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JANUARY 2020
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FROM THE EDITOR ///

For us, 2020 is not only hindsight, but foresight

Years ending with a zero always seem to bring out the nostalgia in people as they look back at what was and plan for what will be.

Ever since *Thermal Processing* began sharing some of the best heat-treat information with the industry, we have constantly changed and morphed to better serve you, our readers.

We've added some new topics to this year's editorial calendar, and we're excited about tackling those angles and, hopefully, bring you some new facts and innovation about the heat-treating world.

And if you're traveling to some of the big trade shows scheduled in 2020, make sure you look for *Thermal Processing*, as we plan to be participating in quite a few of them.

To get you primed for what's sure to be a stellar year for the industry, our first issue of the year takes a look at cryogenics and vacuum heating.

An article from Frederick Diekman focuses on deep cryogenic treatment, and how this process is proving to be advantageous to creating longer lasting products and tools that cost less.

In the world of vacuum heating, TAV Vacuum Furnace explains how vacuum heating will be essential when dealing with additive manufacturing.

And in our Q&A section, I had the pleasure of speaking with Justin Sims, a mechanical engineer with Dante Solutions. In the feature, he stresses how important their software is to helping with not only troubleshooting problems, but it also can aid in design before problems ever crop up.

Make sure you check out what our columnists have cooked up for January as well. They are always sharing some fascinating information.

And since it is the first of the year, I will take this opportunity to remind all of you that I am always on the lookout for articles and other submissions. It's a great way to share your expertise while shining a spotlight on you and your company at the same time. Hit me up if you have an article idea.

Thanks again for making 2019 a great year for us, and we look forward to making 2020 even better.

Happy New Year, and, as always, thanks for reading!

KENNETH CARTER, EDITOR
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OPERATIONS

An aviation manufacturer in China has expanded production with equipment from Seco/Warwick. (Courtesy: Seco/Warwick)

Manufacturer expands with Seco/Warwick equipment

A steady increase in global demand along with advances in precision technology capability has fueled the expansion of a major producer of aviation engines in China.

Seco/Warwick designed, manufactured, and commissioned a 25-kilogram (55 pounds) single crystal furnace and a 50-kilogram (110 pounds) equiax vacuum melting and casting furnace for the production of high quality, premium castings.

A third furnace is included in the recent purchase, adding a Seco/Warwick signature vacuum high-temperature gas quenching furnace to the production line to be used for scale and pollution-free thermal treatment of a wide variety of metals. Professional technical services are included to assure the smooth start-up and operation of the equipment.

In 2019 the company installed in Asia vacuum metallurgy equipment, including advanced JetCaster® technology, that is the first installation of this kind on the Chinese mainland. "Vacuum metallurgical equipment is manufactured for our customers all around the world, and is installed at the regions with the highest demand for high-melting and foundry technologies. Since 2006, Seco/Warwick Group offers comprehensive solutions and access to a wide range of in-house resources, including technology, material, and process development, enabling manufacturers expansion and improvement of production processes," said Sławomir Woźniak, Seco/Warwick Group CEO.

A 25-kilogram single crystal furnace is characterized by advanced Jet Caster technology for more efficient production of the castings with oriented or single crystal structure. The additional gas cooling in the JetCaster system is a result of cooperation between Seco/Warwick's experts and scientists from finest universities, thus this single crystal furnace for aviation blades casting is the state-of-the-art technology. The furnace allows faster and more effective mass production process without any quality loss, which significantly increases the amount of manufactured parts per one work shift.

A 50-kilogram equiax vacuum melting and casting furnace was designed ideally for high-quality equiax castings. The furnace will be comprised of three chambers with two chambers stacked vertically, and separated by an isolation valve. The third chamber will be used for loading ingots into the furnace crucible and, to ease the production process, the furnace will be capable of direct melting in a crucible or using single shot liners.

A vacuum high temperature gas quench furnace will be used for scale-free and pollution-free thermal treatment, which will concern a wide range of materials, from superalloy through stainless steel or titanium alloy, ending with partial structural steel components.

MORE INFO www.secowarwick.com

Wisconsin Oven ships heat treating batch oven

Wisconsin Oven Corporation has shipped one indirect gas fired heavy duty walk-in series oven to a manufacturer in the technology industry. The walk-in oven will be used for heat treating materials used in the production of vehicle batteries.

The walk-in oven has a maximum oven operating temperature of 350°F and work chamber dimensions of 12'0" wide x 6'0" long x 10'6" high. Guaranteed temperature uniformity of ±10°F at 190°F was documented with a nine-point temperature uniformity survey in an empty oven chamber under static operating conditions.

This batch oven is fully tested and adjusted at normal and maximum temperatures before shipment. To ensure heating rates and

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.

A walk-in oven from Wisconsin Oven will be used to heat treat materials used in the production of vehicle batteries. (Courtesy: Wisconsin Oven)

temperature uniformity, it is equipped with combination airflow which includes a combustion air blower and combustion airflow switch.

"We have supplied this customer with over 35 similar units to several of their facilities. This oven comes with a complete turnkey installation package which includes start-up and employee training," said Steve Bertschinger, service sales manager.

Features of this Wisconsin Oven walk-in oven include:

- Burner rating of 420,000 BTU per hour at full load.
- 16,000 CFM @ 15 HP blower.
- Allen-Bradley MicroLogix 1100 PLC and PanelView Plus 200 color touchscreen.
- Bi-parting, side-hinged, horizontal swing doors.
- Digital Eurotherm 3216 temperature controller.
- Tongue and groove panel assemblies.
- Total oven dimensions of 15'6" wide x 7'0" long 16'2" high.
- One Eclipse Series ImmersoPak burner.
- Access ladder with safety swing gate to top of oven.
- Complete turnkey installation.

This batch oven was fully factory tested and adjusted before shipping. All safety interlocks were checked for proper operation and the equipment was operated at the normal and maximum operating temperatures. An extensive quality assurance check list was completed to ensure the equipment met all Wisconsin Oven quality standards.

MORE INFO www.wisoven.com

Registration open for Heat Treat Mexico 2020

Registration is open for the ASM Heat Treating Society's Heat Treat Mexico 2020, scheduled for March 3-5, 2020 in Queretaro, Mexico. The conference is designed to attract maintenance supervisors, metallurgists and production engineering staff, and will provide a bridge for relevant new technology for thermal processing and how it is applied to the production environment in Mexico.

This year's conference will focus on the following topics:

- Origin of CQI-9 standard applied to automotive manufacturing.
- Origin of NADCAP for the aerospace industry.
- Carburizing Furnace: maintenance, safety systems, combustion, quenching.
- Vacuum Furnace/Autoclave: vacuum performance, heating performance and cooling system performance.
- Induction Heating Systems: coil maintenance, maintaining a healthy induction machine; managing process settings.
- At the end of the courses, attendees will obtain a DC-3 official job skills accreditation, valid for the STPS.

Registered conference attendees will receive:

- Two-and-a-half-day heat treating symposium.
- Daily lunch and refreshments breaks.
- Welcome reception with exhibitors.
- Special networking event, with open bar
- Dedicated networking times with exhibitors to learn about the latest products, trends, and technology.
- Conference sessions offered in English and Spanish.
- Free one-year membership in ASM/HTS for non-members located in Mexico.

MORE INFO www.asminternational.org

Voestalpine adds special nitriding capabilities

The High Performance Metals Division of Voestalpine AG in the Czech Republic has expanded its heat-treatment capabilities with the addition of a Nitrex system for nitriding and surface hardening stainless steel for various applications.

Nitrex Metal has entered into an exclusive agreement with Voestalpine AG to bring innovations in stainless steel hardening technologies to the Czech market. The new nitriding system, model NX-820, is configured to process 31.5" diameter by 78.75" high (800 mm by 2000 mm) workloads that weigh up to 3,850 pounds (1750 kg) and complements a prior Nitrex system installed in 2008 that combined Nitreg®-C gas nitrocarburizing technology with ONC® post- oxidizing technology for processing firearms.

Capable of treating 304, 316, and 412 grade stainless steels, the new system with integral process technologies Nitreg®-S and Nano-S™ optimizes the mechanical performance and economic return by making these steels extremely wear- and corrosion-resistant and capable of achieving a longer useful life. Like all Nitreg® brand technologies, post cleaning of treated parts and

Nitrex Metal has entered into an exclusive agreement with Voestalpine AG to bring innovations in stainless steel hardening technologies to the Czech market. (Courtesy: Nitrex) added production steps such as machining are eliminated.

As part of the new system order, Voestalpine and Nitrex have expanded their cooperation, granting Voestalpine the exclusive rights to commercialize Nitreg-S and Nano-S technologies in the Czech Republic. "The agreement builds on a strong partnership and confirms the market potential of hardening technologies for stainless steels. Under the terms of the license, Nitrex will work closely with Voestalpine to help meet their customer demands with research and process development for a variety of applications, materials, and markets," said Marcin Stoklosa, special projects manager of Nitrex Metal.

"We are excited about bringing these innovative heat-treat processes to the Czech Republic market. With this license, Voestalpine will continue to enlarge the size of its prospective customer base and provide the local manufacturing community with much needed access to comprehensive technologies. Nitrex's proven technologies offer numerous benefits to our industrial customers looking to maximize the life span and quality of their engineered parts and components," said Zbyněk Drda, Voestalpine heat treatment manager.

The High Performance Metals Division of Voestalpine Group specializes in high-performance materials and customer-specific services including heat treatment, surface treatments, and additive manufacturing processes to the aerospace, automobile, consumer goods, oil and gas, and tooling industries. Since 2005, Nitrex Metal has been building a lifelong customer relationship with Voestalpine and its affiliates – Assab, Assab Steels, Assab Tooling, and Böhler-Uddeholm. The company operates twelve Nitrex nitriding and nitrocarburizing systems in nine countries including China, the Czech Republic, Hungary, Indonesia, Poland, Slovakia, Taiwan, Thailand, and Turkey.

