

WELDING *Journal*

MAY 2020



Construction Perspectives

Inspiring Welded Art

**The American Welder:
Cutting Technologies**

PUBLISHED BY THE AMERICAN WELDING SOCIETY TO ADVANCE THE SCIENCE, TECHNOLOGY, AND APPLICATION OF WELDING AND ALLIED JOINING AND CUTTING PROCESSES WORLDWIDE, INCLUDING BRAZING, SOLDERING, AND THERMAL SPRAYING

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CERTIFIED WELDING INSPECTOR

Lifetime Achievement Award



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In 2018, The American Welding Society established the honor of the **Certified Welding Inspector Lifetime Achievement Award (CWI-LAA)**. The award is intended to recognize individual members for a career of distinguished service, outstanding accomplishments, exceptional leadership, and innovative contributions in the area of welding inspection and welding inspection technology. Individuals receiving the award may be currently working as a CWI, or have worked as one in the past. The selection committee is seeking nomination packages for qualified individuals who have demonstrated specific accomplishments in one or more of the following areas:

- Advancements in the field of welding inspection.
- Mentorship of individuals entering the field of welding inspection.
- Effective application of existing and new inspection technology.

This could be evidenced by one or more of the following:

1. Development of novel concepts or tools related to welding inspection.
2. Participation in activities directly related to the recruitment, training, education and/or mentorship of individuals entering the field of welding inspection.
3. Leadership in AWS or private industry, particularly as it impacts advancement of the welding inspection profession.
4. Consultancy in technical matters or welding industry business matters, including expert witness activities related to welding inspection.
5. Publication of books, papers, articles or other significant works related to welding inspection.
6. Meaningful participation in AWS committees, Sections or other AWS voluntary contributions related to welding inspection.

For more specifics on the nomination requirements, please contact Malisa Mercado at mmercado@aws.org at AWS headquarters in Miami, or simply follow the instructions on the AWS CWI Lifetime Achievement Award nomination form located at: aws.org/cwilaa.

Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is **July 1, 2020**. The CWI Lifetime Achievement Award Committee looks forward to receiving numerous nominations for 2021 consideration.

Sincerely,

Kerry Shatell

Chair, CWI Lifetime Achievement Award Committee

IMPORTANT Announcement!



Nominate Your Colleague for the American Welding Society CWI Lifetime Achievement — Award —

July 1, 2020 Submission Deadline



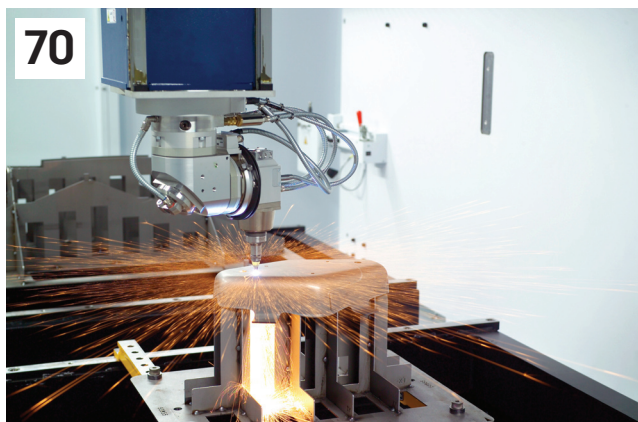
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At the American Welding Society (AWS), we are actively following the Novel Coronavirus (COVID-19) outbreak. The welding and fabrication industries have been determined to be an essential business, especially as it relates to repair and maintenance of key infrastructure. The content of the May 2020 issue of the Welding Journal is intended to be accurate when published, but we recognize that we are in a rapidly changing situation. For AWS's official statement on COVID-19, as well as the latest updates and frequently asked questions, please visit aws.org.

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Patriot Erectors Inc., Dripping Springs, Tex., completed welding on 200 steel canopies at Austin-Bergstrom International Airport. (Credit: ESAB Welding & Cutting Products.)

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AWS Promotes Diversity

AWS values diversity, advocates equitable and inclusive practices, and engages its members and stakeholders in establishing a culture in the welding community that welcomes, learns from, and celebrates differences among people. AWS recognizes that a commitment to diversity, equity, and inclusion is essential to achieving excellence for the Association, its members, and employees.

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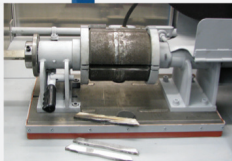
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to exact dimensions in
5 minutes.



Backstrap Removal Tool BSRT-15/10

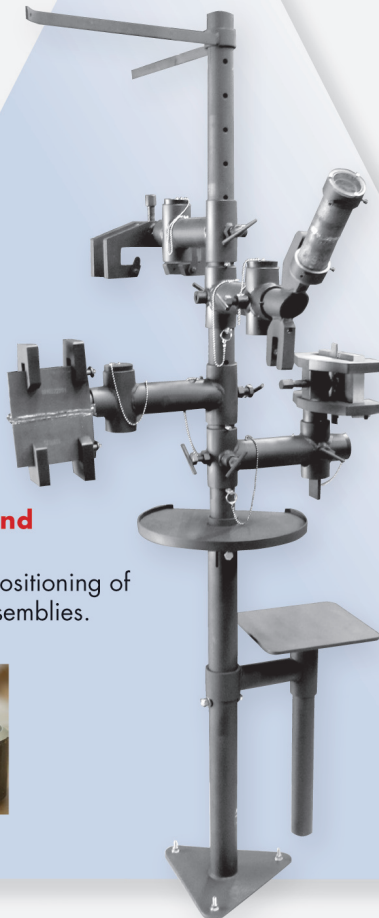
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uniform surface
prep of test bends
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The Role of Resistance Welding



Don DeCorte
RWMA Chairman,
2020-2021

“For those of you out there in our wonderful world of resistance welding, you now have the opportunity to be among the first in the world to earn AWS CRWT certification.”

Hello, my friends in the welding world! This is my first American Welding Society (AWS)-related editorial, and let me say, I am truly honored.

This is a special year for me in many ways, so let me start with the number 40 and go from there.

In June, I will celebrate my 40th year married to the love of my life, Patricia “Trisch” DeCorte.

In October of this year, I will celebrate 40 years as an AWS member. I joined this esteemed Society through the Detroit Section at 19 years old.

I have also worked in the resistance welding industry for a total of — wait for it — yes, 40 years.

Also, through my career in resistance welding, I have visited 40 countries as of 2020. During this time, I have had the pleasure of meeting hundreds of incredible people in our welding world.

And while it doesn’t really have anything to do with 40, I am also honored to have been selected as the chairman of the Resistance Welding Manufacturing Alliance (RWMA, aws.org/rwma) for 2020-2021.

So, you might ask, why all this stuff about 40 years and establishing I am a lucky man? Well, there is one more thing for me to mention, and then I will try to bring everything into alignment.

This year is also special to me because the current AWS President, Robert Roth, is my friend, business partner, and the CEO at Roman Manufacturing Inc., Grand Rapids, Mich., which is celebrating its 40th year in business.

How does all of this align, at least in my mind? The answer is simple: This is the year of resistance welding.

It’s been more than 120 years since the discovery of resistance welding by Professor Elihu Thomson, and the process is still going strong. For example, our current AWS president is from a resistance welding equipment supply company. And in March, AWS rolled out a resistance welding certification, known as the Certified Resistance Welding Technician (CRWT, aws.org/certification/page/certified-resistance-welding-technician).

The CRWT certification was developed through AWS, and is held to the same globally recognized high standards as other AWS certifications.

I know, I know, what’s the big deal? It’s only resistance welding, right?

Well, as I once told AWS Past President Dave McQuaid, my close friend and world-renowned bridge welding expert, “Dave, the bridges you design the welding processes for are obviously important. But the minivan your wife drives the grandchildren in over those bridges is resistance welded, so you tell me how important those welds are?!”

Here’s a quick background on how the CRWT was developed: Originally, the idea was generated by the RWMA before being integrated into AWS as an industry partner. A group of very smart, dedicated resistance welding professionals started to meet and work on the creation of a resistance welding certification. This work continued slowly but surely, even as the RWMA merged to become a Standing Committee within the AWS. Through many more years of hard work, dedication, and collaboration between members of the RWMA along with AWS, the AWS Certification Department created what is now known as the CRWT.

The CRWT gives us a standard we can use to evaluate resistance welding staff. It can help companies determine which of their new hires or current employees are qualified to operate and maintain their equipment. Before even taking the exam, candidates need to show they have qualifying resistance welding education and/or work experience. The exam then tests their skills and abilities in resistance welding principles, processes, and equipment.

For those of you out there in our wonderful world of resistance welding, you now have the opportunity to be among the first in the world to earn AWS CRWT certification. By taking and passing the CRWT exam, you can proudly say and prove you are proficient in the knowledge of resistance welding processes and application.

Speaking on behalf of the resistance welding industry, thanks to all who worked to help bring this important and well overdue certification to life.

I sincerely hope all of you connected to resistance welding, as either an employee or employer, recognize the opportunity to reinforce your commitment to quality through this offering of the CRWT certification. **WJ**

AWS Announces New Executive Director and CEO Gary Konarska



Gary Konarska

The Board of Directors of the American Welding Society (AWS), Miami, Fla., has announced Gary Konarska II as the organization's new executive director and chief executive officer (CEO), effective April 6. Konarska succeeds Ray Shook, who held the position for 15 years and has agreed to remain as executive director emeritus for an interim period to ensure a seamless and successful transition.

"We are very excited to welcome Gary to the American Welding Society, taking on the role of executive director and CEO. Gary brings an exceptional combination of industry knowledge, energy, and proven leadership that make him the ideal leader for AWS. We're confident that Gary will continue to advance the AWS mission and strive to connect welding communities around the world," said AWS President Robert W. Roth.

"I am truly honored and excited to serve as AWS's executive director and CEO," Konarska said. "I look forward to working closely with the AWS Board of Directors, staff, and Ray Shook to ensure a seamless transition in order to continue to serve our Society and industry at large."

The selection of Konarska underscores the AWS Board of Directors' commitment to invest in and support the needs of members as they experience rapid industry advancements.

Konarska brings 20 years of experience in the welding and cutting equipment industry, where he worked with Lincoln Electric Holdings Inc., Cleveland, Ohio. Most recently, Konarska served as vice president, global automation, where he was responsible for 13 automation sites around the world and created business systems to drive metrics and continuous improvement. Throughout his tenure at Lincoln, he focused on international business and sales, strategic planning, and fostered collaboration and relationships among teams.

Konarska spent time living and working in Singapore with The Lincoln Electric Co. (Asia Pacific) PTE Ltd., as managing director for Southeast Asia, South Korea, and Taiwan. He was responsible for all commercial activities in the region, as well as a welding consumable manufacturing plant in Indonesia. Prior to this role, he was based in Shanghai, China, as director of business development, where he led core business functions, including export and import sales, a robotic automation profit and loss (P&L) management, product management, marketing communications, service, and a welding technology center. He started his career as a technical sales representative in Seattle, Wash., and then Tampa, Fla.

Konarska earned a bachelor's degree in industrial and operations engineering from the University of Michigan and a master of business administration degree from the University of South Florida. He is also a graduate of the inaugural Lincoln Electric Global Leadership Program.

AWS Responds to the COVID-19 Crisis

As of press time for the May 2020 *Welding Journal*, the American Welding Society's new COVID-19 website at aws.org/COVID19 included the following information.

- **Official Statement from AWS.** The number one priority for AWS is the health and safety of our members, staff, seminar and exam candidates, conference attendees, and volunteers. As we monitor developments regarding COVID-19 from the Center for Disease Control and Prevention (CDC) and the World Health Organization (WHO), AWS will continue to follow their recommendations as the situation progresses.

- **AWS Members — Frequently Asked Questions and Answers.** This section has queries, from how will the COVID-19 outbreak affect upcoming AWS seminar and exam sittings to will AWS Section meetings and/or AWS Student Chapter meetings take place, as well as responses.

- **AWS Corporate Members — Document on Welding and Cutting Organizations as Essential Businesses.**

A text that may be used as supporting documentation with local, state, and national government representatives details welding and cutting businesses, and the products they provide, critical to public safety and health. Therefore, they should be designated as "essential businesses," in line with other medical equipment manufacturers. Signed by Ray Shook, now the AWS executive director emeritus, it also features industries that rely on essential products from these businesses.

- **Educator Support.** AWS has compiled a list to help educators. Visit careersinwelding.com/educator-resources/.

- **Help for Small Business Owners.** Go to sba.gov/page/coronavirus-covid-19-small-business-guidance-loan-resources.

In addition, here's more AWS-related news at this time.

- **AWS Provides Hardship Relief.** If you are an AWS member or customer who is experiencing job loss due to the Coronavirus, the Society would like to help.

Please contact one of the AWS Customer Service team members by visiting aws.org/about/page/contact (click on "Customer Service / General Inquiries") and send a message noting your hardship, or call (800) 443-9353. We will let you know what type of relief options may be available, e.g., grace period for member dues payment, extension on certification renewal or recertification, for those impacted.

In times of need, to the best of our ability, the Society will make every effort to help you get back on your feet.

- **Informative Threads on the AWS Member Forum.** Through the AWS Member Forum, these threads have garnered much discussion: teaching welding and working through the pandemic, an online discussion for welding instructors, and getting back on track afterward. Check them out.

- **Social Media Highlights from AWS.** "How have you handled the recent events? What have you found to be helpful?" AWS asked on social media. One of the many responses/photos consisted of "Just keep welding, just keep welding!" by @leviveltkamp, providing some positivity during this period. [!\[\]\(4186b6ce3a1c83eabb297c1bfd00309c_img.jpg\)](#)

Lincoln Electric Donates Welding Machines to Vocational School in Indonesia



Managing Director of Lincoln Electric Asia Pacific Cristanto Niklas Bawengan (center, holding sign) celebrates with SMKN 2 Bandung vocational high school students and staff after the donation of six welding power sources.

