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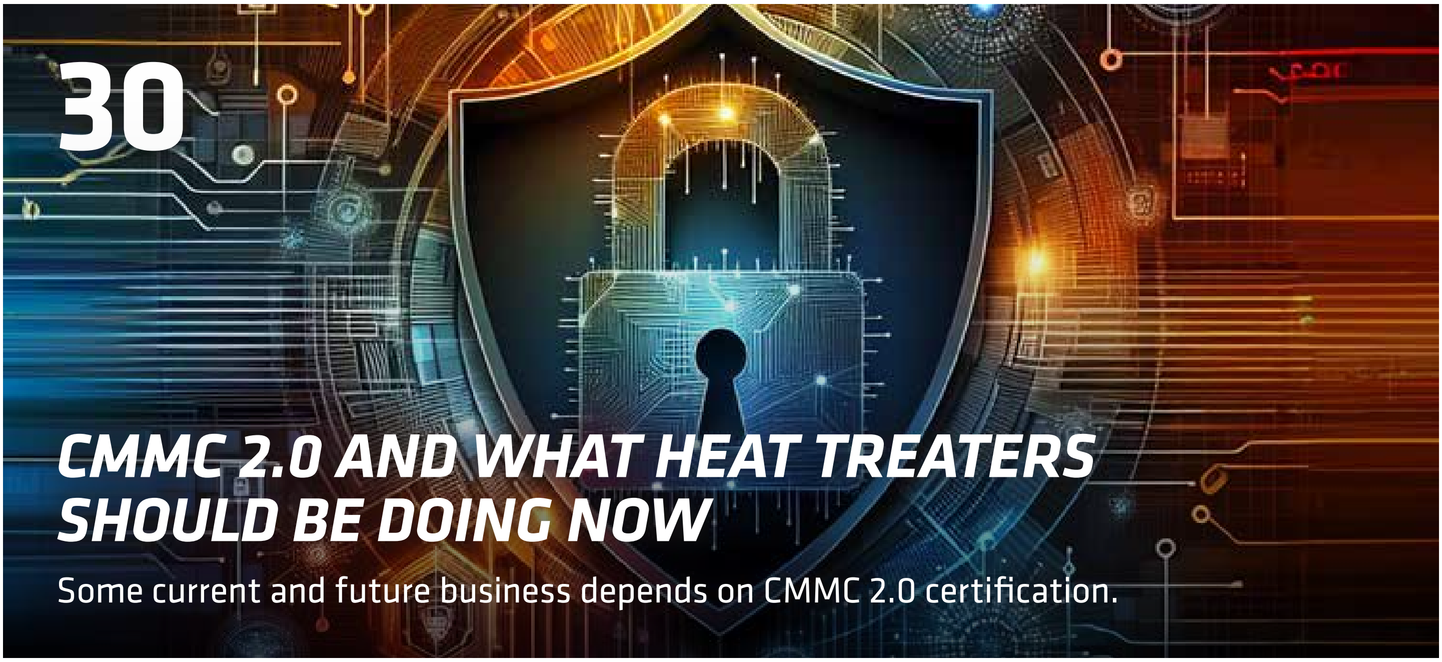

COVER PHOTO: SHUTTERSTOCK

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FROM THE EDITOR ///

October brings a wide-range of heat-treat topics

Part of what I enjoy about being editor of *Thermal Processing* is bringing you information about the heat-treating industry, and it's always an extra pleasure to bring you such a wide scope of topics, especially in a season that is synonymous with cornucopia.

That's right. Our October issue boasts a cornucopia of articles where I'm sure you'll find at least one that's of interest. (Although, I bet you'll find much more than that.)

Certifications are vitally important for many industries, but for the heat treaters, those certifications are critical for parts of all shapes and sizes to function properly — and legally.

In this issue's cover story, Joe Coleman, the cyber security officer and CMMC RPA (Registered Practitioner Advanced) for Bluestreak Compliance™ and Bluestreak | Bright AM™, takes a deep dive into the Cybersecurity Maturity Model Certification (CMMC) 2.0, and what heat treaters should be doing about it now. In the article, Coleman says that, for heat treaters, achieving and maintaining CMMC 2.0 certification is not just about compliance; it is about securing their place in future business opportunities and protecting their current operations from potentially catastrophic cyber threats.

The aerospace industry is an important user of the services and products within the heat-treat industry, so our next story is devoted to that subject.

In the article Abdellah Lahbari, Kenza Bouchaala, Hamza Essoussi, Mustapha Faqir, Said Ettaqi, and El Hachmi Essadiqi share their study findings on the homogenization heat treatment influence on microstructure evolution and mechanical properties for an Al–Li–Cu–Mg–Zr alloy used in lightweight aerospace applications.

This issue's final article from Volker Heuer, Jochen Friedel, David Bolton, Orlando Garcia, and Xin Chen looks at the advanced distortion control for case hardening of transmission components. The article goes into great detail about this low-pressure carburizing and high-pressure gas quenching process that offers a significant potential for advanced distortion control where the gas-quenching process provides a more homogenous heat-transfer coefficient on the surface of the quenched components when compared to quenching with liquids such as oil or polymers.

See what I mean? A lot of interesting articles and much more to exercise your heat-treating brain cells.

Enjoy this month's issue, and, as always, thanks for reading!

KENNETH CARTER, EDITOR
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Ipsen has launched the Field Service Engineer (FSE) Academy, a comprehensive 20-week training program that blends classroom instruction with practical, hands-on experience. (Courtesy: Ipsen USA)

Ipsen launches Field Service Engineer Academy

Ipsen has launched the inaugural Field Service Engineer (FSE) Academy, a comprehensive 20-week training program tailored for both new hires and more experienced field service engineers. The FSE Academy blends classroom instruction with practical, hands-on experience alongside veteran service technicians.

"We'll be focusing on the fundamentals of vacuum furnace repair," said Cavan Cardenas, Ipsen USA's technical training lead. "From day one of week one, we want our technicians to get an overview of our equipment, how it works, and what our customers do with it. We want the technicians to understand the purpose for each product in the line."

Technicians will also be taught important entrepreneurial and soft skills important for efficient, independent operations. "We want to build on their people skills within a busy service lifestyle," Cardenas said. "There's an adjustment to being on the road. We're looking for people who have the right mix of personality, attitude, and ability."

Darci Johnson, Ipsen USA's program and transformation manager, has invested time and effort into creating and implementing this program, grown from a program which ended in 2020 at the start of the COVID pandemic. Recruited by Ipsen leadership in late 2022 to deliver a comprehensive field training solution, Johnson said, "I have a lot of experience in instructional design, leading teams to build training programs from the ground up. As I started at Ipsen, there wasn't a formalized department dedicated to creating technical training programs specific to Ipsen Field Services."

The newly designed FSE Academy directly addresses the training needs of a field service team that is distributed across North America to serve customers from coast to coast. With a stronger, more consistent training program, Ipsen will expand more localized expertise, ensuring customers have more opportunities to work with the technicians they're familiar with.

"The success will lie in working with customers that weren't previously choosing Ipsen service," Johnson said. "Expanding our outreach, building relationships, and letting our furnace buyers know that working with Ipsen service is the best option."

MORE INFO www.ipsenglobal.com

Auto component maker uses Nitrex to enhance operations

A leading European automotive component supplier has successfully digitized its heat-treatment operations with the implementation of the QMULUS digitalization platform from UPC-Marathon, a Nitrex company. This strategic upgrade is set to significantly boost operational efficiency and performance, aligning with the stringent accuracy and precision requirements of the global automotive market.

Imagine trying to piece together a complex puzzle where each piece comes from a different set. This is often the reality in heat-treat environments where data is scattered across various systems — sensors, controllers, machines, ERP (Enterprise Resource Planning) systems, quality management software, and more. Each of these systems speaks its own language, making it nearly impossible to create a coherent picture of operations. This fragmentation leads to inefficiencies, errors, and delays that can cost companies time and money.

Previously, the manufacturer relied on multiple systems to manage its heat-treatment operations. While functional, these legacy systems lacked remote control capabilities and required separate management for different furnaces.

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.

An automotive component manufacturer has successfully digitized its heat-treatment operations with the implementation of the QMULUS digitalization platform from UPC-Marathon, A Nitrex company. (Courtesy: Nitrex)

Recognizing the need for a unified, modern digitalization solution, the company transitioned to QMULUS to integrate and streamline all furnace operations.

The chosen solution, QMULUS Essential & Analytics with the add-on Operations app, provides a comprehensive suite of features, including advanced asset management, chart recording, remote control, recipe building, performance dashboards, and comprehensive operational analytics. QMULUS now oversees three nitriding furnaces and two carburizing belt furnaces, enhancing the management, utilization, efficiency, and overall performance of these five assets.

The integration of QMULUS has already begun transforming operations, leading to more responsive and streamlined processes. Production workers benefit from real-time data and alerts, enabling more accurate monitoring and process adjustments. Maintenance staff can leverage remote diagnostics and alert notifications for swift issue resolution and preventive maintenance, ultimately extending the equipment's lifespan. Plant managers now have access to extensive performance dashboards and analytics, facilitating informed decision-making and optimized plant efficiency. Heads of heat treatment are using detailed operational analytics and recipe management features to enhance the precision of heat treatment processes and ensure consistent product quality.

"Our collaboration with this tier 1/2 supplier has yielded significant improvements in their operational workflows," said Daniel Gonschorek, UPC-Marathon technical sales manager. "The integration of QMULUS is not only advancing their internal processes but also delivering tangible gains in efficiency and performance. By enhancing production efficiencies and reducing waste, QMULUS supports their commitment to innovation and aligns with the highest quality and sustainability standards. This digital transformation positions them strongly within the competitive automotive supply chain."

MORE INFO www.nitrex.com

Tenova to supply three ACL to Sanbao Iron & Steel

Tenova LOI Thermprocess and Tenova Technologies (Tianjin) signed three contracts in September for the supply of three annealing and coating lines (ACL) for non-grain oriented (NGO) silicon steel with the Sanbao Group during a signing ceremony held at the headquarters of Sanbao Iron & Steel Co., Ltd. in Zhangzhou, China. Tenova LOI Thermprocess is one of the leading companies supplying industrial furnace systems for the heat treatment of metals and is part of Tenova, a provider of sustainable solutions for the green transition of the metals industry.

The event was organized by the Sanbao Group and included the participation of Wang Guangwen, chairman; Dong Guibo, vice general manager of Sanbao Group; Sascha Bothen, senior vice president of sales; and Wolfgang Eggert, general sales manager, both from Tenova LOI Thermprocess.

The scope of the contracts includes three annealing and coating lines (ACL) for NGO silicon steel heat-treatment furnaces that will be supplied by Tenova LOI Thermprocess and Tenova Technologies (Tianjin). These important contracts represent the beginning of Sanbao Group's entry into the field of silicon steel production and are part of the "Cold rolled Silicon Steel and Metal Products Deep Processing Project," Sanbao's new ambitious greenfield project for electrical steel that aims to obtain the highest surface quality and best magnetic properties in NGO electrical steel for Southeast China.

Tenova LOI Thermprocess took part in the on-site signing ceremony in Zhangzhou with the Sanbao Group, for a new silicon steel project for high-grade NGO annealing and coating heat treatment lines. (Courtesy: Tenova)

The contracts cover the design and supply of the advanced process equipment including commissioning, and underline the effective cooperation between Tenova and the Sanbao Group. Two electric arc furnaces (EAF) contracted by Tenova Group have been put into operation and are running smoothly.

"Tenova and Sanbao have already collaborated successfully establishing Tenova's Consteel® technology and the successful references of Tenova LOI Thermprocess in the heat treatment of electrical steel and great efforts in the research & development in this sector fully convinced us to this investment," said Guangwen.

"It was a great honor for us to participate in the signing ceremony of the Sanbao Group in Zhangzhou, which emphasizes their trust in our technology," said Bothen. "We are proud to further strengthen the cooperation and work together to help propel forward the green energy transition in the steel industry."

Sanbao Group was founded in 1999 and has become a comprehensive modern steel leading enterprise with both long and short processes and advanced equipment in China and abroad. The group currently has more than 5,000 employees and has fixed assets of over 20 billion yuan. In 2023, the Sanbao Group won for the first time the honors of "Top 500 Enterprises in China," the honors of "National High-tech Enterprise," and "National Green Factory," as well as many other awards.

MORE INFO www.tenova.com
www.loi.tenova.com

Analytic Stress Relieving names Lunsford CEO

Analytic Stress Relieving, Inc. (ASR), a provider of on-site heat-treating services, announced the appointment of Kregg Lunsford as chief executive officer. ASR is backed by Capstreet, a Houston-based lower middle market private equity firm.

Lunsford joins ASR after more than a decade as president of TNT Crane & Rigging, headquartered in Houston, where he led the company's geographic expansion through organic and acquisitive growth. He began his career at Arthur Andersen.

"I'm delighted to join ASR and look forward to building on the Company's strong foundation to help grow our geographic footprint and our menu of services," Mr. Lunsford said. "ASR's commitment to safety, customer satisfaction and a strong team-based culture is important to me, and I look forward to leading the Company into the next phase of its evolution."

Capstreet Partner Paul De Lisi added, "Kregg brings exceptional leadership and deep experience in safety and operations across a range of relevant industries. We believe his stewardship will help ASR expand its operations strategically through organic and acquisitive growth."

MORE INFO www.analyticstress.com or www.capstreet.com

Wisconsin Oven ships small batch oven for curing parts

Wisconsin Oven has announced the international shipment of one electrically heated small batch oven to a Canadian manufacturer of automotive components. The oven will be used for curing parts.

This small batch oven has a maximum temperature rating of 650°F and chamber dimensions of 4' W x 4' L x 4' H. Guaranteed temperature uniformity of ±10° F was documented prior to shipment with a nine-point profile test conducted in an empty oven chamber under static operating conditions.

The unit is constructed using patented high-efficiency panel seams that provide 25 percent better insulating efficiency than traditional designs and a 4-inch-thick insulated floor. Two carbon steel shelves were included for loading parts and each shelf is rated for five pounds per square foot.

A small batch oven shipped by Wisconsin Oven to a Canadian manufacturer will be used for curing parts. (Courtesy: Wisconsin Oven)

The batch oven uses combination airflow to maximize heating rates and temperature uniformity of the product. The temperature is controlled by a Watlow F4T digital controller with easy-to-use color touch screen, PID temperature control with adaptive tuning, and Ethernet communication capabilities. A digital process timer with audible alarm and blue pilot light is also included on the oven

"The guaranteed temperature uniformity of ±10°F at the customer's process set points ensures consistent curing results and optimal part quality," said Tom Trueman, senior application engineer. "Wisconsin Oven is an industry leader in providing industrial ovens that meet tight uniformity requirements."

Unique features of this small batch oven include:

» Motorized dampers for controlled heating.

» Guaranteed temperature uniformity of ±10° F at 258°F.

» Side-hinge horizontal swing door.

» Two carbon steel shelves.

Shinning Alloy designed this versatile basket bottom, offering customers the flexibility to use it as both a base tray or basket, depending on specific operation needs. (Courtesy: Shinning Alloy)

» Watlow F4T digital controller with auto-tune function.

» Four-inch-thick insulated floor.

This electrically heated batch oven was fully factory tested and adjusted prior to shipment. 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

Shinning Alloy develops versatile basket product

Shinning Alloy has launched a new basket designed for multiple purposes, offering customers the flexibility to use it as both a base tray or basket, depending on specific operation needs.

The two half-trays connect the basket bottom, and the sides can be easily disassembled with a simple screwing mechanism, ensuring a user-friendly experience. This is a unique and premium product. The team at Shinning designed the basket after thorough communication with the customer about the furnace size and operation processes, resulting in the delivery of a high-quality product that not only meets the customer's requirements but also exceeds their expectations.

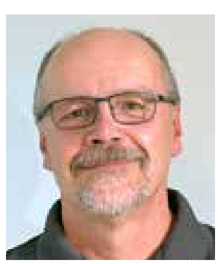
With years of experience working alongside international heat treaters and furnace makers, Shinning Alloy has honed its ability to design fixtures tailored to customers' specific needs.

MORE INFO www.shinningalloy.com

Ipsen promotes Chris Martin to regional service manager

Ipsen USA has promoted Chris Martin to regional service manager for the Southeast United States. In his new role, Martin will be responsible for leading a team of seven that includes six field service engineers and one service administrator.

Since joining Ipsen in 2018, Martin has served as a field service engineer in the Northeast. He came to Ipsen with decades of experience, including a multi-year furnace installation project in Germany. Martin plans to lead his region by sharing the lessons he's learned throughout his career. "The most important lesson I've learned is the value of treating customers with respect and honesty," said Martin. "Good customers will appreciate that and treat you the same way."



Chris Martin

"Throughout his tenure with Ipsen, Chris has been recognized for his 'can-do' attitude and the positive impact he delivers to our customers," said Dave Choate, Ipsen USA's director of field service. "As the new regional service manager, Chris will continue to foster the growth of our field service team through his mentorship approach."

Martin joins an experienced team of five other regional service managers, covering Southern California, the Northeast, Midwest, Southwest, and Western United States. Together, they have over 42 years of experience working with Ipsen's customers.

The Southeast region includes Tennessee, Alabama, Georgia, Florida, North and South Carolina, Virginia, Maryland, and Delaware.

MORE INFO www.ipsen.com

LECO releases new line of metallographic sectioning machines

LECO has launched the CX300 Series, an advanced line of metallographic sectioning machines designed to improve lab efficiency, safety, and ease of use — all while saving valuable bench space. Compact but powerful, the CX300 Series elevates metallographic sample preparation with cutting-edge technology and a user-centric design.

Available in three models, the CX300 offers a range of capabilities — from manual, quick cuts to fully-automated sectioning that allows operators to walk away during operation. This makes it the ideal solution for labs looking to increase output without sacrificing accuracy.

"Our CX300 Series delivers the reliability, safety, and performance LECO is known for, while offering innovative features for an excellent sectioning experience," said Matthew Germscheid, metallographic product manager at LECO.

Since 1936, millions of samples worldwide have been analyzed using LECO instruments for elemental analysis, gas chromatography, spectrometry, hardness testing, optical analysis, and more.

MORE INFO www.leco.com

Graphalloy bearings solve high-temp application issue

The senior project manager at a company that developed a new technology to recycle plastics reached out to engineers at Graphite Metallizing, manufacturers of Graphalloy self-lubricating high-temperature materials, to solve their bearing issues.

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®

Graphalloy's type 845-39 insert was used by a company recycling post-consumer and post-industrial plastics into new plastics to solve a production issue. (Courtesy: Graphalloy)

type UCFCS206-20, 4-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 pounds.
- SPD: 1,000 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 our 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 and said, "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."

A few weeks later, the project manager said 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.

MORE INFO www.graphalloy.com

Volkan Steels enhances production with Nitrex system

Volkan Steels Powders Metal San. Tic ve Ltd. Şti. (V'Steels), a leading Turkish tool steels supplier, has boosted production capabilities with the installation of a new Nitrex nitriding/nitrocarburizing system.

This addition aligns with V'Steels' commitment to expanding its value-added heat treatment services, ensuring top-quality tool and stainless steels for customers seeking to enhance the performance and durability of their tooling.

The new Nitrex turnkey system, model NX-1015, features a 2,000 kg (4,400 lb.) capacity, enabling V'Steels to perform advanced nitriding, nitrocarburizing, and post-oxidation treatments using Nitreg®, Nitreg®-C, and ONC® technologies. These advanced processes are essential for improving the wear resistance, fatigue strength, and overall durability of various tooling, including aluminum extrusion dies, die-casting dies, forging dies, and plastic injection molding dies, across diverse industries such as energy, petrochemistry, defense, and maritime.