MORE INFO www.nitrex.com

Gasbarre consolidates thermal processing systems production

Gasbarre Products, Inc. reports that at the end of 2019 all thermal processing systems will be manufactured in its 50,000-square-foot facility in St. Mary's, Pennsylvania.

In 2011, Gasbarre acquired the JL Becker brand of industrial furnace equipment. Over the last eight years, Gasbarre has run parallel manufacturing facilities in Michigan and Pennsylvania for its furnace equipment. Consolidating the manufacturing of its common product lines allows for the most efficient use of its floor space, equipment, and manufacturing processes.

Gasbarre CEO Alex Gasbarre said, "This move is not only beneficial to our current operations, but it will directly impact our customers. Our St. Mary's facility has a track record of on-time delivery, quality, safety, and efficient processing. Those factors will drive competitive pricing with quick delivery."

Gasbarre will maintain a strong presence in the Detroit area with a sales, engineering, and service facility. Ben Gasbarre will retain his leadership role within the Plymouth, Michigan, location. Gasbarre has plans not only to design and service its equipment but to eventually establish a technical center for process testing and demonstration purposes.

"The move will allow us to better utilize our highly-skilled personnel to accelerate advancements to our products, technology and services," said Ben Gasbarre.

Expansion in St. Mary's will be necessary, so plans have begun for an additional 12,000 square feet of manufacturing space with additional office and conference room capacity. This will be a significant investment in the furnace operations to drive manufacturing, technology, and growth into the future.

Additionally, Gasbarre recently installed its new vacuum purge nitriding furnace for the growing demand in the U.S. market. This system has been fully developed by the Gasbarre team partnered with SSI for the furnace control system.

It gives the domestic market a fully integrated system, designed and supported in the United States.

MORE INFO www.gasbarre.com

Solar Manufacturing builds MuShield's first vacuum furnace

The MuShield Co. of Londonderry, New Hampshire, has commissioned Solar Manufacturing to design its first vacuum furnace.

The furnace, built with a SolarVac® Polaris control system and fully compliant to AMS2750E pyrometric specification, is designed to accommodate loads up to 36" wide x 36" high x 72" deep, and a maximum weight of 5,000 pounds. The Solar furnace operates at a vacuum level of 10^{-5} Torr with the capability of maximum temperatures up to 2,400°F, and features an external quench system designed for pressures up to two bar. MuShield is expanding with additional space that will house the new Solar furnace. The company aims to better serve the magnetic shielding industry by providing material designed to protect sensitive electronics from magnetic fields.

"MuShield was already aware of our excellent reputation in the industry, and they were impressed with our facility when they visited earlier this year," said Jason Davidson, Solar Manufacturing's Northeast regional sales manager. "They were also impressed with results of testing performed for them by Solar Atmospheres, so we're pleased they have placed confidence in Solar Manufacturing to provide their first vacuum furnace."

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

MORE INFO www.solarmfg.com

The two new lines process automotive and aerospace industry grade aluminum alloys (series 5XXX,6XXX and 7XXX), with strip width ranging from 1,000 up to 2,200 mm and thickness ranging from 0.5 up to 4 mm. (Courtesy: Tenova)

Tenova and Chalco Ruimin sign FACs for aluminum lines

Tenova and Chalco Ruimin Co., Ltd officially signed the Final Acceptance Certificates for a continuous annealing line and a chemical pre-treatment line for processing aluminum strip coils.

The new plant is located in the Fuzhou Economic Technical Development Area, on China's South Eastern Coast. Chalco Ruimin Co., Ltd, is a company belonging to Aluminium Corporation of China (Chinalco), one of the world's largest aluminum producers.

The two new lines process automotive and aerospace industry grade aluminum alloys (series 5XXX, 6XXX, and 7XXX), with strip width ranging from 1,000 up to 2,200 mm and thickness ranging from 0.5 up to 4 mm.

The total production rate for the continuous annealing line is 100,000 tons/year with a process speed of 80 m/min, whereas the chemical line production rate is 120,000 tons/year, with a process speed of 60 m/min.

Both lines are equipped with the latest state-of-the-art technologies for producing qualities and grades requested by automotive and aerospace industry top applications.

Tenova exceeded Chalco's expectations by commissioning and starting-up both lines well ahead of the planned schedule.

"This project confirms Tenova's experience and reliability in supplying leading technologies and plants for the aluminum and steel strip processing industry. With more than 10 reference plants supplied in the last few years for auto and aerospace highest grades applications, Tenova confirms its leading position in the market," said Nicola Cavero, senior vice president Tenova Italimpianti. "In the next couple of years, several additional lines we are currently supplying will start their production, further strengthening our leading position. We are ready to continue to provide our customers with our experience and our technology."

MORE INFO www.tenova.com

INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

Great programming, great networking at the 2020 Annual Meeting

Get ready to sail! IHEA's 2020's Annual Meeting promises to deliver important and timely presentations and as always, entertaining networking opportunities on board Royal Caribbean's Brilliance of the Seas. Scheduled for March 12–16, 2020, members will enjoy a cost-effective meeting while gaining all the benefits of a land-based event. The ship offers ideal meeting space for IHEA to bring in outstanding general session speakers, as well as breakout rooms for IHEA's committee meetings. Attendees will hear from the following experts and will benefit from having them on board to continue conversations and gain additional insight from them during the social activities.

CHRIS KUEHL, ARMADA CORPORATE INTELLIGENCE

Economic Update: Does the Roller Coaster Continue?

An annual favorite, IHEA's economist Chris Kuehl will give an economic update with his take on what lies ahead in a presidential election year! Will the economy continue on its roller coaster ride in 2020?

OMAR NASHASHIBI, THE FRANKLIN PARTNERSHIP

The Race for the White House: How Manufacturing is Adapting to Tariffs and the Outlook for Trade

Omar Nashashibi will present two important sessions. With all eyes and ears on Washington as the 2020 presidential election unfolds, Nashashibi will give an election watch rundown from an "insider's" perspective. Nashashibi's second presentation will focus on how manufacturing is adapting to tariffs and the outlook for trade.

CHIEF MASTER SGT. (RET.) BOB VASQUEZ, UNITED STATES AIR FORCE

The Power of SUPERvision

One of IHEA's most popular speakers, Chief Master Sgt. Bob Vasquez returns with a new presentation based on his recently published book: The Power of SUPERvision! Every supervisor who aspires to become a SUPERvisor needs SUPERvision! SUPERvision starts with how you see yourself. What you see is what you'll be. How do you see those people entrusted to you? How you see them is how they'll be. How do they see you? They're watching. You can count on that. Vision is important. SUPERvision is critical.

Go to www.ihea.org/event/AM2020 to view the 2020 Annual Meeting registration brochure that provides complete details. Follow the links in the brochure to register and book your cabin online.

We have planned a great mix of business meetings and social gatherings to bring industry peers together. Here is a glimpse of the Annual Meeting itinerary:

Thursday, March 12: Tampa, Florida

Noon	Attendees Board Brilliance of the Seas
4 p.m.	Sailaway - Casual Gathering
7:15 p.m.	Welcome Get Together
8:30 p.m.	Dinner

Friday, March 13: At Sea

8:30 a.m. – noon	General Session
8:30 a.m.	Spouse/Guest Breakfast
Noon – 1 p.m.	Attendees Free for Lunch
1:15 – 5 p.m.	Committee Meetings
7:15 – 8:15 p.m.	President's Reception
8:30 p.m.	Dinner

Saturday, March 14: Cozumel

8 a.m. – 6 p.m.	Explore Cozumel on your own
8:30 p.m.	Dinner

Sunday, March 15: At Sea

8:30 a.m. – Noon	General Session
Noon – 1:30 p.m.	Lunch
1:30 – 3 p.m.	Mini golf tournament
7:15 – 8:15 p.m.	Pre-Dinner Drinks
8:30 p.m.	Farewell Dinner

Monday, March 16: Disembark

8:30 a.m.	Guests Disembark

This unique meeting venue is perfect for IHEA members to gather and enjoy meeting new members and reconnecting with old friends. Don't miss the 2020 Annual Meeting on board Royal Caribbean's

IHEA's 2020 Annual Meeting sets sail on board Brilliance of the Seas.

The pool deck on Brilliance of the Seas is the perfect place to network between meetings during IHEA's 2020 Annual Meeting.

Brilliance of the Seas.

Become a member. Join IHEA today at www.ihea.org.

ABOUT THE INDUSTRIAL HEATING EQUIPMENT ASSOCIATION

The Industrial Heating Equipment Association (IHEA) is a voluntary trade association representing the major segments of the industrial heat processing equipment industry. Established in 1929 to meet the need for effective group action in promoting the interests of industrial furnace manufacturers, the organization has expanded and currently includes designers, manufacturers, and end users of all types of industrial heat processing equipment and serves as the knowledge base and authoritative voice for industrial process heating worldwide. For more information, visit www.ihea.org.

IHEA 2020 CALENDAR OF EVENTS

MARCH 12–16

IHEA 2020 Annual Meeting

IHEA's 91st Annual Meeting will be held on Royal Caribbean's *Brilliance of the Seas,* sailing from Tampa, Florida. In addition to IHEA's committee meetings, business presentations and networking opportunities, the itinerary includes a day to enjoy Cozumel, Mexico.

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

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LEE ROTHLEUTNER
GROUP LEADER FOR MATERIAL CONVERSION ///
THE TIMKEN COMPANY

Grain size is a critical metallurgical characteristic. Several techniques are available for assessing that, but there are pros and cons to each.

Determining austenite grain size

Grain size is a critical metallurgical characteristic, significantly influencing design parameters such as strength and toughness. Austenite grain size (often referred to as prior-austenite grain size) is of particular interest to users of heat-treated plain-carbon and low-alloy steel components — so much so that industry standards such as ASTM E-112 [1] and ISO:643 [2] outline a variety of procedures for determining austenite grain size.