The Lincoln Electric Co. Asia Pacific, headquartered in Singapore, has donated six welding power sources to SMK Negeri (SMKN) 2 Bandung, a vocational high school located in Bandung, West Java, Indonesia. In partnership with PT. Asian Welding Specialist, a local provider of technical and vocational welding education, training, and support, the high school offers a welding training program that is aligned to American Welding Society's (AWS's) Schools Excelling through National Skills Standards Education (SENSE) guidelines.

"With this generous donation, students of SMKN 2 can practice and continue to improve their practical welding skills using Lincoln's current technology power sources," said Saepudin Zuhri, lead welding instructor at SMKN 2 Bandung. "[The technology] blends well with the established AWS-SENSE-aligned entry-level welder curriculum being presented to these students."

To mark the occasion, a ceremony was held at the high school. Attendees included Cristanto Niklas Bawengan, managing director, Lincoln Electric Asia Pacific; Dina Septriana Snyder, director/quality assurance manager, PT. Asian Welding Specialist; and Tatang Gunawan, principal, SMKN 2.

L&T Equips Rural Women in India with Welding Skills

Larsen & Toubro (L&T), a technology, engineering, construction, manufacturing, and financial services conglomerate headquartered in Mumbai, India, has launched an initiative to train rural women in welding technology. Its aim is to enhance the technical skill sets of female students from socially and economically underprivileged areas.

"While welding isn't a traditional occupation for women, it will be a defining moment for the first batch of nine young women to be able to fulfill their dream of getting into the highly specialized and remunerative industrial occupation," explained Yogeshchandra S. Trivedi, senior vice president at L&T.

The welding training will be provided at the company's Vadodara Heavy Engineering Works (VHEW) facility, which manufactures equipment and systems for exotic metals and advanced composites materials, with the facility's senior management acting as mentors. The initiative's curriculum has been designed to meet the demands of the local welding industry.

After the successful completion of their training, the students will be awarded a certificate from L&T and the Shroff Foundation Trust, an organization that works to improve the lives of people living in impoverished communities. The students will also have the option to undergo additional training through L&T's workshops at VHEW.

Universal Robots Offers Cobot Leasing Program to Aid in Australia's Recovery Efforts



Universal Robots' leasing program helps farmers and manufacturers impacted by Australia's bushfires upgrade their existing cobots, purchase additional units, and perform cobot tests without an up-front capital investment.

Universal Robots (UR), a manufacturer of collaborative robots (cobots) headquartered in Odense, Denmark, has debuted a financial services leasing program to help manufacturers and farmers in Australia rebuild after the recent bushfires that consumed more than 12 million acres of land and destroyed 2500 homes and businesses. The goal is to propel the use of cobots, which can be programmed to perform an array of functions safely alongside humans, in the recovery efforts.

"We encourage farmers and food producers to enlist cobots to hasten the rebuilding process and implement technological advancements by tackling some of the more tedious and repetitive tasks in industry," affirmed Darrell Adams, head of Southeast Asia and Oceania, UR.

Under the program, manufacturers would be able to upgrade existing cobots, add more units, or test cobots without the initial capital outlay, allowing them to maximize productivity, quality, and profitability.

"We want all business owners, including those who suffered losses in Australia's bushfires, to be able to immediately put cobots to work without an up-front capital investment," said Adams. "Universal Robots' financial services offers a fast, low-risk, and financially friendly model to accelerate automation." **WI**

Lakeland The Construction Group Chosen to Design-Build Great Lakes Power Products



Lakeland The Construction Group has been selected as the design-build general contractor for the Great Lakes Power Products new world headquarters in Madison Village, Ohio.

Lakeland The Construction Group, Painesville, Ohio, which specializes in design-build construction, metal building systems, and construction management, has been selected as the design-build general contractor for the Great Lakes Power Products (GLPP) world headquarters in Madison Village, Ohio.

"This is a very exciting time for Lakeland. We are proud to be working with GLPP to help develop their new world headquarters. Our design team is working closely with GLPP management to accommodate their existing operations in Mentor and Perry into the new facility," said Fahim F. Gemayel, President of Lakeland The Construction Group.

The first phase of the project will consist of a new 110,000-sq-ft building, on 15 acres, on which Lakeland is set to break ground early this spring. The remaining 35 acres are under design for future development.

The company has plans to include a local workforce as an initiative to promote economic growth in Madison. Further details will be available on its website later this spring.

NCCER Releases Updated Curricula

NCCER, Alachua, Fla., an education foundation that provides construction curricula, has released the following revised curricula: *Sheet Metal Levels 1-4* and *Your Role in the Green Environment*. *Sheet Metal* provides the latest in tool technology, while *Your Role in the Green Environment* has been updated to meet version 4.1 of the U.S. Green Building Council's Leadership in Energy and Environmental Design rating system.

Updated for the first time since 2009, *Sheet Metal* includes information regarding computers and software used for sheet metal fabrication, estimating and construction documentation software, as well as 3D scanning. This curriculum now contains material from other NCCER craft curricula, including welding, mechanical insulating, and heating, ventilation, and air conditioning. It also offers a large commercial drawing package to download for free.

Your Role in the Green Environment focuses on the building design and construction rating system and provides information about additional green building rating systems.

A team of subject-matter experts, representing both industry and academia, contributed to the development of the training curricula to ensure they meet or exceed industry standards.

Ferra Aerospace Launches Manufacturing Facility in Arkansas

Ferra Aerospace, an advanced machining and complex assembly company, has acquired a new manufacturing facility in Rogers, Ark., to bring more skilled jobs to the area. The facility will have 26 employees with a 24,000-sq-ft manufacturing floor and nine high-speed machines. The company currently operates a facility in Grove, Okla., that is undergoing an expansion to double its 50,000-sq-ft manufacturing floor to 100,000 sq ft.

"This new facility allows Ferra Aerospace to expand our capacity in the region and provide additional advanced machining capabilities for our aerospace customers. We have been greatly impressed by the caliber of the Arkansas advanced machining workforce and are delighted to bring them into the Ferra family," said Jerry Cook, president of Ferra Aerospace USA.

The Arkansas facility will provide services to many industry companies. Cleve Jernigan will serve as the facility's site director.

Huntington Ingalls Employees Honored at 34th Annual Black Engineer of the Year Award



Employees from Ingalls Shipbuilding, Newport News Shipbuilding, and Technical Solutions divisions were recognized for achievements in STEM-based fields during the 34th annual Black Engineer of the Year Award STEM Global Competitiveness Conference.

Huntington Ingalls Industries, Newport News, Va., a military shipbuilding company, has announced that 11 employees from its Ingalls Shipbuilding, Newport News Shipbuilding, and Technical Solutions divisions were recognized for achievements in science, technology, engineering, and mathematics (STEM)-based fields during the 34th annual Black Engineer of the Year Award STEM Global Competitiveness Conference.

Dorian Newton, an engineering director at Technical Solutions, received the Educational Leadership — Corporate Promotion of Education Award, which recognizes individuals who demonstrate a commitment to enhancing the opportunities for minorities in technology-based careers

through the promotion of scientific and technical education programs. Eight employees received the Modern Day Technology Leader Award, which recognizes efforts in shaping the future of engineering, science, and technology. Two employees received the Science Spectrum Trailblazer Award. The award recognizes efforts in creating new paths for others in science, research, technology, and development. **[WJ]**

Website Created to Help Career and Technical Education (CTE) during COVID-19

With the manufacturing industry already facing a skilled labor shortage, and the onset of the COVID-19 crisis, an additional challenge is presented for educational institutions, temporarily closing schools across the nation and interrupting face-to-face learning.

To help meet the task of building the industry's future workforce, the newly formed CTE Coalition — led by Lincoln Electric, Tooling U-SME, NC3, camInstructor, Haas Automation, and SkillsUSA — mobilized to create the website Keep CTE Moving (ctecoalition.com). At this central portal, instructors and students can access needed resources, including hundreds of online classes, videos, and instructional materials in areas such as machining, welding, mechatronics, industry 4.0, and programming.

All online materials are produced and supplied by coalition partners, including the American Welding Society (AWS). The goal is to help career and technical education faculty, as well as students, continue their teaching and learn quickly in a new virtual environment.

"A lot of CTE courses are in areas like welding, CNC, automotive, manufacturing, and construction, and are very hands-on," said Jason Scales, business manager, education, Lincoln Electric. "Many instructors simply don't have online training content. This noncompetitive group of industry-leading companies each maintain a robust set of e-learning modules and other resources. Together, we agreed to share our resources in an unprecedented manner. With this opportunity, tens of thousands of CTE students can keep learning, even while they may not be allowed to gather in a physical classroom or lab."

As a coalition partner, AWS is offering the AWS Safety in Welding Course for free (unless a user elects to obtain a Certificate of Completion or Professional Development Hours) at careersinwelding.com/educator-resources. Based on the ANSI Z49.1:2012, *Safety in Welding, Cutting, and Allied Processes*, this course includes a broad range of topics. In addition, Weld-Ed is offering two of its more popular Module PowerPoint slides sets, on metallurgy and joining and cutting processes, as free downloads via Dropbox.

Due to the changing nature of the COVID-19 situation, CTE instructors are urged to periodically visit ctecoalition.com for additional remote learning resources and guidance that will likely evolve over time.

Honeywell Expands Face Mask Production; Ford Collaborates to Speed Fabrication of Respirators, Ventilators; and More Updates

During the assembly of this magazine in early April, many industry stories about the production of face masks, respirators, and ventilators were in the news. Detailed here are a handful of highlights.

- On March 22, **Honeywell**, a provider of safety solutions, announced it would immediately expand manufacturing operations in Smithfield, R.I., to produce N95 face masks in support of the U.S. government's response to



The importance of an N95 mask, from removing 95% of 0.3+ micron-particles to having a tough, yet flexible nonwoven polypropylene fiber, is explained at honeywell.com. (Credit: Honeywell.)

COVID-19. The company is ramping up operations to produce millions of N95 disposable masks to help support the need for critical safety equipment.

"We are honored to support the U.S. government's efforts to protect Americans with personal protective equipment made right here in the United States," said Dariusz Adamczyk, Honeywell chairman and CEO.

The company anticipates the addition of the mask production line in Smithfield will create at least 500 new jobs.

- Additionally, **Ford Motor Co.**, Dearborn, Mich., joining forces with firms including **3M** and **GE Healthcare**, is lending its manufacturing/engineering expertise to quickly expand production of medical equipment and supplies for healthcare workers, first responders, and patients fighting COVID-19. The automaker plans to assemble more than 100,000 face shields per week and utilize its in-house 3D



Ford Motor Co., in cooperation with the United Auto Workers, will assemble more than 100,000 plastic face shields per week at one of the automaker's manufacturing sites to help medical professionals, factory workers, and store clerks. (Credit: Ford.)

printing capability to produce components for use in personal protective equipment.

"This is such a critical time for America and the world. It is a time for action and cooperation. By coming together across multiple industries, we can make a real difference for people in need and for those on the front lines of this crisis," said Bill Ford, Ford's executive chairman.

Team members are working with 3M to increase the manufacturing capacity of their powered air-purifying respirator designs and working jointly to develop a new design using parts from both companies. Ford and GE Healthcare are also working together to expand production of a simplified version of GE Healthcare's existing ventilator design.

- Some companies are giving away supplies. FOX4 in Kansas City, Mo., reported that Jon Lawson, the owner of **Lawson Welding**, is donating more than 1500 respirator masks to St. Joseph Medical Center and *rochesterfirst.com* detailed how **Rochester Arc + Flame Center**, Rochester, N.Y., donated 200 masks to the University of Rochester Medical Center.

Inaugural Inspection Expo & Conference Surpasses Expectations

The inaugural Inspection Expo & Conference (IEC) took place on January 21-23 in Houston, Tex., where experts from the American Welding Society (AWS), the American Institute of Steel Construction (AISC), The American Society for Nondestructive Testing (ASNT), and NACE International (The Corrosion Society) joined forces to offer a vast array of



Kenji Thomas, retired staff sergeant, The United States Army, opened the conference with an inspiring keynote presentation.

presentations about topics common to corrosion engineering, nondestructive examination, steel construction, and welding inspection.

The conference program was designed to offer attendees practical knowledge and the latest technology and research in quality control, drawings and documentation, visual inspections, procedures, and examination processes. The conference was attended by almost 400 professionals and featured 30 speakers offering expert presentations, as well as 55 exhibitors showcasing their products and services.

Kenji Thomas, retired staff sergeant, The United States Army, presented an inspiring keynote presentation to open the event. He captivated the audience with incredible stories of extraordinary individuals and how they fought to bring each other home, then delivered an uplifting message about leadership.

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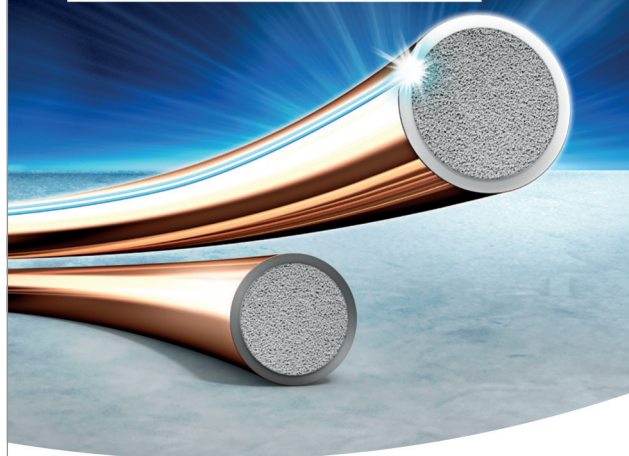
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The conference concluded with a dynamic panel discussion about business practices and the inspection industry in general. Panelists included (from left) Cal Pepper, Southeastern Louisiana University; George Fairbanks, Fairbanks Inspection & Testing; Brent Boling, Arc-Tech Welding/Arc-Tech Inspections; Randall Stremmel, Oso Development Partners; and Lee Pielat, Pioneer Steel Services.

