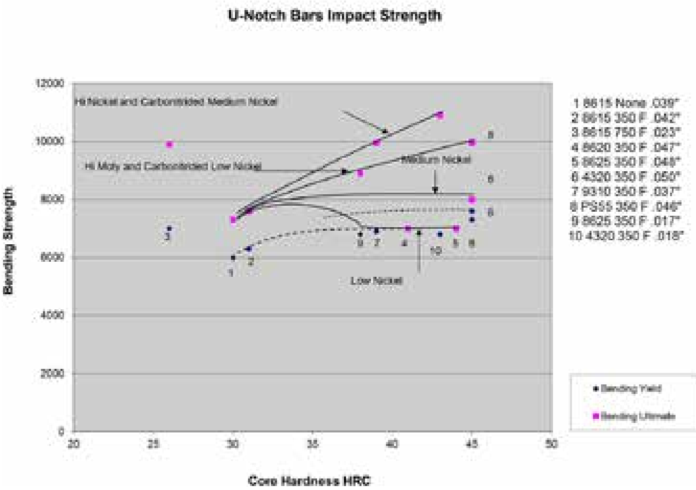

Figure 3

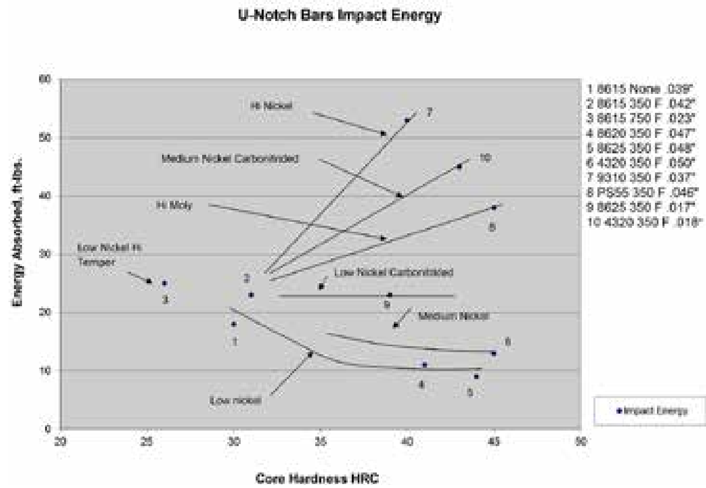

Figure 4

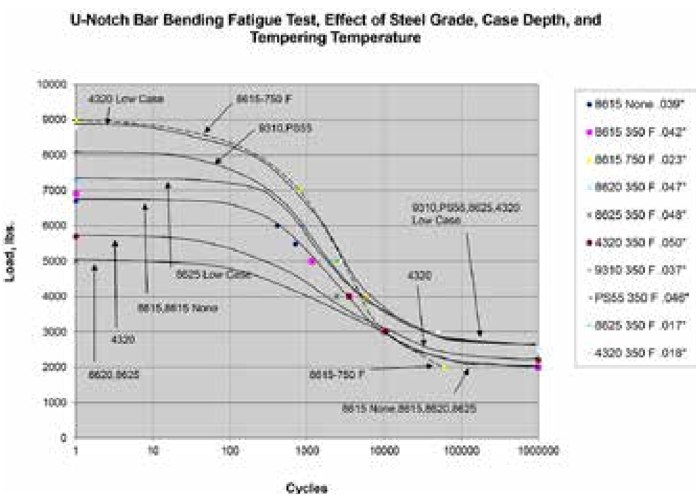

Figure 5

Figure 3 shows the bending strength under impact conditions for the same series of samples used in Figure 2 [3]. An instrumented Charpy tester was used to obtain this data. Figure 3 is actually very similar to Figure 2. The major difference is the U-Notch test bars are stronger in bending under high strain rate impact conditions. In this test, the 4320 carburized sample appears to be slightly stronger in bending compared to the 8615 carburized sample. This is not in agreement with the actual differential gears from the vehicle test.

Figure 4 shows the results for the absorbed energy from the impact test [3]. The baseline sample representing the differential gear is sample 2 the 8615 carburized steel with a 350°F temper. The low temperature temper did provide a 27 percent increase in absorbed energy compared to Sample 1 with no temper. In Sample 3, the 8615 with the 750°F temper, which was tied with 9310 for the highest bending strength, provided only a small increase in absorbed energy over the 350°F temper.