Techniques include delineation of austenite grains with pro-eutectoid phases (ferrite and cementite), selective oxidation or etching of austenite grain boundaries, and analysis of electron backscatter diffraction (EBSD) data of finely polished metallurgical specimens [3]. Each method has its benefits and limitations, but some techniques may characterize your heat-treatment process better than others. For example, the Kohn oxidation method [2] and the McQuaid-Ehn carburization method [1, 2] require atmospheres and heat treatments that may not be representative of the process requiring characterization. As a result, selective etching techniques are considerably more appealing.

Figures 1–4 show examples of some of the more widely used techniques. Figure 1 shows a specimen of modified 15V41 that was forced-air cooled from forging temperature, held for 30 minutes at 700°C, then quenched to room temperature and etched using 2 percent nital. Figures 2–4 represent examples of specimens that underwent no special heat treatment but use an etchant similar to Brownrigg et al. [7] to reveal the austenite grain size. Figure 2 shows the case region of an induction hardened 10V45 shaft. Figure 3 shows the core of a furnace-austenitized and quenched-modified 8620 specimen. Figure 4 shows an isothermally transformed bainitic modified 52100 specimen.

SELECTIVE ETCHING TECHNIQUES

Selective etching techniques such as the Bechet-Beaujard method [2] and its variants [7, 8] as well as a variety of other etchants [9–11] have distinct benefits over all other techniques. These etchants allow through hardened (both martensitic or bainitic) specimens to be examined with no additional heat-treatment steps that can bias the true austenite grain size of the process. However, achieving results that can be easily interpreted is far from a trivial task. Often each alloy and heat treatment requires a slightly modified methodology.

EXAMPLE ETCHANT AND GUIDELINES

The simplest austenite grain size etchant is water-based saturated picric acid solution but slight variations in the etchant, sample preparation, and methodology can dramatically improve results. It is believed that this etchant attacks trace elements such as phosphorus (P) that segregate to austenite grain boundaries at austenitizing temperatures. Therefore, special temper embrittlement heat treatments have been shown to improve etching results in alloys with low P content [8]. One instance in which this step is necessary is laboratory heats of steel that have very low P content. Another factor that is often overlooked is the specimen polish. A freshly polished metallographic specimen (1 μm or finer) provides the best results. Below are an etchant and general procedure as well as a list of considerations developed from a review of the literature [7–11] that will provide a starting point for developing a procedure that will work for your process.

ETCHANT

1. 13 g/L picric acid in deionized (DI) water

› This is slightly above the solubility limit to ensure the solution is saturated.

2. 3% Teepol

› Wetting agent. Substitutions can be made depending on availability of Teepol.

› Increasing the concentration for lower carbon levels (i.e. 0.2 wt.% C) has been shown to improve results.

3. 1% hydrochloric acid

› Exact concentration depends on alloy. Sometimes this addition is not needed.

PROCEDURE

1. Heat etchant to 65°C while stirring with magnetic stirrer. Keep etchant covered while not in use to prolong life.

› Each batch of etchant typically only lasts 2–3 specimens.

› Temperature can be reduced if etchant is observed to be too aggressive.

2. Immerse specimen in etchant for 5–10 seconds. Specimen will tarnish significantly.

› Preheating the specimen on the hot plate or with a heat gun improves results.

3. Rinse with DI water followed by ethanol.

4. Lightly polish specimen by hand on a stationary medium- to high-nap polishing cloth with 1 μm or finer diamond compound.

› Counting the number of revolutions around the pad helps repeatability. Less than 10 revolutions are typically all that is necessary.

5. Clean with ethanol and dry with clean compressed gas.

6. Inspect with light microscope.

› Try dark-field illumination to reveal the grain boundaries if bright-field produces marginal results.

7. Repeat steps 2–6 until acceptable results are achieved.

REFERENCES

[1] Standard Test Method for Determining Average Grain Size, ASTM E112-13, ASTM International, Oct. 2013.

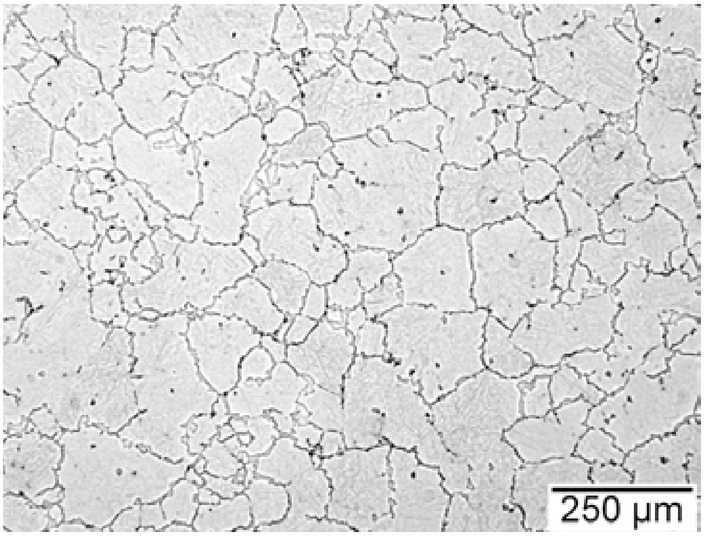

Figure 1: Optical micrograph showing austenite grain boundary delineation using isothermally transformed ferrite in a modified 15V41 [4]

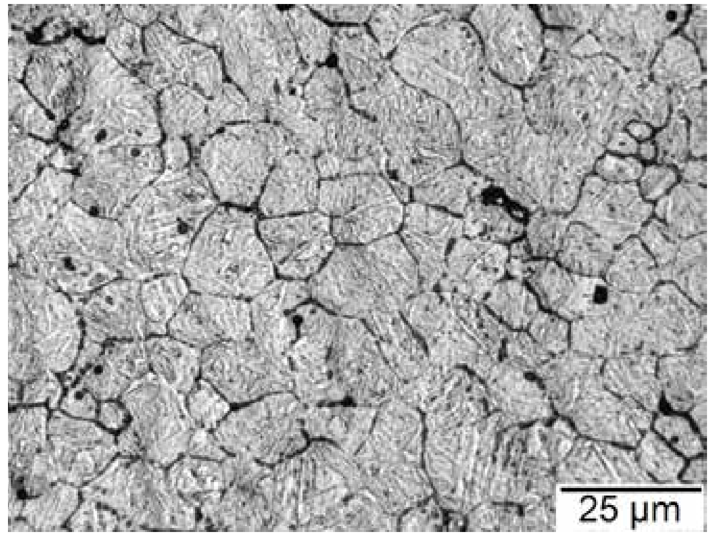

Figure 2: Optical micrograph showing selective etching of austenite grain boundaries in an 10V45 induction hardened case [5]

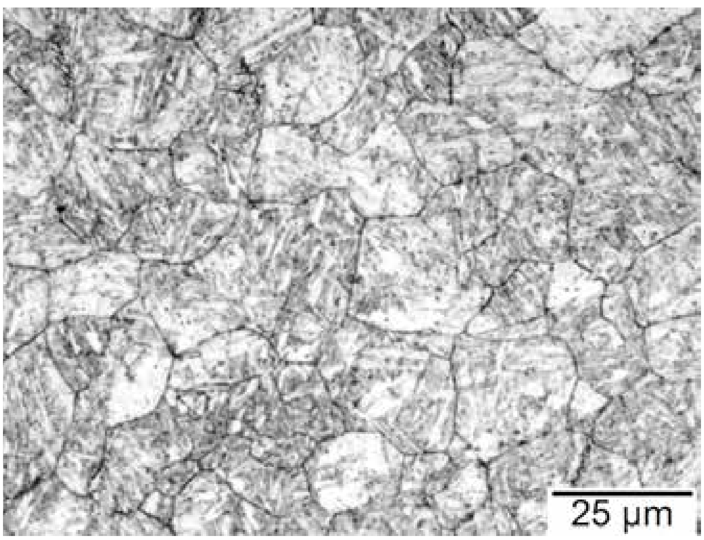

Figure 3: Optical micrograph showing selective etching of austenite grain boundaries in a quenched and tempered modified 8620.

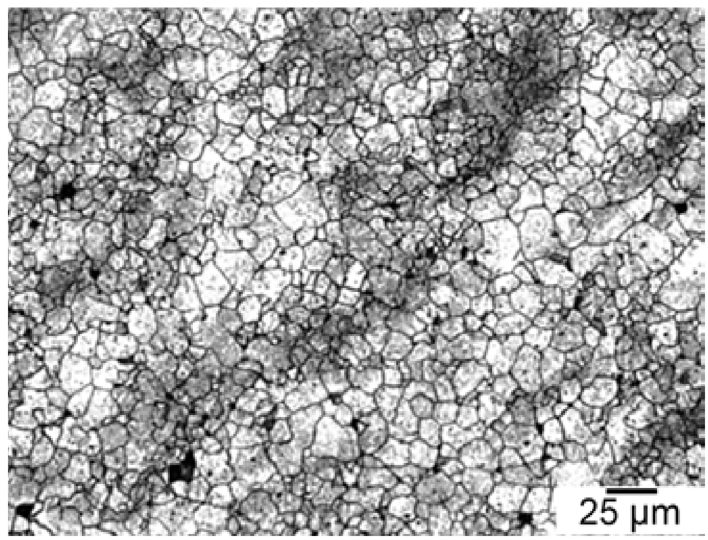

Figure 4: Optical micrograph showing selective etching of austenite grain boundaries in a bainitic modified 52100 [6].

[2] Steels – Micrographic Determination of the Apparent Grain Size, ISO 643:2003, International Organization for Standardization, 2003.

[3] Cayron, C., B. Artaud, and L. Briottet. "Reconstruction of Parent Grains from EBSD Data." Materials Characterization, vol. 57. no. 4, 2006, pp. 386-401.