The three-day conference was packed with breakout sessions categorized as visual inspections; drawings and documentations; nondestructive examination; procedures; auditing; inspection; higher-level inspections; metallurgy; and industry standards. In addition, the sessions were grouped according to their corresponding associations (AWS, AISC, ASNT, and NACE International). Professionals from each corner of the industry had the opportunity to become familiar with processes and technologies from different inspection categories.

A common theme that surfaced during the presentations was how Certified Welding Inspectors (CWIs) could benefit by obtaining other inspection certifications, from associations such as ASNT and NACE International, for example.

The 11th Weld Cracking Symposium, a continuation of the long-running and top-rated AWS conference series, also took place the day before IEC at the same venue (the Hyatt Regency Houston). The symposium focused on the subjects of weldment cracking, inspection techniques, and technology. It provided the fabrication and construction industry with leading information on cracking mechanisms, materials of construction, inspection methods, and mitigation techniques.

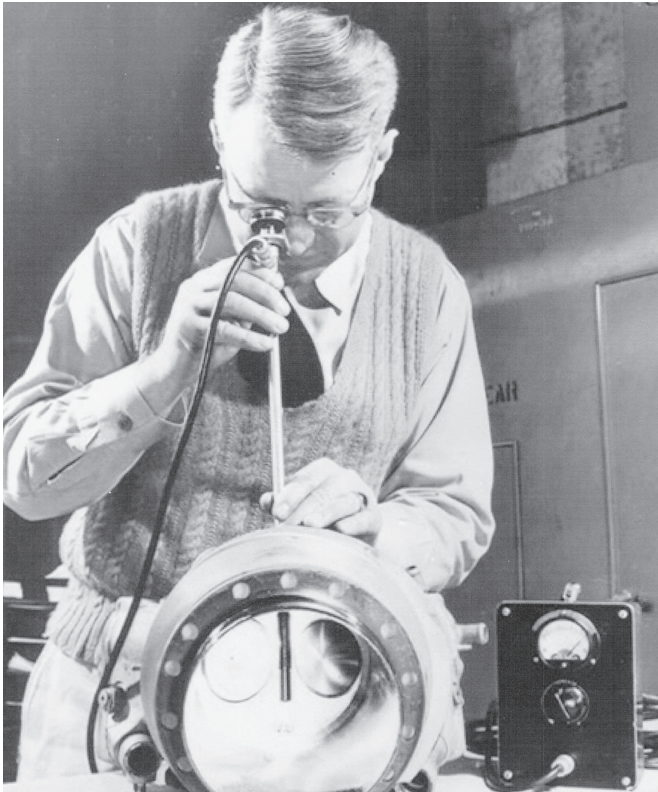
Look for a comprehensive article about the IEC and its presentations in the May 2020 issue of *Inspection Trends*.

— Carlos Guzman (cguzman@aws.org), managing editor, digital and design, Welding Journal

Lenox Instrument Commemorates 100 Years

Lenox Instrument Co., Trevose, Pa., a manufacturer of remote visual inspection/monitoring instruments, is celebrating its 100th anniversary.

The company started in 1920 with the development of the industrial borescope used for internal inspections of steam turbines and continued into the early 1940s designing and manufacturing borescopes and periscopes for the war effort. In 1942, Lenox began production of a new borescope for the first nuclear application, the Manhattan Project. Continued development in the early 1950s to today has led to production of high-temperature lens tube optical systems used worldwide.



Established in 1920, Lenox Instrument Co. marks its 100th anniversary this year. The historic photo above shows a Pan Am Airways employee using a Lenox borescope to inspect a cylinder from an aircraft engine. (Credit: Lenox.)

More Than 150 Craft Students Graduate from ABC Pelican's Baton Rouge Training Center



ABC Pelican graduated 156 craft professionals for completing course work in skills such as welding, mobile crane, and site safety. (Photo credit: Eye Wander Photo.)

The Pelican Chapter of the Associated Builders and Contractors (ABC) honored 156 craft students at a graduation ceremony for completing craft training programs in welding, electrical, heavy equipment, millwright, mobile crane, instrumentation, pipefitting, project supervision, and site safety last fall at its Baton Rouge Training Center in Louisiana. The ceremony was at L'Auberge Baton Rouge.

— continued on page 67

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Q: We are working on a prototype piece of material handling equipment. The designer specified welding 4140 alloy steel to 304 stainless steel, then hardening the 4140. We tried gas metal arc welding (complete joint penetration fillet welds in $\frac{3}{8}$ -in. material) with 0.035-in. (0.9-mm) ER309L filler metal, but the root pass was cracked when we finished welding. Then we tried making the same weld with ER312 filler metal, and those welds did not crack, although the filler metal is very expensive. Next, we tried a procedure qualification using a double-V-groove weld in $\frac{3}{8}$ -in. (10-mm) materials, followed by heating the assembly to 1550°F (845°C), oil quenching, and tempering at 750°F (400°C) to achieve about 40 Rockwell C hardness in the 4140 alloy steel.

We realize 4140 alloy steel at 40 Rockwell C hardness is not very ductile. Online datasheets indicate 5 to 10% elongation. We used the equation in AWS B4.0, *Standard Methods for Mechanical Testing of Welds*, Clause 6.6.4, to select a bend radius for a $\frac{3}{8}$ -in.-thick side bend, assuming 5% elongation. The equation is as follows: $A = T(50/e - \frac{1}{2})$, where A = bending radius (in.), e = elongation, and T = specimen thickness. This calculates to a bend radius that is a bit less than 4 in. (100 mm).

Accordingly, we tried a transverse bend over an 8-in. (200-mm) outer diameter pipe. To our surprise, the weld metal, not the 4140 steel, snapped in a brittle fashion. What happened? And how can we remedy this behavior?

A: First, the root cracking with the ER309L filler metal should come as no surprise. The high carbon of the 4140 alloy steel (see Table 1), with normal dilution into the 309L filler metal, causes the root pass to solidify as primary austenite, which is known to be sensitive to solidification cracking. On the other hand, the ER312 filler metal

can tolerate this carbon and still provide crack-resistant primary ferrite solidification because of its higher ferrite potential.

There is a fairly common misconception that 312 filler metal is a nominally austenitic filler metal due to its designation beginning with a 3, just like 308L, 309L, or 316L filler metals.

For example, the *Metals Handbook* (Ref. 1) includes 312 filler metal in a table of austenitic stainless steel electrodes, but 312 is not an austenitic filler metal; it is essentially a duplex ferritic-austenitic stainless steel filler metal. Typical as-welded ferrite content of undiluted 312 weld metal is 50 to 80 Ferrite Number (FN), which is at the high end of the ferrite content found in other duplex stainless steel weld metals, and nothing like the 3 to 15 FN commonly found in the 308L, 309L, 316L, and other nominally austenitic weld metals. The main metallurgical difference between 312 and other duplex filler metals is that 312 uses carbon to promote some austenite formation in the as-welded condition, rather than using nitrogen as, for example, 2209, 2553, and 2594 filler metals do. Table 1 presents the compositions of 4140, 304, ER309L, ER312, ER2209, and ER2553 for comparison. The fact that the weld metal is duplex has important ramifications when it comes to heat treatment of a weld made with 312 filler metal.

A quench and temper heat treatment, such as the one mentioned previously for the 4140 base metal, will induce some of the ferrite in a nominally austenitic weld metal like 309L

Table 1 — Compositions of 4140, 304, ER309L, ER312, ER307, and G 18 8 Mn

Material	Composition, weight percent (single value is a maximum)									
	C	Mn	P	S	Si	Cr	Ni	Mo	Cu	N
4140	0.38 to 0.43	0.75 to 1.00	0.035	0.040	0.15 to 0.35	0.80 to 1.10	N.S.	0.15 to 0.25	N.S.	N.S.
304	0.08	2.00	0.045	0.030	0.75	18.0 to 20.0	8.0 to 10.5	N.S.	N.S.	0.10
ER309L	0.03	1.0 to 2.5	0.03	0.03	0.30 to 0.65	23.0 to 25.0	12.0 to 14.0	0.75	0.75	N.S.
ER312	0.15	1.0 to 2.5	0.03	0.03	0.30 to 0.65	28.0 to 32.0	8.0 to 10.5	0.75	0.75	N.S.
ER2209	0.03	0.50 to 2.00	0.03	0.03	0.90	21.5 to 23.5	7.5 to 9.5	2.5 to 3.5	0.75	0.08 to 0.20
ER2553	0.04	1.5	0.04	0.03	1.0	24.0 to 27.0	4.5 to 6.5	2.9 to 3.9	1.5 to 2.5	0.10 to 0.25
ER307	0.04 to 0.14	3.30 to 4.75	0.03	0.03	0.30 to 0.65	19.5 to 22.0	8.0 to 10.7	0.5 to 1.5	0.75	N.S.
G 18 8 Mn	0.20	5.0 to 8.0	0.03	0.03	1.2	17.0 to 20.0	7.0 to 10.0	0.5	0.5	N.S.

Note: N.S. = not specified

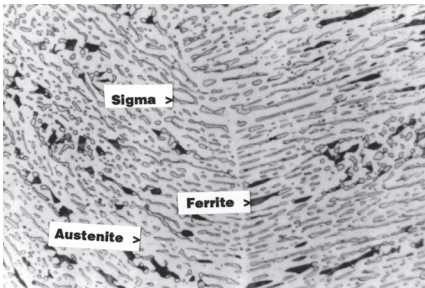


Fig. 1 — Microstructure of 2553-type weld metal for 2 h at 1900°F (1040°C). The ferrite is etched darkly, sigma is outlined, and austenite is untouched by the etchant (X400, Murakami's etch).

to transform to the sigma phase, is very brittle. Sigma is an iron-chromium intermetallic compound that forms readily in the ferrite of stainless steel weld metal when heating in the temperature range between about 1200°F (650°C) and 1830°F (1000°C). Other intermetallic compounds are also possible, but they are generally lumped together with sigma for their detrimental effect. Once sigma forms, still higher temperatures are required to dissolve it. In a 309L weld metal, the embrittling effect of the sigma phase is minor because not a lot of ferrite is initially present to allow sigma to form. However, in a duplex weld metal such as that from 312, 2209, 2553, or 2594 filler metal, a great deal of ferrite is initially present and the heat treatment causes enough sigma to form to severely embrittle the weld metal. I believe that is what happened to the 312 weld metal under consideration.

I have not personally worked with heat treatment of 312 weld metals, but I have with 2209 and 2553 duplex stainless steel weld metals. In particular, I found only 1 to 2% elongation in 2553-type weld metal (modified by enriching the nickel content to promote some austenite formation as-welded) after quenching from 1040°C (1900°F) due to a lot of the ferrite transforming to sigma (Ref. 2).

Figure 1 shows the microstructure of a 2553 weld metal modified with about 10% Ni; a large amount of sigma can be seen. As-welded, the ferrite measured 45 FN, but only 2 FN was found after the heat treatment. The 1550°F (840°C) temperature used for austenitizing the 4140 is "perfect" for forming a great deal of sigma very quickly in the 312 weld metal. Sigma

can be eliminated by austenitizing at considerably higher temperatures than you used. I expect you would have to austenitize at more than 2000°F (1090°C), followed by a quench, to avoid sigma in the 312 weld metal.

There is a better approach than using 312 filler metal for this application, and it is not an expensive filler metal like ER312 or a nickel-based alloy. In Europe, a very popular filler metal for dissimilar joints and difficult-to-weld materials like 4140 is G 18 8 Mn. This filler metal is similar in composition and applications to American Welding Society (AWS) ER307. An internet search for ER307 generally produces G 18 8 Mn as a near match. The main differences are that AWS ER307 is extremely difficult or impossible to find commercially, while G 18 8 Mn is readily available from many suppliers, including U.S. suppliers, and ER307 contains more molybdenum but less manganese than G 18 8 Mn. These compositions are also included in Table 1.

The important feature of ER307 and G 18 8 Mn is that the high manganese of these nominally austenitic filler metals makes the weld metal highly resistant to solidification cracking even when no ferrite is found due to dilution effects from steels like 4140, unlike the weld made with ER309L filler metal. And since the weld metal will contain little or no ferrite, embrittlement of the weld metal as a result of the quench and temper heat treatment will not occur. I think G 18 8 Mn is the most suitable filler metal for the application. **WJ**

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DAMIAN J. KOTECKI is president, Damian Kotecki Welding Consultants Inc. He is a past treasurer of the IIW and a member of the AWS A5D Subcommittee on Stainless Steel Filler Metals, D1K Subcommittee on Stainless Steel Structural Welding, and WRC Subcommittee on Welding Stainless Steels and Nickel-Base Alloys. He is a past chair of the A5 Committee on Filler Metals and Allied Materials, and served as AWS president (2005–2006). Questions may be sent to Damian J. Kotecki c/o Welding Journal, 8669 NW 36 St., # 130, Miami, FL 33166-6672, or via email at damian@damiankotecki.com.



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This issue's RWMA Q&A includes eight questions and answers addressing common concerns in the resistance welding industry.

Q: We are having trouble getting consistent weld strength. We have to keep changing the weld heat percent to get good results for the same exact part. Sometimes we'll have it set to 75%, but then the next time it'll need to be set to 85%. We are used to minor adjustments, but this seems excessive. I suspect the silicon controlled rectifiers (SCRs) are misbehaving since they do all the work.