As a first-time Nitrex customer, V'Steels selected the large-capacity batch furnace, NX series, for its proven performance and the expertise of Nitrex's metallurgical and engineering teams. The NX-1015 not only matches V'Steels' current production capacity but also offers room for future expansion, enabling the company to efficiently meet growing demands and enhance its service offerings. The system's accelerated cooling feature reduces process times, leading to faster turnaround, increased productivity, and consistent, high-quality results.

"The decision to integrate a Nitrex system was influenced by the expertise of the V'Steels team, several members of whom have prior experience with Nitrex from their previous roles," said Utku Inan of BDI Metal, Nitrex sales representative in Türkiye. "Our strong relationship and the team's deep understanding of Nitreg technologies made this an easy choice. We managed the installation and startup seamlessly, ensuring optimal performance from the start. V'Steels' positive feedback underscores their satisfaction with both the Nitrex system and our comprehensive support."

"The integration of the Nitrex system will significantly enhance the performance and reliability of tool steels, resulting in longer-lasting and more efficient tooling for V'Steels' customers," said Marcin Stoklosa, technical sales manager – EMEA region at Nitrex. "By utilizing Nitreg technologies, V'Steels is set to offer finished tooling that endures longer

Volkan Steels has recently expanded its capabilities by adding a Nitrex system for advanced nitriding and nitrocarburizing. This will allow Volkan Steels to offer even more comprehensive heat-treating services. (Courtesy: Nitrex)

under operational stress, translating into increased throughput and reduced downtime for their clients. This advanced treatment not only boosts tool durability but also improves operational value, giving V'Steels' customer a competitive edge through superior tool steel quality and consistency."

"Our heat treatment services, which began in 2023, have been strengthened by our recent investment in a Nitrex furnace," said Belgin Mert, general manager of V'Steels. "This enhancement allows us to comprehensively meet the heat-treatment needs of our long-standing business partners in the tool steel industry, enabling them to achieve higher performance. We are grateful to the Nitrex team and BDI Metal for their support at every stage throughout this process."

The order for the NX-1015 system was placed in October 2023, and production commenced in April 2024.

MORE INFO www.nitrex.com

Seco/Warwick will supply vacuum furnace for Huake

The Seco/Warwick Group will supply a horizontal vacuum heat-treatment furnace with a graphite heating chamber and a 15 bar absolute gas quenching system to Huake Casting Control Technology Co., Ltd. in China. The solution will be used to produce components used in the aviation and energy industries.

The Seco/Warwick Group's solutions are characterized by innovation and reliability. They are distinguished by modern control systems and precise charge-feeding systems. Vector® is the most versatile single-chamber vacuum furnace operating in more than 70 countries, heat treating millions of components meeting the highest standards every day. Vector vacuum furnaces provide a wide range of processes, and the compact, modular design allows the furnace to be adapted to specific needs. That is why they are one of the most frequently ordered vacuum furnaces for metal heat treatment, not only in Asia, but around the world.

The Vector furnace family guarantees the high quality of processed parts and surface protection. Thanks to the uniformity of temperature, work results are very repeatable. It is an ideal solution used in production requiring precision results. At the same time, it is a furnace characterized by low energy and process gas consumption. The solution's low rate of emissions translates into environmental friendliness, which aligns with the company's philosophy – SECO/ECO.

A Seco Warwick horizontal vacuum heat-treatment furnace with a graphite heating chamber and a 15 bar absolute gas quenching system supplied to Huake Casting Control Technology Co., Ltd. in China will be used to produce components used in the aviation and energy industries. (Courtesy: Seco/Warwick)

"Huake Casting Control Technology has become our customer as the result of the Seco/Warwick Group's increasing reputation in Asia," said Liu Yedong, managing director of Seco/Warwick China. "On the Chinese market, long-term relationships with customers are an important value. We want to provide partners with solutions which will allow them to grow and achieve their intended goals related to production, quality, and profitability.

Seco/Warwick's Chinese branch can now produce 20 CAB lines, eight to 10 VAC vacuum furnaces, and two to three VME furnaces per year. Seco/Warwick doubled the area of the manufacturing facilities in China last year. Today both production plants in China offer 10,000 m2 of production space.

China is a very important region for Seco/Warwick. Year after year, more metal heat treatment equipment is entering the market, frequently manufactured in the company's Chinese plants. The Seco/Warwick Group supplies solutions to the largest Chinese industry giants, which are on the Global Fortune 500 list. The new contract for the Vector furnace shows how important the value of partnership, quality, and a proven solution with many references is in the Chinese market.

"We were convinced to choose the Vector furnace because of its wide range of heat-treatment processes and applications, fast cycles with high pressure gas quenching, and low consumption of energy, process gases and other media," said Li Naixu, chairman of Huake Casting Control (Shanghai) Technology Co., Ltd. "Another undoubted advantage is that Vector is environmentally friendly and has low process gas emissions."

The 15 bar Vector vacuum furnace, with high-pressure gas quenching for Huake, can operate at high temperatures — up to 1,400°C — and has a maximum gross load weight of 800 kg. It will be ideal for producing precision gas turbine components and aircraft parts.

MORE INFO www.secowarwick.com

PAI Industries, ECM partner to increase efficiency

PAI Industries, manufacturer and distributor of high-quality parts to the heavy-duty truck industry, has partnered with ECM to bring heat treatment in-house with a NANO vacuum furnace system.

Adding to the already impressive 112,000-square-foot manufacturing facility with state-of-the-art machinery in Suwanee, Georgia, and outsourced heat treating, this in-house system expands PAI's capabilities to expedite production and increase capacity.

Transitioning from primarily outsourced heat treatment to in-house vacuum technology, they will be able to perform low-pressure carburizing and through-hardening 24/7, thanks to the modularity of the ECM NANO system, an external loader, three-position temper oven, and queuing positions. Additional benefits provided by vacuum technology include no IGO, zero CO2 furnace emissions, no fire hazards/open flames, increased repeatability, and improved metallurgical results.

Prior to project acceptance, testing was conducted in the ECM NANO located in the ECM USA Synergy Center (Pleasant Prairie, Wisconsin) to further validate improved metallurgical properties.

MORE INFO www.ecm-usa.com
www.paimanufacturing.com

Sinosteel, Tenova complete successful Energiron DRI test

Sinosteel Engineering & Technology Co., Ltd., a leading industrial technology and engineering service provider offering low-carbon metallurgy full lifecycle solutions, and Tenova, a leading developer and provider of sustainable solutions for the green transition of the metals industry, have recently agreed on the successful completion of the performance test for Baosteel Zhanjiang Iron & Steel Co., Ltd.'s new hydrogen-based 1,000,000 metric tons/year Energiron Direct Reduction (DR) plant.

The plant, designed by Tenova using Energiron, the innovative DRI technology jointly developed by Tenova and Danieli, and completed with the engineering by Sinosteel, is installed in the Zhanjiang Economic and Technological Zone, Guangdong Province. During the performance test, the plant achieved a milestone production of a total of 21,620 metric tons of direct reduced iron, after 168 hours of continuous full-load production, with a metallization rate of more than 94 percent and using a 70 percent hydrogen-based reducing gas.

The Energiron solution is the most flexible DR technology for virgin metallic unit production in terms of makeup gas utilization, and the most sustainable as it is designed to maximize reduction of CO_2 emissions. The plant installed at Baosteel, a Baowu Group company, has the flexibility to use different reducing gases, such as hydrogen (H_2), natural gas (NG), and coke oven gas (COG), in any combination or proportion, using the same Energiron Zero Reformer (ZR) scheme.

The full plant capacity is 1,000,000 metric tons/year, making it the largest and first-of-its-kind hydrogen-based DRI facility in China. It has been additionally designed to capture CO_2 that can be sold commercially, further reducing the plant's overall CO_2 emissions and providing an added revenue stream for the plant operations.

"The successful operation of the Baosteel Zhanjiang million-(metric)-ton hydrogen-based shaft furnace stands as a pivotal initiative in Baowu's efforts to promote low-carbon production," said Liang Lisheng, assistant general manager of Baosteel Zhanjiang Iron & Steel Co., Ltd., and director of the ironmaking plant. "Thanks to this project, Baosteel is proceeding towards its path of reducing carbon emissions, paving a new way for green steel produc-tion."

"Congratulations to Baosteel Zhanjiang on the successful completion of the 168-hour performance test of the million-(metric)-ton hydrogen-based shaft furnace," said Hua Guanglin, executive deputy managing director of Sinosteel E&T and general manager of Sinosteel MECC. "We are grateful to Baosteel for their support and pay tribute to the relentless efforts of the team. Building on this significant achievement, we will continue to dedicate our technology and engineering expertise to advancing the steel industry towards carbon neutrality goals."

"We are really satisfied with this project which confirms the great collaboration among all parties that participated in this achievement," said Stefano Maggiolino, president and CEO at Tenova HYL, the company center in direct reduction technology. "Thanks to our Energiron technology, we have provided Baosteel with the first direct reduction iron production line integrating hydrogen, natural gas, and coke oven gas for industrial production."

The sustainable hydrogen-based 1,000,000 metric tons/year Energiron Direct Reduction (DR) plant demonstrated the nominal production of DRI, reducing carbon dioxide emissions and marking a significant step in the green steel industry. (Courtesy: Tenova)

MORE INFO www.tenova.com
www.sinosteel.com

Seco/Warwick to deliver furnace for pharmaceutical use

Adamus, a European manufacturer of punch tools and spare parts for tablet presses, capsule presses, and blister machines used in the pharmaceutical industry, has ordered a Vector vacuum furnace to efficiently heat treat a wide range of punches used in tablet production.

The Vector vacuum furnace on order solves the partner's challenge to grow production in order to meet the increased demand for the number of punch hardening processes for tablet production.

"Adamus contacted us for the fourth time," said Maciej Korecki, vice president of the Vacuum Furnaces Segment at Seco/Warwick. "This time, the partner wanted to replace an older, inefficient vacuum furnace with oil hardening, with a modern, more ecological and more economical vacuum furnace with gas hardening. Vector will perfectly meet these needs. It is compact, so it will not take up much space, it is efficient and ensures process purity, which is extremely important in the pharmaceutical industry."

The Vector for Adamus is equipped with numerous options, including convection, directional cooling, and isothermal quenching, which increase the solution's efficiency and effectiveness. Thanks to the inverter control, users can switch on the optimal cooling power in the appropriate process segment. Another big advantage is low heat loss and good temperature uniformity in the graphite heating chamber.

The pharmaceutical industry is one of the most demanding in terms of standards, procedures, and technical parameters, which must be met by equipment involved in the production process. Complex components used in the pharmaceutical production process must be characterized by excellent workmanship and precision results. These finished components are integral to the manufacturing process, ultimately determining not only the final medical product, but also human health and life. Therefore, manufacturers of stamping tools, tablet presses, capsule machines, and other machines used in the pharmaceutical industry, when choosing solutions for their hardening plants, are guided primarily by quality, reliability and experience.

Vectors are very universal furnaces performing many complex processes. Graphite insulation and wide heating elements ensure long-term and reliable equipment operation in industrial conditions. During cooling, the cooling gas circulation, using a nozzle blowing system, optimizes and ensures uniform cooling of the processed elements. This is extremely important when processing elements for such a demanding industry as high-tech.

MORE INFO www.secowarwick.com

Mexico's Medal of Civic Merit awarded to Rafael Colás Ortiz

Prof. Rafael Colás Colás. (Courtesy: Universidad Autónoma de Nuevo León)

The Medal of Civic Merit of the Mexican state of Nuovo León was awarded to IFHTSE Executive Committee member Prof. Rafael Colás Colás by the state governor.

Colás was honored for his work on Technological Development through his post as professor at Facultad de Ingeniería Mecánica y Eléctrica of Universidad Autónoma de Nuevo León in collaboration with metal processing companies in Northeast Mexico and institutions in Europe and the Americas.

CONFERENCE UPDATES

Third International Conference on Quenching and Distortion Engineering
May 6-8, 2025 | Vancouver, Canada

The Third International Conference on Quenching and Distortion Engineering will be in conjunction with AeroMat 2025, May 5-8, in Vancouver, Canada. This is a continuation of the successful Distortion Engineering conference series and the Quenching and Distortion conference series. The first QDE was in Chicago in 2012 and has occurred at about five-year intervals. There is a strong focus on the effects of residual stress during manufacturing and methods to control distortion and residual stress.

Beyond the enlightening sessions and informative presentations, attendees can connect with peers during breaks, receptions, and special networking events. Moreover, the co-located exhibit hall, featuring cutting-edge technologies and products from AeroMat, ITSC, and AeroTech, will provide an ideal setting for fostering new relationships and exploring potential collaborations.

QDE will be co-located with AeroMat 2025, AeroTech 2025 and the International Thermal Spray Conference and Exposition (ITSC) 2025.

Motion in Heat Treatment – Heat Treatment in Motion
June 4-6, 2025 I Prague, Czech Republic

Motion in Heat Treatment — Heat Treatment in Motion is the fifth in its series. This conference is sponsored by AZTK (ASOCIACE PRO TEPELNÉ ZPRACOVÁNÍ KOVU) and will be at the Kaiserstein Palace in Prague. This event follows the third conference in Prague in 2016 and the fourth conference in Spartanburg, South Carolina. While the previous focus of the event was primarily on automotive applications, the focus has been widened to all transport applications including automotive, rail, and aircraft and marine applications of heat-treated and surface-engineered components. The event is combined with the European Conference on Heat Treatment.

IMPORTANT DATES

- **Abstract submission:** November 15, 2024.
- **Full paper submission:** March 15, 2025.
- **Submission of presentations:** May 15, 2025.

30th IFHTSE World Congress
August 18-21, 2025 I Suzhou, China

The 30th IFHTSE World Congress, sponsored by the Chinese Heat Treatment Society (CHTS), follows the 25th World Congress in Xi'an in 2018. More details are forthcoming as available. Deadline for abstract submission is February 28, 2025, with notice of acceptance March 10, 2025. The event will be at the Suzhou Shishan International Conference Center, Suzhou City, Jiangsu Province, China.

The long-history friendship between CHTS and the IFHTSE has already led to successful cooperation on several significant events, such as the Third International Congress on Heat Treatment of Materials in Shanghai in 1983, the 14th IFHTSE Congress (Shanghai, 2004), the 20th IFHTSE Congress (Beijing, 2012), the 25th IFHTSE Congress (Xi'an, 2018), and the Second International Conferences on Energy and the Future of Heat Treatment and Surface Engineering (Beijing, 2014).

This world congress will be focused on the organization of a congress that will deal with tradition and innovation in heat treatment and surface engineering. The 30th IFHTSE World Congress will be a good opportunity for delegates from a wide range of industrial and academic backgrounds to discuss and disseminate the recent progress, innovations, and developments in the field of heat treatment and surface engineering.

FOR MORE INFO ifhtse2025.com/index.html

IFHTSE EVENTS

MARCH 24–27, 2025
Tooling 2025
Trento, Italy

MAY 5–8, 2025
3rd QDE - International Conference on Quenching and Distortion Engineering
Vancouver, Canada

JUNE 4–6, 2025
Motion in Heat Treatment – Heat Treatment in Motion
Prague, Czech Republic

AUGUST 18-21, 2025
30th IFHTSE World Congress
Suzhou, China

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

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ONLINE www.ifhtse.org I **EMAIL** info@ifhtse.org

Breaking Ground: Decarbonization SUMMIT – Can you risk doing nothing?

IHEA's two-day SUMMIT will tackle the decarbonization challenges in the industrial heating industry. (Courtesy: Shutterstock)

The hottest topic facing the industry today will take center stage at the Industrial Heating Equipment Association's (IHEA) first Industrial Heating Decarbonization SUMMIT at the Conrad Indianapolis October 28-30. This high-level forum will tackle decarbonization challenges with a comprehensive mix of available technologies as well as those in development that allows companies to reduce their carbon footprint now while planning for the future. The SUMMIT is designed to be a gateway to the future of manufacturing heating processes, leveraging the energy and carbon connection, and sustainable environmental stewardship. It will help answer the question: Can you risk doing nothing?

"I think it's critically important that all parties being affected by decarbonization efforts come together to discuss both the opportunities and the challenges that companies face in moving forward," said IHEA Executive Vice President Anne Goyer. "We encourage everyone to bring their concerns to the SUMMIT, so our experts that make up the SUMMIT program, along with DOE and our exhibitors, can have honest discussions that will be productive for all who attend."

The two-day SUMMIT program contains a lineup of topics that will inform and guide attendees in their journey to decarbonization, along with a tabletop exhibition where attendees can visit with suppliers to learn more about the products and services that will help them navigate the decarbonization efforts.

TUESDAY, OCTOBER 29

Keynote Presentation

»**Understanding the US DOE Industrial Decarbonization Initiatives:** Dr. Avi Shultz.

Before undertaking change, it's critically important to understand why change is necessary and learn about ways companies can strategically work to engage the change to benefit their business. The U.S. Department of Energy through its new Industrial Efficiency and Decarbonization Office (IEDO), is committed to assisting companies to both understand and begin to implement changes that will help industrial processes to decarbonize. Dr. Avi Shultz will open IHEA's Industrial Heating Decarbonization SUMMIT with a keynote address that will lay the groundwork for embracing ways to start the decarbonization process.

The Energy-Carbon Connection

»**Energy Consumption and the Resulting Carbon Emissions:** Michael Stowe, senior energy engineer, Advanced Energy.

»**The Scopes of Greenhouse Gas Emissions:** Michael Stowe, senior energy engineer, Advanced Energy.

Pathways to Decarbonization

»**Combustion Processes:** Jason Safarz, regional sales manager., Karl Dungs, Inc.

»**Electrical Processes:** Michael Stowe, senior energy engineer, Advanced Energy.

»**Carbon Capture & Sequestration (CCS):** John Carroll, principal engineer — net zero technologies, Southern Company.

Improving Efficiency in Thermal Processes

»**Reducing Fuel Consumption:** Brian Kelly, Applications Engineer Mgr., Honeywell Thermal Solutions; Keenan Cokain, Corporate Sales & Applications manager., Bloom Engineering Co., Inc.

»**The Impact of Automation, Controls and Ancillary Equipment:** Jeff Rafter, VP Sales & Marketing, Selas Heat Technology Co. LLC; Bob Fincken, VP Sales, Super Systems, Inc.

Alternatives to Fossil Fuel Combustion

»**Low Carbon Fuels & Hydrogen:** Brian Kelly, applications engineer manager., Honeywell Thermal Solutions;

»**Erik Anderson, Vice President, Ambient Fuels.**

»**An Overview of Direct Versus Indirect Electrification:** Perry Stephens, principal technical leader, EPRI.

Reception and Visit with Exhibitors

WEDNESDAY, OCTOBER 30

Resources & Programs

»**DOE Programs and Tools:** Paulomi Nandy, manufacturing energy efficiency research analysis group, ORNL.

»**ISO 50001 & 50001 Ready Program:** Michael Stowe, senior energy engineer, Advanced Energy.

Reaching Net-Zero

»**Reducing, Converting, and Trading to get to ZERO Carbon:** Sandeep Alavandi, program manager, GTI Energy.

Benchmarking: A Global Perspective

»**The State of Decarbonization in Europe:** Dr. Joachim Wuenning, president, WS Thermal Process Technology Inc.; Dr. Christian Schwotzer, Group Manager, Renewable Energy, RWTH Aachen University.

»**The State of Decarbonization in Japan:** Hiroyuki Akita, Heat Treatment Engineering Section, Daido Steel Co., Ltd.

Industry Adoption

»**Economic & Business Concerns:** Bryan Stern, Product Development Mgr., Gasbarre Thermal Processing Systems.

»**Codes and Standards:** Jason Safarz, regional sales manager., Karl Dungs, Inc.

»**Grants and Funding Sources:** Micki Vandeloo, president, Lakeview Consulting.

»**The Risk of Doing Nothing:** Nathan Roberts, U.S. DOE, Energy Efficiency & Reneable Energy Industrial Efficiency and Decarbonization Office.