[4] L.M. Rothleutner, "Influence of Reheat Temperature and Holding Time on the Interaction of V, Al, and N in Air-cooled Forging Steels," Thesis, Colorado School of Mines, 2012.

[5] L.M. Rothleutner, "Assessment of the Microstructure and Torsional Fatigue Performance of an Induction Hardened Vanadium Microalloyed Medium-carbon Steel," Diss., Colorado School of Mines, 2016.

[6] M. Jiang, private communication, June 5, 2017.

[7] A. Brownrigg, P. Curcio, and R. Boelen, "Etching of Prior Austenite Grain Boundaries in Martensite," Metallography, no. 8, 1975, pp. 529-533.

[8] D.R. Barraclough, "Etching of Prior Austenite Grain Boundaries in Martensite," Metallography, no. 6, 1973, pp. 465-472.

[9] R. Riedl, "The Determination of Austenite Grain Size in Ferrous Metals," Metallography, no. 14, 1973, pp. 119-128.

[10] G.F. Vander Voort, Metallography Principles and Practice, ASM International, Materials Park, OH, 1999, pp. 219-223.

[11] G. Petzow, Metallographic Etching, 2nd Edition, ASM International, Materials Park, OH, 1999, pp. 98-99.

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ABOUT THE AUTHOR

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

This powerful, data-rich test method that can ensure that a part is made to specification.

Understanding the Jominy end quench test

The Jominy end quench test [1][2] (ASTM A255 [3]) is an extremely simple and useful test that is applicable to many materials besides steel [4][5]. This test can provide basic information on the hardenability of a material and be used for specifying incoming material for heat treatment. It can also be used to predict the expected hardness of an as-quenched heat-treated part [6] as well as specifying materials during initial product design [7].

The Jominy end quench test consists of a simple bar 25 mm in diameter by 100 mm long. A small flange is machined at the end of the specimen for support. The bar is heat treated at normal austenitizing temperatures for the specific alloy for approximately one hour. The specimen is removed from the furnace, and hung in a special fixture (Figure 1).

As soon as the specimen has been hung in the fixture, a water valve is turned on, allowing water to cool the bottom of the specimen (the quenched end). A gradient of quench rates occurs along the length of the sample, with the quenched end exhibiting the highest quench rate and distances away from the quenched end showing progressively slower quench rates (Figure 2).

Once the specimen has cooled, two flats the length of the specimen are machined on opposite sides of the bar. Harness measurements are taken at either 1mm- or 1/16-inch intervals along the length of the bar, starting from the quenched end. This data is then plotted as a function of distance from the quenched end. An example of the Jominy end quench plots for several alloys is shown in Figure 3.

In Figure 3, it can be observed that, at identical quench rates (or distance from the quenched end of the Jominy end quench specimen), the hardness of each of the alloys is different. This very clearly shows the differences in hardenability of the different alloys.

There will be a range of Jominy data depending on the chemistry of the alloy. This is illustrated in Figure 4.

This data can be useful for determining the minimum hardenability needed for parts. To determine this, it would be necessary to consult the Lamont [8] charts. In these charts, the hardness of round bars of different thickness is correlated to the Jominy end quench data (Figure 5). For instance, if the needed as-quenched hardness at the center of a 2.0" diameter bar is needed to be HRC 50, and the quench media is a fast quench oil (H = 0.7), then the incoming material would be specified as requiring a hardness of HRC 50 at J8. One of the drawbacks of this is the value of the Grossman H-value [9]. Often it is not known. However, it usually can be determined from cooling curve data or from your oil supplier. This will be the subject of another article.

Assuming that the Grossman H-Value is known either from calculation or from the quenchant supplier, this data can be used to predict the expected hardness, or to select an alloy to be used for a possible part. For instance, say the part is 2 inches in diameter and is quenched in water (H= 1.0). From Figure 5, the surface hardness would correspond to J4, and the center hardness would correspond to J9. A tabulation of Jominy end quench data would be examined [10], and an alloy would be chosen that satisfies the required surface and center hardnesses at those distances from the quenched end.

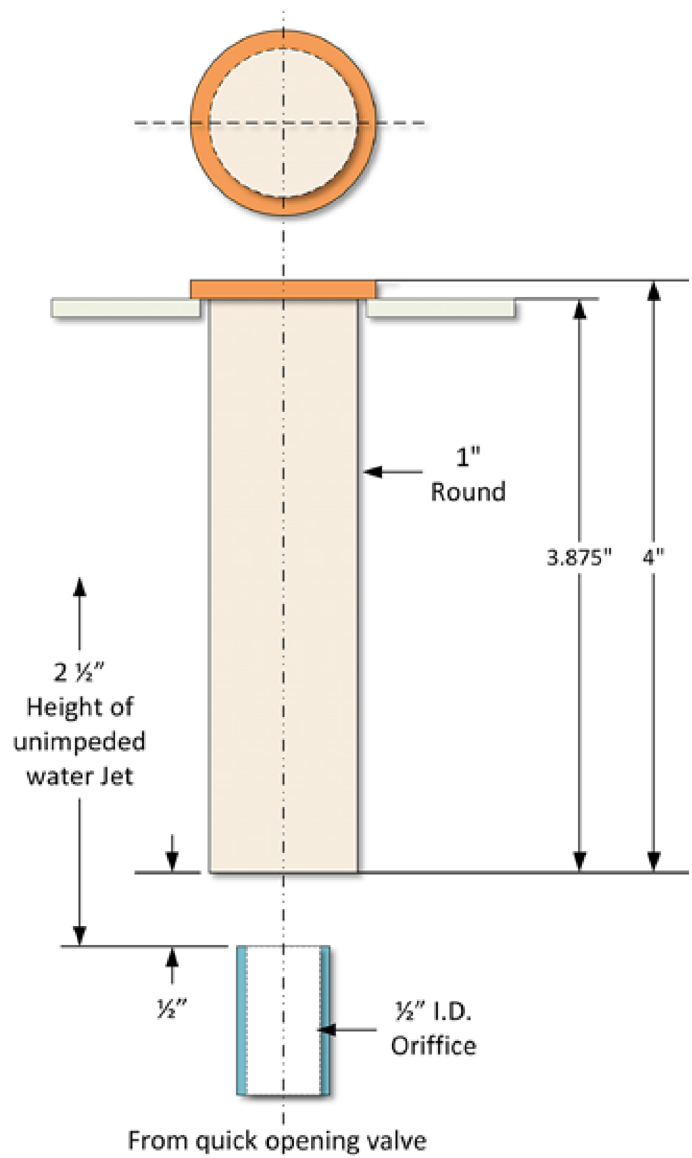

Figure 1: Jominy apparatus per ASTM A255.

In the same fashion, after a material has been chosen, the data can also be used to select a quenchant to be used to achieve the desired surface and core properties. This is useful to ensure that, once the part has been designed, it can be manufactured and not be prone to cracking or distortion.

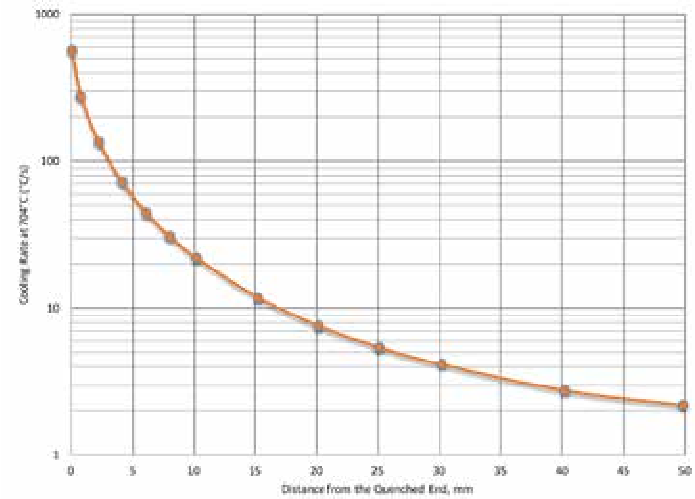

Figure 2: Quench rates at 704°C as a function of distance from the quenched end for the Jominy end quench.

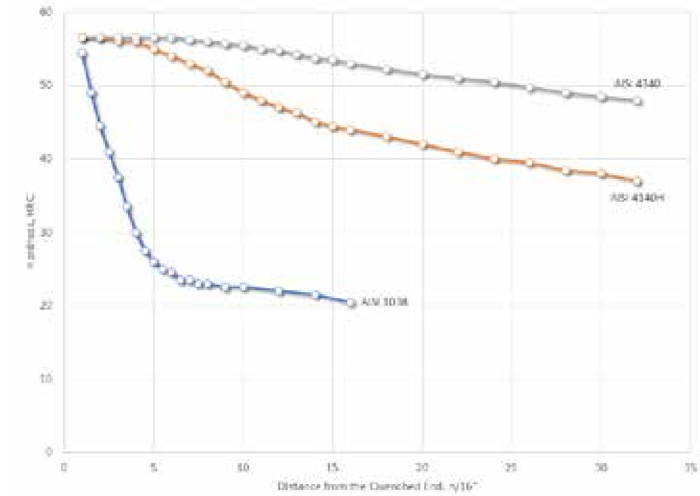

Figure 3: Jominy end quench hardness data for several typical alloys. Data extracted from [11].

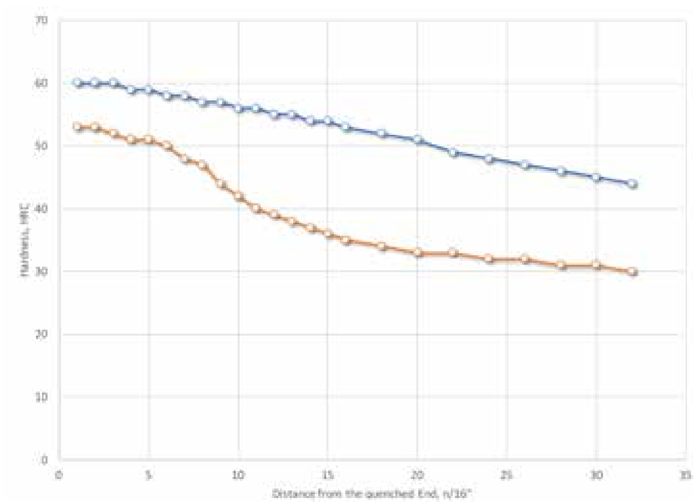

Figure 4: Range of Jominy end quench data for AISI 4140H. Data taken from [11].