A: Since the control is digital, I doubt this change is due to the control program, and an SCR contactor either works or it doesn't. Since the SCR consists of two independent SCR elements, if one is not firing correctly, the welding transformer will saturate and you will hear loud grunting sounds from the welding machine.

The welding control only puts a

percentage of the line voltage into the welding transformer primary. The actual welding current is a function of the stepped-down secondary voltage of the welding transformer and the secondary impedance of the welding machine. If this impedance increases, the welding current will drop. The usual culprit is one or more junctions on the welding machine secondary that have high resistance. This can be where conductive parts bolt to the welding machine secondary pads, where the flexible shunt connects to the moving ram or rocker arm, where the electrode holders connect to the arms, or where the electrode connects to the electrode holder. These areas are where I would start to look first.

I had the same question many years ago on a press welding machine. It turned out the lower electrode holder had a 5-RW threaded adapter. The holder was apparently leaking where it had been threaded into the holder, and where a maintenance person, rather than replacing the compression washer, inserted an O-ring. As a result, the

welding current was being conducted through threads that, after time, started to arc away and give different currents throughout the day.

Q: I was doing preventive maintenance on our spot welding machine and think the welding transformer is shorted. I measured resistance across the open electrodes with the power off and it shows a dead short. I also found there is a dead short from the electrodes and the frame of the welding machine. Should I replace the transformer?

A: Welding transformers are confusing even to "electrical types." If you opened the transformer, you would find that the secondary of the transformer is just a solid wrap of copper. This looks like a dead short to a direct current continuity measuring system like your meter, but it has impedance for an alternating current (AC) voltage. So your measurement is normal for a single-phase AC welding transformer.

One side of the secondary has to be

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MULTI-PISTON AIR CYLINDER



Fig. 1 — Press welding machine with fixture cylinder.

grounded to the frame to be legal. This connection on pedestal resistance welding machines is normally due to having the lower arm structure bolted to the welding machine frame. The upper moving structure should have an insulator system at some point before

Table 1 — Typical Model Number Chart for Multipiston Air Cylinders

Brand	Typical Model Number	Effective Area of Cylinder (in. ²)
Savair	C-G-584-6N	5.84
ACP	AC-C-G-937	9.37
Grossel	2-GA-1157-1.5	11.57
Milco/TG	TG-CG-1143-8N	11.43

the electrode holder. So, reading a dead short between both the welding machine frame and the secondary is the required condition.

Q: I am trying to use resistance welding charts to set up a 100-kVA spot welding machine — Fig. 1. I know that I need to calculate the area of the cylinder to convert air pressure to force at the electrodes. The cylinder has only a 1½ in. diameter on the outside. Allowing for the tube wall thickness, the inside diameter would be about 1½ in. Therefore, the calculated area would be 1.77 in.². With 80 lb/in.², it could only develop 141 lb of force at the electrodes. Obviously, for a 100-kVA weld-

ing machine, this is not right. What am I doing wrong?

A: Having a 100-kVA welding machine that can only provide 141 lb of electrode force makes no sense. You will need to check the welding machine cylinder.

The cylinder has two or three pistons inside to increase the effective area. They are known as fixture cylinders. They are becoming common for many press welding machines and provide fast follow-up during welding, especially when doing projection welding. Look at the marking on the side of the cylinder body. You should see model numbers stamped onto the

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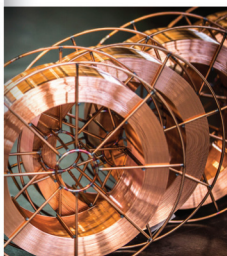
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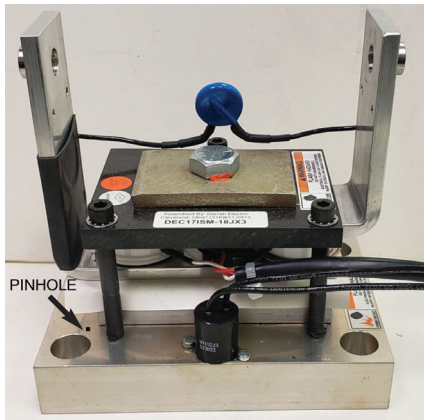


Fig. 2 — Pinhole leak in aluminum water-cooling SCR base.

metal. On most of these cylinders, there is a three- or four-digit number as part of the model number. For example, 584 would indicate that the cylinder has an effective area of 5.84 in.², and 1157 would be for a cylinder with an effective area of 11.57 in.². See Table 1 for examples on popular brands. If in doubt, I would contact the cylinder manufacturer or welding machine manufacturer for the proper effective area.

There are also fixture cylinders that have three areas where hoses are connected. These cylinders will typically be marked OHMA. One port will be marked INTENSIFIER. The welding machine will include a tank that holds oil. The third and fourth numbers in the model stamped on the cylinder will indicate the effective area as shown in Table 2.

Q: We had the inside of our welding control fill up with water and damage everything inside. On inspection, we

found the SCR contactor had a pinhole in the aluminum water-cooling base — Fig. 2. Is there a way to prevent this from happening in the future?

A: The answer is very simple. Just install nonmetallic (PVC or nylon) hose barb fittings into the two holes in the aluminum water-cooling base. If you use brass or galvanized-steel fittings threaded into the aluminum water-cooling SCR base, depending on the water chemistry, many of them eventually cause a pinhole at the end of the threaded hole. It is also a good idea to check if you have other welding controls with the same potential problem and change these fittings now before you fill another control with water.

Q: We are installing weld nuts on bracket assemblies. Every once in a while, the operator installs the weld nut upside down, goes through the weld, and doesn't notice the error. The nuts end up falling off at assembly or, even worse, when they get to the customer. Is there a simple way to detect this and prevent welding?

A: There are many solutions available. Your resistance welding supplier should be able to help you with this. Some equipment have built-in distance sensors in the lower electrode holder or on a rod that travels with the upper electrode. However, there is another way to achieve this if you have the Soft Touch operator protection system installed on your welding machine. This device protects the operator from crushing or amputating a finger if caught between the electrodes.

Getting back to your question, if you use the type of weld nut that has

Table 2 — Intensifier Cylinder Model Number Example

Typical OHMA Model Number	Effective Area of Cylinder (in. ²)
8832-RH-10-12A	32

weld projections protruding past the edges (Fig. 3), just install insulated nut covers (Fig. 4) on the upper electrode. When making a weld, the Soft Touch sensor system will only allow welding to start if the nut is in the correct position and not upside down.

Q: We have a welding machine that has eight welding guns, with two of those welding guns connected to each of the four welding transformers. One of the guns stopped making good welds. Do you think the problem is in the control or welding transformer?

A: I don't think it is in either component. If you have two guns on one transformer and only one has a problem, this would eliminate both the control and transformer. The probable culprit is the heavy cable that brings voltage from the transformer to the welding gun, or the cable that brings voltage to the lower electrode holder. Cables can lose part of their conduction if they are old and have been operated beyond their rating. Additionally, with water-cooled cables (water hoses going into each end of the cable), this can easily happen if they have been run without proper water flow.

This can also happen if the bolt that secures the cable to the transformer side or welding gun side is loose. A loose bolt will create a lot of



Fig. 3 — Weld nuts with projections that are past the side of the fastener.



Fig. 4 — Insulated nut covers used with Soft Touch for upside down detection.

heat at this junction and burn many of the fine wire conductors inside the crimped end. If a bolt on either end of the cable is obviously not tight, tighten it and see if the problem goes away. If not, change the cable. By the way, if a cable is getting too hot to touch after welding for some time, it can be that it is undersized, or it needs replacement for the reasons stated above.

Q: We manufacture 1/8-in.-thick structural galvanized angle assemblies. The resistance welding requires three rows of welds 1 1/2-in. apart. When we pull test a sample weld on the same material, the pull strength is about 6000 lb. But when we pull test a section of the part that has eight welds, the strength is about 24,000 lb, which is about 3000 lb per weld. What is happening here?

A: You are seeing a common result of shunting. When making a group of welds, some of the welding current finds a path through the previously welded spots. This subtracts from the current passing through the new weld location. Typical welding charts show the minimum distance between welds on 1/8-in. steel is 2 in. As you decrease this distance, the strength of each weld decreases, as you found out. In this case, you could reduce the number of welds to four, each spaced about 2-in. apart with a total strength of about the same as the original eight welds.

Q: We are welding a plate with projections to another flat plate. The parts are loaded into a fixture to hold them over the lower electrode. We are getting random metal expulsion and even some holes in the lower part. Any ideas?

A: After talking with this person, it was determined the fixture holding the parts put the underside of the lower part just above the lower electrode. Some of the force coming from the upper electrode was used to push the parts down to the lower electrode. This reduced the actual contact force between the lower electrode and the part, causing metal expulsion and holes. The solution is to raise the lower electrode so when the parts are loaded in the fixture, there is nothing in the fixture to prevent the parts from going down to, and making full contact with, the lower electrode. It should be noted that when you put

welding force on the lower electrode, it will always flex downward. Therefore, the vertical floating space be-

tween a part and the fixture should more than just touch the lower electrode. **WJ**

ROGER HIRSCH is past chairman of the Resistance Welding Manufacturing Alliance, a Standing Committee of the American Welding Society; an Elihu Thompson Resistance Welding Award winner; and president of Unitrol Electronics Inc., Northbrook, Ill. Send your comments and questions to Roger Hirsch c/o Welding Journal, 8669 NW 36 St., #130, Miami, FL 33166-6672, or via email at roger@unitrol-electronics.com.

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Research Paper Sparks Questions

I had the opportunity to read the research paper titled "Effect of Silicon and Retained Austenite on the Liquid Metal Embrittlement Cracking Behavior of GEN3 and High-Strength Automotive Steels," by M. Tumuluu that appeared in the December 2019 issue of the *Welding Journal*.

This research paper reports quite a lot of experimental work on the liquid metal embrittlement (LME) cracking behavior of bare and electrogalvanized (EG) annealed Generation 3 (GEN3) test strips during resistance spot welding (RSW) and Gleeble® simulation and examination. However, it appears to me what should have been a parametric evaluation for producing crack-free RSW in GEN3 steels has morphed into a metallurgical study on the effects of Si content and retained austenite, besides coincident site lattice (CSL) boundaries. I have several misgivings about the published research. Based on the results reported, it appears to me that a parametric evaluation focused on achieving the required nugget size ($4\sqrt{t}$) control of current range, force, and displacement would have eliminated weld expulsion, and the occurrence of LME cracks in EG test panels.

This research has principally addressed silicon content (at three levels) and the associated retained austenite content on LME cracking behavior, but includes the effects of a comprehensive set of related factors, such as tensile strength, elongation (or ductility), elevated temperature strength, welding current range, shear tension strength, cross tension strength, applied force vs. displacement, applied peak force required for cracking, difference in peak force between bare and EG Gleeble® test strips, total energy absorbed pre- and post-cracking of Gleeble® test strips at different test temperatures, CSL boundaries, etc., on LME cracking and behavior.

This research classifies LME cracking in the weld metal (under electrode indentation) as Type I and in the weld heat-affected zone (HAZ) as Type II. For example, Fig. 1 showed LME cracks in steels, but unfortunately doesn't offer additional insight to distinguish the

cracks as either Type I or Type II. Based on the equiaxed morphology and grain structure, these intergranular cracks appear to be Type II.

The primary conclusions of this research are that increasing the Si content reduces the operational window for an expulsion-free spot weld, and one could witness weld HAZ cracking well below the weld expulsion currents. Austenite content didn't seem to affect LME cracking, except that a higher Si content led to a higher austenite content and higher ductility. Low Si content also appeared to result in low-angle CSL boundaries that offered a higher resistance to LME cracking. The research recommends Si content preferably between 0.6 and 0.8 wt-% to avoid LME cracking.

It is well known that electrogalvanizing provides a zinc coating that would normally melt, wet, and spread, or ball-up during RSW or Gleeble® examination of test strips. One would expect that when the substrate and/or the partially solidified weld metal showed evidence of microcracking, the liquid metal would back-fill the crack and crack tip, when there is adequate proximity and channel access (aided by capillary forces) for the liquid metal at nominal stress levels. When there is inadequate channel access for the liquid metal, one would see further evidence of macrocracking in the weld metal and/or substrate in the weld HAZ depending on stress levels. Such macrocracks would not show backfilling with Zn, and couldn't be classified as LME cracking.

Based on prior literature, this research paper cites that the liquid metal would penetrate (presumably high-angle) grain boundaries, reduce ductility, and thus promote LME cracking. The paper enumerates the (simultaneous) presence of three prerequisites for LME: 1) a liquid metal of embrittling type containing Zn and/or Cu; 2) tensile stresses; and 3) a susceptible microstructure, but doesn't offer insight on susceptible microstructure except to allude that transformed or migrated cell boundaries and high-angle grain structure would promote either Type I and Type II cracking, respectively.

Considering that Type I cracking occurs in the weld metal, one should be concerned about the prevalent weld solidification mechanism (depending

on RSW conditions, particularly applied load, welding current, displacement, and duration of weld cycle) and the resultant weld metal microstructure and the occurrence of discontinuities and defect types. Similarly, while considering Type II cracking occurring in the HAZ, one should be concerned about the solid-state phase transformation and the resultant HAZ microstructure. Unfortunately, this research paper doesn't address the aspects related to both liquid-solid transformations in the fusion weld and solid-state transformations in the weld HAZ, but limits the discussion to the effect of CSL boundary type in weld metal and HAZ.