In Sample 6, the carburized 4320 sample had about half of the absorbed energy compared to the baseline 8615 sample. This does agree with what we saw with the vehicle impact test. From Figure 4, the best options for increasing the absorbed impact energy of the differential gear would be carbonitrided 4320 or carburized 9310. Carbonitriding was used on these early samples because it was an available process able to produce a light case depth. The ammonia addition is not necessary for alloy steels, and it was eliminated, and there was no difference in mechanical properties or performance. Based on this information, light case carburized 4320 was used to solve the differential gear impact problem. It was the same material previously tested in the vehicle but with a lower case depth.

HIGH CYCLE AND LOW CYCLE FATIGUE

Figure 5 shows the results for the 3-point bending fatigue test [1]. The major changes are all on the left side of the graph in the low cycle regime below 1,000 cycles. This is where the material and heat treatment make the biggest difference. This would include overload, impact, and low cycle fatigue situations.

On the right side of the chart, the differences are much more subtle. This would be considered to be high cycle fatigue. In general, what does well on the left side of the chart also does well on the right side. The only exception is the 8615 carburized sample tempered at 750°F. It performs very well in low cycle fatigue but appears to be headed below the other samples in high cycle fatigue. Elimination of the compressive residual stresses is likely an important factor here. The graph does show that carburized 8615 does outperform carburized 4320 in the low cycle area, which is the area of concern with the differential gear. In the high cycle area, that appears to change, and the 4320 has a little higher life.

Figure 6 shows a graph of bending strength vs. case depth for three different steels: 1018, 8615, and 8625 [3]. The 1018 steel had a core hardness of 16 HRC; the 8615 steel had a core hardness of 31 HRC, and the 8625 steel had a core hardness of 46 HRC. The case depth is shown as a percent of the 10.8 mm cross section thickness at the bottom of the U-Notch bar radius. The optimum case depth for the 8625 steel is 0.0 percent. This is because the case is actually weaker

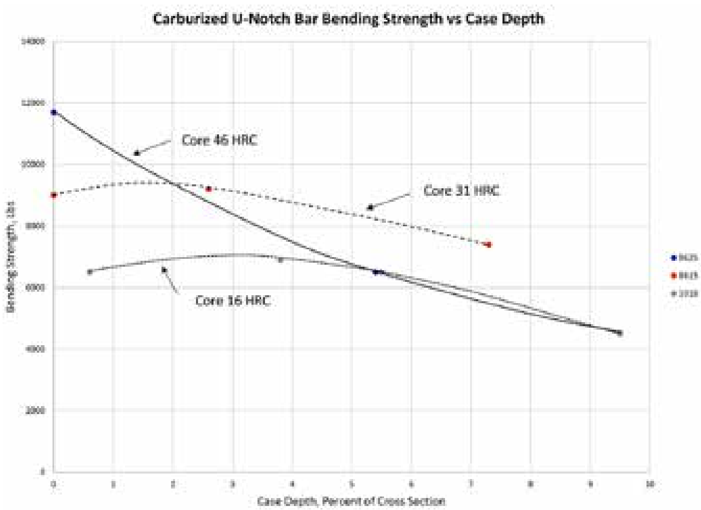

Figure 6

than the core. Even so, it is not recommended to eliminate the case as this will eliminate the residual compressive stress at the surface, which is important for good fatigue life. The optimum case depth for the 8615 steel is about 1.5 percent, and the optimum case depth for the 1018 steel is about 3.5 percent. As the core hardness decreases, the case becomes stronger than the core and hence more beneficial. Typical light vehicle gear case depths are approximately 6.0 to 12.0 percent of the tooth cross section at the root radius.

CONCLUSION

Carburized steel behaves differently depending on whether or not a radius or stress concentration is present. The carburized case suffers from quench embrittlement and, as a result, is weaker than the hardness would predict. Case depth, core hardness, and steel composition all play an important role in determining part performance. In general, higher steel alloy content, higher core hardness, and less case depth are all good. It is important to keep in mind that all of this information is valid for bending conditions. A gear tooth also must provide adequate contact strength and life. What is good for bending may be the opposite of what is good for contact and the material and heat treatment may require a compromise. The actual failure mode must be determined before addressing any problems.