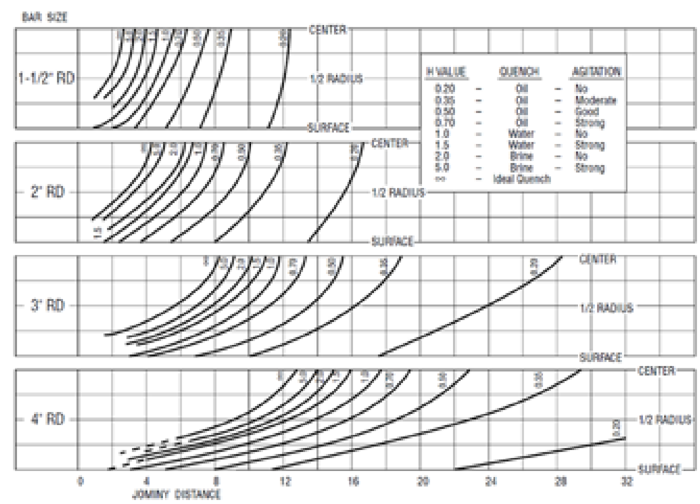

Figure 5: Lamont charts for different size diameter round bars, correlated to Jominy end quench distance. Graph taken from [11].

CONCLUSION

In this short article, the Jominy end quench test has been described. The method of conducting the test has been briefly discussed. The practical application of the data provided in the Jominy end quench test to specifying minimum hardenability requirements for incoming material for heat-treated parts was illustrated using Lamont charts. The selection of material for a part, based on the center and surface hardness, and a typical quenchant were also illustrated.

In summary, the Jominy end quench test is a powerful and data-rich test method that can be used by heat treaters, quality engineers, and designers to ensure that a part is made to specification.

Should there be any questions on this, or if you have suggestions for topics to be discussed, please contact the editor or myself.

REFERENCES

[1] J. E. Jominy, "Standardization of Hardenability Tests," Metals Progress, vol. 40, pp. 911-914, December 1941.

[2] W. E. Jominy, Hardenability of Alloy Steels, Cleveland: American Society for Metals, 1939.

[3] ASTM, "Standard Test Methods for Determining Hardenability of Steel," ASTM International, West Conshocken, PA.

[4] D. S. MacKenzie, Quench Rate and Aging effects in Al-Zn-Mg-Cu Aluminum Alloys, Rolla, MO: University of Missouri - Rolla, 2000.

[5] J. W. Newkirk and D. S. MacKenzie, "The Jominy End Quench for light-weight alloy development," Journal of Mat. Eng. Perf., vol. 9, no. 4, pp. 408-415, August 2000.

[6] M. Asimov, W. F. Craig and M. A. Grossman, "Correlation between Jominy Test and Quenched Rounds," SAE Trans., vol. 49, no. 1, pp. 283-292, 1941.

[7] F. J. Otto and D. H. Herring, "Gear Heat Treatment," Heat Treating Progress, no. June, pp. 1-5, 2002.

[8] J. L. Lamont, "How to Estimate Hardening Depth in Bars," Iron Age, no. 10, pp. 64-70, 1943.

[9] M. A. Grossman, "The Nature of the Quenching Process," in Elements of Hardenability, Metals Park, OH: American Society for Metals, 1952, pp. 61-91.

[10] American Society for Metals, Heat Treaters Guide Standard Practice and Procedures for Steel, Metals Park, OH: ASM International, 1982, pp. 423-426.

[11] Timken, Practical Data for Metallurgists, 17th Edition, North Canton, OH, 2014.

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JASON SCHULZE
METALLURGICAL ENGINEER /// CONRAD KACSIK

As furnace operators take the place of heat treaters, there is less need for metallurgical knowledge and more emphasis on internal procedures.

Determining heat-treat operator training

With the fast pace of change in the heat-treat industry, it is understandable that more automation is in demand. This automation inevitably improves repeatability and reduces quality risks. Automation can include control-based automation, where the furnace control system automatically cycles temperature and associated events based on pre-programmed parameters. It is more common now for engineers to document the required parameters based on material and customer requirements and flow this down to the heat treater who operates the furnace. It seems heat treaters are becoming less common and furnace operators are taking their place. By this I mean that furnace operators are running the furnace but not necessarily determining parameters based on the requirements from customers. With this comes a different approach to training. In this article we will discuss more modern methods of operator training that are in line with the changes in the heat-treat industry.

TECHNICAL TRAINING

Before the rise of furnace automation, heat treaters typically operated the furnace and, at times, determined process parameters based on material and customer requirements, albeit more commonly in the commercial heat-treating industry. When I started in the aerospace heat-treat industry, it was not uncommon for a heat treater to receive, say, A2 with a requested hardness and nothing more. The heat treater would then choose the temperature and time needed to achieve the required hardness. The heat treater would typically check hardness as well. Heat treaters who performed these tasks required training that included some level of metallurgy as well as furnace operation and maintenance.

OPERATIONAL TRAINING

As furnace operators take the place of heat treaters, the training required for furnace operators will differ greatly than that of a heat treater. For a furnace operator, a good training plan will include in-house procedures and less industry specification and metallurgical training. Training can be focused on internal procedures that specify not just how to operate a furnace, but how to charge a load, place load thermocouples, and what to do with out-of-tolerance conditions. No level of metallurgical knowledge is necessary any longer. This is due to engineering documenting the process parameters on standard work (i.e. procedure, router, work instruction, etc.) and flowing this down to furnace operators. With the rise of furnace automation, it is simply a matter of furnace operators selecting the furnace program that is stated on the standard work since the programs stated are pre-set with process parameters that apply.

NADCAP TRAINING REQUIREMENTS – HEAT TREAT

There are several questions within the Nadcap baseline heat-treat checklist that address training. For those who are Nadcap accredited, it is important to read each question in detail to ensure compliance.

Paragraph 4.1.1: Are there training procedures that assure personnel performing contract review, job planning, heat treating, and associated quality and test functions are competent to perform assigned tasks?

Reading this question carefully, you can see there are several requirements within this single question. Do personnel performing 1) contract review, 2) job planning, 3) heat treating, and 4) quality-related tasks receive training that ensures they are 5) competent to perform the task? In this article we are discussing training for furnace operators, but as you can see, this question includes training for other areas that have the potential to affect heat treat. The way question number five is worded should push us more toward competency training that would include internal procedures and policies, less metallurgy, and industry/prime specifications.

It is more common now for engineers to document the required parameters based on material and customer requirements and flow this down to the heat treater who operates the furnace. It seems heat treaters are becoming less common and furnace operators are taking their place.

SUMMARY

Of course, training furnace operators will have its challenges. It is important to find furnace operators with the approach that is best for your operations. Assuming the training plan is sufficient for furnace operators to perform their job successfully, operator error should be seen as an opportunity for engineering, quality, and management to re-examine their training program to mitigate possible mistakes.

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TAKE ANOTHER LOOK AT DEEP CRYOGENIC TREATMENT

Research being done on this process is showing that it can be advantageous to creating longer-lasting products and tools that cost less.

By FREDERICK DIEKMAN

What is happening in the world of Deep Cryogenic Treatment (DCT)? Research into this field is exploding. Research is coming from companies and major universities in China, India, Hungary, Turkey, Pakistan, Poland, Iran, Italy, the United Arab Republic, Korea, and others. The research is covering many facets of DCT. There are three major research topics now.

1. DOES IT WORK?

The first topic is the perennial theme of determining if DCT "works" and what it works on. The present papers are well written and include research into tool performance, use of DCT on grinding and EDM situations, the use of DCT on various automotive components and tooling components, electrical components, and in a variety of situations. Many different tests are performed to establish what can be expected of the process. Tests include fatigue tests, abrasive tests, corrosion tests. wear tests, electrical tests, and more. Originally thought to only work on hardened steel, DCT has now been absolutely proven by formal research to work on a wide variety of materials and a large variety of uses.

An example of this is a research paper analyzing the results of DCT Kevlar fibers. The title of the article is "Modification of tensile, wear, and interfacial properties of Kevlar fibers under cryogenic treatment" [1]. This research paper tested fibers treated with two time/temperature profiles of treatment. It then tested tensile strength, surface morphology, interfacial shear strength (IFSS), molecular structural changes, and abrasion resistance. They found tensile strength increased 24.9 percent, morphology changes that increased the IFSS 18.9 percent, and abrasion resistance enhanced more than 50 percent.

Another example is "Influence of Deep Cryogenic Treatment (DCT) on Thermo Mechanical Performance of AISI H13 Tool Steel" [2]. This paper explores thermal mechanical performance of H13 using pin-on-disc high temperature wear testing and stress rupture tests. Stress rupture time increased by more than 11 percent, impact resistance was improved by 18 percent, and wear rate was reduced by 32 percent when compared to conventional heat-treated sample.

Tests like these are being done on many alloys of steel, copper, stainless steel, and other materials. They are also being done on cutting tools and on EDM situations.