Interestingly, both brazing and soldering technologies use liquid metal to make high-integrity joints. One essential feature of the liquid metals used for brazing and soldering is that they wet and spread on similar and/or dissimilar metal substrate surfaces, but do not cause LME cracking as microcracks on substrate surfaces do not create adequate capillary forces for the liquid metal to reach and fill the crack tips. Therefore, the ability to wet and spread by itself doesn't make the liquid metals an embrittling type. Additionally, capillary forces are required to form brazed and soldered joints. However, brazed and soldered joints are not known to exhibit LME cracking despite the use of liquid metals. Consequently, one could surmise that the presence of an embrittling type liquid metal by itself does not promote LME cracking.

LME is essentially propagation of preexisting microcracks or crack-like defects under applied and residual stress that exceed yield stress (Ref. 1). When there is adequate channel access, aided by capillary forces, the liquid metal reaches and fills the crack tip, lowers the energy at or ahead of the crack tip, and allows the crack to propagate at much lower stress intensities. Instead of a crack, if the preexisting discontinuity or defect was a void or shrinkage cavity, the liquid metal would just fill the discontinuity or defect as in brazing and soldering, but would not lead to cracking, per se.

Materials are known to have microcracks (i.e., these are called discontinuities as they either remain undetectable using regular nondestructive test [examination] methods, or their

size stays below the relevant acceptance limit), more so based on the nature and severity of thermomechanical processing history. For example, a cold rolled material may show a higher incidence of microcracks than an annealed or normalized material of the same composition and processing history except for the above difference in thermal treatment. Suitable thermomechanical treatment may allow the formation of low-angle CSL boundaries that could potentially enable a substantial reduction in the incidence of microcracks (Ref. 2).

During RSW, certain fitup and set-up (operational window) conditions could cause some of these microcracks to grow or open up in the HAZ, and the presence of liquid metal nearby could facilitate Type II LME cracks. Similarly, in the case of Type I LME cracks, the welding conditions could affect weld solidification parameters such as local temperature gradient and solid/liquid interface velocity that could promote the formation of weld discontinuities and/or defects due to the combined effects of applied force, displacement, and expulsion of molten metal.

The above observations show that LME cracking would not occur if discontinuities in HAZ didn't turn into crack-like defects, or weld metal didn't produce crack-like defects during RSW, further reinforcing the importance of RSW conditions or parametric evaluations in avoiding or eliminating LME cracking.

Here, the experimental results reported by Tumuluru provide several useful insights. In particular, Fig. 20 is instructive in that the test temperature (aim peak temperature) should be much less than 850°C, and the bare specimen showed substantial necking but no cracking while the EG specimen showed extensive cracking. However, the Si content of these sets of specimens could not be readily ascertained despite a careful reading.

Figure 6 showed that the room temperature tensile and yield strength of the steel strips with three levels of Si content are almost similar, meaning, the YS/UTS ratios did not differ significantly among the three heats. It is commonly known that the advanced, higher strength steels with a higher YS/UTS ratio show limited operational envelope during secondary processing (Ref. 3). Based on this metallurgical perspective, one could expect the GEN3 steel with a higher Si

content and a higher YS/UTS ratio may have a reduced operational window despite improved elongation or ductility. Figure 7 showed the elevated temperature strength, and the difference at any temperature among the three different strips range between 10 and 30 N/mm². Figure 8 showed that the useful current range to achieve the required nugget size ($4\sqrt{t}$) without expulsion is below 2000 A. Figure 13 showed results of the Gleeble® examinations of both bare and EG specimens. The respective force displacement plots revealed that it is preferable to limit the peak temperature (much) below 850°C, and the force displacement areas are quite narrower for EG specimens, requiring the useful force is held at less than 3000 N, and the corresponding displacement is held at about 1 mm.

In essence, a parametric evaluation focused on achieving the required nugget size ($4\sqrt{t}$), current range below 2000 A, force below 3 kN and displacement about 1 mm would have eliminated weld expulsion, and the occurrence of both Type I and Type II cracks in the EG test panels.

The primary aim of the parametric evaluation should be to identify and use weld parameters that avoid the formation of weld defects under electrode indentation, and to prevent the growth and propagation of microcracks in the HAZ (Refs. 4, 5).

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— Krishna Sampath

I would like to thank Mr. Sampath for some of the comments he made in his letter. The research work, as noted in the paper, had two clear goals. These goals were to examine 1) the effect of silicon content in the steel, and 2) the role of retained austenite on the liquid metal embrittlement (LME) cracking behavior of a Generation 3 (GEN3) advanced high-strength steel. The only variable changed in the study was the welding current, and it was changed to determine the welding current range (the welding current between that which produces the minimum weld size of $4\sqrt{t}$ and weld expulsion). Welding current ranges are used to determine weldability of steels in resistance spot welding. Therefore, it is inaccurate to state that the study “morphed” into a parametric study. A parametric study involves changing several welding variables that affect the weld performance (LME cracking in this case) and examine their role in weld cracking. However, this was not done in this study. Furthermore, the goal of this study was not to produce “crack-free welds.” Steps to produce possible LME crack-free welds were presented by the author elsewhere and provided in Refs. 1 and 2.

To study the effect of silicon content in the steel, laboratory heats at three different silicon contents were melted, hot and cold rolled, heat treated in a laboratory simulator to produce the required microstructures, and then electroplated using a laboratory electrolytic cell. To achieve GEN3 properties steels contain complex microstructures, and achieving such structures involves complex heat treatments. Therefore, production of electrogalvanized material possessing required microstructures involved several procedural steps of heat treatment and plating. Therefore, a lot of experimental work is involved just to produce required samples for the study.

The effect of silicon was studied using two methods. One was on resistance spot welds using tensile testing, metallographic evaluations to examine the extent of cracking and quantify it for comparison among the three silicon levels. The second method was using Gleeble® evaluations on reduced cross section tensile samples, which would allow us to look at energy requirements for crack initiation and propagation. Such an examination is important to know whether the mere presence of LME cracks would be detrimental to weld performance if such LME cracks show minimal tendency for catastrophic propagation. To understand the role of silicon on the nature of grain, therefore,

electron backscattered diffraction (EBSD) technique was used. Thus, only analytical techniques used were metallographic techniques (both optical and electron optical with EBSD capability) and mechanical testing.

Regardless of the type of cracks, all three types classified in this study (Type I, II, and III) display intergranular morphology and show the presence of solidified zinc. Both Types I and II initiate in the coarse grained HAZ and propagate further down. Note that there is a HAZ under the electrode indentation area as well, unless there is significant weld expulsion. The cracks shown in Fig. 1 are actually Type I. However, it is not important to state the type of cracks in Fig. 1, as the morphological features are the same for both types of cracks.

For LME cracking to occur, the zinc coating would have to wet the surface of the substrate. Otherwise, cracking will not occur. Increasing the surface tension of the coating results in the “balling up” of the melted coating and such a balled up coating does not wet the substrate. However, if the coating does not wet the surface, bare (uncoated) spots would result during electroplating and affect coating adhesion requirements. Wetting the substrate and “balling up” by molten zinc are two opposing situations. When the coating “balls up” there is no penetration of zinc into the substrate and LME cracking does not occur. Wetting of the substrate by the coating is a prerequisite for LME to occur. Therefore, the statement “... zinc coating that would normally melt, wet, and spread, or ball-up during RSW or Gleeble® examination of test strips” does not properly characterize the situation.

The statement regarding the presence of microcracks to initiate LME cracks is not supported in this and other studies referenced in the published paper. Examination of numerous samples and surfaces of both electrogalvanized and bare samples in a scanning electron microscope at magnification as high as 5000X revealed no microcracks. Microcracks (of several micrometers in length) are easily distinguishable in a SEM. Further, the stated mechanism for LME cracks that “the liquid metal would back-fill the crack and crack tip, when there is adequate proximity and channel access (aided by capillary forces) for the liquid metal at nominal stress levels” was not evident. It would have been helpful to see references for the presence of microcracks as a prerequisite for LM cracking to occur.

One of the prerequisites for LME cracking to occur is the presence of an

austenitic microstructure. It is clearly mentioned in numerous places in the paper that austenitic microstructures are prone to LME cracking. When heated above the upper critical temperature (as in the HAZ) the microstructure of the steel would consist of austenite. Therefore, regardless of the starting microstructure, the HAZ predominantly shows an austenitic microstructure and becomes susceptible to LME cracking, especially Type I cracks, which the author classified as manufacturing related (Ref. 2). The use of high currents near expulsion conditions would promote Type I cracks in all grades of steels, including low-strength, interstitial-free (IF) steels with a nominal strength of 300 MPa.

With regard to the mechanism of LME cracking, three different theories have been discussed in the paper and appropriate references provided. None of these theories discuss the presence of microcracks as a prerequisite for LME to occur. Furthermore, not all types of liquid metals on steel substrate are known to cause LME cracking. Copper and zinc are two species identified to cause LME cracking under certain conditions as discussed in the paper. If, as stated by Sampath, “Materials are known to have microcracks (i.e., these are called discontinuities, as they either remain undetectable using regular nondestructive test methods, or their size stays below relevant acceptance limit), more so based on the nature and severity of thermomechanical processing history,” then LME should be seen with all types of coatings on steel. However, this is not the case. Furthermore, if microcracks are present in GEN3 or transformation-induced plasticity (TRIP) steels, they would open up during stamping of these steels when producing automotive parts. Experience shows that GEN3 and TRIP steels are routinely stamped and successfully used in automotive body parts.

In Ref. 2 it was shown that lack of control on certain manufacturing conditions can cause LME cracks. These conditions include poor fitup, misorientation of welding tips with reference to the sheets being welded, the amount of coating (coating thickness), and the welding current used. The cracks caused by poor manufacturing conditions are the Type I and Type III cracks. Despite having ideal conditions, such as good fitup, no weld tip misorientation, and welding current well below expulsion conditions, LME cracks of the Type II were still seen in certain steel grades. This was the case with high-silicon steel. The present study showed

that limiting silicon in steel to around 0.8 wt-% or below can eliminate Type II cracks.

LME cracks occur in the HAZ in or out side of the electrode indentation area when molten zinc is in contact with the steel substrate. Therefore, weld imperfections from solidification do not contribute to LME crack initiation but can influence crack propagation, as was noted in the paper. Welding parameters can influence the development of tensile stresses from heating and cooling. Low-heat input certainly is beneficial to eliminate Types I and III. However, in steels with high silicon, such as the 1.4 wt-% steel studied here, heat input control is not helpful to eliminate Type II cracks as the temperature range over which these cracks can occur is wider compared to lower silicon steels.

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— Murali Tumuluru
Author 



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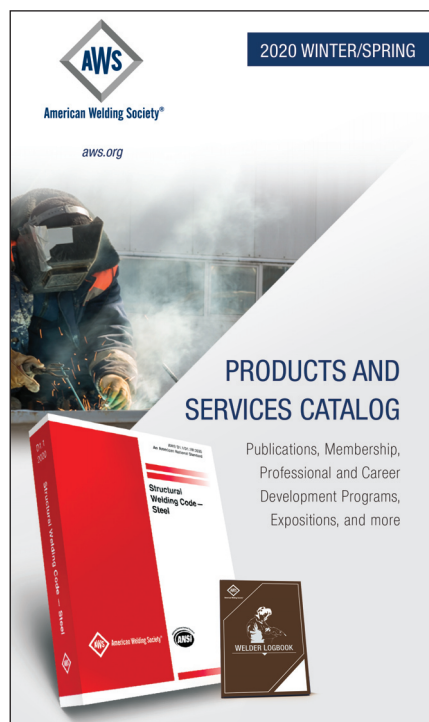


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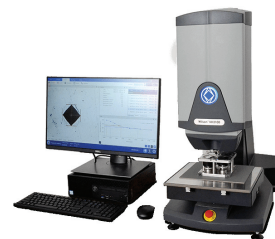
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The Challenges of Finding Skilled Labor in the Construction Industry

Data were used to analyze various aspects of the business

BY NICHOLAS BRATTON HARDY

Construction has been a part of history for nearly the entirety of human existence. As far back as 4000 B.C., there is evidence of construction practices such as bricklaying and carpentry, and those processes infer the existence of early craftsmanship and skills development. Construction is a reasonable to strong indicator of the health of an economy and makes obvious the distribution of wealth throughout a society.

Skilled construction labor has always been and always will be a high-demand opportunity for those who are interested. However, as quickly as the construction industry changes and grows, the image of the industry changes with it. Iconic photos such as *Lunch Atop a Skyscraper* unwittingly promoted the unsafe nature of the construction industry and set a tone that has not been changed.

In 2008, the U.S. economy experienced a financial recession and a vast majority of construction work came to a halt, leaving thousands of skilled construction workers with a decision to make: Do whatever it takes to wait out the lack in available hours, or find another industry. Twelve years later, the industry is still trying to recover.