Decarbonization Implementation Panel

»Jeff Kaman, manager, Energy Supply and Sustainability, John Deere.

»Tim Hill, general manager, Sustainability Solutions, Nucor.

»B.J. Bernard, president, Surface Combustion, Inc.

»Sandeep Alavandi, program manager, GTI Energy.

TABLETOP EXHIBITORS (AS OF 9/12/24)

»Bloom Engineering

»Chiz Bros

»Excelitas Noblelight America LLC

»Fostoria Infrared - a Div. of TPI Corp.

»Gasbarre Thermal Processing Systems

»Heat Treat Today

»Honeywell Thermal Solutions

»IHEA

»PRE-Heat

»Surface Combustion, Inc.

SUMMIT GENERAL INFORMATION

»**Location:** Conrad Indianapolis

»**Monday, October 28:** 5-6:30 p.m.

»**Tuesday, October 29:** 7:30 a.m.-7 p.m.

»**Wednesday, October 30:** 7:30 a.m.-4:30 p.m.

»**To register go to:** www.summit.ihea.org

EVENT SPONSORS

»Honeywell

»WS Thermal

»Heat Treat Today

JASON MEYER
MECHANICAL ENGINEER /// DANTE SOLUTIONS

Modeling the cold expansion process to improve fatigue life in aerospace applications.

Cold expansion an efficient strengthening solution

In flight, aerospace components are in a state of constant cyclic stress. The term "flying fatigue machines" is commonly used by those in the industry for a good reason. The dynamic forces planes and helicopters experience during service, while hopefully well below the yield strength of the material, require attention to potential fatigue-related issues during the design stage. The tiniest crack can be propagated by fatigue into a major failure.

There are several ways to reduce the risk of fatigue failure, including modifying component geometry to reduce stress concentrations or by surface treatment. In modifying part geometry, it is important to keep in mind that these components are required to be as lightweight as possible. Strengthening the material is another valid option to combat fatigue without increasing part weight. Structural components in planes are often held together with rivets or bolts, requiring holes to be drilled or punched before the fasteners can be applied. These holes act as concentrators to any stresses that are developed in service. Figure 1 shows a classic example of stress concentrations around a hole in a plate which is loaded axially. Notice the tension at the 3 o'clock and 9 o'clock positions, and the compression in the 12 o'clock and 6 o'clock positions from the vertical load. In service, these stresses will cycle the edges of any hole through tension and compression, and any micro-cracks or defects around the edges of the holes will eventually lead to crack propagation and failure.

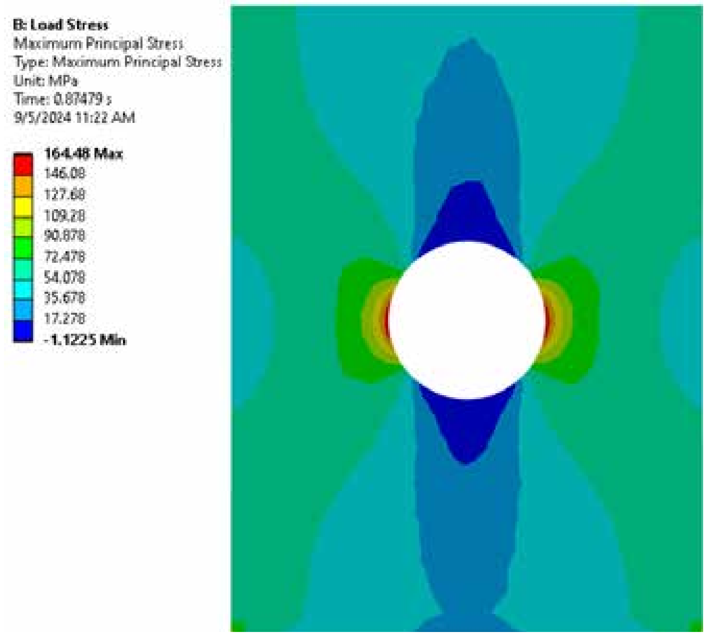


Figure 1: Example of stress concentration around the hole in a plate in tension.

The most common and effective way to reduce the effect of fatigue on the fastener holes is to cold work the material, inducing compression along the inner edge of the hole, in a process called cold expansion. In cold expansion, the hole is produced undersized and widened to the required dimensions, inducing a layer of compression around the hole from the subsequent elastic response of the surrounding material as it attempts to return to the undeformed state.

There are several common methods for widening the holes. One method uses a lubricated mandrel that is pulled through the hole, and another uses a ball that is pushed through the hole. Both methods provide a directional burnishing effect from the frictional forces on the inner surface, potentially producing undesired tension on the leading edge of the hole. A better approach uses a mandrel and a split-sleeve as a buffer between the mandrel and hole, and the split sleeve is simply discarded after the process. This method allows the force of the mandrel to be directed radially, thus having a more uniform radial deformation while removing the axial frictional forces from a mandrel-only process. The split in the sleeve does leave behind a small pip which must be removed after the process.

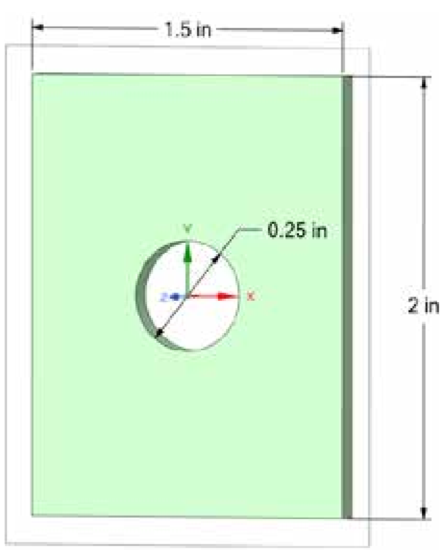


Figure 2: Geometry of an eighth-inch thick plate with a hole in the center.

The level of compression achieved by the cold expansion process depends on the amount of expansion and the yield strength of the material. For example, a quarter-inch diameter hole widened 3 percent would produce a hole 0.2575 inches in diameter. The elastic-plastic response of a workpiece undergoing a cold expansion process, along with the contact behavior between the mandrel and split sleeve, can be simulated using nonlinear finite-element analysis. Using simulation, engineers can ensure the required magnitude and depth of compression is achieved.

CASE STUDY

A case study has been developed to explore the cold expansion process and to quantify the magnitude and depth of compression achieved. The geometry for the FEA model includes an eighth-inch plate with dimensions shown in Figure 2. The quarter-inch hole in the center of the plate will be expanded by 3 percent and 6

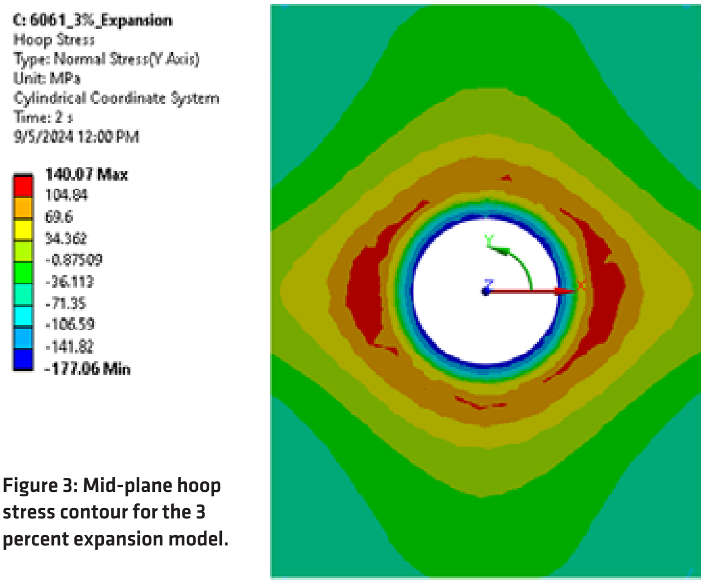


Figure 3: Mid-plane hoop stress contour for the 3 percent expansion model.

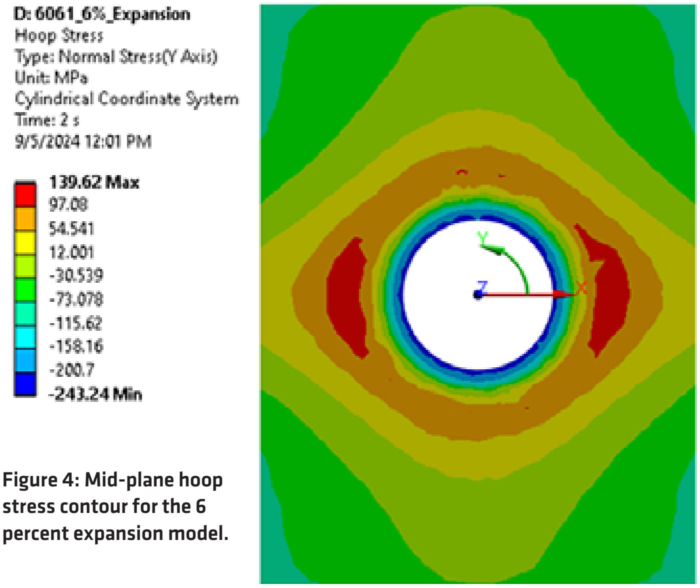


Figure 4: Mid-plane hoop stress contour for the 6 percent expansion model.

percent, over two seconds, to explore differences in magnitude and depth of compression achieved by each process. The plate is made from aluminum alloy 6061 in the T6 temper condition. DANTE's material and elastic-plastic model, based on the Bammann-Chiesa-Johnson (BCJ) model, will be used to solve the material response as the BCJ model is well-suited for high strain-rate applications. To save computational costs, the mandrel will not be modeled. Instead, the inner surface of the hole will be expanded uniformly in the radial direction to model the deformation using a cylindrical coordinate system centered on the hole. The resultant hoop stress will be reported along the midplane of the plate.

The hoop stress contour and coordinate system for the 3 percent expansion model are shown in Figure 3. The contour shows the achieved compression in the range of 22 ksi (~170 MPa) which falls off with depth from the inner surface of the expanded hole. Surrounding the compression, a layer of tension exists to satisfy the stress equilibrium within the plate. This tension is lower in magnitude but covers more area within the part than the compressive case. The stress away from the hole is not circumferentially uniform because the plate is rectangular in this model.

The hoop stress contour for the 6 percent cold expansion model is shown in Figure 4. The achieved magnitude of compression for this model is higher than the 3 percent model, about 34 ksi (240MPa), which is closer to the reported yield strength of 6061-T6 aluminum. The magnitude and area of tension surrounding the compressive case is comparable to the 3 percent expansion model.

A path plot was developed to compare the residual hoop stress for each of the two processes. The path is taken from the midplane, along the X-axis, from the inner surface of the hole to the right edge of the plate, as shown in the previous contours. Figure 5 shows the collected stress values converted to ksi units. The plot shows good compression in the inner surface of both models, with the 6 percent model showing a higher magnitude. The depth of compression is also greater in the 6 percent cold expansion model. The 3 percent expansion model transitions to tension at about 0.075 inches, while the 6 percent expansion model transitions to tension at about 0.1 inches. The predicted level of tension surrounding the case is comparable for both models with a slightly higher peak magnitude that is deeper for the 6 percent model.

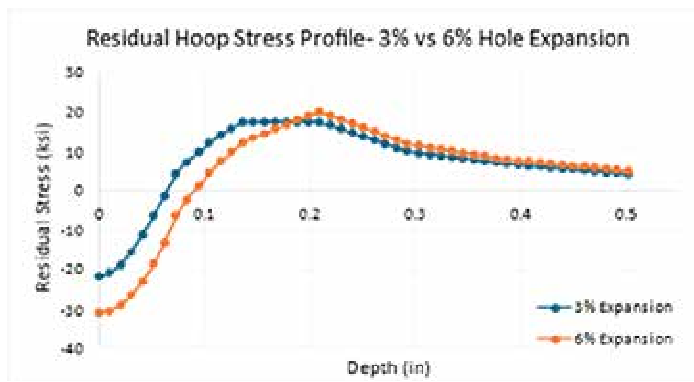


Figure 5: Hoop stress path plots for the 3 percent and 6 percent expansion models.

CONCLUSIONS

Cold expansion is a quick and efficient method for strengthening the material around fastener holes for aerospace applications without adding weight. There are several different methods for cold hole expansion, but they all aim to provide compressive residual stress through plastic deformation and elastic recovery. The imparted compressive stress from the process increases fatigue life by offsetting tensile loads that form at the stress concentrations near the holes. The residual compression reduces the early onset of fatigue crack initiation near the surface. The process was successfully modeled with two levels of deformation, 3 percent and 6 percent expansion, to compare the resulting hoop stress. The hoop stress contours show the 6 percent expansion model results in a higher magnitude of compression and deeper case than the 3 percent model. The results of these models can be further used in loading models to ensure the depth and magnitude of compression is sufficient for the application, or to predict the stress balance from final machining. In the ever-expanding world of aerospace applications, engineers using simulation can fill in the holes from production and ensure you are not left out in the cold.

ABOUT THE AUTHOR

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

D. SCOTT MACKENZIE, PH.D., FASM
QUAKER HOUGHTON FELLOW /// QUAKER HOUGHTON INC.

Cleanliness is achieved by degrees, and what works for one heat-treated product may not be acceptable for another. There are many variables for achieving the desired results.

Cleaning for heat treatment

First in a series » Among the many specifications applied to finished heat-treated goods, the cleanliness of those goods is increasingly important in appearance, performance, and customer satisfaction. In this series of articles, I'll break down the why and how of cleaning for heat treatment.

In this short column, we will discuss the importance of cleaning in heat-treating operations.

INTRODUCTION

The demands on heat-treated goods are increasing. Not only do they have to meet property and straightness requirements, but they also must meet increasingly stringent appearance specifications. Cleaning is the removal of dirt and soil from a surface. A cleaner is a formulated chemical system or product, dispersed in water, which removes unwanted dirt, soil, grease, and other similar matter from a surface.

Cleaners are used in nearly all industrial plants where metal-working operations are found. Almost all soil and dirt needs to be removed to some extent. Thus, if a plant uses coolants, drawing compounds, rust preventatives, or heat-treating oils, then the plant will likely have a strong requirement for cleaning.

Cleanliness is a relative term. The total process will dictate the degree of cleanliness. For example, a part is being cleaned during various states of manufacture to remove chips or machinery fluids. The cleaner will leave behind a residual rust protective film. Although there is residual film on the part, it is considered clean. In the case of electroplating, blackening, or enameling, the part must be chemically clean. This is often referred to by the term "water break free." After cleaning, if a part is rinsed in clear water, the water should run down the part in a continuous, unbroken film. This indicates a water-break free part. If the film is interrupted, this indicates some soil is remaining on the surface. Cleanliness should be determined by the customer. During a cleaner trial, it is good policy to allow the customer to make the initial comments concerning cleanliness. A part which may appear to be dirty to an operator could be quite acceptable to the final customer.

FACTORS AFFECTING INDUSTRIAL CLEANING

With a few exceptions, there are basic variables that apply to all types of cleaning. These are concentration of the cleaner, time required for cleaning, temperature, agitation, and water quality (hardness).

» **Concentration.** The concentration necessary for good cleaning is geared to the method of agitation. Thus, disregarding any foam problems, it is possible to get similar cleaning from the same alkaline cleaner at 8 to 12 oz./gal. by soaking, 1/2 to 1oz./gal. by spraying, 1/10 to 1/2 oz./gal. by steam cleaning, or 2 to 4 oz./gal. in a high-pressure water spray at room temperature.

» **Time Required for Cleaning.** This is determined by the conditions of temperature, soil, concentration, agitation, etc. Keep in mind that it does take some time for the detergency process to take place. In a static bath, cleaning may take 5 to 15 minutes; in a high-pressure spray of quality detergent, it may take a few seconds. It is expensive in equipment, labor, and chemicals to reduce cleaning time, and there are situations in which the expense is not justified.

The time available for cleaning is very closely related to the economics of the cleaning operation not only from a direct production viewpoint, but also based on time lost in recleaning, rejects, or customer complaints when inadequate cleaning results from an unsuccessful balance of cleaning factors.

Influence of Process Variables

Time	Temperature	Agitation	Concentration	Part Orientation
• Increasing time increases cleaning • Allows time to remove difficult deposits	• Increasing temperature increases cleaning • Dependent on cleaner • Excessive temperature may cause rusting	• Increasing agitation increases cleaning • Lifts deposits	• Increasing concentration improves cleaning • Diminishing return • Increases likelihood of residual cleaner residue	• Must be adequate to allow cleaner to reach all parts • Adequate part spacing (1T)

Figure 1: Summary of the effect of process variables on cleaning.

» **Temperature.** The effect of temperature depends on the type of soil and cleaner. A first consideration is that enough temperature to melt a soil that can be melted, such as a fat, grease, or wax, makes a tremendous difference in the rate of cleaning. For most oils, increase of temperature reduces the viscosity of the oil, makes it more mobile, and therefore more easily removed. There is a well-established principle that the rate of chemical reaction is doubled for every 10°C or 18°F increase in temperature. If cleaning is by chemical reaction between a fatty oil and alkali, or if a paint or foodstuff is being decomposed by chemical action, or if a rust or scale remover is acting chemically, this same relationship occurs. Most industrial cleaning is carried out at temperatures of 140-180°F.

» **Agitation.** Variation in agitation represents the greatest difference in the methods of cleaning that I have discussed so far. An important factor is that it costs money in equipment or labor, or both, to provide high levels of agitation. Equipment design has the objective of getting the amount of agitation necessary to remove the soil as rapidly as is needed at the lowest cost; the last two factors often require a compromise. Agitation should be used with the idea of moving the soil. Circulation or stirring the cleaner is far less effective but is sometimes useful. High-pressure spraying of cleaner is most effective. A great deal of attention has been paid to obtaining good agitation to improve cleaning. This may vary from the unsophisticated scrub brush to mild-pressure sprays (5 - 40 psi), to high-pressure sprays (300 – 1,000 psi), to the current density electro-cleaning, to high-intensity ultrasonic cleaning, etc. Bubbling air through the cleaner or stirring with a mixer, or sloshing the work piece around in the cleaner are less effective methods of agitation. Major limitations of agitation are equipment expense, foaming, generation of irritating fog, toxic vapors, or flammable gases.

» **Water Hardness.** Water hardness depends upon the concentration of chemical salts dissolved in the water. These salts, in the presence of heat or alkalinity, may react to produce insoluble material which precipitates out of solution in the form of hard water scale. Unless this formation of hard water scale is prevented, several undesirable results are possible. The major undesirable result is the buildup of hard-water scale. This scale may be precipitated on the heating coils of wash tanks, reducing the efficiency and wasting energy and money.

Scale may build up in spray nozzles and on belt conveyors, impairing cleaning efficiency. The effectiveness of the spray is reduced, and scale may block the solution from reaching and cleaning the objects on the belt. Scale may also build up in the rinse tanks in extremely hard water situations due to alkaline carryover of cleaner into the rinse tank. Hard water salts regularly react with fatty acid soaps to yield insoluble residues on parts being cleaned. The harder the water is, the greater the susceptibility to rusting parts and the washer. Hard water is not conducive to good cleaning.

A summary of the effects of process variables on cleaning is shown in Figure 1.