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ABOUT THE AUTHOR

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

COMPANY PROFILE ///

ASTARAS, INC.

DELIVERING INNOVATIVE TUNGSTEN ALLOYS

Astaras offers tungsten solutions in the Americas for a host of industries including aerospace, high-temperature applications, die casting, medical, homeland security, nuclear, oil and gas, precision tooling, automotive, and high-performance racing applications.

By KENNETH CARTER, Thermal Processing editor

Die casting is an important production process for many different industries, and the alloys used to manufacture these permanent dies must be durable and heat resistant.

Astaras and its sister company, Weldstone, have been selling customized tungsten and tungsten alloys used in welding, die casting, and other processes for more than 20 years, which means the company touches a lot of different industries, including heat treating. The mentioned metals are sintered at very high temperatures up to 2,500°C. This necessitates tungsten-equipped furnaces, which Astaras and Weldstone can produce and provide.

HEAT-RESISTANT ALLOYS

"In the aluminum die-casting industry, our products are used as core pins, inserts, and sprue bushes," said Jim Brown, Astaras' senior sales representative for tungsten heavy alloys. "Our material holds up well in the heat. Tungsten has the highest melting point of any metal. There's no furnace that I know that's made where you can put tungsten in and melt it. It's a powder metallurgically produced material. What they do is they take the tungsten ore, and they chemically process it to very high purity and then reduce it into a very fine metal powder, almost like baby powder, and then they take this powder, and they mix it with two, sometimes three, different other binders like nickel, iron, copper, and molybdenum. Then they press the part into a near-net shape, and it's put into a tungsten-lined sintering oven. That oven bakes the product, and those other materials bind the heavy alloy together. It's then machined into the product you need."

The same size piece of tungsten alloy with the same dimensions of a steel piece is going to weigh more than double, according to Brown.

"It's going to weigh two to three times more, so the same weight fits into smaller spaces," he said. "It's used in weights; it's used in radiation shielding, including medical and security uses, instead of lead. It's safer for the environment, and it's a better shielding than lead. And they are used as vibration-damping toolholders in the machining industry because they don't have as much bending due to their high stiffness."

And when it comes to aluminum die casting, issues can be avoided, which can be a problem with tool steel, according to Brown.

"If you have a core pin of tool steel and you have a core pin of Anviloy® tungsten, the core pin of Anviloy tungsten actually helps the product cool faster, and it lasts longer," he said. If you're punching out casting aluminum engine blocks, an extra two seconds per engine block means a lot of cost saving and capacity increase in the long run, and our product gives you that. The heavy alloy costs more, but it effectively saves you money in the long run. It's going to be mainly used where melted aluminum is poured into a die cast or a mold."

The Astaras team will machine your parts and supply them finished according to 2D and 3D data. (Courtesy: Astaras)

3D PRODUCT, CONFORMAL COOLING

Astaras is always in search of ways to improve its processes and strive for new and innovative solutions to offer its customers, according to Brown.

"We've proven that with one of our products called Anviloy 3D," he said. "A lot of people talk about 3D printing, but it is difficult and expensive to 3D print alloys. And there's an issue with porosity in that process. We have come up with what we call 'conformal cooling' inside a piece of solid Anviloy tungsten metal. Die casters want these cooling channels because the products should be cooled as quickly as possible so that the properties of the cast part improve, and the die casters can break it out earlier from the mold and make another part."

There are many industrial products such as combustion chamber inserts used to manufacture multi-cylinder engines (not engines, but cylinder heads) made with low-pressure die casting (LPDC) that take advantage of these properties. In high-pressure die casting (HPDC) of thin-walled structural parts, there is an area in the gate that must be particularly resistant because it receives all the heat of the molten aluminum. At the same time, there is a large node of solid metal there.

The Astaras and Weldstone teams have special technologies that enable cost savings compared to conventional CNC machining. (Courtesy: Astaras)

The node is called a biscuit, and it takes the longest to solidify because the large amount of aluminum must solidify before the mold can be opened. Astaras' process can cool faster; the die can open faster, and the cycle time can be reduced, which lowers costs and increases capacity, according to Brown.