A Modern View

According to the Associated General Contractors of America Chief Economist Ken Simonson, in 2018 the modern construction industry contained more than 670,000 contractors and employed seven million individuals (Ref. 1). In a survey conducted by Si-

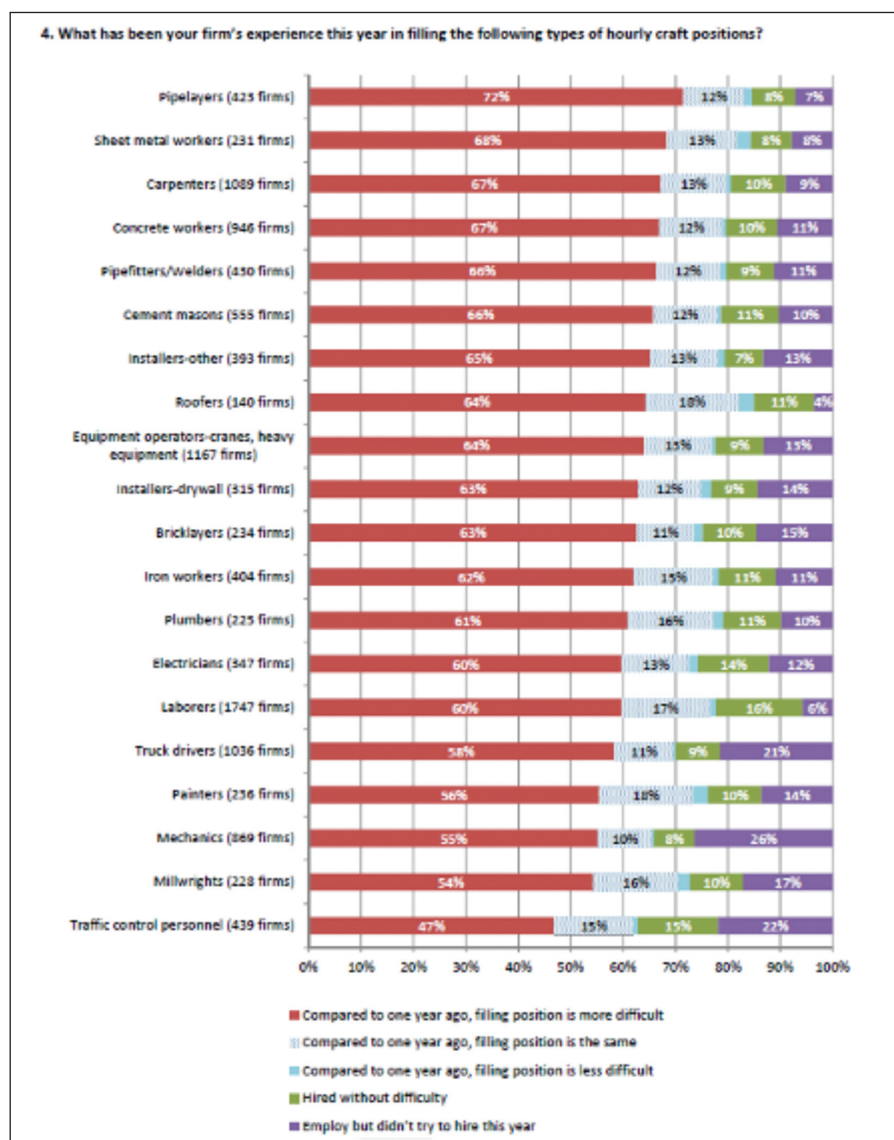


Fig. 1 — More than 2500 construction industry firms took part in a 2018 national survey that showed 80% were having a hard time filling positions in the field. (Credit: AGC of America.)

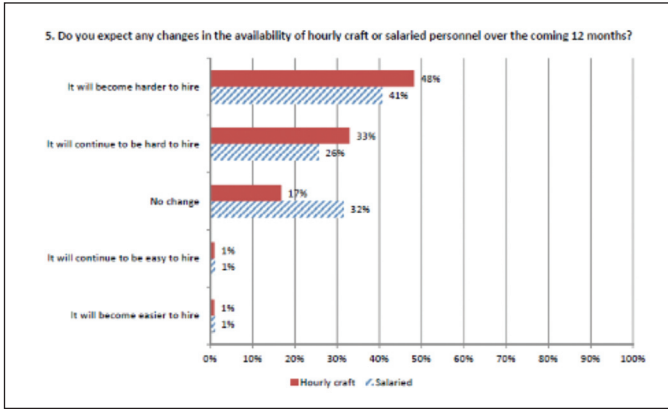


Fig. 2 — This report from a 2018 national survey demonstrated 48% of respondents in construction industry firms anticipated it would become harder to hire hourly craft people in the coming year. (Credit: AGC of America.)

CONSTRUCTION BACKLOG INDICATOR				
Region	Months of Backlog	% Change from Q1 2018		Change from Q2 2017
Northeast	10.40	9.1%	+	0.70 months
South	11.18	10.5%	+	2.17 months
Middle States	7.23	-0.7%	-	-0.68 months
West	10.69	28.3%	+	3.87 months
Industry				
Commercial/Institutional	10.11	10.1%	+	1.72 months
Heavy Industrial	7.81	33.0%	+	2.31 months
Infrastructure	10.06	0.5%	+	-1.60 months
Company Size				
<\$30 Million	8.51	5.2%	+	0.99 months
\$30-\$50 Million	15.07	61.0%	+	4.17 months
\$50-\$100 Million	11.59	4.6%	+	2.39 months
>\$100 Million	13.48	66.6%	+	2.37 months

Fig. 3 — A 2018 construction backlog indicator tool to track work on the books that had to be completed. (Credit: Associated Builders and Contractors Inc.)

monson, 80% of more than 2500 surveys collected from contractors nationwide reported challenges in filling hourly craft positions (Ref. 1).

With an overall decline in labor participation projected by the Bureau of Labor Statistics, it is easy to infer that a smaller available selection pool, coupled with the retirement of the baby boom generation, has led us to this point.

The various trades that make up the modern construction industry are unique in many aspects, from what they bring to a project to the types of people that excel in a particular position. However, the level of available diversity that is present is grossly underutilized in today's market.

Some common misconceptions have been fostered throughout the past four decades and perhaps longer. The idea that construction work is overly demanding, unsafe, and poorly compensated has created a paradigm for youths in which the only choice for a happy and prosperous life involves advanced degrees from expensive universities.

This way of thinking has been propagated by an idea that is nearly 60 years old: go to college, get a job, work for the same company for 50 years, then retire. While this idea is antiquated, it can still be found in the modern household.

Attitude of Counselors

Melinda Scott Krei and James E. Rosenbaum presented a paper in which findings from 35 interviewed counselors and 80 interviewed vocational teachers stated students are en-

couraged to attend at least a two-year college (Ref. 2).

In a survey conducted at Thomas Downey High School, Modesto, Calif., 64% of students had no interest in pursuing a career in construction (Ref. 3). The same survey found that 71% of students knew someone currently working in construction. This suggests that awareness of construction is not a key issue, but understanding the benefits of skilled trades is not evident.

These research findings further the ideas that students do not know about opportunities and benefits in construction or trade school, nor where to find out about such inroads, and the individuals charged with informing high school students are coming up short.

College Over Trade School

Decisions being made by high school students can carry serious long-term commitments that the decision maker does not fully appreciate. Furthermore, all of the available options are not being made clear to allow for an educated decision to be reached.

A research survey compiled from students worldwide was conducted with two answers accounting for 53% of the responses. When asked about their reasoning for attending a four-year college, 30% stated it was the natural progression after high school, and 23% chose to attend a four-year college because it was expected of them (Ref. 4). This means many students are taking on thousands of dollars in unsecured debt because it is expected of them or it just feels like the next logical

step. This is exacerbated by the fact that countless trade schools, specifically in the construction industry, offer programs that cost a fraction of the price compared with a four-year college; allow a student to earn while they learn with hands-on training and apprenticeship programs; and, often times, include an associate degree path.

Present Practice

A lack of skilled labor, as previously mentioned, is not a new issue and many avenues have been explored with varying levels of success. Organizations such as Helmets to Hardhats connect both active duty and retired military service members to skilled training and quality career opportunities in the construction industry. The United Association's Veterans in Piping (VIP) program is similar to Helmets to Hardhats, with the major difference being that it is geared specifically toward the piping trades. Both of these organizations, along with several others, continue to have a positive effect on the available labor pool.

As previously mentioned, Figure 1 shows results (from a 2018 national survey) that out of more than 2500 construction industry firms, 80% were having a hard time filling some or all positions. When looking specifically at pipe fitter/welding, 430 firms reported with 66% of those firms stating hiring is more difficult than the previous year. Additionally, 48% of all respondents reported anticipating that it would become harder to hire hourly crafts people in the coming year — Fig. 2.

Effect of Skilled Labor Shortage on Projects

As with any industry, construction is profit driven and the lack of skilled labor is having a direct and lasting effect on both the overall cost of projects and extending the timelines of projects. The lack of available skilled labor also plays a role in the cost of existing skilled trades people to contractors that need them on the job. With low levels of new talent entering the skilled trades, those that currently occupy such positions are demanding premium wages.

This lends concern to contractors, and those concerns were reflected in a 2018 survey conducted by USG + US Chamber and published as the Commercial Construction Index. As with all recent Commercial Construction Index quarterly publications, multiple concerns were listed, but cost of skilled labor was seen as a concern by 90% of reporting contractors (Ref. 5).

Additionally, a report filed in 2015 by FMI Corp. predicted these hardships with a top-five list of positions that will be difficult to fill, with pipefitter coming in at number four (Ref. 6).

Along with the rising costs of existing skilled labor, project run times are also increasing. Sriram Changali et al. found that 77% of the world's mega projects are at least 40% behind schedule (Ref. 7). While that entire number is not exclusively caused by the skilled labor shortage, it is contributing to the problem.

While projects are indeed being slowed by various challenges, this does not mean customers are backing off the idea of new construction or built environment renovation. Associated Builders and Contractors Inc. uses a construction backlog indicator tool consisting of a mathematical algorithm to track work on the books that has yet to be completed — Fig. 3. In the second quarter 2018, the year-over-year backlog numbers hit an all-time high with three of the four regions reporting measurable improvement from 2017 — Fig. 4.

Challenges and Opportunities

The long-term nature of this problem creates a multitude of both challenges and opportunities. The issue has been seen as noncritical for such a long

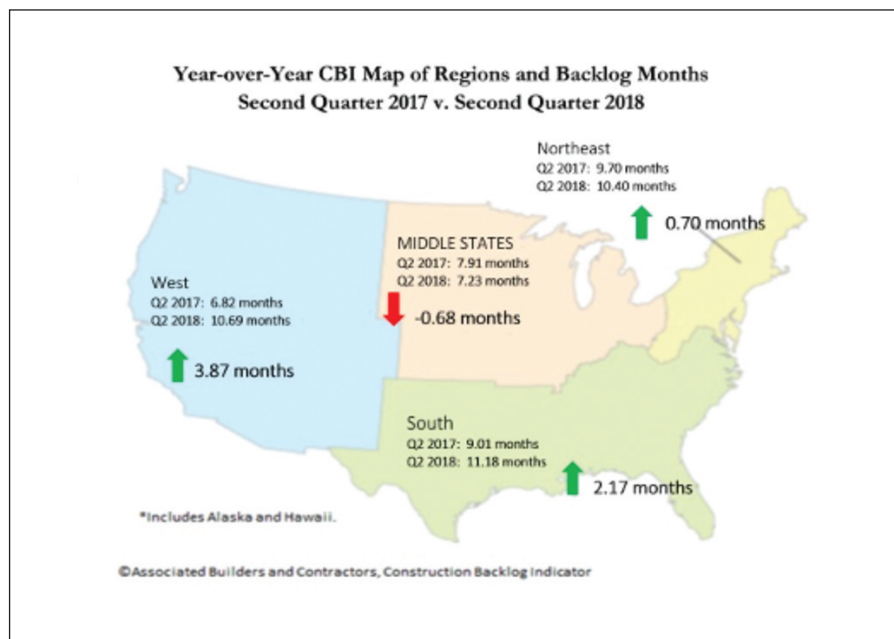


Fig. 4 — Year-over-year CBI map of regions and backlog months. Second quarter 2017 vs. second quarter 2018. (Credit: Associated Builders and Contractors Inc.)

period of time that new issues have sprouted from it and potential resolutions are more prevalent than ever.

The first challenge that needs to be addressed will be accepting skilled labor in construction as a must for a healthy industry, and the issue of lack of skilled labor is not going to resolve itself. A paradigm shift is needed to make real progress on the skilled labor front.

The next challenge is to improve the image of trade schools and craft training programs to place them on the same plane as four-year universities in terms of earning potential and prestige. The antiquated thought that the only path to a successful and prosperous life is a bachelor's degree has to be changed. Furthermore, the construction industry as a whole needs to continue its image improvement efforts, in both work appeal and safety, through ongoing programs.

The opportunities that we are presented with are numerous in both scope and potential reach. Programs like VIP, Helmets to Hardhats, and Build America need to be expanded and new programs need to be developed to expose the next generations of students, both high school and college, to the potential construction holds in the skilled trades.

The construction industry must ramp up efforts to diversify and get women involved at a more in-depth level.

Technology must continue its progress in the industry in new and innovative ways, such as the development of new tools that allow highly skilled workers to become more productive and sustain their careers past retirement age. This will allow the skills gap to be tightened over a shorter period of time and perhaps create new job paths.

The use of virtual reality to spark an interest in future generations is also important, to show them the vast opportunities that exist and how that can fulfill their desire to not only create something lasting, but also contribute to society in a meaningful way.

Development of new tools that require the knowledge of skilled work but eliminate the physical demand on aging workers could be a significant improvement at many levels.

Future Research

The questions that have been raised here are as follows: What means and methods need to be developed going forward to capture the interest of pre-full-time, work-age individuals and drive them toward a career in construction? Also, can virtual reality be a tool that allows current skilled trades people to remain productive while newcomers improve skill levels and make themselves more marketable?

The evolution of both the construction industry and the life-after-high-

school paradigm will need to continue shifting toward new and better methods of making decisions and addressing the ideas and perceptions of the past. In doing so, new opportunities will be created and embraced to allow for the next generation to meet their full potential. **WJ**

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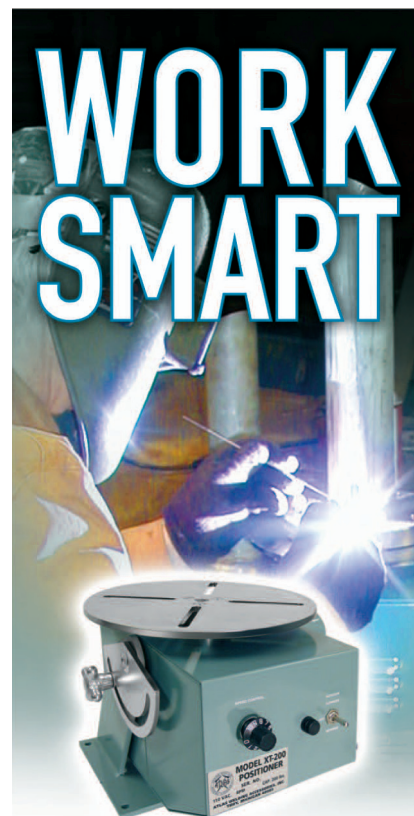
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Please note that this article was written in late 2019.