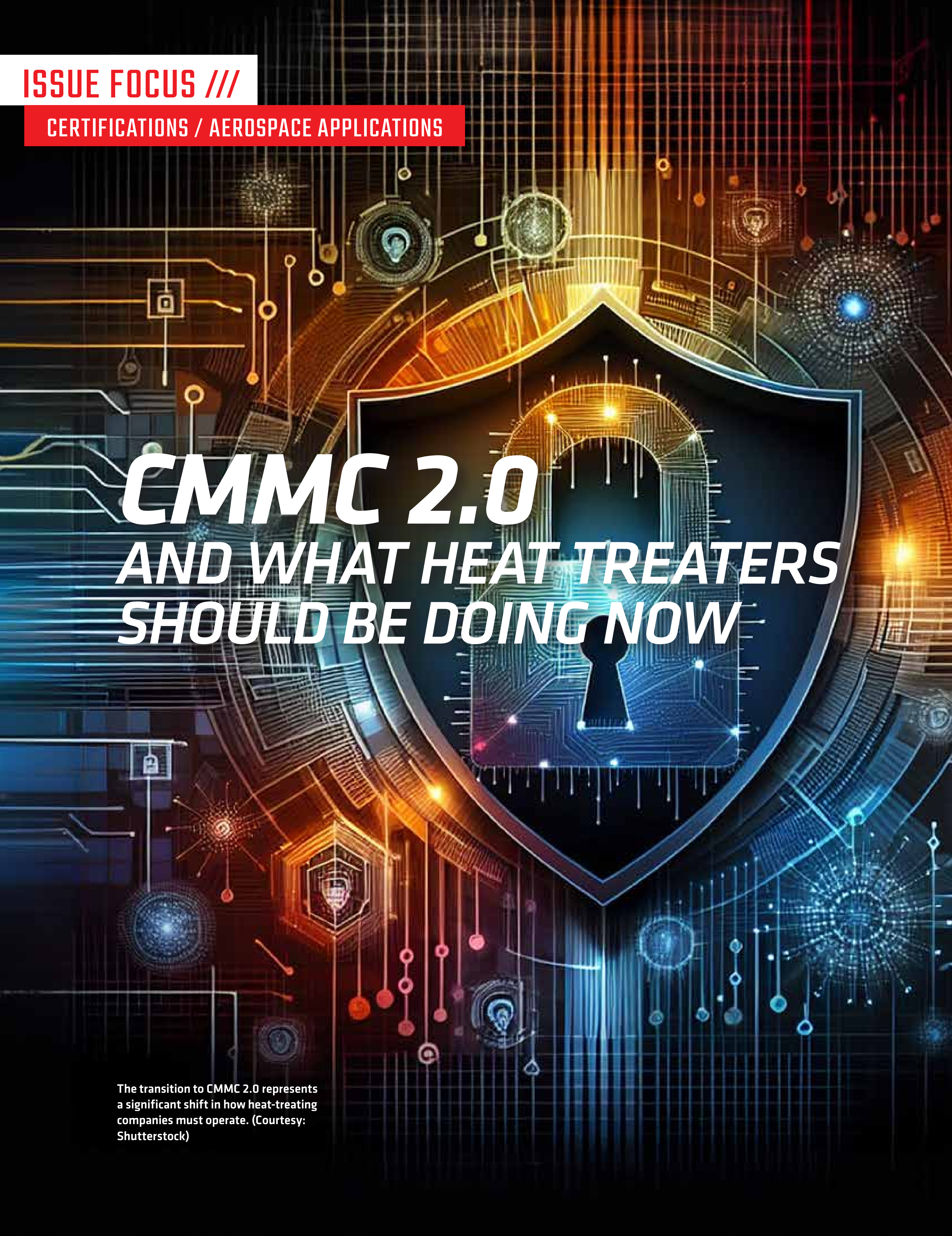
CONCLUSION

In this column, I have discussed the effect of various process variables on cleaning. In the next column, I will discuss types of soils on heat-treated parts.

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

ABOUT THE AUTHOR

D. Scott MacKenzie, Ph.D., FASM, is a Quaker Houghton Fellow, past president of IFHTSE, and a member of the executive council of IFHTSE. For more information, go to www.quakerhoughton.com.



CMMC 2.0 AND WHAT HEAT TREATERS SHOULD BE DOING NOW

The transition to CMMC 2.0 represents a significant shift in how heat-treating companies must operate. (Courtesy: Shutterstock)

Some current and future business depends on CMMC 2.0 certification.

By JOE COLEMAN

The heat-treating industry, while traditionally focused on metallurgical and heat-treating processes, has increasingly become integrated with the digital world. As a critical component in the supply chains of defense, aerospace, and other high-tech industries, heat treaters have now become custodians of sensitive and controlled unclassified information (CUI). With the Cybersecurity Maturity Model Certification (CMMC) 2.0 coming by the end of 2024 or early 2025, the U.S. Department of Defense (DoD) has made it clear cybersecurity is no longer optional but a mandated standard for anyone involved in the defense industrial base (DIB). For heat treaters, achieving and maintaining CMMC 2.0 certification is not just about compliance; it is about securing their place in future business opportunities and protecting their current operations from potentially catastrophic cyber threats.

UNDERSTANDING CMMC 2.0: THE BASICS

The CMMC 2.0 framework was developed by the DoD to create a unified cybersecurity standard across its contractors and subcontractors. The original CMMC 1.0 model, introduced in 2020, had five cybersecurity maturity levels, ranging from basic cyber hygiene to advanced and progressive practices. However, recognizing the complexities and challenges faced by small- and medium-sized businesses (SMBs), the DoD revised the model, resulting in CMMC 2.0.

This updated version simplifies the certification process by reducing the levels from five to three, making it more accessible, while ensuring robust cybersecurity practices.

THE THREE LEVELS OF CMMC 2.0

» **Level 1 (Foundational):** This level is designed for companies that handle federal contract information (FCI). It requires 17 basic cybersecurity practices, which are derived from the Federal Acquisition Regulation (FAR) 52.204-21. This level represents the minimum level of protection and is self-assessed annually.

» **Level 2 (Advanced):** This level applies to companies that handle CUI. It is closely aligned with the 110 security controls in the National Institute of Standards and Technology (NIST) Special Publication (SP) 800-171. Most heat-treating companies dealing with defense contracts will need to meet Level 2 requirements, which involve a certified third-party assessment every three years for certain contracts.

» **Level 3 (Expert):** Aimed at the highest-risk contracts involving critical national security information, Level 3 is based on a subset of NIST SP 800-172 standards and all 110 controls of NIST SP 800-171 R2. This level involves government-led assessments and is relevant for only a small percentage of defense contractors.

CMMC 2.0 ensures companies across the defense supply chain and defense industrial base (DIB) have the safeguards to protect against increasingly common and sophisticated data breaches and cyber espionage.

WHY CMMC 2.0 MATTERS TO THE HEAT-TREATING INDUSTRY

Heat-treating companies, especially those in the defense and aerospace sectors, are critical links in the DoD supply chain. The parts and components they process often require adherence to stringent specifications and standards, including cybersecurity-related ones. So, CMMC 2.0 is not just a regulatory hurdle but a business imperative.

The CMMC 2.0 framework was developed by the DoD to create a unified cybersecurity standard across its contractors and subcontractors. (Courtesy: Bluestreak Consulting)

KEY REASONS WHY CMMC 2.0 IS CRUCIAL FOR HEAT TREATERS

» **Supply chain security:** The nature of modern cyber threats means hackers looking to penetrate larger, more secure systems can target even small subcontractors to "get a foot in the door." Heat treaters, who may possess detailed specifications for defense-related parts, are prime targets for these attacks. CMMC 2.0 certification ensures all companies in the supply chain adhere to a baseline level of cybersecurity, reducing the overall risk of a data breach.

» **Compliance and contractual requirements:** Without CMMC 2.0 certification, heat-treating companies could find themselves ineligible to bid on or renew contracts with the DoD and other defense-related entities. As the DoD begins to enforce CMMC 2.0 requirements,

CMMC 2.0	Highlevel	Purpose	Assessment
Level 1 Foundational	17 Practices Basic cyber hygiene	FCI Protection	Annual Self-Assessment
Level 2 Advanced	110 Practices Basic on NIST SP 800-171	FCI and CUI Protection	C3PAO-Led Assessment Every 3 Years Annual Self-Assessment For Some Organizations
Level 3 Expert	110+ Practices Based on NIST SP 800-171 & NIST SP 800-172	FCI, Stricter CUI Protection, and Implementation Plan	DoD-Led Assessment Every 3 Years

CMMC 2.0 is expected to be placed in DoD contract, RFPs, and PFIs starting in Q1 2025. (Courtesy: Bluestreak Consulting)

compliance will become a prerequisite for doing business with the DoD or providing downstream services. This is particularly important for heat treaters, who often serve as subcontractors to larger companies that will require proof of certification from their entire supply chain.

» **Protection of intellectual property (IP):** Many heat-treating companies work with proprietary processes or handle parts subject to IP protections. A cybersecurity breach could lead to the theft of this IP, resulting in significant financial and reputational damage. CMMC 2.0 helps ensure robust cybersecurity measures are in place to protect this valuable information.

» **Customer trust and competitive advantage:** Certification under CMMC 2.0 signals to customers and partners that a company takes cybersecurity seriously. This can be a significant competitive advantage, especially in an industry where trust and reliability are paramount. Companies that achieve certification may find themselves better positioned to win contracts and attract new business.

» **Financial and legal implications:** A cyberattack can have severe financial repercussions, including ransom payments, legal fees, and lost business. Additionally, non-compliance with CMMC 2.0 could lead to penalties, contract termination, and potential litigation. Investing in compliance is far less costly than dealing with the fallout from a breach.

PREPARING FOR CMMC 2.0 COMPLIANCE: A STEP-BY-STEP GUIDE FOR HEAT TREATERS

Achieving CMMC 2.0 compliance is a significant undertaking, particularly for SMBs that may not have extensive cybersecurity resources. However, with careful planning and execution, it is possible to meet the necessary requirements. The following steps outline a strategic approach for heat-treating companies seeking CMMC 2.0 certification.

1. Conduct a Preliminary Assessment

The first step in preparing for CMMC 2.0 is to conduct a thorough assessment of current cybersecurity practices. This should include a gap analysis comparing existing measures against the requirements of the relevant CMMC 2.0 Level 2 for heat treaters. Key areas to evaluate include:

» **Access control:** Who has access to sensitive information and systems? Are there measures to ensure that only authorized personnel can access this data?

» **Physical security:** How is access to physical locations, such as production facilities and data centers, controlled and monitored?

» **Network security:** Are firewalls, encryption, and other network security measures in place to protect against unauthorized access and cyberattacks?

» **Incident response:** Does your company have a plan to respond to a cybersecurity incident? Are employees trained in how to handle potential breaches?

2. Develop a Remediation Plan

Once the assessment is complete, the next step is to develop a remediation plan to address any gaps identified. This plan should include:

» **Prioritization:** Identify the most critical vulnerabilities and prioritize them for remediation. This ensures the most significant risks are addressed first.

» **Timeline:** Establish a timeline for implementing the necessary changes. This should include milestones and deadlines to keep the project on track.

» **Resources:** Determine the needed resources, including personnel, technology, and budget. This may involve hiring cybersecurity professionals or investing in new tools and systems.

» **Policies and procedures:** Update or create cybersecurity policies and procedures to align with CMMC 2.0 requirements. This includes documentation of all practices and controls.

3. Implement Necessary Changes

With a plan in place, it's time to begin implementing the necessary changes to your cybersecurity infrastructure. This may include:

» **Upgrading technology:** Implementing or upgrading firewalls, encryption tools, multi-factor authentication (MFA), and other cybersecurity technologies.

» **Training employees:** Conduct regular training sessions to ensure they understand the importance of cybersecurity and are familiar with the newly adopted policies and procedures.

» **Strengthening physical security:** Enhance physical security measures, such as access controls, surveillance systems, and secure storage for sensitive materials.

» **Testing and validation:** Once changes are implemented, conduct thorough testing to ensure they work as intended and that all vulnerabilities have been addressed.

While CMMC 2.0 presents challenges, it also offers growth opportunities. Companies that achieve certification will have a competitive edge as customers increasingly prioritize security in their supply chain partners.

4. Engage a Third-Party Assessor

A third-party assessment is required for Level 2 and Level 3 certifications. These assessors, known as certified third-party assessment organizations (C3PAOs), will evaluate your company's compliance with CMMC 2.0. It is essential to choose a reputable C3PAO and schedule your assessment well in advance, as demand for these services is expected to be high.

It is also highly recommended you hire a CMMC registered practitioner organization (RPO), a CMMC-registered practitioner (RP), or a registered practitioner advanced (RPA) to guide or lead you through this complicated process and to help you be prepared for your CMMC assessment by a C3POA.

During the assessment, the C3PAO will review your documentation, interview key personnel, and assess your systems to ensure they meet the required standards. It is crucial to be well prepared for this process, as any deficiencies identified during the assessment will need to be addressed before certification can be granted.

5. Maintain and Monitor Compliance

Achieving CMMC 2.0 certification is not a one-time event. Continuous monitoring and maintenance are required to ensure ongoing compliance. This includes:

» **Regular audits:** Conduct internal audits to verify all cybersecurity practices and controls function as intended.

» **Monitoring systems:** Implement continuous monitoring tools to detect and respond to potential threats in real time.

» **Staying informed:** Stay current with the latest developments in cybersecurity and CMMC standards to ensure your company remains compliant with any changes.

» **Re-certification:** For Level 2, a re-certification assessment is required every three years. It is important to maintain all documentation and continue best practices to ensure a smooth re-certification process.

6. Consider the Broader Implications

Beyond meeting CMMC 2.0 requirements, heat treaters should consider the broader implications of cybersecurity on their business. This includes:

» **Supply chain relationships:** Work closely with your supply chain partners to ensure they are also compliant with CMMC 2.0. A weak link in the supply chain can compromise your security, even if your own practices are robust.

» **Customer communications:** Be transparent with your customers about your cybersecurity practices and CMMC 2.0 certification. This can help build trust and potentially lead to new business opportunities.

» **Cyber insurance:** Consider investing in cyber insurance to mitigate the monetary impact of a potential breach. This can provide additional protection and peace of mind.

THE FUTURE OF HEAT TREATING IN A CYBERSECURITY-DRIVEN WORLD

As the heat-treating industry continues to evolve in the way they do business, cybersecurity's importance will only increase. With the implementation of CMMC 2.0, the DoD has made it clear that cybersecurity concerns not just large defense contractors, but every company involved in the supply chain. For heat treaters, cybersecurity must become a core component of their business strategy.

ADAPTING TO A NEW BUSINESS REALITY

The transition to CMMC 2.0 represents a significant shift in how heat-treating companies must operate. No longer can cybersecurity be seen as an afterthought or a secondary concern. Instead, it must be integrated into every aspect of the business, from production processes to customer communications. This shift requires not only technical upgrades but also a cultural change within organizations. Employees at all levels must understand the importance of cybersecurity and be trained to follow best practices.

OPPORTUNITIES FOR GROWTH

While CMMC 2.0 presents challenges, it also offers growth opportunities. Companies that achieve certification will have a competitive edge as customers increasingly prioritize security in their supply chain partners. Additionally, as cybersecurity standards continue to evolve globally, CMMC 2.0 compliance could open doors to international markets where similar standards are being adopted.

The future looks promising for heat-treating companies that are proactive in achieving CMMC 2.0 certification. By securing their operations against cyber threats, these companies cannot only protect their current business but also position themselves for future growth in a cybersecurity-conscious market.

THE COST OF INACTION

The cost of failing to achieve CMMC 2.0 compliance is high. Companies that do not meet the required standards may find themselves excluded from defense contracts and other critical business opportunities. Moreover, the financial and reputational damage caused by a cybersecurity breach can be devastating, particularly for SMBs. Investing in CMMC 2.0 compliance is not just a regulatory requirement; it is a necessary step to ensure the long-term viability of your business.

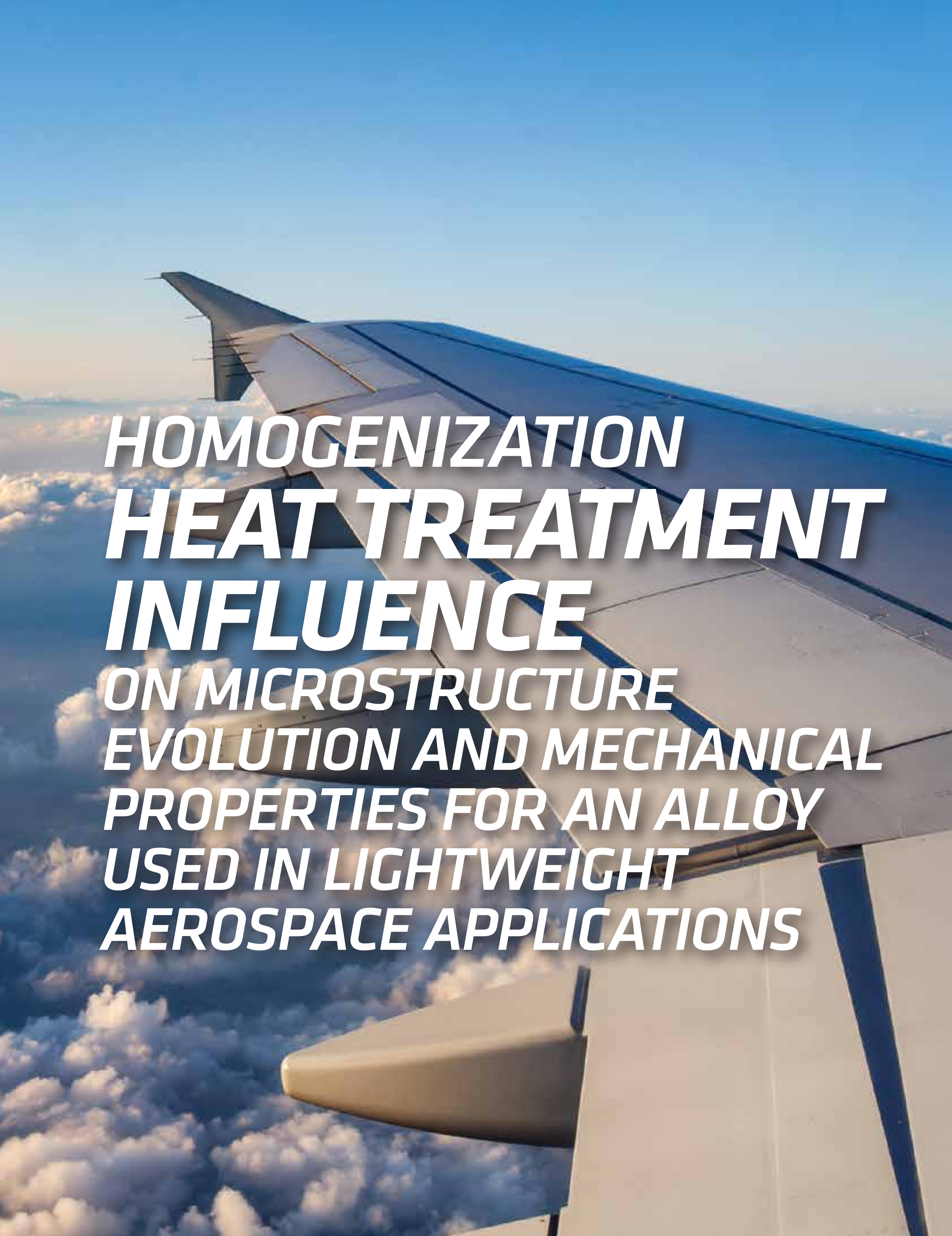
CONCLUSION

CMMC 2.0 represents a significant development in the way cybersecurity is managed across the defense industrial base. For heat treaters, achieving certification is critical to maintaining current business relationships and securing future opportunities. By understanding the requirements, conducting a thorough assessment, and implementing necessary changes, heat-treating companies can position themselves as trusted and secure partners in the defense and aerospace industries.

As the global landscape of cybersecurity continues to evolve, the importance of CMMC 2.0 will only grow. Heat-treating companies that take proactive steps to achieve and maintain certification will not only protect their operations but also gain a competitive edge in an increasingly security-conscious market.