"Most of these chambers are two at the bottom and two at the top where they have these channels that go through with fluid," he said. "They are all in one line on the bottom. Our product uses only two holes with the tungsten heavy alloy, but it also has cooling chambers inside of it. The fluid enters in the top, swirls through the chambers, and exits at the bottom — or however the customer wants the product designed. We do conformal cooling, which means we put the cooling channels homogeneously distributed through the part and close to the surface to provide high and homogeneous cooling."

This material ends up having four times the thermal conductivity than that of other products, according to Brown, which means, the quicker aluminum parts can be produced and cooled, more can be made.

"In the die-casting world, time is money," he said.

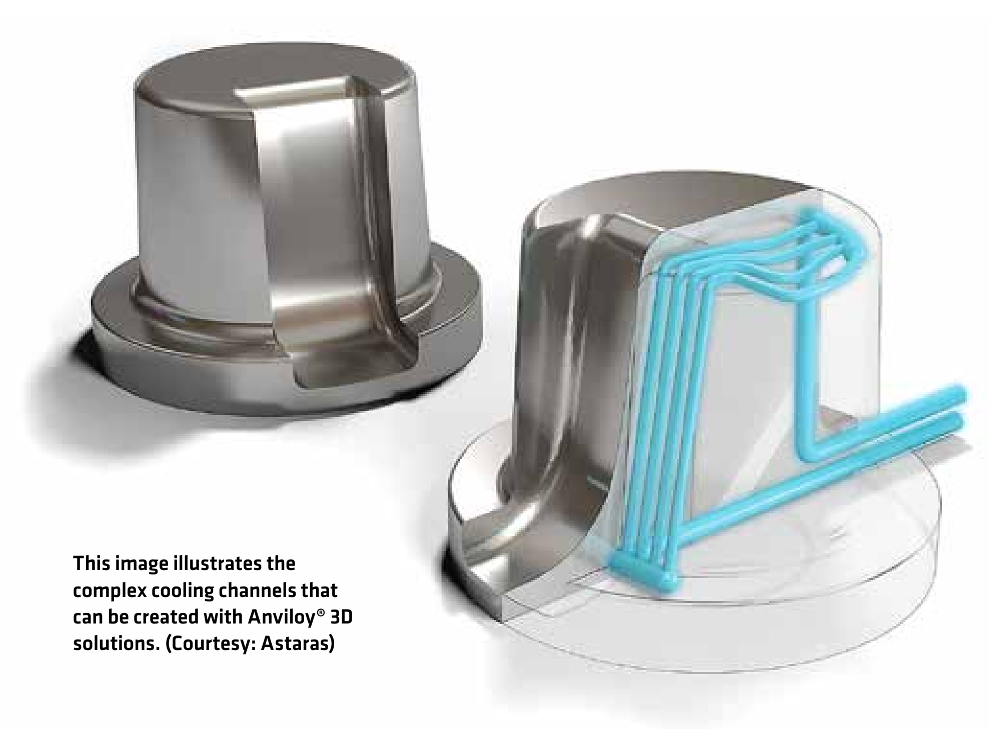
And to add to Astaras' impressive list of product accomplishments, there is an Anviloy welding rod for wear enhancement and repair that can be used not only on tool steel, but also on Astaras' own tungsten materials, Brown said.

"If you have a part of a die that's wearing out, you can take our Anviloy weld rod and repair it," he said. "It's going to last a lot longer than regular steel welding — I mean a lot longer. Of course, it doesn't get affected by heat like steel does. Our cooling rates, our wear resistance, our products last longer. Those are the ways that we have become innovators in the industry as it changes. You'll see now how more companies are using more aluminum in their automotive products. We're becoming ingrained with those innovative leaders because they see what we can do."

EXPERT ADVICE AVAILABLE

In order to work with a rising list of customers, it's important that Astaras has the expertise to back up its products as well as being able to offer those potential customers the right advice moving forward, according to Brown.

"We have a technical scientific and engineering team in Germany that help us with that," he said. "The expert who came up with conformal cooling solution, if you tell him your problem, he can help you figure out a better way to do it. He's not going to tell you, 'This is what you need to do,' but 'These are some things that you might look at,' and let them make that choice; 99 percent of the time, they're going to use our product because they see the benefits of it. We've actually done some tests with some companies and colleges where they use our product, and those products are just performing really well. Some of them now are hitting the marketplace after many years of testing. We work with universities; we work with manufacturers and their teams and with our teams, and we come up with different ways to find success."