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The Beauty of Welding

From fancy figures to goth-inspired creations, these artists bring metal to life

BY KRISTIN CAMPBELL, CARLOS GUZMAN,
KATIE PACHECO, AND CINDY WEIHL

The *Welding Journal* recently interviewed four individuals who design striking artwork by combining their creativity with welding and other processes. They are all accomplished in their own right and not only shared personal stories but also detailed how they make different masterpieces. These artists prove that when beauty and fabrication converge, the result is breathtaking.

Sean Flottmann 'Dabs' in Stainless Steel Artwork



Sean Flottmann

Ever since Sean Flottmann got into welding by happenstance more than 20 years ago, he's never looked back.

"I luckily stumbled into a welding and fabrication shop as a temporary employee," the Missourian recalled. He began

an entry-level position in the grinding room, but quickly developed an interest in gas tungsten arc welding (GTAW), and wouldn't stop until he secured a role at one of those tables.

"I was fascinated because, let's be honest, what young man doesn't love having a perfectly good excuse to play with fire, masquerading as gainful employment?" Flottmann said.

All of his training has been on the job. That's led him to be a professional GTA welder, predominantly welding food packaging equipment, and moonlighting as an artist — Fig. 1.

Many of Flottmann's adventures are on Instagram @dabswellington. More than 104,000 followers see his personality shine through welding and amusing meme posts.

"My work started out as little goofy cartoons and characters that would appeal to my daughter," Flottmann said. Realizing the rest of the world would not be so impressed, he perfected his technique. "Today, my workload is heavily dictated by the customer. However, I do get to play around and have some fun from time to time," he added.

His favorite medium is stainless steel sheet, #8 polish, which looks like a mirror. On that canvas, he generally outlines designs with an engraving tool that his father gave him; checks there's enough shielding gas to keep from running out in the middle of crafting a creation; operates a digitized GTA alternating/direct current power source; uses a GTAW torch with a larger, flooding-style cup to provide a wide coverage area; "dabs" in 308L or 316L wire; and later applies glass cleaner to the surface and wipes it with acetone to remove residuals.

"Everything from start to finish is done by hand," Flottmann said.

Stainless steel and GTAW play well to his strong suits.



Fig. 1 — Sean Flottmann prefers GTAW and stainless steel. For practice here, he performed GTAW to join several six-sided pieces of stainless steel into a soccer-ball sculpture. “You don’t want your skills to be static,” he said. Oversized cubes he crafted can also be seen.



Fig. 2 — This 14 x 16 in. Buddha, fabricated on stainless steel sheet with GTAW, was kept by Flottmann. “The Buddha is just an image/philosophy that brings me peace and a feeling of calm,” he said. It’s within an etched frame that’s been heat activated with a chemical patina, then grinded, set in place, and clear coated.

Often, his welds look like stacks of dimes with a rainbow appearance. To achieve a good rhythm, he puts in earbuds and listens to beat-driven music.

“I’m trying to make stuff that’s not cookie cutter,” Flottmann said. Over time, he’s crafted several shapes, including Buddhas, mended hearts, patriotic themes, and logos — Figs. 2, 3.

“Typically, plaques take a few hours to create. My Instagram videos really don’t translate the time and effort that goes into each piece,” he said.

Flottmann’s branched out and made other pieces, too — Fig. 4.

“The greatest thing about the recent notoriety is the spotlight it puts onto the ‘creative’ side of welding...the artwork reinvigorated my creativity and passion, and I hope it has the same effect on others,” he said.

Flottmann’s daughter is also on Instagram @the_tiny_tigger.

“Ava is my little shadow. We spend a lot of time hanging in my little oasis [home studio] in the backyard,” he said. “She enjoys welding, and I enjoy the time we spend learning together. Her future is much brighter than following in my footsteps, but I want to be sure she is well rounded and has fabrication knowledge.”



Fig. 3 — Flottmann has made many mended hearts from steel, including this 12 x 14 in. version for a couple’s wedding anniversary, by cutting them with a cut-off wheel or handheld plasma device, GTAW the halves together with silicon-bronze wire, placing them on stainless steel sheets, adding angel wings, and incorporating a frame. But their inspiration remains grounded. “The mended heart is a portrayal of the love that I share for Heather [Mrs. Dabs] and the struggles that we have overcome,” he said.



Fig. 4 — Before and after shots of a bracelet made from twisting ERTi-2 titanium filler metal, GTAW, flame treated to achieve a blue/purple appearance, and finishing with a flannel buffing wheel, as well as jewelers rouge.

David Madero Turns Sights, Dreams Into Welded Metal



David Madero

David Madero is a Mexican-American sculptor and furniture designer who grew up moving back and forth between the United States and Mexico.

His father, Rogelio Madero (1936–2014), was a master sculptor who specialized in welded art. A true pioneer, he began welding artwork back in the 1950s, when welding was mostly used for commercial and industrial fabrication. He would craft amazing metal sculptures in their one-car garage, with his trusty old Victor® torch. When Madero was about four years old, he would bug his father constantly until he let him mess around with the torch and scrap metal.



Fig. 5 — This 50-in.-tall, carbon-steel sculpture was crafted with an oxyacetylene torch and GTAW, polished, and clear coated.



Fig. 6 — El Manto de la Virgen (Virgin Mary's Veil). A 100-ft.-tall religious monument commissioned for the city of Torreon, Mexico, made of carbon steel using GMAW and SMAW, and finished with enamel paint.

“Seeing that molten metal could be turned into anything I could ever dream up was enough for me, and I just knew this was what I wanted to do for the rest of my life,” Madero said.

In 2013, Madero was lucky to be able to open a workshop and metal art company called Madero/Co. (<http://madero.co>, Instagram @madero_co) in Torreon, Mexico. It is known for making unorthodox welds and trippy metal finishes on artwork. Madero makes all of the smaller sculptures, and he has a team of metalworkers who help with monumental sculptures and functional art — Figs. 5–8.

They work with carbon steel, stainless steel, bronze, and copper. Also, they use a variety of welding and cutting techniques that include gas metal arc welding (GMAW), GTAW,



Fig. 7 — Dueling Stallions. A 35-in.-tall sculpture made of carbon steel using GMAW and an oxyacetylene torch, polished, and clear coated.



Fig. 8 — Eagle and Serpent. The eagle and serpent are Mexico's coat of arms. This 25-ft-tall national monument, commissioned for the entrance of the presidential residence in Mexico City, Mexico, was made of carbon steel using GMAW and SMAW, polished, and clear coated.

shielded metal arc welding (SMAW), oxyacetylene welding, and plasma arc welding. They do a massive amount of grinding and polishing, as well. The team has a vast arsenal of different welding textures, patinas, and finishes. Madero is always experimenting and coming up with new techniques.

"My job is a little unconventional because I turn things that I see, feel, and dream about into welded metal. I could be meeting you for the first time and my first thought would be, 'What would you, your face, and your expressions look like as welded art?' I get inspired by so many things around me. The key is taking these inspirations and finding creative ways of translating them into metal," Madero said.

He's a perfectionist, so it can take him a few months to fabricate sculptures, which are made from scratch and welded drop by drop. Madero mentioned the most rewarding thing about what he does is seeing the amazing reactions from his clients after they see their finished art pieces.

"It's also gratifying, always, to be working with my hands and being paid well for sculpting crazy things. I'm obsessive-compulsive about good craftsmanship. This is all acceptable when it comes to my sculptures, but the challenge is leaving work at work and not keep obsessing, which can disrupt my personal life," Madero concluded.

Barbie Parsons Illustrates Gothic Elegance



Barbie Parsons

New York-based Barbie Parsons is living proof that sometimes life imitates art — Fig. 9. Popularly known as "Barbie the Welder," Parsons became determined to learn welding after watching the opening scene for the movie *Cast Away*, which depicts a woman welding giant angel wings. Little did Parsons know that a few short years later she'd also be creating angelic metal wings.

Fueled by the desire to become a metal sculptor, Parsons began saving money for welding classes at the age of 31. Saving money was difficult for Parsons, who was a single mother surviving on welfare, but she was willing to make sacrifices to achieve her aspiration.

"I knew I would love to weld the moment I saw that



Fig. 9 — Angel of Sorrow. This gas metal arc welded, 5-ft piece was created using 18-gauge patchwork scrap steel with 1/4-in. round bar for the body, 1/2-in. square bar from a plant hanger for the head, and 3/8- to 1/2-in. round bar for the hands. The sculpture is currently displayed at Sullivan's Funeral Home in Horseheads, N.Y.

woman welding the wings," she recalled. "I dreamt about it every day during the nine months it took me to save for the welding class, so when I finally did get to weld, it felt epic!"

After completing a six-month welding program in 2007, Parsons secured employment as a welder, where she remained for five years and reached journeyman status. The job allowed her to repair her credit, purchase a home and vehicles, and establish her own workshop complete with welding equipment. Despite the financial security, Parsons left her job and took out a personal loan to start her own business as a metal sculptor.

"Every decision I made — taking the welding class, working at Cameron Manufacturing & Design, learning the art of fabrication, fixing my credit to buy a home with a garage —



Fig. 10 — Metal Sculptor Barbie Parsons brought this 55-lb, 18-in.-tall Grim Reaper to life using scrap bolts and steel metal, which she gas metal arc welded and then ground.

everything supported my dream to be a sculptor,” she explained. “I knew I would quit my job to go full-time as an artist before I ever started that job.”

However, Parsons made no money during her first nine months as an independent sculptor. The financial turning point came when she began doing demonstrations and exhibitions. Today, she owns a successful metal sculpture business (barbiethewelder.com), is a well-known social media influencer, and is a published author.

“Although creating one-of-a-kind sculptures and bringing a client’s or my vision to life makes my heart so happy, the most rewarding thing I do today is teach others to create metal art through my books, YouTube videos, and metal art welding kits,” she said. “I truly love seeing someone else find bliss in the creation process.”

Parsons is known for her elegantly macabre artistic style. Her goth-inspired works take the form of morose angels, bony skeleton hands, ornate spider webs, and towering undead beings — Figs. 10–12.

Although Parsons’ creations feature the extraordinary, her ideas actually spring from everyday, ordinary life.

“I find inspiration in the most unexpected places. I can listen to a speech and something will pull at me, or I will be standing in the shower, watching a movie, or driving down the road and something will spark a vision,” she said.

Once Parsons has a vision, she’ll mentally maul over the entire creative and fabrication process from beginning to end without drawing it out. Her masterpieces can take anywhere from a few days to several weeks.

“When I start the sculpting process, because I’ve built the sculpture hundreds of times in my head already, the sculpture just comes through me. It’s like driving somewhere but you kind of zone out, and next thing you know you’re at your destination. I see my hands creating like I’m watching a movie, I hear the music playing in the shop, and a sculpture materializes,” she affirmed.

Parsons’ masterpieces are typically conceived with aluminum, stainless steel, and steel using GTAW and GMAW. But the vast majority of her works have been forged using GMAW and steel, and shaped with sanding disks, cut-off wheels, and burr bits.

Parsons also utilizes a great deal of scrap metal, saying, “I absolutely love taking materials most people throw away and turning them into something that is beautiful! I feel like I’m giving the material a second chance.”

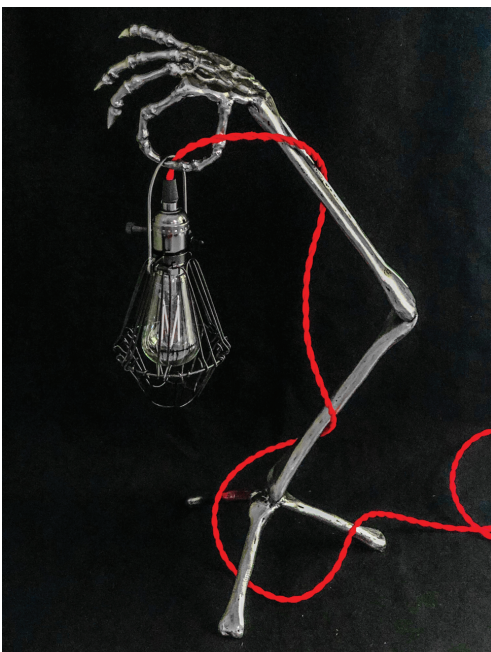


Fig. 11 — This gas metal arc welded, 15-lb skeleton hand desk lamp was crafted using 3/8-round bar scrap steel from a plant hanger, as well as 11-gauge scrap steel.