ABOUT THE AUTHOR

Joe Coleman, the Cyber Security Officer and CMMC RPA (Registered Practitioner Advanced) for Bluestreak Compliance™ and Bluestreak | Bright AM™, an RPO (Registered Practitioner Organization), has more than 35 years of manufacturing, management, and engineering experience. He holds extensive cybersecurity training, DFARS, NIST SP 800-171, and CMMC.



HOMOGENIZATION HEAT TREATMENT INFLUENCE ON MICROSTRUCTURE EVOLUTION AND MECHANICAL PROPERTIES FOR AN ALLOY USED IN LIGHTWEIGHT AEROSPACE APPLICATIONS

This study investigates the effects of homogenization heat treatment on an Al–Li–Cu–Mg–Zr alloy; through thermal analysis, dilatometry, metallography, SEM/EDS, XRD and Vickers microhardness testing, comprehensive insights were gained regarding the alloy's thermal behavior, microstructural evolution, precipitates formation and mechanical properties.

By ABDELLAH LAHBARI, KENZA BOUCHAALA, HAMZA ESSOUSSI, MUSTAPHA FAQIR, SAID ETTAQI, and EL HACHMI ESSADIQI

Al–Li–Cu–Mg–Zr alloys are widely used in the aerospace industry for different applications and make an excellent concurrent to high-performance composites. This family of alloys has remarkable properties such as low density, high elastic modulus, high strength and specific stiffness, fracture toughness, fatigue crack growth resistance, and improved corrosion resistance.

The present work aims to investigate a family of Al–Li alloys by employing suitable characterization techniques such as computer-aided cooling curve analysis and thermal dilatometry to characterize the as-cast alloy. The characterization temperatures of the alloy were obtained, and the phase-transformation temperatures were concluded as thermal expansion inflection points as well. Furthermore, the homogenization heat-treatment effect of the alloy is examined through optical microscopy (OM), scanning electron microscopy (SEM), energy-dispersive X-ray spectroscopy (EDS), X-ray diffraction (XRD), and Vickers microhardness testing to determine the optimum heat-treatment time. The results reveal the formation of δ', δ, and β' precipitates in the alloy after different hours of homogenization heat treatment. Notably, our investigation identifies the optimum heat-treatment time for the alloy as 26 hours at 515°C, resulting in reduced hardness and barely any chemical segregation. These findings contribute to the characterization of as-cast Al–Li alloys and the understanding of microstructure evolution and mechanical properties during homogenization heat treatment that offer a valuable insight for enhancing their performance in aerospace applications.

1 INTRODUCTION

In recent decades, Al–Li alloys have gained a place in aerospace materials panoply as lightweight materials with relatively good mechanical properties [1]. These alloys have found applications in aircraft wings, space rocket oxygen tanks, and plane floor beams [2, 3, 4]. Binary Al–Li alloys exhibit a 6%-8% increase in elastic modulus while reducing density by 3% for every 1% addition of lithium [5, 6]. To further enhance the alloy properties, the industrial Al–Li alloys are typically alloyed with the addition of several elements. Cu, Mg, and Ag are added for solution strengthening and precipitate strengthening. Zn improves corrosion properties, while Zr and Mn contribute to texture control and govern the recrystallization process [7,8]. The precipitates in Al–Li alloys such as δ'(Al_3Li), T_1(Al_2CuLi), and T_B($Al_{7.5}Cu_4Li$) are the milestone with regard to the material mechanical properties. The strengthening is ensured by the precipitates δ', T_1 and T_2(Al_6CuLi_3), and S'(Al_2CuMg). The

Element	Li	Cu	Mg	Zr	Mn	Al
%	2.2–2.5	1.3-1.8	0.8	0.1	0.1	Bal.

Table 1: Material chemical composition in weight.

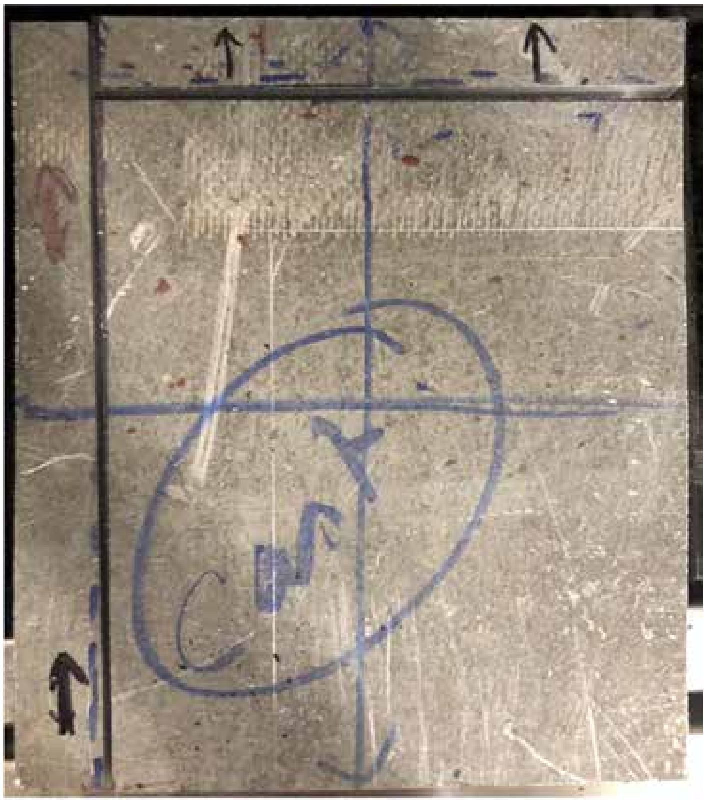


Figure 1: As-cast ingot.

precipitates T_1, T_2, and T_B contribute to the toughness of the alloy, whereas β' (Al_3Zr) acts as a pin in the grain boundaries, regulating recrystallization and controlling texture [7,9].

The casted slabs of metals need homogenization heat treatment to avoid segregation and eliminate non-equilibrium eutectic phases. This heat treatment is conducted in 3 steps: heat-up, soak, and cool down, and it precedes generally high temperature forming such as extrusion, hot forging, or hot rolling [10]. This process leads to a more workable material with better uniformity of internal structure. Several studies have focused on investigating the as-cast and homogenized states of Al–Li alloys using various approaches. For instance, Wei et al. [11] studied a systematic homogenization heat treatment on an Al–Li–Cu–Mg–Zr alloy and found the best combination was 530°C for 24 hours, followed by air cooling. Rezaei et al. study [12] investigated the homogenization of an Al–1Li–3Cu-0.1Zr and Al–2Li–3Cu-0.1 Zr concluding the heat treatment should be conducted at 500°C for 24 hours. Zhang et al. [13] examined the as-cast and homogenized AA2099 alloy, revealing the presence of a severe dendritic structure. They optimized the heat-treatment process in a two-step approach (515°C for 18 hours followed by 525°C for 16 hours). A quasi-in-situ study [14] focused on the microstructural evolution of AA2195, and the observed results showed the precipitates T_B, S, and θ(Al_2Cu) at each temperature level. Li et al. [15] explored the homogenization process of AA2060 alloy and deduced the optimum two-stage homogenization treatment of the studied alloy was 460°C for 4 hours followed by 490°C for 24 hours. Shengli et al. [16] investigated single-step and double-step homogenization for an Al–Cu–Li alloy determining the optimum heat treatment schedule was 498°C for 24 hours followed by 515°C for 24 hours.

In the present article, we aim to conduct a thermal analysis study on the as-cast alloy. Moreover, we will investigate the homogenization treatment of an Al–Li–Cu–Mg–Zr alloy to identify the optimal heat treatment before the rolling process. The outcomes of this research will contribute to the understanding of the behavior of Al–Li alloys and give valuable insight into its homogenization heat treatment.

2 MATERIAL AND EXPERIMENTAL PROCEDURE

The studied material is an Al–Li–Cu–Mg–Zr alloy characterized by a density of 2,540 kg/m^3. The detailed chemical composition of the alloy is presented in Table 1. Knowing the explosive nature of lithium metal especially at high temperatures, the ingots of the alloy were prepared using a closed-casting process [17,18]. The resulting as-cast ingot with the dimensions 200*200*45 mm^3, depicted in Figure 1, serves as a starting point for subsequent investigations and analysis.

The as-cast alloy was characterized by two fundamental techniques: Thermal analysis of cooled sample and thermal dilatometry. In the thermal-analysis technique, the alloy underwent controlled heating until it reached the molten state, followed by cooling in ambient air. The temperature evolution during cooling was recorded as a function of time using a computer-aided cooling curve analysis technique, enabling the determination of crucial thermal parameters (refer to Figure 2(a and b)).

The second technique, dilatometry, also known as thermal dilatation analysis, was employed to analyze the linear change of dimension of the specimen as a function of temperature. The dilatometry measurements were carried up to a temperature of 570°C as shown in Figure 3(a and b). This technique provided the phase transformation temperatures as they present inflection points of the dilatometry curve.

For the investigation of homogenization heat-treatment effects, the specimens were cut from near the center of the as-cast ingot and subjected to a series of homogenization heat treatments with respect to the following schedule: Zero hours (reference), 16 hours, 26 hours, 38 hours, and 48 hours at a temperature of 515°C (Figure 4). A comprehensive examination of the specimens was conducted through metallographic inspection, SEM combined with EDS, XRD, and Vickers microhardness in each case.

To prepare the specimens for metallographic and SEM analysis,

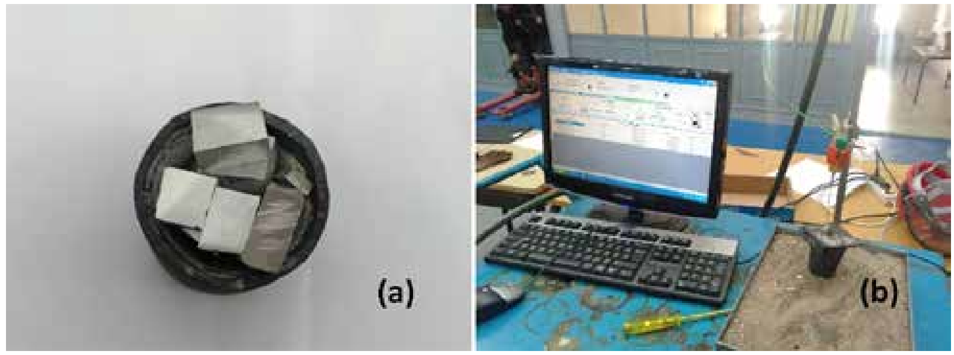


Figure 2: Computer-aided cooling curve analysis (a) sample (b) experimental set-up.

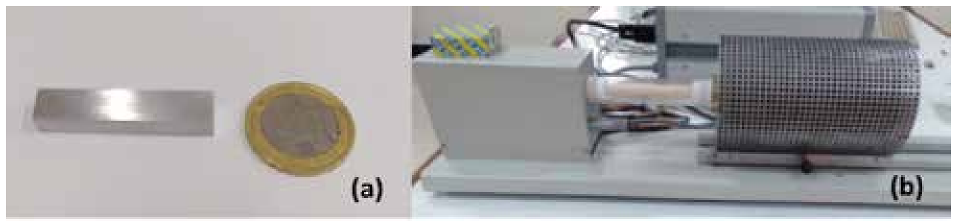


Figure 3: Thermal dilatation analysis (a) sample (b) experimental set-up.


Figure 4: Homogenization specimens in the furnace.

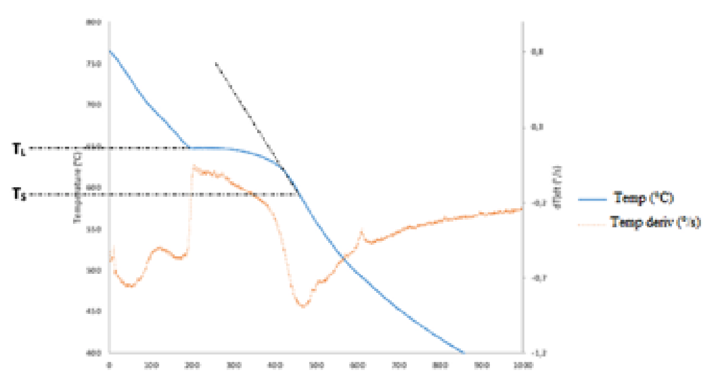


Figure 5: Cooling curve and its derivative.

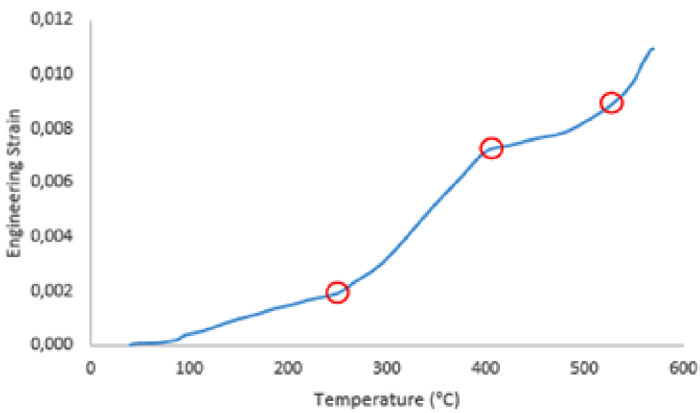


Figure 6: Dilatometry curve.

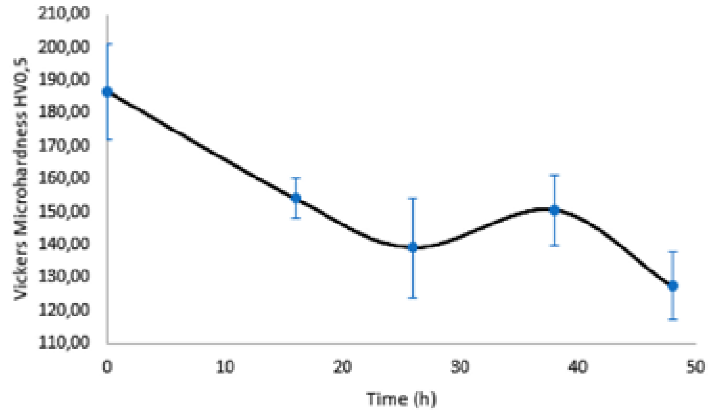


Figure 9: Vickers microhardness HV0.5 testing results.

precise cutting, then grinding, were carried out using progressively finer abrasives, namely 240P, 320P, 600P, 800P, and 1,200P. Subsequently, the specimens underwent polishing on 6 µm and 1 µm diamond pads with diamond solutions. The chemical etching was done by HF for a duration of 2-3 seconds.

In the case of XRD and Vickers microhardness specimens, they underwent grinding and polishing using the same aforementioned procedure. Vickers microhardness testing was done by a 10g mass and dwell time of 10 seconds, and seven was the number of measurements for each specimen. The scanning rate during XRD analysis was at 4°/min and the 2θ scan covered a range from 5° to 90°. The experimental measurements were conducted using a Bruker XRD machine.

3 RESULTS AND DISCUSSION

3.1 As-cast alloy characterization

The as-cast alloy is characterized by thermal analysis of the cooled sample and dilatometry techniques (Figure 2, Figure 3). Analysis of the cooling curve derivative revealed a distinct minimum peak corresponding to the solidus temperature, which was found approximately 625°C. The liquidus temperature corresponds to the temperature that has a derivative equal to zero where a small isotherm appears, and it has a value of 650°C to the first. The cooling curve of the alloy is illustrated in Figure 5.

The dilatometry analysis gave the curve of dilatation in the function of temperature, as shown in Figure 6. Significant shifts in the thermal expansion coefficient were observed at temperatures of 250°C, 400°C and 515°C. These transitions (highlighted in red circles in Figure 6) are attributed to phase transformations in the alloy, which play a crucial role in dictating its mechanical properties. Notably, the prominent change in the thermal coefficient at 515°C is of particular significance because it's the closest curve inflection to the solidus point. Based on the last result, the homogenization heat-treatment temperature was chosen as 515°C.

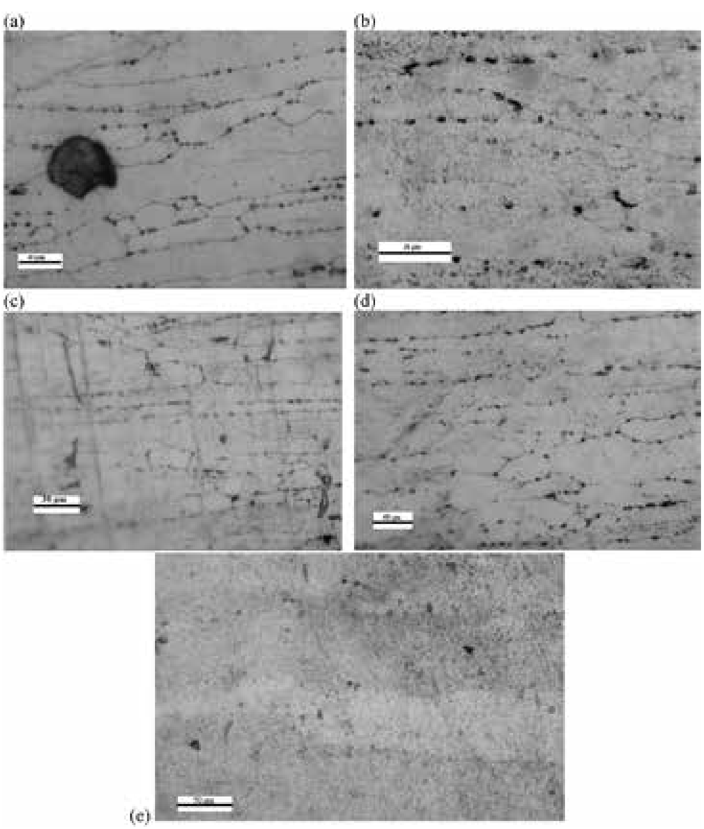


Figure 7: Optical microscope images, (a) 0h, (b) 16h, (c) 26h, (d) 38h and (e) 48h.