Research is pouring in from all over the world proving that deep cryogenic treatment is the finishing touch to products that makes them perform head and shoulders above untreated products. (Courtesy: Frederick Diekman)

2. WHY DOES DCT WORK?

The second topic of research is investigating *why* DCT works. DCT was originally thought by rather uninformed metallurgists to only work due to the conversion of austenite to martensite in ferrous metals. But that did not account for it working on various metals, carbide, plastics, and other materials. Austenite-to-martensite conversion does not account for treated brake rotors lasting seven times as long as untreated as in the U.S. Postal Service tests done in the laboratory. Normal cast-iron brake rotors have pearlitic microstructure and no detectable austenite. It does not account for the increase in sound acuity achieved by treated vacuum tubes and other sound reproduction gear. It does not account for the substantial increase in strength available in Kevlar and other fibers. So, something else is happening to the structure. A lot of research is being done on carbide formation, the precipitation of elements in the crystal structure, and the movement of atoms in the crystal structure. Researchers are trying to find out precisely why the process works so they can optimize the results.

An example of a paper that illustrates this second topic is: "Effect of deep cryogenic treatment on internal friction behaviors of cold work die steel and their experimental explanation by coupling model" [3].

This paper looks into the internal friction behavior in cold work tool steel. It is tested before and after DCT. The experimental results include the Snoek relaxation and its dependence on carbon concentration with the soaking time at liquid nitrogen temperatures. It discusses the Snoek–Ke–Koster (SKK) relaxation and explains by coupling model, which is based on the considering of the cooperative migration of the foreign interstitial atoms C, N, O (FIAs) caused by two kinds of interactions. These interactions include the FIAs themselves and interactions between the FIAs with time-dependent strain field of dislocations. The decreasing of the Snoek peak height is indicated by the solute C amount in matrix being reduced after DCT treating. Moreover, the carbon atoms segregated to nearby dislocations, producing a strong Snoek–Ke–Koster relaxation. The paper concludes:

"In this paper, the experimental features of Snoek relaxation and Snoek–Ke–Koster relaxation in cold work die steel carrying out DCT treating are investigated. The decreasing of Snoek peak height demonstrated that the solute carbon amount in matrix is reduced after DCT treating as well as increasing soaking duration at the lowest temperature. Moreover, a successfully application of the coupling model to explain the Snoek–Ke–Koster relaxation and the motion of dislocations dragging along the Cottrell cloud of FIAs is presented. The results were shown that the interstitial carbon atoms segregate to nearby dislocations in the process of deep cryogenic treatment. These segregated carbon atoms nearby the dislocations act as growing into nuclei for carbide during tempering."

Much work is being done on the movement of carbon atoms and other alloying elements. This is helping to explain the formation of carbides, the relief of residual stresses, and changes in the crystal structure. It is making it clear the changes done by DCT are often in the crystal structure, not just in the microstructure.

3. THE OPTIMIZATION OF THE DCT PROCESS PARAMETERS

The third topic of the research that we are now seeing is the optimization of DCT. Research is being done in order to find the optimum time/temperature profile to run on a given material. It turns out that some materials perform better with long soak times, and some are better with short times. It is also being found that some materials such as fibers respond better when the initial decrease in temperature is drastic. Some testing is being done so the shortest processing time can be done for production purposes.

An example of this is: "Tensile Properties and Microstructures of a 2024 T351 Aluminum Alloy Subjected to Cryogenic Treatment" [4]. This paper tested tensile properties of samples treated with a hold of 2, 4, 6, 8, and 12 hours. This paper found that the improvements of tensile properties were related to the time spent at the low temperature point but started to decrease after a six-hour hold. It also found that grains in treated specimens were more uniform. Thus, a hold of six hours was the optimum for these tested properties.

TAKE A NEW LOOK AT THIS PROCESS

Look at DCT with both your production processes and your product design in mind. Why? Because research is pouring in from all over the world proving that DCT is the finishing touch to products that makes them perform head and shoulders above untreated products. Many companies are finding that by offering superior products that last longer and reduce customer expense, they can take over market share. A number of these companies are moving into markets where they have little-or-no current participation in. This minimizes the effect DCT has on their own present sales at the expense of the sales of their competition. If their competition does not respond with improved products, the competition will lose market share. The fact that many of these companies are using DCT to penetrate markets that are not producing in the U.S. makes it difficult for U.S. companies in their current effort to make American products the best available.

There are other reasons to look into DCT. Currently, climate change is a hot topic with many people. Making products last longer goes a long way in mediating the effect that building the product has on the environment. DCT reduces the energy, raw materials, and the labor needed to accomplish the same job an untreated component does.

Currently The Cryogenic Society of America's data base on DCT research articles contains 178 peer reviewed scientific papers from major colleges, universities, and government laboratories. Many more await review, and the influx of new papers is accelerating. DCT is a process that will make a huge difference in the future of many products. The data base is available at cryogenictreatmentdatabase.org.

If your goal is to make excellent, long-lasting products, as well as reducing your tooling costs, take a new look at this wonderful and useful process.

REFERENCES

[1] Modification of tensile, wear, and interfacial properties of Kevlar fibers under cryogenic treatment; Fujun Xu, Wangxizi Fan, Yinnan Zhang, Yang Gao, Zhemin Jia, Yiping Qiu, David Hui; Composits Part B 116 (2017) 398-405; www.elsevier.com/locate/compositesb.

[2] Influence of Deep Cryogenic Treatment (DCT) on Thermo Mechanical Performance of AISI H13 Tool Steel; Valmik Bhawar, Shreyans Khot, Prakash Kattire, Mohan Mehta, Rajkumar Singh; Journal of Materials Science and Chemical Engineering, 5, 91-101; dx.doj.org/10.4236/msce.2017.51013; Published January 16, 2017.

[3] Effect of deep cryogenic treatment on internal friction behaviors of cold work die steel and their experimental explanation by coupling model; Shaohong Li, Lihui Deng, Xiaochun Wu, Hongbin Wang, Yong'an Min, Na Min; Materials Science and Engineering A 527 (2010) 7950-7954; www.elsevier.com/locate/msea.

[4] Tensile Properties and Microstructures of a 2024 T351 Aluminum Alloy Subjected to Cryogenic Treatment; Jianzhong Zhou, Sugiang Xu, Shu Huang, Xiankai Meng, Jie Sheng, Haifeng Zhang, Jing Li,Yunhui Sun, Emmanuel Agyenim Boateng; Metals 2016, 6,279, doi:10.3390/met6110279 October 13, 2016.

ABOUT THE AUTHOR

Frederick J. (Rick) Diekman is president of Controlled Thermal Processing, Inc. He graduated from Iowa State University in 1972 with a degree in engineering. He has worked in both the plastics industry and the wear resistance industry. He has worked in wear and failure resistance projects for entities such as Ford Motor Company, General Motors, American Motors, Cummins Diesel, Fel-Pro, Rubbermaid, Illinois Institute of Technology Research Institute, the U.S. Arms Aviation and Missile command, Honeywell, and others on wear and failure resistance of both tooling and products. He became active in the field of Deep Cryogenic Treatment in the mid 1990s. He was founder and chair of the ASM Cryogenic Processing Sub Committee, taught an ASM course on Deep Cryogenic Treatment, lectured on DCT at ASM functions, and has written multiple articles for ASM. He wrote the definition of DCT for ASM's Handbook 4A. He was instrumental in the formation of the Cryogenic Society of America's data base on research articles in the field.

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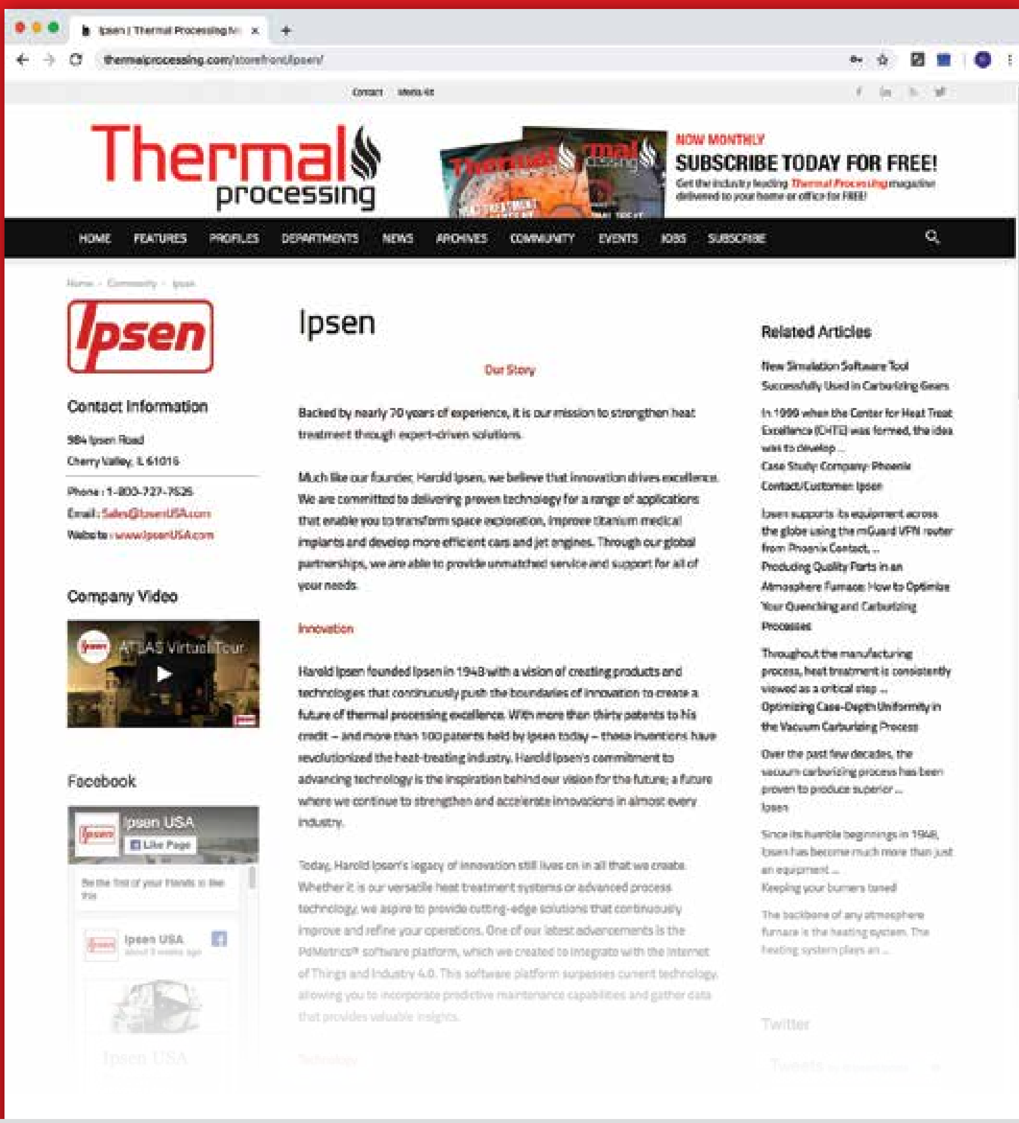

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VACUUM HEAT TREATMENT

FOR ADDITIVE MANUFACTURING

Figure 2: Detail of a TAV furnace hot chamber in molybdenum.