This image illustrates the complex cooling channels that can be created with Anviloy® 3D solutions. (Courtesy: Astaras)

Weldstone tungsten alloys available through Astaras also keep production changeover problems to a minimum, especially when working with aluminum, according to Brown.

"They're much better than the old tool steel that they're using now — you'll see this as time goes on," he said. "People try to figure out how to save time. When you have a die that goes down, you have to stop production. When they stop production at a major motor manufacturer, they're not happy. They've got to stop and change. They have some backup dies, but they still have to stop the production to put new dies in there. Our Anviloy products help with that because they last longer. We haven't had any failures that I know of."

SERVING MANY INDUSTRIES

That longevity is what makes Astaras' catalog of alloys appealing to many industries, according to Brown. The medical field uses it as radiation shielding, and in the oil and gas sector, it aids in the search for oil deposits.

"You can pinpoint where you're sending your beam of radiation; if someone has a brain tumor or something like that, they don't want the radiation beam to go everywhere; they want to pinpoint that tumor, so that's what our products do," he said. "And they're safer for the environment. They're used in aerospace for vibration dampening for helicopter rotors. They're used for airplane wings to dampen vibrations from a fluttering wing. They're also used in engine turbines as a stabilizer, so the engine won't get out of balance. It's a weight. Like I said, since it's two to three times denser than steel, a smaller piece of metal will fit in a spot and still give you the same weight. We work with all of those folks, but mainly the big industry that we see innovations in, is going to be automotive — especially in North America."

Anviloy® products are used to remove heat quickly and minimize heat checks as well as improve stability of dimensions. (Courtesy: Astaras)

"If you have a part of a die that's wearing out, you can take our Anviloy weld rod and repair it. It's going to last a lot longer than regular steel welding – I mean a lot longer."

FLORIDA ROOTS

With the help of the IBG Group, Astaras first opened its doors in 2000 in Largo, Florida, with a focus on delivering OEM-quality private label (store brand) MIG guns and consumables, as well as TIG torches and carbon electrodes for the North American welding industry.

Astaras, owned by the IBG Group based out of Cologne, Germany, soon started a heavy alloys division and began selling Anviloy tungsten and Tucomet® tungsten copper alloys in North America, which are the company's brands for its tungsten heavy alloy and tungsten copper products. The IBG Group is a family-owned business with more than 2,500 employees worldwide. It also has 75 subsidiaries and affiliated companies in 38 different countries.

Astaras' European counterpart, Weldstone, is one of the world's largest leaders of tungsten and tungsten-based products, which includes tungsten heavy metal, tungsten copper, and tungsten special alloys.

The powder used for the company's heavy alloy and welding products comes from Astaras' Chinese counterpart, Shandong Weldstone, a powder-production facility in Zibo, China, owned by the IBG Group, according to Brown.

"That's where all of our heavy alloy products come from," he said. "We control our powder, whereas a lot of companies don't. Other companies buy their powder. We make our own powder, so we can control the process very well."

EYES ON WHAT'S NEXT

Astaras and its various sister and parent companies have carved out an important niche in supplying industries with quality tungsten alloy products that will continue to serve the market well into the future. Brown pointed out that the next important point on the horizon will be the EV industry, and he emphasized Astaras will be front and center and ready to serve its needs.

"As I mentioned, the automotive side is going to be a big area to grow in because of the renewable energy push when it comes to lighter cars, and that's where we're innovative," he said. "We're not just a sales organization; we're a problem solver, and we work with some of the largest automotive manufacturers in the world with our products. Anytime they have an issue, we've gone in and helped them fix these things, and they stay with us."

MORE INFO www.anviloy.com

Core pins are used in die casting dies. They are a fixed element used to create a void providing the desired shape in the molded or cast part. (Courtesy: Astaras)

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NIALL SWEENEY /// MARKETING AND SALES SPECIALIST /// SUPER SYSTEMS INC.

"Electronic flow meters offer several key features and benefits for various industries; the thermal-processing industry in particular benefits from such technology."