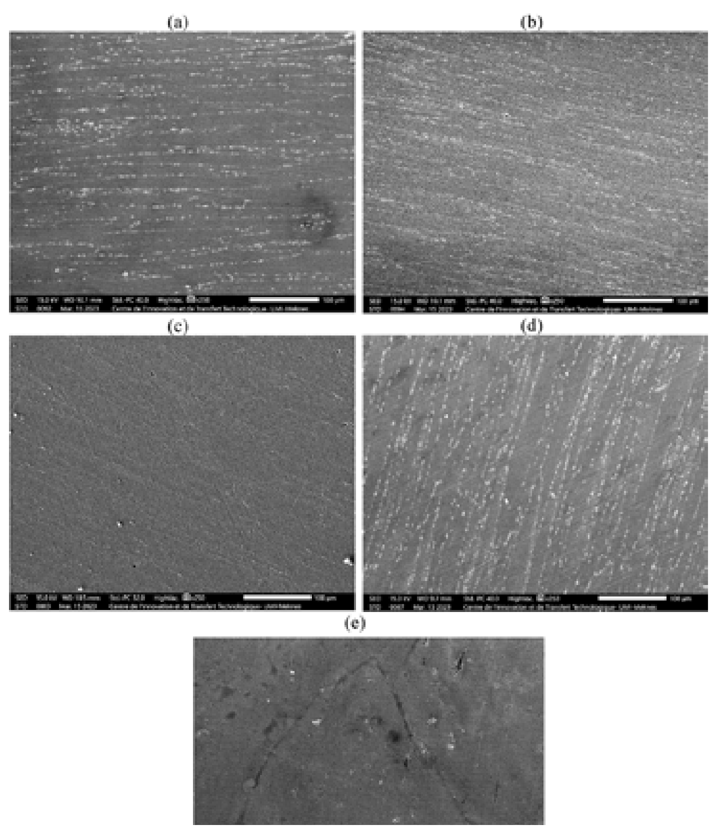
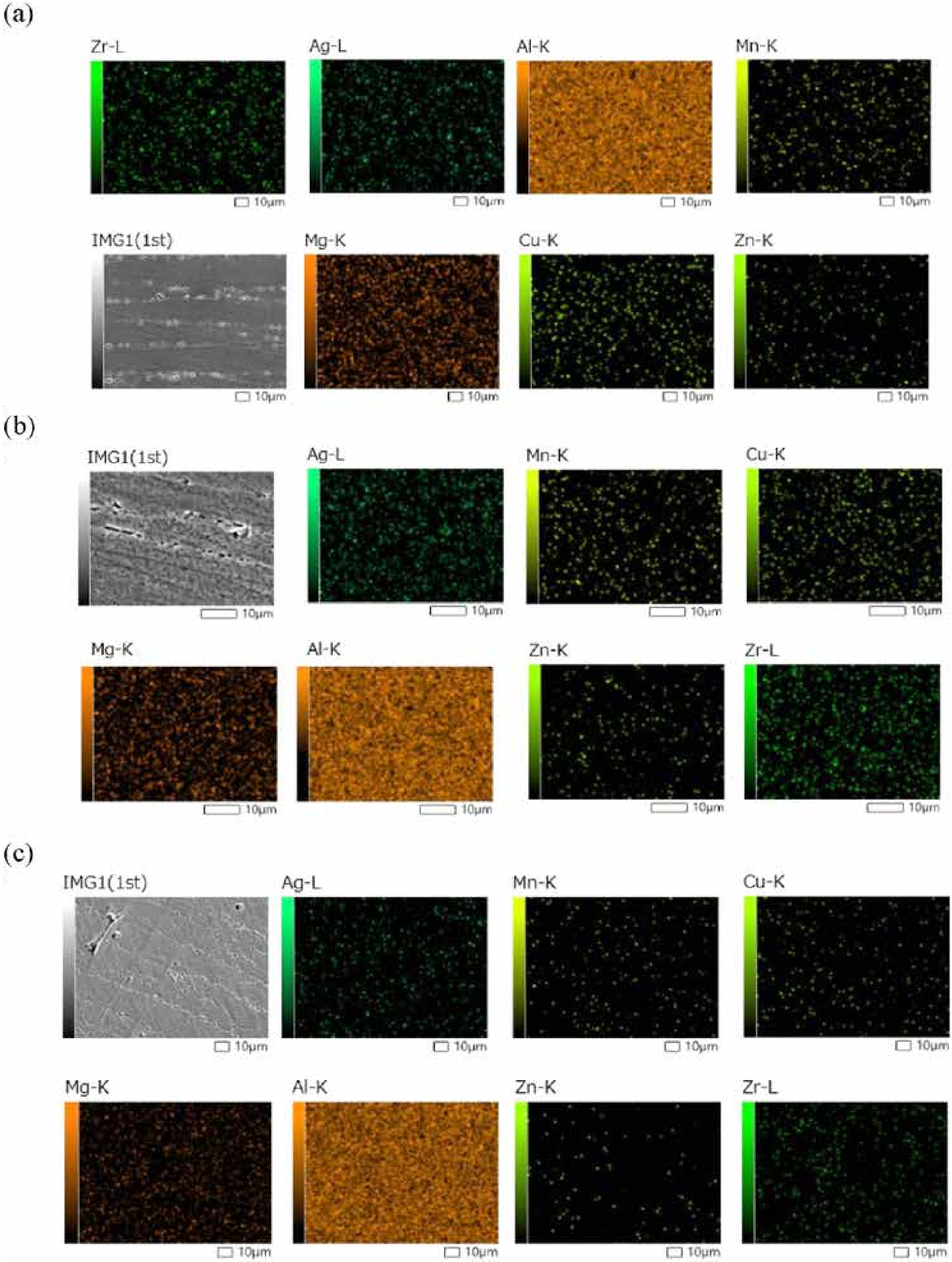


Figure 8: SEM images (a) 0h, (b) 16h, (c) 26h, (d) 38h and (e) 48h.


(a)
Zr-L
Ag-L
Al-K
Mn-K
10μm
IMG1(1st)
Mg-K
Cu-K
Zn-K
(b)
IMG1(1st)
Ag-L
Mn-K
Cu-K
Mg-K
Al-K
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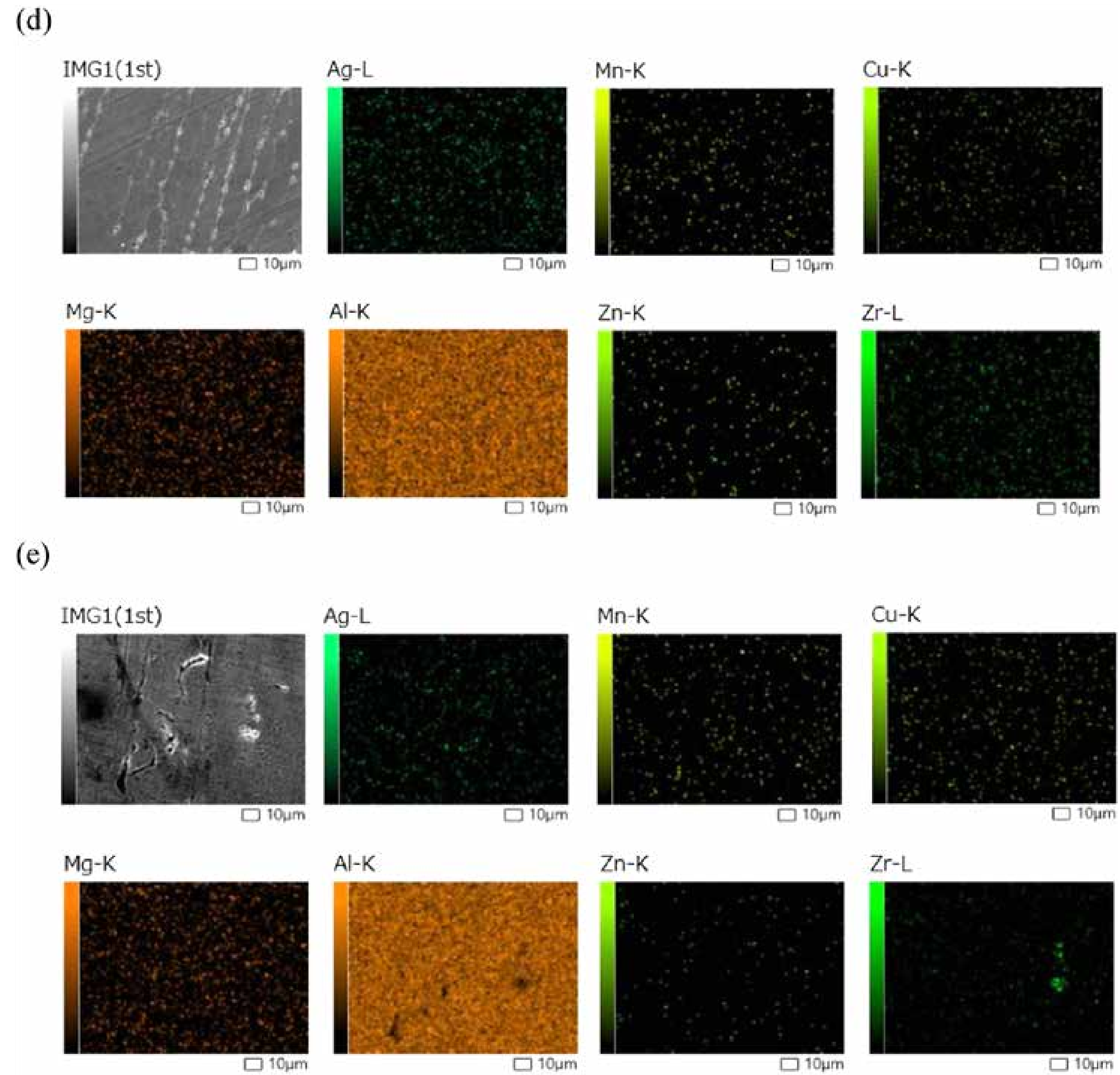

Figure 10: EDS analysis, (a) 0h ref, (b) 16h, (c) 26h, (d) 38h, (e) 48h.

3.2 Homogenization heat treatment investigation

3.2.1 Optical microscope images, SEM images and Vickers microhardness

The metallographic images of the homogenized samples are shown in Figure 7(a–e). No dendritic structure was observed in any of the homogenized samples. Dark dots basically representing precipitates were prominently present at the grain boundaries. The grain boundaries are noticeable in all homogenization samples except the last one in Figure 7e, which presents 48 hours of homogenization heat treatment. The last sample has coarsened grains and hardly any grain boundaries are sighted.

SEM images shown in Figure 8(a-e) provide further insights into the evolution of grain boundary precipitates with varying homogenization times. After 26 hours of heat treatment, the size of the precipitates is minimal as shown in Figure 8c. The size of the precipitates decreases from the as-cast till the 26-hour homogenization heat-treatment sample, and it increases until what appeared as the dissolution of those precipitates in the 48-hour sample as shown in the last image of SEM in Figure 8e, where the grain boundaries are hardly visible. Those findings are close to the results of Amichi and Bourahla [19] where the last homogenized sample of nearly the same Al–Li alloy for 24 hours at 530°C has coarsened grains with no grain boundaries precipitates. Vickers microhardness results are illustrated in Figure 9 where the as-cast alloy has an approximate value of 186 HV0.5. Ghosh et al. [20] found that the as-cast alloy has a hardness value of 165 HV10.

The microhardness plotted curve shows a local minimum hardness value after 26-hour heat treatment, which coincides with the minimal size of the grain boundaries precipitates. As the grain boundaries precipitate size increased, the microhardness value also increased. The last case (after 48 hours of heat treatment) exhibited the lowest microhardness value. The SEM and optical images can explain it as they show no precipitates at the grain boundaries, indicating precipitates dissolution and coarsened grains. This phenomenon aligns with the findings of Rezaei et al. [12] who investigated two Al–Li alloys with Al–3Cu-1(2)Li-0.1Zr chemical composition and found a fluctuation in hardness depending on the homogenization time at a constant temperature of 500°C.

3.2.2 EDS analysis and XRD patterns

EDS analysis is presented in Figure 10(a-e) as a surface mapping of each homogenized sample, which revealed the absence of dendritic segregation in EDS mapping in all the homogenized samples. The homogenized sample for 48-hour EDS in Figure 10e showed minor segregation of Zr, which is responsible for the formation of β' precipitate. After 48 hours of homogenization heat treatment, the grain boundaries are coarse, suggesting the dissolution of β' precipitates which are responsible for grain boundary pinning.

XRD analysis, illustrated in Figure 11(a-e), displayed the presence of the aluminum α phase, δ', δ, and b' precipitates. The δ(AlLi) phase disappeared after 26 hours of homogenization, leaving behind the remaining precipitates of δ, β'. The T_1 phase is not spotted in the XRD patterns as it should appear after the age-hardening heat treatment. It's worth mentioning the formed precipitates in this study are not the aging hardening precipitates responsible for the strengthening of the alloy. A previous study conducted by Amichi and Bourahla [19] investigated an alloy with proximate chemical composition and found the as-cast alloy exhibits the precipitates β' and θ. Chen et al. [21] found in AA2196 alloy AlLi, Al_3Li, Al_2Cu and Al_2CuLi phases in the as-cast state. However, after a homogenization heat treatment at 500°C for 24 hours, only the Al_3Li phase remained. Wei et al. [11] found only θ precipitates after subjecting an alloy with a composition of 2.65% Cu, 1.47% Li, 0.33% Mn, 0.27% Mg and 0.12% Zr (wt. %) to a heat treatment of 530°C for 24 hours. The differences in the precipitates for each alloy are due mainly to the composition of the alloy; it differs when %Cu<%Li from the opposite case.

4 CONCLUSION

This study investigates the as-cast alloy and the effects of homogenization heat treatment

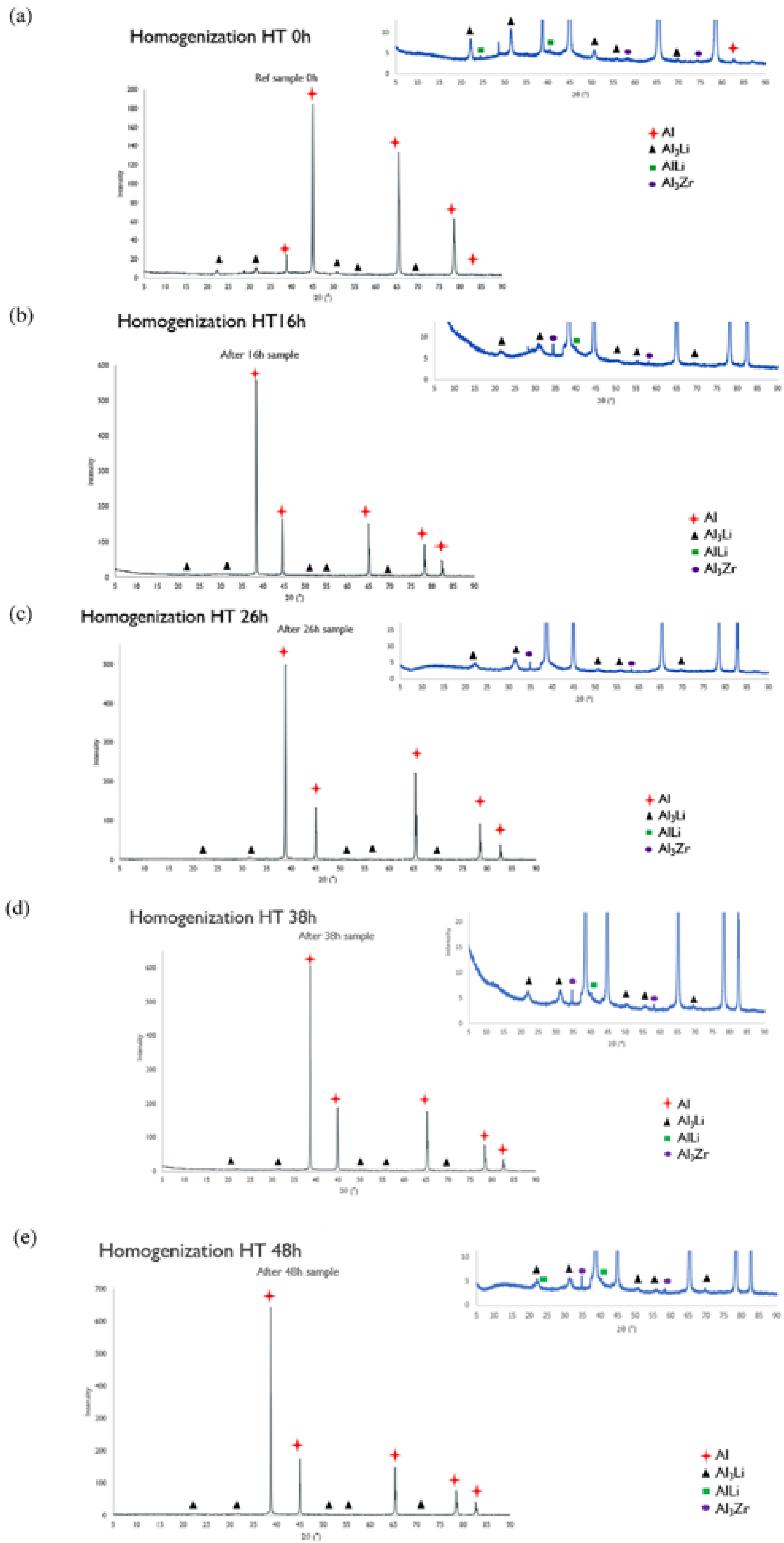

Figure 11: XRD patterns, (a) 0h ref, (b) 16h, (c) 26h, (d) 38h and (e) 48h.

on an Al–Li–Cu–Mg–Zr alloy. Through thermal analysis, dilatometry, metallography, SEM/EDS, XRD, and Vickers microhardness testing, comprehensive insights were gained regarding the alloy's thermal behavior, microstructural evolution, precipitates formation, and mechanical properties.

The as-cast alloy was characterized using cooling-curve thermal analysis and thermal expansion via dilatometry. The first technique gave the solidus temperature of the alloy as 625°C, and the temperature of liquidus was 650°C phase. The second technique revealed the fluctuation in unidirectional deformation at 200°C, 45°C, and 515°C. Based on these findings and on that 515°C temperature corresponds to the closest inflection point to the solidus temperature, the optimal temperature for the subsequent homogenization heat treatment was chosen as 515°C.

During the homogenization in investigation, optical microscopy and SEM examinations demonstrated the absence of dendritic structure and the presence of grain boundaries precipitates. The size of those precipitated was minimal after 26 hours of heat treatment, coinciding with a local minimum in Vickers microhardness value. EDS analysis confirmed the absence of dendritic segregation, while XRD patterns identified the presence of aluminum α phase δ', δ, and β' precipitates. The dissolution of β' precipitates was observed after 48 hours of homogenization heat treatment with coarsened grains. Based on all the findings of this work, the best homogenization time is 26 hours as a process preceding rolling.

DATA AVAILABILITY STATEMENT

The raw/processed data required to reproduce the above findings cannot be shared at this time as the data also forms part of an ongoing study.

ADDITIONAL INFORMATION

No additional information is available for this article.

CREDIT AUTHORSHIP CONTRIBUTION STATEMENT

Abdellah Lahbari: writing — original draft, data curation, conceptualization. Kenza Bouchaala: writing - review and editing, supervision, methodology. Hamza Essoussi: resources, conceptualization. Mustapha Faqir: project administration. Said Ettaqi: investigation.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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ADVANCED DISTORTION CONTROL FOR CASE HARDENING OF TRANSMISSION COMPONENTS

The low-pressure carburizing and high-pressure gas quenching process offers a significant potential for advanced distortion control where the gas-quenching process provides a more homogenous heat-transfer coefficient on the surface of the quenched components when compared to quenching with liquids such as oil or polymers.

By VOLKER HEUER, JOCHEN FRIEDEL, DAVID BOLTON, ORLANDO GARCIA, and XIN CHEN

In many applications the high demands regarding fatigue properties of transmission components can be reached only by the application of customized case hardening. This case-hardening process results in a wear resistant surface layer in combination with a tough core.

However, as a side effect, the components get distorted during heat treatment. This distortion has a significant cost impact because distorted components need to be hard machined after heat treatment. Therefore, the proper control of distortion and the variation of distortion is an important measure to minimize production costs.

By applying the technology of low-pressure carburizing (LPC) and high-pressure gas quenching (HPGQ), heat-treat distortion can be significantly reduced. Especially for e-drive components, significant cost-savings can be achieved compared to other process-combinations such as atmospheric carburizing with oil quenching.

HPGQ provides a very uniform heat-transfer coefficient. The predictability of movement during quenching is more certain and uniform throughout the load. Further improvements can be achieved by optimizing the gas-quenching parameters. Proper fixturing is another factor for distortion control. Modern CFC materials (carbon-reinforced carbon) are well suited as fixture material for gas quenching. When compared to traditional alloy, CFC demonstrates no deflection or distortion after many subsequent years of use.

This article provides insight into distortion values of transmission components for various applications after optimizing process parameters and the design of heat-treatment fixtures.

1 INTRODUCTION

Distortion control is one of the major challenges in modern manufacturing. Distorted gear components cause noise in the transmission and may even create problems during transmission assembly. Especially battery-operated electric vehicles (BEV) and other electrified vehicles (such as hybrids) require a low-noise transmission with high-precision components.

Distortion has a strong cost impact because distorted components often need to be hard machined after heat treatment.

Better control of distortion means:

- Less cycle time per part in hard machining.
- Less hard-machining capacity needed.
- Less tooling cost for hard machining.

With an excellent control of distortion for some applications, hard machining can be completely eliminated. For some other applications, the use of a cost-intensive press quench can be eliminated if an excellent distortion control is established.