Vacuum heat treatment is a necessary post process step when specific components and materials processed with SLM technology are taken into consideration.

By ALESSANDRO FIORESE

Additive manufacturing means any technology capable of obtaining a final component starting from a 3D CAD file and adding material layer by layer. At a theoretical level, additive manufacturing only coincides with the 3D-part construction phase. In reality, in order to fully understand this technology, a series of other preprinting and postprinting activities must be considered, which constitute the entire supply chain of additive manufacturing.

In this article we will analyze the activities that precede and follow 3D printing, paying particular attention to the requirements of the materials and the processes necessary to obtain a high quality production.

THE PREPRINTING PHASE

If we limit the field of additive manufacturing to the single and more widespread powder bed technology selective laser melting (SLM), during the entire supply chain it is essential to take care of the atmosphere that surrounds the material in all its production steps.

For example, considering the production of powders as a preprinting phase, it is necessary to pay a lot of attention to how they are produced. If the powders were obtained through an atomization process in an unsuitable atmosphere, we could find, in the printing phase, oxidized powders, which could be particularly difficult to melt or could melt generating defects inside the material of the molded component.

Assuming that the starting point of the powders is optimal, that is that the powders have been produced correctly in terms of geometry and absence of oxides, even during the process of 3D printing it is essential to control the atmosphere inside the accretion chamber. This is easily understood since 3D SLM printing can be compared to a continuous welding process in which the fused pool must be continuously protected by inert gas. Despite the inertization of the interface between the molten pool and the chamber environment, small residues of oxygen or slight impurities contained in the gas, not perfectly pure, can result in unwanted inclusions within the final piece with consequent unacceptable colors and a deterioration of mechanical performance in a future use.

Also, the postprinting phase is important to optimize the mechanical properties of the components. TAV Vacuum Furnaces has achieved some interesting results in the lab using vacuum heat treatments.

THE POSTPRINTING PHASE

After 3D printing, most of the materials that can be printed with SLM technology always need a heat treatment. This heat treatment can be de-tensioning (to release most of the internal tensions accumulated in the material during the printing phase) or of another type (to try to optimize the mechanical properties of the component according to its specific application).

Usually these treatments are carried out in air or in a controlled atmosphere.

In reality, TAV Vacuum Furnaces has experimented in its internal

Figure 1: The TAV Vacuum Furnaces R&D Laboratory.

Figure 3: SLM samples in 316 L steel before heat treatment. The samples were printed by SAIEM and analyzed by the University of Genoa (DCCI).

Figure 4: SLM samples in 316 L steel after heat treatment. The samples were printed by SAIEM.

Figure 5: SLM samples in Ti6Al4V before heat treatment printed at the CNR, Institute of Chemistry of Condensed Materials and Energy Technologies, CNR ICMATE, Lecco site.

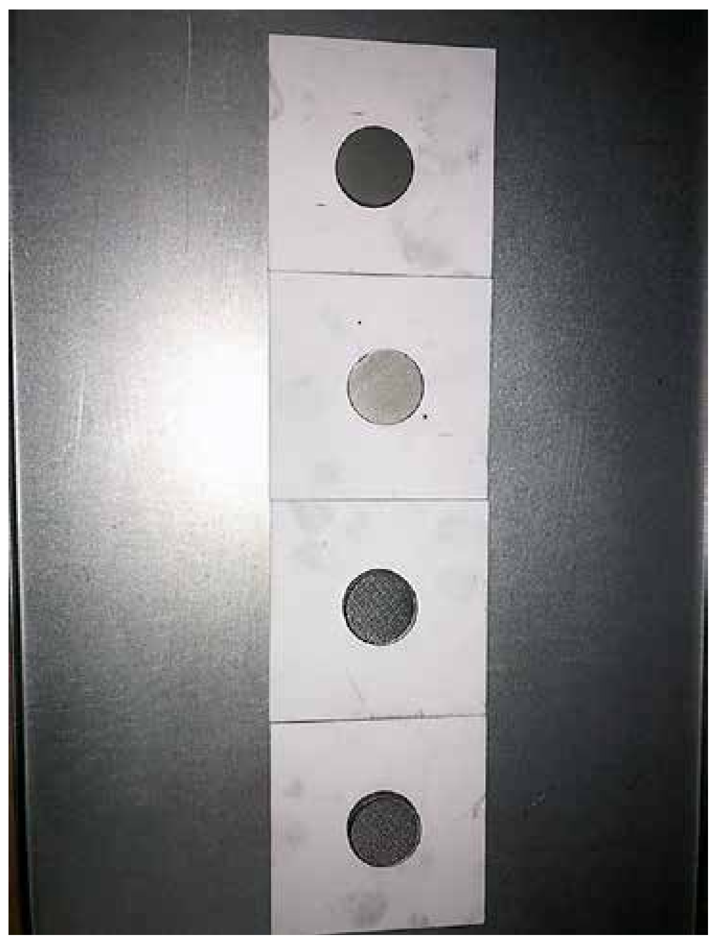

Figure 6: SLM samples in Ti6Al4V after heat treatment printed at the CNR, Institute of Chemistry of Condensed Materials and Technologies for Energy, CNR ICMATE, Lecco site.

If we limit the field of additive manufacturing to the single and more widespread powder bed technology selective laser melting (SLM), during the entire supply chain it is essential to take care of the atmosphere that surrounds the material in all its production steps.

Figure 7: SLM samples in Ti6Al4V for pre-heat treatment fatigue tests.

Figure 8: SLM samples in Ti6Al4V for post-heat treatment fatigue tests.

laboratory (Figures 1 and 2) that on specific components and materials, such as stainless steel (Figures 3 and 4), titanium superalloys (Figures 5, 6, 7 and 8), superalloys of nickel and CoCr alloys, the use of vacuum is required.

In the case of titanium, even a low vacuum level around 10-3 mbar is not sufficient.

CONCLUSIONS

Our experience, resulting from collaborations with our customers and different universities, teaches us that vacuum is able to:

› Minimize surface contamination at high heat treatment temperatures, leading to a consequent improvement in the mechanical response of the component.

› Make mechanical and corrosion verification tests of the various printed components extremely repeatable.

› In some cases, it can clean up the samples surfaces contaminated by printing processes, making them shine, that, as we have already seen, take place in a controlled atmosphere but not in total absence of oxygen.

In addition to these benefits, there is also the fact that the materials mentioned are mostly used for aerospace and medical applications, in which very strict rules must be respected to reduce surface contamination and to maximize mechanical properties.

For what has been presented so far, the vacuum heat treatment turns out to be a mandatory post process step when specific components and materials processed with SLM technology are taken into consideration.

ABOUT THE AUTHOR

Alessandro Fiorese is R&D Chief Engineer at TAV Vacuum Furnaces SPA. He attended the Engineering University at the Politecnico of Milan. There he developed theoretical knowledge in the field of materials (cementitious materials, composites, metals, polymers, ceramics, and advanced ceramics) and nanotechnologies. In 2017, a research and development laboratory was set up at TAV, which involved the installation of the following machines: a vacuum furnace, a PVD coater, a durometer, and an optical microscope. Fiorese's current role is to encourage, through collaborations, the scientific exchange between TAV and various research centers, universities, and companies to develop knowledge in the field of new technologies (e.g. additive manufacturing) and vacuum heat-treatment processes.

INDUSTRIAL HEAT TREATING

OFFERING HONESTY AND EXPERIENCE

Industrial Heat Treating's large capacity aluminum furnaces can accommodate a wide variety of customer needs. (Courtesy: Shutterstock)

Industrial Heat Treating — one of the largest aluminum heat treaters in the New England area — has been offering commercial heat-treating services to a myriad of industries for more than 75 years.

By KENNETH CARTER, Thermal Processing editor

Industrial Heat Treating has been heat treating metal for decades, and the company is packed with experience to make sure jobs are done right, done efficiently, and done quickly.

And Industrial Heat Treating has made quite the reputation for being able to tackle just about any job, according to Brian Fisher, CEO and CTO of Industrial Heat Treating.

Industrial Heat Treating offers a diverse selection of processes to meet today's growing industry and technology. The company's large capacity aluminum furnaces can accommodate a wide variety of customer needs, and it is one of the largest aluminum heat treaters in the New England area.

The company does a lot of aluminum heat treating and has a car bottom furnace for treating big orders of steel such as billets. It has atmospheric furnaces, induction furnaces, and vacuum furnaces. Essentially, no part is too big or too small for Industrial Heat Treating to process, according to Fisher.

SERVING MANY INDUSTRIES

Industrial Heat Treating's customer base encompasses many industries such as medical, auto, government, power generation, musical instruments, food industry, safety and alarm systems, electronics, and many more.

"Medical parts go in the vacuum furnace, because they're very clean and shiny," Fisher said. "Anything you want very, very, very shiny has to go in the vac, because it gets quenched with nitrogen. The nitrogen is delivered in liquid form, but when it goes in that tank, we have a vaporizer to change it into a gas. As soon as the furnace shuts off, the nitrogen gets pumped in. And instantaneously, the temperature goes from 2,250 Fahrenheit to 50 degrees."