In which particular product area has Super Systems observed an increase in demand over the past couple of years?

One particular area we have experienced high levels of demand in is our flow technology, particularly our eFlo 2.0 product line. We have found that a large portion of our customer base are moving from mechanical gravimetric flow meters to electronic flow meter technology. The electronic meter provides greater precision for control along with data collection of the actual flow.

What are the applications and compatible gases associated with SSi's flow meters?

SSi's flow meters can be used in a variety of applications where accurate flow measurement is critical. They are particularly useful in applications where gravimetric meters are used or where precision is necessary for achieving a suitable result.

One area where SSi's flow meters are commonly used is in industrial processing, particularly in batch and continuous furnaces, as well as generators. In these applications, the flow meters are used to accurately measure the flow of materials such as gases, liquids, and solids.

SSi's flow meters can also be applied in new and emerging applications such as FNC (ferritic nitro carburizing) where precise measurement is critical for achieving accurate results. Overall, the applications for SSi's flow meters are diverse and can be found wherever precise flow measurement is necessary for optimal performance.

SSi's flow meters are capable of supporting a wide range of gases, including natural gas, air, endothermic gas, propane, ammonia, nitrogen, exothermic gas, methanol, water, dissociated ammonia gas, hydrogen, and more, making them ideal for use in a variety of applications, including industrial processes, power generation, and many others.

Can you describe the technology and design of SSi's flow meter?

SSi's flow meter utilizes a differential pressure measurement method to determine the flow rate of gases through an orifice. The eFlo includes two absolute pressure transducers that are located on either side of the orifice. These transducers measure the differential pressure across the orifice, which is directly proportional to the flow rate of the gas.

In order to ensure accurate readings, the flow meter is equipped with temperature compensation technology. This technology allows for precise adjustments to be made to the flow rate measurement based on changes in temperature, ensuring that the readings are accurate and reliable even in varying temperature conditions.

The two pressure transducers used in the flow meter not only provide differential pressure measurement, but they also measure the inlet pressure of the gas being supplied. This allows for a comprehensive understanding of the flow characteristics of the gas and provides additional data for further analysis and optimization of the process.

What are some key features and benefits of using electronic flowmeters, particularly eFlo 2.0, and how does this help heat treaters?

Electronic flow meters offer several key features and benefits for various industries. The thermal-processing industry in particular benefits from such technology. One such benefit is their ability to data log flow, providing accurate measurements of fluid or gas flow rates over time. This is especially useful for diagnostics, such as detecting furnace problems due to an increase in gas flow caused by furnace leaks.

Additionally, electronic flow meters allow for flow control to customer specifications and provide proof of process with digital charts. These meters offer both flow mode and valve mode, which allows for very precise low flow control applications. Another benefit is flow verification using a manometer for the CQI9 specification requirements.

SSi's eFlo 2.0 meters are compatible with a wide range of gases and are resistant to water, oil, carbon, and other contamination due to their limited moving parts. They offer Ethernet and RS485 RTU communications, and their small footprint lowers installation costs. SSi flow meters also come with a built-in webpage for diagnostics, calibration verification, configuration, and troubleshooting. Other features include inlet pressure indications and configurable alarms. Our eFlo 2.0's provide accurate and reliable measurements for fluid and gas flow rates, making them a valuable tool for heat treaters across the globe.

What are the data acquisition capabilities and why are they offered?

SSi's flow meters are equipped with data acquisition capabilities that allow for easy communication and data logging. The meters are offered with the option of communication over Ethernet or twisted pair wires, depending on which works best for a particular application.

The ability to acquire and log data from the flow meter is beneficial in a number of ways. For example, knowing the flow rate of a gas can be used to calculate usage and cost, allowing for better management and control of resources. Additionally, data logging can be used to track changes in flow rate over time, allowing for analysis of trends and patterns that can inform decision-making and optimization of processes.

Furthermore, the data acquisition capabilities of SSi's flow meters can be useful in calculating a carbon footprint. By accurately measuring the flow rate of gases, it is possible to calculate the amount of greenhouse gas emissions associated with a particular process or application. This information can be used to identify areas where emissions can be reduced, leading to improved sustainability and environmental performance.

MORE INFO www.supersystems.com