1.1 Distortion mechanisms

The plastic deformation of metallic components during heat treatment is referred to as distortion. Distortion occurs if the stress in the material exceeds the yield stress of the material. During case hardening, the components are exposed to high temperatures in the range of 880°C to 1,050°C, and the yield stress decreases strongly with increasing temperature of a component. Three different types of stress in the material need to be distinguished:

- Residual stresses (They are induced before heat treatment by casting, forging, machining, etc.) [1]
- Thermal stresses (They are caused by the temperature gradient while heating and quenching.)
- Transformation stresses (They are caused by the transformation from ferrite to austenite during heating and transformation from austenite to martensite/bainite during quenching.)

These three types of stresses overlay with each other and add up to the total stress in the component. They are influenced by part geometry, steel grade, casting, forging, machining, etc., and they are influenced by the heat treatment. If the total stress in the component exceeds the yield stress, then plastic deformation (distortion) of the component takes place. The chronology and the height of the three types of stresses leading to distortion are dependent on numerous influencing factors, see Figure 1.

When analyzing distortion, it should be distinguished between size change and form change. Size change refers to the homogenous growth or shrinkage of the treated component while maintaining its shape (e.g., the homogenous growth or shrinkage of the diameter or the length of the component). Form change refers to a change of the shape of the part (e.g., roundness of a gear, bending of a gear shaft, or deformation of gear-tooth geometry).

All carburized components will have some size change due to the transformation of microstructure from ferrite into martensite. The size change must be controlled with green machining. For example, if an outside diameter grows 10 microns during heat treat, it should be machined 10 microns smaller before heat treatment.

There are many different characteristics affected by form change. However, it helps to better understand form change by simplifying distortion into two main parameters: flatness and roundness.

Form change for shafts is mainly straightness. When analyzing gears, flatness can be determined by the amount of "helix variation," or "lead variation." Roundness is a measurement of "circularity."

Helix average also changes during heat treat. The helix average changes in a minus direction, meaning the tooth is unwinding. For instance, the helix angle may be 15 degrees in the green state, but it may change to 14 degrees after heat treat. This must be compensated with green machining.

1.2 Low Pressure Carburizing in combination with High Pressure Gas Quenching

By applying the technology of low-pressure carburizing (LPC) and high-pressure gas quenching (HPGQ), heat-treat distortion can be reduced significantly. LPC is a case-hardening process performed in a pressure of only a few millibars using acetylene as the carbon source. During HPGQ, the load is quenched using an inert gas stream instead of a liquid quenching media. Usually, nitrogen or helium is used as a quench gas [2,3,4].

HPGQ offers a significant potential to reduce heat-treat distortion. Conventional quenching technologies such as oil or polymer quenching exhibit inhomogeneous cooling conditions. Three different mechanisms occur during conventional liquid quenching: film boiling, bubble boiling, and convection. The distribution of the local heat-transfer coefficients on the surface of the component is very inhomogeneous as a result of these three mechanisms. These inhomogeneous cooling conditions cause high thermal and transformation stresses in the component and subsequent distortion. During HPGQ, only convection takes place, which results in much more homogenous cooling conditions, see Figure 2 [5, 6]. Significant reductions of distortion by substituting oil quench with HPGQ have been published [7, 8].

Another advantage of HPGQ is the possibility to adjust the quench intensity exactly to the needed severity by choosing quench pressure and quench velocity. Typical quench pressures range from 2 bar to 20 bar. The gas velocity is controlled by a frequency converter. Typical gas velocities range from 2 m/s to 20 m/s. Quench pressure and gas velocity are chosen depending on the part geometry and the steel grade of the component to achieve optimum results.

The following equation describes the heat-transfer coefficient as a function of gas velocity, gas density and the type of gas [2]:
where

$$\alpha = C \cdot w^{0,7} \rho^{0,7} d^{-0,3} \eta^{-0,39} c_p^{0,31} \lambda^{0,69}$$

C is constant factor (depending on quench cell).
w is gas velocity.
ρ is gas density.
d is diameter of component.
η is viscosity of the gas.
c_p is specific heat capacity of the gas.
λ is thermal conductivity of the gas.

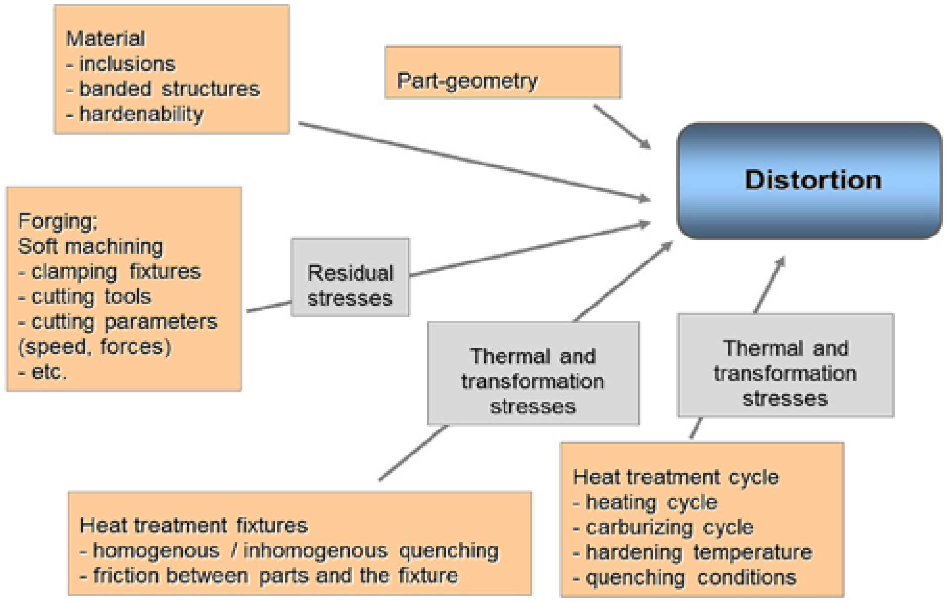

Figure 1: Factors influencing distortion.

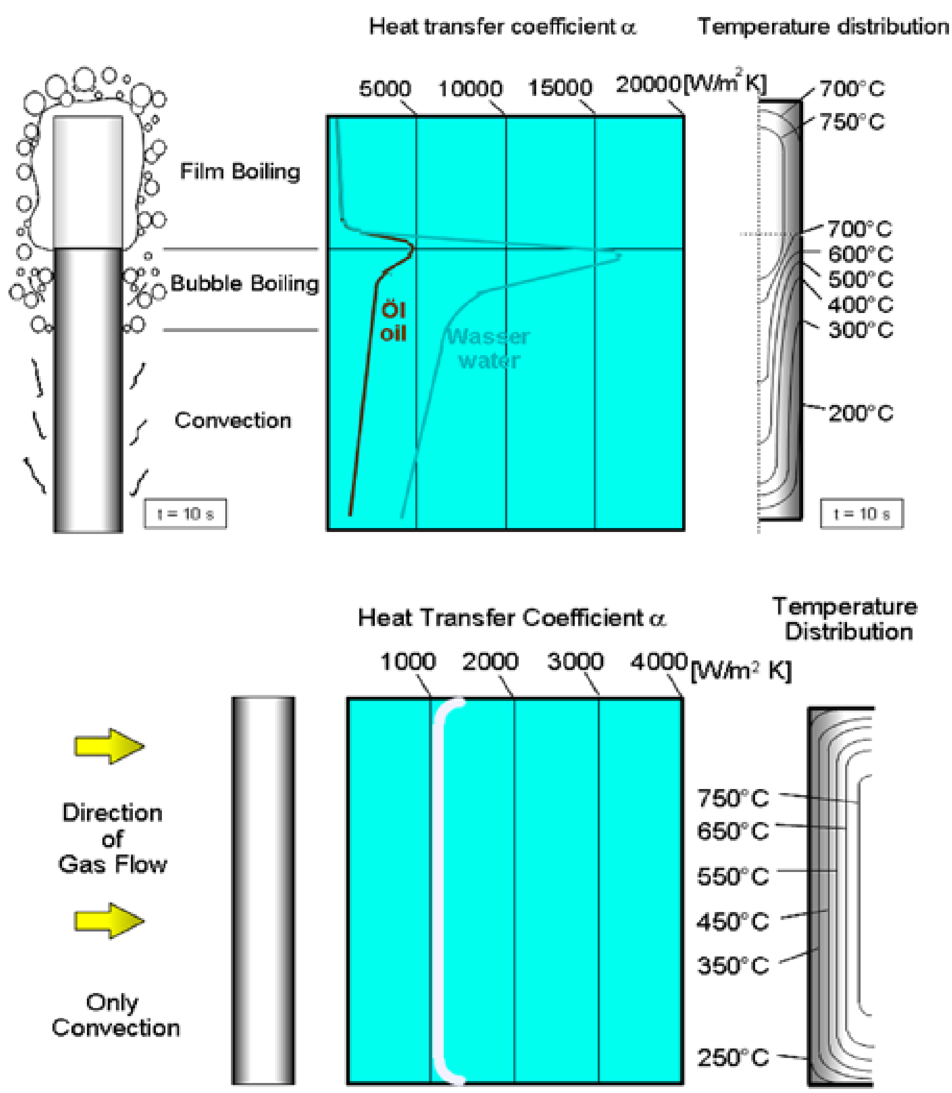

Figure 2: Heat-transfer coefficient and temperature distribution in liquid- and gas-quenching [5].

Typical gases applied for HPGQ are nitrogen and helium [2]. To achieve the required core hardness in gears of low-alloyed case hardening steels, helium as a quenching medium and a gas pressure of 20 bar is necessary for many applications.

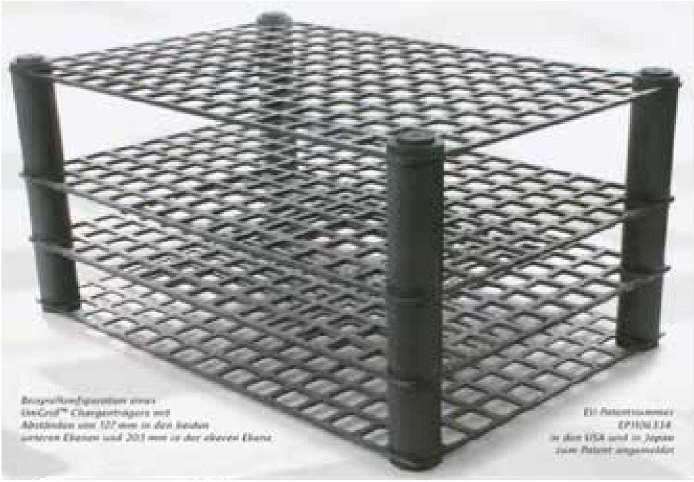

Figure 3: Fixture made of CFC (Source: Schunk GmbH).

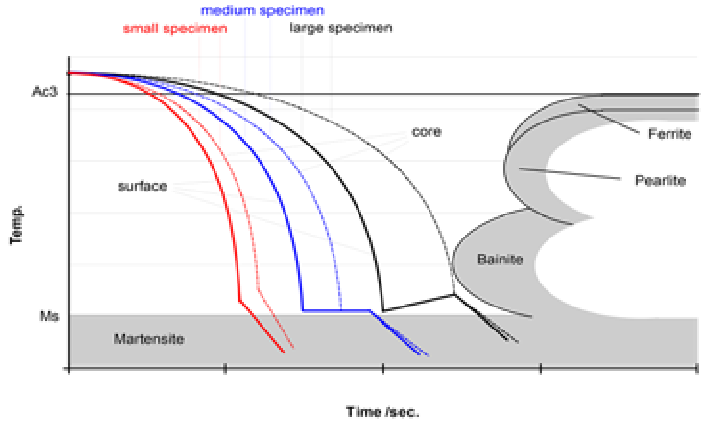

Figure 4: Schematic illustration of dynamic quenching for specimen of different sizes.

For many applications, it is not the absolute height of distortion causing manufacturing problems but the spread of distortion. The spread of distortion cannot be compensated with green machining. So, for many applications, the challenge is to optimize the HPGQ in such a way that it provides a heat-treatment process with very little variation of distortion within a load and, over time, from load to load.

2 STRATEGIES FOR DISTORTION CONTROL WHEN APPLYING HPGQ

As described earlier, the gas-quenching process offers two major advantages when compared to liquid quenching in terms of distortion control:

» More homogenous heat-transfer coefficient around the surface of the quenched component.

» The flexibility to tailor the quench intensity, specifically for the needs of the quenched component.

To fully exploit the benefits of HPGQ, it is important to optimize the design of the heat-treat fixtures. The fixture should provide a horizontal loading of the components and should allow a homogenous gas flow around the treated components during quenching as much as possible. Figure 3 shows an example of a fixture made of carbon-reinforced carbon (CFC).

In addition, the HPGQ process offers more options for further reduction of heat-treat distortion. These process modifications are explained in the following:

2.1 Dynamic Quenching

Dynamic quenching is a process where the quenching parameters' gas pressure and/or gas flow velocity are stepwise varied during quenching, see Figure 4. This process is typically divided into three steps [9]:

» **Step 1:** High quenching severity until a certain part-temperature is reached.

» **Step 2:** Quenching severity is reduced for a set time to allow for temperature equalization in the part.

» **Step 3:** Quenching severity is increased again until the end of the quenching process.

The control system in the quenching chamber allows to control the different quenching steps of "dynamic quenching" in a very accurate way with a good reproducibility. Optimum results are achieved when using helium. The light-quenching-gas helium can be decelerated and accelerated very precisely for optimum distortion control.

The application of dynamic quenching leads to a reduction of thermal stresses during quenching, and, thus, it offers the potential to reduce heat-treat distortion for certain applications. In addition, a positive effect on fatigue properties can be achieved as well by applying this process modification.

2.2 Reversing Gas flow

High-pressure gas quenching is typically performed with a flow direction from top to bottom through the load. However, modern-gas-quenching chambers offer the possibility to reverse the direction of the gas flow during quenching. Reversing the gas flow means the flow of gas is alternated back-and-forth from top-to-bottom and bottom-to-top. By alternating the gas-flow direction, there is less difference in the cooling curves of parts placed in different layers. This reduces the

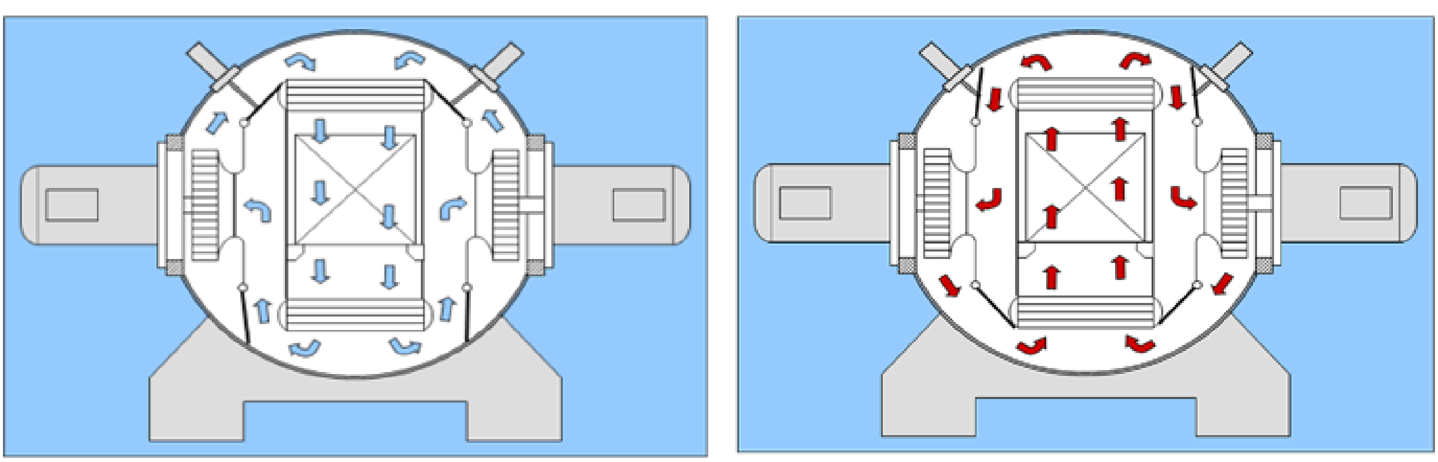

Figure 5: Reversing gas flow.

variation of distortion inside the load.

A schematic view of a quench chamber with reversing gas flow is shown in Figure 5. To allow for the alternating flow direction, the chamber is equipped with flaps operated pneumatically. Depending on the setting of the valves, either top-to-bottom or bottom-to-top flow direction is put into effect. The alternation of the flow direction is time controlled.

3 DISTORTION STUDIES

3.1 Comparison of LPC and HPGQ vs. Atmospheric carburizing and Oil quench

Sliding gears made of 8620 material used to be carburized in atmosphere and quenched in oil. For this application, the hardenability of 8620 material was too low to allow for gas quenching. Therefore, the steel grade was changed to 4320H material.

The gears have an outer diameter of 92 mm, an inner diameter of 30 mm, and a height of 24 mm. The specification after heat treatment calls for a surface hardness of 58-64 HRC, a core hardness of 35.1-43.3 HRC, and a case-hardening depth CHD at the pitch of 0.75mm-1.3mm. The microstructure in the case-hardened layer must consist of a minimum of 90% martensite, not more than 10% retained austenite, and no bainite.

For a distortion study, one load with gears made of 8620 material was carburized in atmosphere and oil quenched, and one load made of 4320H material was low-pressure carburized and gas quenched. An image of the LPC-load is in Figure 6.

Twenty parts were measured in each load. Figure 7 and 8 show the absolute geometrical values after heat treat, not the change during heat treatment.

Four teeth are measured per each gear. “Helix average” is the average helix value from those four teeth of one gear. Figure 7 shows the average values from 20 measured parts of helix average as well as the maximum and minimum value from those 20 parts for both processes. The spread of “helix average” is clearly reduced with the LPC and HPGQ process.

“Helix variation” is the difference of maximum and minimum helix value from the four measured teeth per each gear. Figure 8 shows the average values of “helix variation” from 20 measured parts as well as the maximum and minimum value of “helix variation” from those 20 parts.

The “helix variation” is strongly reduced when applying LPC and HPGQ, see Figure 8. For the left flank, the average “helix variation” is reduced by 59 percent and, for the right flank, by 48 percent. When applying LPC and gas quenching, the “helix variation” is safely within the maximum tolerance of 50 microns. This offers a significant potential for cost savings in hard machining.

3.2 Size change of pinion gears when applying LPC and HPGQ

The size change of pinion gears was monitored during serial production when applying LPC and HPGQ. The pinion gears are made of SAE 5120H material with an outer diameter of 34 mm, an inner diameter of 20 mm, a height of 15 mm, and a weight of 0.055 kg per part, see Figure 9. The case-hardening depth CHD after heat treatment is specified as 0.5 – 0.8 mm.

Three parts each from 140 production loads were measured. Figure 10 shows the size change of the inner diameter. The inner diameter is shrinking by an average of 39 microns. The shrinking is stable and predictable within a load and from load to load.

Gear shafts made of 20CrMnTi material were analyzed regarding shrinking of the inner diameter at the spline. Figure 11 shows the

Figure 6: Load of sliding gears (CFC fixture consisting of 12 layers).

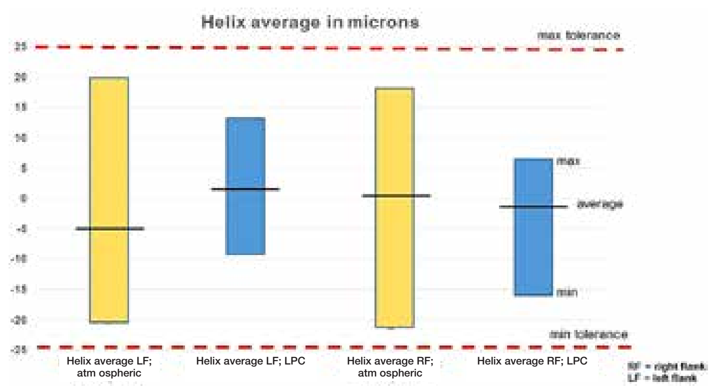

Figure 7: Helix average of sliding gears; comparison of atmospheric carburizing and oil quenching vs. LPC and gas quenching.