The car bottom furnace can get up to 2,000 degrees Fahrenheit, and Industrial Heat Treating's atmospheric furnaces can get up to 1,900 degrees Fahrenheit, according to Fisher.

"Those are generally for smaller parts," he said. "And they have an internal quench tank, so that once the time is over for the heat process, the door will open internally, and two chains will take the basket and bring it further into the furnace where the oil quench tank is. There's an elevator that lowers it into the tank to quench the parts. That's all self-contained."

Although Industrial Heat Treating mainly deals with aluminum and steel, Fisher said bronze is also something the company is equipped to process.

"We don't do a lot of bronze, but we advertise that we could do any metal, and I believe it," he said. "I would say the person with the least experience here has 35 years of experience, and the person with the most has 40."

EFFICIENCY IS THE GOAL

That experience is vital to the efficiency that Industrial Heat Treating boasts, according to Fisher.

"When the truck pulls up, they don't even have to look at the paperwork," he said. "They know just by looking at it who it belongs to. They come up with a forklift, and they take what they know is theirs — especially aluminum."

To that end, Fisher points out that nothing is ever done really wrong.

"We have quality control; we test everything for hardness, and basically that's what we sell: hardness," he said. "Or if it's annealed, then softness. But you still can test that. We have all kinds of quality-testing machines for hardness. So, if I can add speed — get it back a day or two sooner than normal — then they're happy."

Quality control experts survey and calibrate the company's equipment each week, according to Fisher.

"They give us a third-party report that's available if the customers want to see it," he said.

Industrial Heat Treating takes pride in its ability to offer quality and service, but Fisher likes to add one more item to that list: efficiency.

"I know we can get it done faster than a lot of people, because the guys here have been here so long," he said.

TAKING CARE OF CUSTOMERS

With all the jobs that are well within Industrial Heat Treating's area of expertise, occasionally, a job may not fall into that window. But Fisher said it's important that a customer know that up front.

"There is some work we can't do," he said. "Customers usually




Industrial Heat Treating's customer base encompasses many industries including medical in which equipment is treated in a vacuum furnace, because it needs to be very clean and shiny. (Courtesy: Shutterstock)

want every job quoted. I'll get an email; the quote will come in, and I'll bring it downstairs. Basically, what I'm looking for is numbers: What's it going to cost? Sometimes, they put, 'NQ' — no quote. And then I say, 'Well, why?' And they say, "Well, here's the story: If I try to get it to that hardness, I'm going to destroy the parts. They're going to get destroyed.'"

To that end, it's important to his customers to ultimately get their job done, so part of Fisher's routine is to suggest the names of other potential heat-treaters — but with a caveat.

"I would tell them: Don't send them everything," he said. "Send them one or two parts, especially with something that's intricately machined. That costs a lot of money for the guy. And I think they appreciate that. Honesty is the big thing. To me, a job isn't as important as keeping the customer. You've got to keep the customer happy, so he'll come back. If you think you can gouge them, that's not a good relationship. You've got to be honest with them. You've got to be fair."

STARTED IN 1942

Being located near Boston, Massachusetts, Industrial Heat Treating began its long history in 1942 where they used to aid in building ships for the U.S. Navy. The company set up shop on the Neponset River, which empties into the Atlantic Ocean. In the beginning, barges would bring the ships' massive gun barrels in to be treated. And since the parts were so large, the company had to treat the metal using sodium cyanide or potassium cyanide, according to Fisher.

"If you had a part that you couldn't get in a furnace, you made a bed of this sodium or potassium cyanide, and you put the metal in it and you just kept turning it," he said. "And the reaction made the metal hard."

Industrial Heat Treating is a third-generation, family-owned and operated business that reaches customers throughout the U.S. The company has continued to build on that reputation in the decades that followed World War II, and Fisher said since he has taken over the company, he has strived to make improvements that will only help make the services he offers even more lucrative.

TIME, TEMPERATURE, AND QUENCH

"Wherever the industry is going, I know what I'm trying to do," he said. "I'm trying to make sure the furnaces that we have are running. And it's time, temperature, and quench. And it's always going to be metal."

And although Industrial Heat Treating doesn't implement the latest, most-advanced furnaces, Fisher said he more than makes up for it with what the company can offer its customers on a daily basis.

"I'd say honesty and experience are the two major things here," he said. "And we have a huge customer base — huge. When we do it, it's done right. It doesn't come back. That's important."

Fisher said his team at Industrial Heat Treating prides itself in having outstanding customer service and quick turnaround.

"As part of the manufacturing process, we encourage our customers to allow us to participate with them in the production of a better product for their consumer," he said. "It is our goal to join our customer in delivering a superior product by choosing the right material from the start. Our employees are knowledgeable and experienced in the industry and are available to offer recommendations and suggestions to improve the end product."

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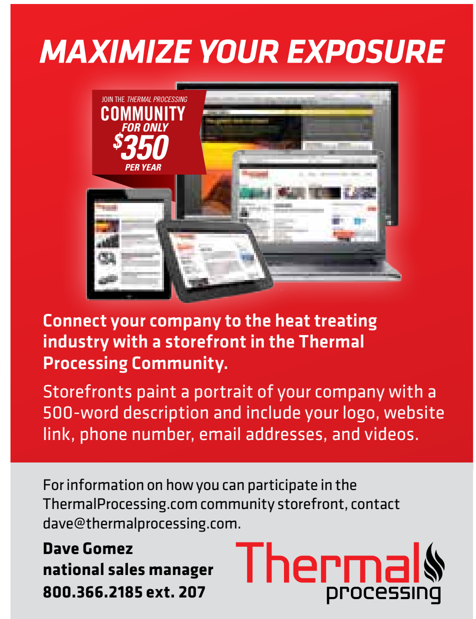

ADVERTISER INDEX ///

JUSTIN SIMS /// MECHANICAL ENGINEER /// DANTE SOLUTIONS

"The Dante software can be a tremendous help to the industry where it can be used for troubleshooting and root cause failure analysis from quench cracking."

Who is Dante Solutions, and what do you do with the company?

Dante Solutions is an engineering company with a main focus on improving heat treatment processes by application of sophisticated modeling tools. We do this so we can better understand the metal's response to heat treatment. This provides part-performance improvement through control of dimensions, control of microstructure, and control of final part stress state.

Our Dante software is a big part of this company, though it's far from who we are as a whole. As a whole, we're a group of mechanical engineers, process engineers, and software engineers, and we all have backgrounds in manufacturing processes, metallurgy, and failure analysis.

I'm a mechanical engineer here, and my job duties are generally principal engineer on consulting projects and training new Dante users. But I also do marketing, sales, IT, a little bit of everything.

What does Dante do for the heat treat industry?

We really have two main avenues to help the industry: Our first is our flagship software Dante. The second is our consulting services for troubleshooting existing processing problems or by taking more of a proactive approach and actually helping in process design. The tools and services we offer allow for faster implementation of new alloys and processes. They also help make part performance more reliable by having more dimensionally consistent parts from the processes, as well as consistent microstructure and hardness, while avoiding detrimental heat-treat related issues such as quench cracking, carbide formation, poor case depths, and bad residual stress profiles.

What is the Dante Flagship software, and how is it beneficial to the heat-treat industry?

Our flagship software is called Dante, which is an acronym for Distortion Analysis for Thermal Engineering. It's used to predict the metallurgical phase fractions, hardness, distortion, and residual stress from a thermal process. Our software also has a large database of materials that gives us a leg up over the competition. Chances are users won't even have to supply their own data, which is really significant because this isn't like a normal stress simulation where you just need room temperature values. We have to collect data over an entire range of temperatures all the way from room temperature to 2,000 F. Having that data on hand for our customers is really big.

The Dante software can be a tremendous help to the industry where it can be used for troubleshooting and root cause failure analysis from quench cracking. But while that's a great use, we also like to see it used as a design tool. By using the software, green shapes can be fine-tuned for current processes or processes can be fine-tuned for a specific geometry. Grind stock can be determined accurately because you'll know the final dimensions after heat treat. Materials can be determined based on processing options and cross-sectional thickness. If you're stuck with one process, then what materials can I use? We even consider the carbide growth and dissolution for materials with strong carbide forming elements, so we're beyond Fick's second law of mass diffusion. But as far as troubleshooting of the heat-treat process goes, the biggest benefit is that it removes that black box.

What is the black box?

In the past in heat treating, you know what goes in as far as microstructure and dimensions, and you know what comes out, but you really have no idea what happens in between. It's basically a mystery. That's the "black box." By using the Dante software, one is able to see what happens during heat treatment in terms of thermal and microstructural stresses and strains. And then one's able to determine where the stresses and strains come from, which are usually related to phase transformation timings. Then you're able to use the software to conduct virtual trials to eliminate or reduce these unwanted stresses and strains. The software really does allow for a fundamental understanding of the heat treat process.

Where do you see heat treat in 10-20 years, and Dante's place in that future?

With respect to the heat-treatment simulation software, which is really where we want to be, we still want to offer consulting services just to stay current and to help those customers who don't have the capabilities to run the software. But we really want our focus to be on the software side. In the next decade or two, we see a big movement toward making modeling part of the heat-treat process path definition. And what I mean by that is we see part designers beginning to use the software to actually define the heat treatment of their parts as opposed to providing specifications. The downside then becomes: Where does the heat treater stand in all this? And the heat treater can turn around and use simulation to essentially advance the technology.

By using the software, they can run virtual trials instead of actual physical experiments to optimize processes, which reduces cost and time tremendously. But heat treaters can also use the software as a training tool for new hires as a way to offset "brain drain" from those experienced personnel who are retiring. We really feel that that's one of the big benefits of simulation.

MORE INFO dante-solutions.com