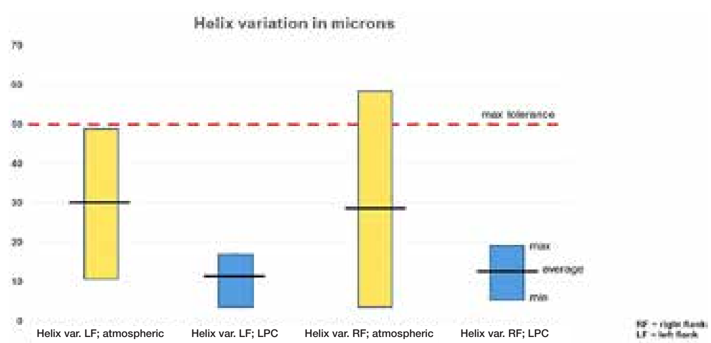

Figure 8: Helix variation of sliding gears; comparison of atmospheric carburizing and oil quenching vs. LPC and gas quenching.

measurement positions.

The shafts have an outer diameter of 48 mm, a height of 233 mm, and a weight of ca. 2.7 kg. The specification after heat treatment calls for a case-hardening depth CHD = 0.6-0.9 mm and a surface hardness of 59-63 HRC.

Twenty shafts were analyzed regarding size change of the inner diameter after applying the process of LPC and gas quenching.

Figure 12 shows the average shrinking and the variation of shrinking at the positions a, b, and c of the inner spline. A homogenous shrinking on the three measurement positions is demonstrated.

3.3 Optimized fixturing

Final drive ring gears made of 4121 mod material (see Figure 13) were treated with different designs of fixture to improve distortion control. The parts have an outer diameter of 226 mm with 59 external teeth, a height of 32 mm, and a weight of ca. 4.2 kg.

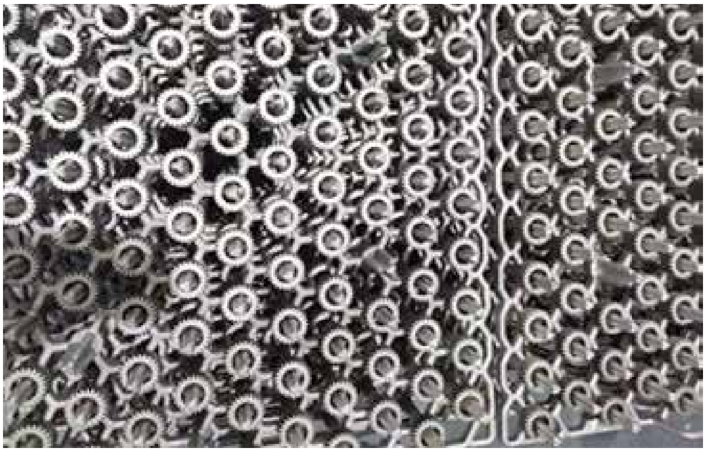

Figure 9: Load for heat treatment of pinion gears made of SAE 5120H material.

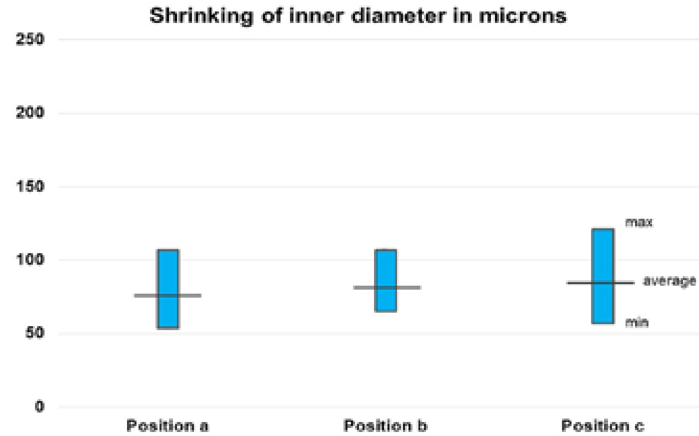

Figure 12: Shrinking of the inner spline of a gear shaft on different positions after LPC & HPGQ.

The case-hardening depth CHD is specified as 0.7-1.1 mm, the surface hardness as 64-69 HR45N, and the core hardness is specified to be above 28 HRC.

Figure 13 shows the standard fixture used in serial production. Three new designs of fixturing were tested to improve distortion control.

The average change of flatness and average change of roundness are given in Figure 14. With "Fixture 3," the distortion control was clearly improved:

» Change of flatness was reduced by 49%.

» Change of roundness reduced by 24% compared to standard fixturing.

As the new design could not be validated in a PPAP (production part approval process), it was not yet possible to implement this improvement into serial production. But it was clearly demonstrated that fixture design has the potential for improving future distortion control.

3.4 Reversing Gas flow

The following gives an example for the application of the reversing gas flow process as described in Section 2.2. The treated gears are made of 5120 materials, have an outer diameter of 31 mm, a height of 32 mm, and have 24 external teeth, see Figure 15. One load consists of 1,056 pieces treated in nine layers.

Figure 16 shows the improvement achieved when introducing the reversing gas-flow process. When applying unidirectional gas flow, the gas is flowing only from top-to-bottom through the load. With

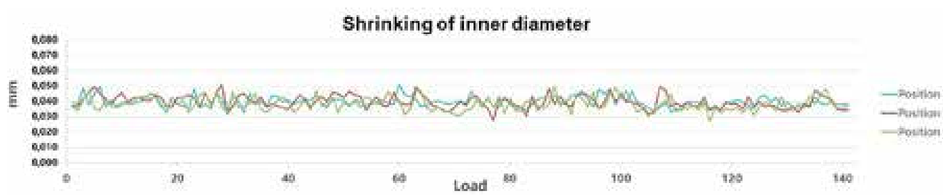

Figure 10: Size change of inner diameter of pinion gears after LPC and HPGQ; 3 parts measured each from 140 production loads.

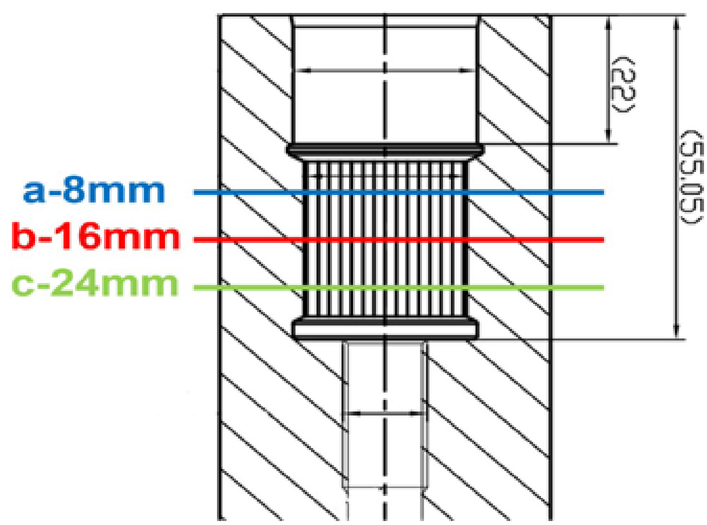

Figure 11: Measurement positions for inner spline of a gear shaft.

Figure 13: Final drive ring gear and production load consisting of nine layers.

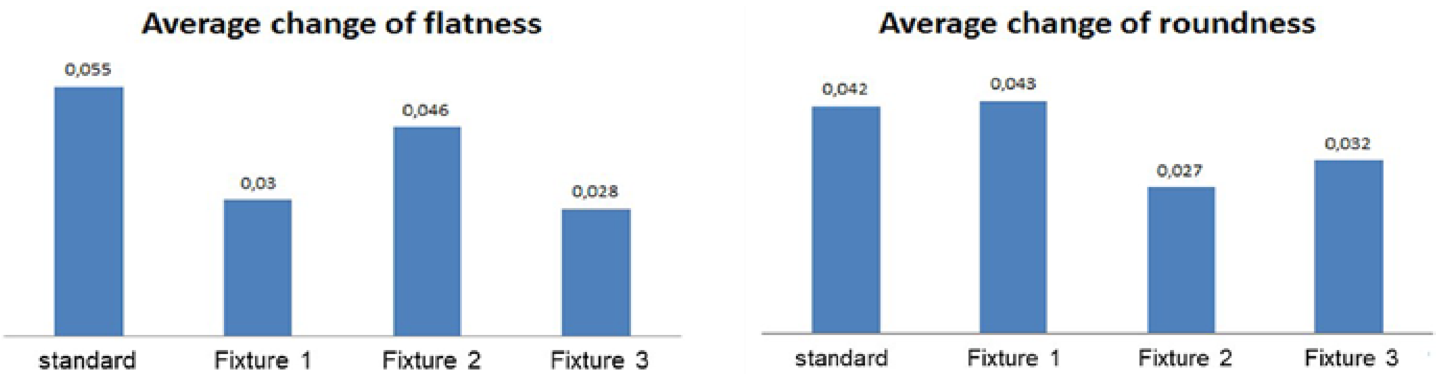

Figure 14: Change of flatness and change of roundness of final drive ring gears using different fixtures applying LPC and HPGQ (values in mm).

reversing gas flow, the flow of gas alternates back-and-forth from top-to-bottom and bottom-to-top, as illustrated in Figure 5. As shown in Figure 16, with unidirectional flow, the parts in the middle and top layer of the load exhibit excessive distortion. With reversing gas flow, the helix angle variations were significantly reduced. For example, for the right flank of the gears from the top layer of the load, the maximum helix angle variation was reduced by 61 percent.

With the optimized reversing gas-flow process, it is not necessary to machine the teeth of these final-drive pinion gears after heat treatment. Only the bores and faces of the gear are machined after heat treatment. This example shows the significant potential to reduce distortion with reversing gas flow.

Figure 15: Final-drive pinion planetary gear (diameter = 31 mm, 24 teeth).

3.5 Optimized HPGQ-process parameters

The distortion control of drive gears made of 20CrMnTi material was improved by optimizing the HPGQ- parameters. The gears have an outer diameter of 127 mm with 79 external teeth, a height of 12 mm, and weight of ca. 0.3 kg, see Figure 17.

The specification after heat treatment calls for CHD = 0.5-0.8 mm, a surface hardness of 58-62 HRC, and the core hardness needs to be above 30 HRC.

Figure 18 shows roundness values after LPC and HPGQ. Three sets of quench parameters were tested and 100 pieces were measured in each test.

With "Quench 1," the gas-flow direction was from top-to-bottom. With "Quench 2," the gas-flow direction was changed, so the gas is flowing from bottom-to-top. This resulted in a significant reduction of roundness values. With "Quench 3," the quench intensity was slightly reduced compared to "Quench 2," which did not, however, result in further improvements.

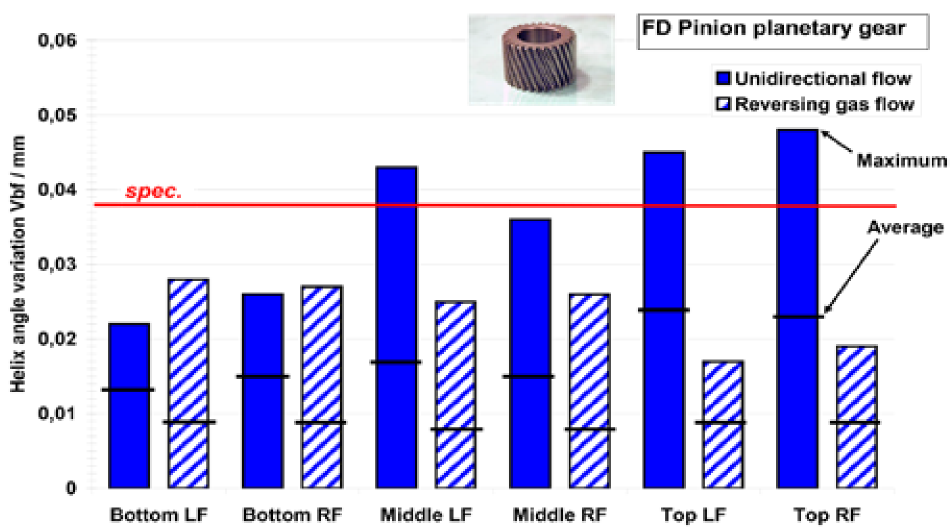

Figure 16: Reduction of distortion by application of reversing gas flow: comparison between unidirectional and reversing gas flow (helix angle variation of final-drive pinion gears after heat treatment in bottom, middle, and top layer of the load; LF = left flank; RF = right flank).

4 SUMMARY

The LPC (low-pressure carburizing) and HPGQ (high-pressure gas quenching) process offers a significant potential for advanced distortion control. The gas-quenching process provides a more homogenous heat-transfer coefficient on the surface of the quenched components when compared to quenching with liquids such as oil or polymers. In addition, the HPGQ process provides the flexibility to tailor the quench intensity specifically for the needs of the quenched components. The quench intensity can be tailored by defining the quench pressure (from 2 bar to 20 bar) and the gas velocity (from 2 m/s to 20 m/s).

For slide gears, it was demonstrated that distortion control was strongly improved when changing from atmospheric carburizing and oil quenching to LPC and HPGQ. For the left flank, the average "helix variation" was reduced by 59 percent and, for the right flank, by 48 percent. In this application, the steel grade was changed from 8620 material to 4320H material to allow for HPGQ. This change results in higher costs for the material. However, the higher costs of material are overcompensated for by the cost savings in the field of hard machining resulting from the improved distortion control.

The size change of pinion gears was monitored during serial production when applying LPC and HPGQ, demonstrating stable shrinking of the inner diameter within a load and from load to load.

Figure 17: Drive gear.

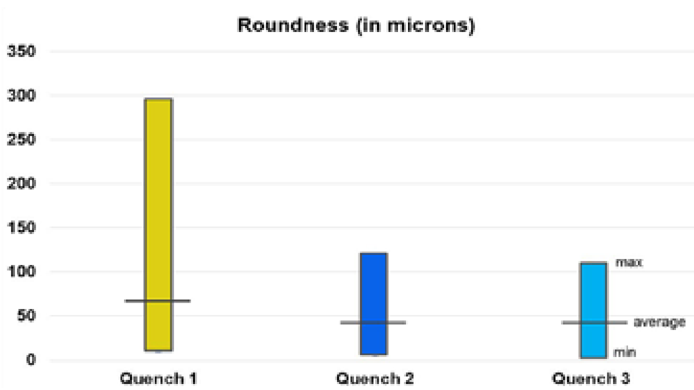

Figure 18: Roundness of drive gears with different HPGQ parameters.

On gear shafts, it was demonstrated that a homogenous size change (shrinking) of the inner splines was achieved with LPC and HPGQ.

A distortion study on final drive ring gears showed the importance of fixture design. The change of flatness was reduced by 49 percent and change of roundness was reduced by 24 percent when improving fixture design.

The HPGQ process offers further options such as "dynamic quenching" (variation of the quench intensity during the quench) or "reversing gas flow" (alternating gas flow direction during the quench) to improve distortion control.

The process modification "reversing gas flow" was applied on final drive pinion planetary gears. With reversing gas flow, the flow of gas alternates back-and-forth from top-to-bottom and bottom-to-top. By doing so, the helix angle variations were significantly reduced. For example, for the right flank of the gears from the top layer of the load, the maximum helix angle variation was reduced by 61 percent.

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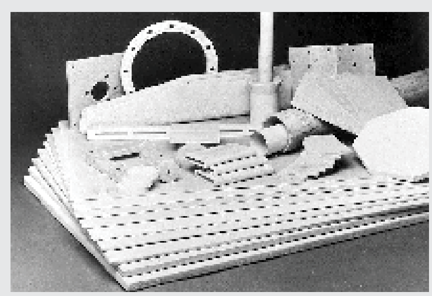

JOHN DYKSTRA /// CHIEF SERVICE OFFICER /// IPSEN USA

"Having well-rounded and trained technicians is crucial to Ipsen to ensure that we, one, keep our customers happy, but two, really keep our furnaces running as they should."

Why is the role of field service engineer a crucial part of the services Ipsen offers?

For me, field service is paramount because from the time that equipment leaves our facility until the time it's taken out of service, field service engineers, in many ways, become the face of Ipsen, they are the conduit by which we keep in contact with our customers and how we ensure our customers remain happy.

Having well-rounded and trained technicians is crucial to Ipsen to ensure that we, one, keep our customers happy, but two, really keep our furnaces running as they should over the many, many thousands of cycles in their lifetime.

What makes Ipsen's field service engineers superior to your competitors?

One: sheer volume. We have more technicians across the world than any of our competitors, and they're Ipsen employees. They're not third parties; they're not other people that work for Ipsen; they are Ipsen employees out there fixing our furnaces.

That gives us the ability to do quality control. We have the ability to really hold onto our technicians. Many of them have worked for us for up to 30 years. That's a significant amount of vacuum furnace knowledge — and not just Ipsen knowledge, but all of the brands out there. If a customer calls us, and if they happen to have competitor furnaces, we're able to maintain, support, and repair those, too.

Our newer technicians always have somebody they can rely on to help them if they're getting a little stuck in some process, which is a huge benefit.

What new initiatives have you implemented for the hiring and training of field service engineers?

We recently launched the TDC — the Ipsen Technical Development Center. It's a highly-intense, six-month program. We're hiring field service engineers (FSEs), and we're giving them time to prove themselves in the field for a short period of time, and then we enter them into the technical development center.

Over six months, they'll be trained on all aspects of the furnaces, whether it's here in our Cherry Valley facility or on hot zones or in our Souderton, Pennsylvania, facility. They're learning a block of knowledge, and then go into the field and use that knowledge to prove they're capable of doing what they just learned and developing them into Ipsen FSEs.

We've invested a lot from not just a manpower perspective in hiring with this first group of a half dozen technicians, but by having those technicians go through this whole program, it's an investment from the organization to make sure we're developing and delivering high-quality technicians to the field.

Parts inventory, ordering, and shipping processes can often be complicated, and challenges can cause potential delays in customer service. What has Ipsen done to make these areas more efficient?

When I came here three years ago, there were two things I realized we really needed to work on: One was focusing on getting the right amount of people to support our customers' demands and to establish new roles to better support our customers in the future.

Another piece of the parts organization we have focused on is looking at process improvements and improving our digital tools to better support our customers. Kaizen events drive overall process improvements, foster internal communication and help drive process efficiencies, in this case specifically looking at the end-to-end order process and improving many facets of that process.

From a digital perspective, we implemented a new customer portal, which is live, and we're expanding that pretty rapidly throughout the entire customer base. They're able to log in and make service and parts requests and easily interact with Ipsen. We also implemented a new call routing software so customers can more easily contact who they need and when they need them and a new case management software to better track parts orders through the process.

You recently expanded your aftermarket team. What made that move necessary?

We're changing our mentality on how we support our customers, and we're trying to support our customers at an even higher level than we've done in the past. We've launched four HUBs to date: in the Midwest and Southeast. With those HUBs, we're purposefully increasing the staffing of our field service engineers and focusing on significantly improving our response times to customers, so you don't have to wait a week to get an Ipsen FSE. The wait should be, at most, 24 hours.

Additionally, we expanded our service administration team and continue to expand it. Instead of having one or two service administrators overseeing all service requests, now we have service administrators overseeing designated HUB areas to ensure a high level of support. We've grown significantly over the last three years, and that trajectory is not going to stop.

What has been the customer response to these service changes?

The response from the customers that have HUBs in their areas has been very, very strong. We do annual customer service surveys, but the initial response is our parts group is getting back to them faster; our service team is responding better.

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