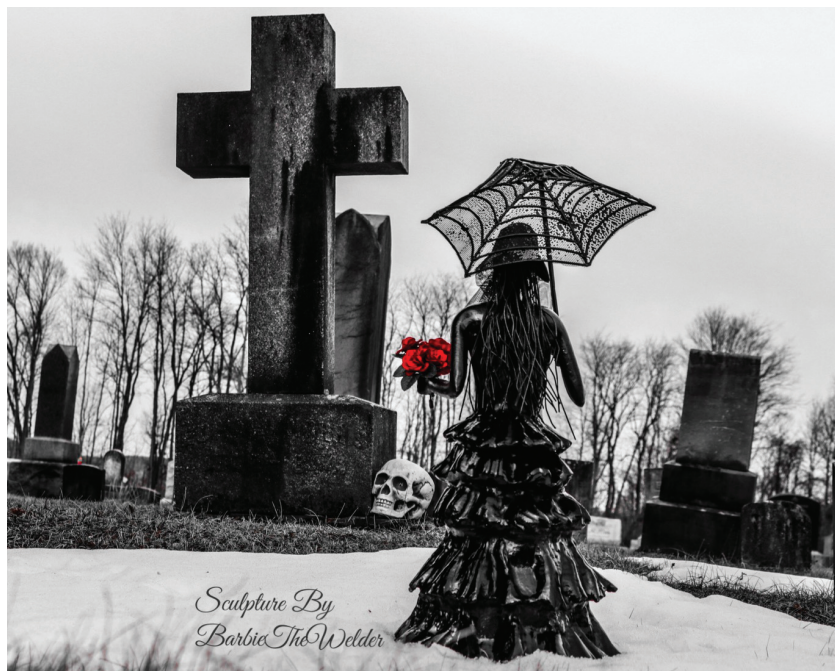
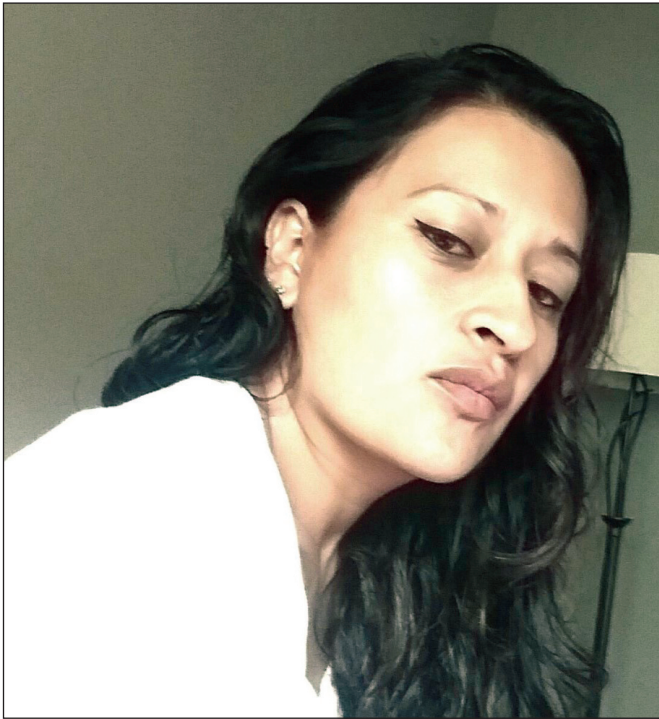


Fig. 12 — Death’s Widow. This 45-lb, gas metal arc welded sculpture was devised with 1/4-in. plate scrap steel, a sink screen for the hat, 1/8-in. round bar scrap steel for the spiderweb umbrella, and silk for the roses.

Amelia Riojas



Amelia Riojas



Fig. 13 — Riojas made this scorpion as a birthday gift for her best friend, whose November birthday is represented by the Scorpio zodiac sign. It was made out of a bike chain, screws, barbed wire, the end of a drill bit for the stinger, and nuts and bolts for the eyes. The tail, arms, and eyes move.

Taking chances and new adventures are two things Amelia Riojas has never backed down from. That's what led the young welding instructor at Clover Park Technology Center in Lakewood, Wash., to start welding 14 years ago and, more recently, to convert her love of welding metals into art.

After receiving her General Education Degree and trying unsuccessfully to continue on to college, she would go on to work 16- to 22-h days at a fish processing company in Dutch Harbor, Alaska, before returning home to Washington to work minimum wage jobs.

Life took a turn one day when her younger brother, Antonio, asked her if she wanted to go to work with him and see what welding was about. She jumped at the chance, and although welding scared her at first, Riojas couldn't get it off her mind. Soon after, she took a leap of faith and signed up



Fig. 14 — Master Sword Warrior. Riojas made this piece for a young boy who loves to read and is really into fighting-game characters. She designed him to carry two swords that are ready for battle and two more on his back for a quick replacement.



Fig. 15 — This intricate ornamental welding hood holds special significance to Riojas who wants viewers to see it for its complexity.

for a welding class at Olympic Community College in Bremerton, Wash.

“My whole life changed. It was the best and most challenging decision I had made in my life,” she said.

After graduation, Riojas would expand her welding experience and knowledge while working at several companies throughout the state of Washington. She’s been involved in building or repairing ships, welding nuclear casings, submarines, huge generators for GE, and Washington State ferries.

Her skills and knowledge range from structural to pipe welding and she has extensive knowledge in flux cored arc welding, GTAW, GMAW, and SMAW.

In 2019, she took another chance, applying for the job of a welding instructor at Clover Park Technical College. In her new career as an educator, Riojas has found both stability and hope that she is leading a new generation on a good path.

“I have been where my students are. I have struggled and I have overcome. I know what it’s like to need just one person to believe in me. I want to be that person for someone else. I am very passionate about welding and of all the possibilities that can come from this career,” she said.

Teaching has also allowed her the time to explore welding art.

“I have always wanted to do welding art and have always been interested, but I could never find the time for it until last year,” she stated.

Riojas likes using recycled, scrap, or donated metal and mostly uses the GMAW process. She also uses plasma arc cutting, grinding, shears, paints, solvents, and good old-fashioned elbow grease to get any polishing done.

As of right now, Riojas is not selling any of her artwork but instead gifts it to friends and family on special occasions — Figs. 13, 14. Her favorite piece is an ornamental welding hood she created — Fig. 15.

Inspired by her own experience as a welder, she wants viewers to see this piece as mysterious, complex, interesting, exciting, and a busy work of art. Some of the gears were cut in half to express that nothing is ever whole. The keys represent opportunity, knowledge, and the freedom that if one door is a dead end, another door might not be. The mirror is to self reflect and encourage others to continue when they may want to walk away and give up on a trade that is unkind, at times, and that can be hard on the mind, body, and soul.

“You cannot quit! So you look in the mirror and tell yourself that you got this! And then reach for your hood,” Riojas exclaimed.

The rose, she said, is to remind you that you are beautiful inside and out — even when you are surrounded by cold, dirty, rusted steel — with slag chips in your hair, smoke fumes penetrating your clothes, dirt under your fingernails, and grinding dust on the back of your neck. [WJ](#)

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Figures 1–4 are courtesy of Sean Flottmann; Figs. 5–8, David Madero; Figs. 9–12, Barbie Parsons; and Figs. 13–15, Amelia Riojas.

NOMINATION DEADLINE FOR AWS FELLOW OF THE SOCIETY



American Welding Society®

Friends and Colleagues:

The American Welding Society, in 1990, established the honor of Fellow to recognize members for distinguished contributions to the field of welding science and technology, and for promoting and sustaining the professional stature of the field. Election as a Fellow of the Society is based on outstanding accomplishments and the technical impact of the individual. Such accomplishments will have advanced the science, technology and application of welding, brazing, or soldering, as evidenced by:

- Sustained service and performance in the advancement of welding and joining science and technology
- Publication of papers, articles and books which enhance knowledge of welding and allied processes
- Innovative development of welding and allied technologies
- Society and Section contributions
- Professional recognitions

I want to encourage you to submit nomination packages for those individuals whom you feel have a history of accomplishments and contributions to our profession consistent with the standards set by the existing AWS Fellows. In particular, I would make a special request that, in considering members for nomination, you look to the most senior members of your Section or District. In many cases, the colleagues and peers of these individuals who are the most familiar with their contributions, and who would normally nominate the candidate, are no longer with us. I want to be sure that we make the extra effort required to ensure that those truly worthy are not overlooked because no obvious individual was available to start the nominating process.

For specifics on nomination requirements, please contact Chelsea Steel at csteel@aws.org at AWS headquarters in Miami, or simply follow the instructions on the Fellow nomination form located at www.aws.org/fellow. Please remember, we all benefit in the honoring of those who have made major contributions to our chosen profession and livelihood. The deadline for submission is **August 1, 2020**. The Fellows Committee looks forward to receiving numerous Fellow nominations for 2021 consideration.

Sincerely,

Dr. Sudarsanam Babu
Chair, AWS Fellows Committee

IMPORTANT Announcement!



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August 1, 2020
Submission Deadline

Bringing Architects' Visions to Life



Patriot Erectors Inc., Dripping Springs, Tex., completed welding on 200 steel canopies at Austin-Bergstrom International Airport four months ahead of schedule by switching to the submerged arc welding process.

A structural steel fabricator reduced costs and expedited delivery times after switching from FCAW to SAW

BY DOUG ZOLLER

Known as the live music capital of the world, Austin's eclectic spirit has helped double the city's population in 25 years. To keep up with the increased air traffic, the Austin-Bergstrom International Airport (ABIA) in Texas is in the midst of a multiyear expansion. The ABIA expansion included nearly 200 hollow structural section canopies for a new parking garage and entry plazas to the parking lots, garages, and rental car facility.

The canopies' fabricated steel elements are both functional and ornate — Fig. 1. With a span of 40 ft, the canopies feature "wings" spreading out from a vertical I-beam. Each wing is fabricated from two 19-ft-long ASTM A500 Grade B tubes that are 0.625-in. thick. To create the wing effect, the tubes taper as they extend out, requiring the use of an automated oxyfuel table to cut the tubes, which are then joined with welds on each side.

Ready for the challenge, Patriot Erectors Inc., Dripping Springs, Tex., a provider of steel fabrication and erection services, took on the project.

"Today, architectural firms emphasize aesthetics as much as functionality. That's especially true for Austin, a city that promotes itself as an artist-oriented community and embraces the motto 'keep Austin weird.' Here, the design of structural steel shapes continues to morph," said Jason Puckett, safety and quality director for Patriot Erectors; president of Iron Workers Local 482; and American Welding Society (AWS) Certified Welding Inspector. "As a leading custom structural fabrication company, our challenge is to figure out cost-effective methods of executing what architects and engineers envision."

Patriot Erectors' headquarters is just west of Austin on a 30-acre site with a 75,000-sq-ft production facility. Drawing on the talent of Iron Workers Local 482, the company employs about 500 people, including a large field erection crew. In 2019, the company opened an 18,000-sq-ft facility in Rio Vista, Tex., and acquired Trinity Steel Fabricators. Located 90 miles north of Houston, the Trinity Steel acquisition added 85,000-sq-ft of fabrication space and 120 skilled fabricators to the company.

"We are one of just three companies in the state that holds dual AISC [American Institute of Steel Construction] certification for shop fabrica-



Fig. 1 — The 40-ft, hollow structural section canopies at Austin-Bergstrom International Airport emphasize aesthetics as much as functionality.

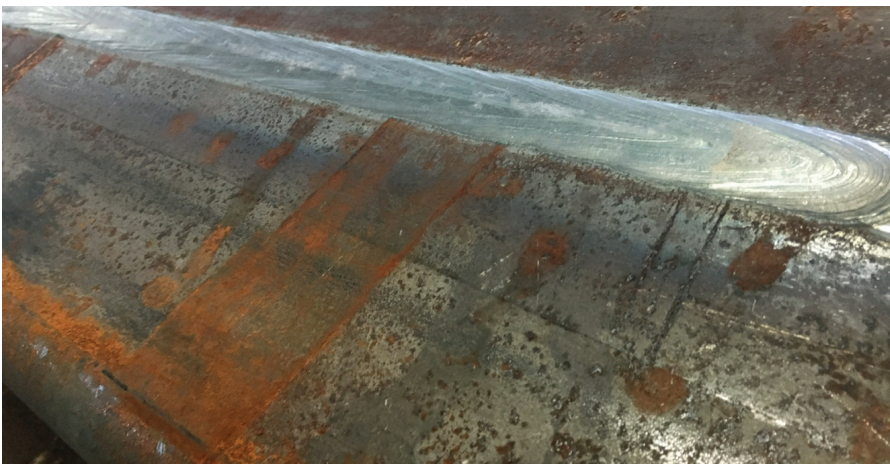


Fig. 2 — Pictured is a finished joint on a canopy. The canopies at ABIA required 15,200 ft of welds just for the main seams alone.

tion and field erection,” said Bobby Feil, quality manager, Patriot Erectors.

The certification has allowed the company to better control its workflow.

“We control our own destiny by being able to manage quality and productivity every step of the way,” Puckett added. “That’s one of the reasons Austin Commercial, general contractor for the ABIA expansion, selected us for the canopy project. We have a reputation as the company you call for items that are difficult and intricate. That re-

quires some out-of-the-box thinking. Having in-house engineers and senior project managers who understand the industry and can identify complex needs allows us to have more latitude in the projects we take on.”

Instrumental to the company’s success in completing ABIA’s project was its switch from flux cored arc welding (FCAW) to submerged arc welding (SAW). This change allowed the company to better control costs and improve project delivery times.

Making the Switch from FCAW to SAW

Because the 200 ornate canopies required 15,200 ft of welds just for the main seams alone, Patriot Erectors knew it had to find a process that would deposit enough weld filler metal to make the project profitable while still completing the project in a timely manner for the customer — Fig. 2.

The initial welding procedure specification (WPS) called for a B-U2a-GF-type joint (a single-V-groove with a 45-deg angle, 0.25-in. root opening, and 0.25-in.-thick A36 steel backing plate or ceramic backing tape) and welding in the flat position with an .045-in.-diameter E71T-1 FCAW electrode. This joint requires more than 22 lb of weld metal to fill. Welding at an average of 225 A/28 V (a median range for this electrode) deposits approximately 7.1 lb of weld metal per hour. Using two experienced FCAW operators, the joint would have taken nearly 11 h to complete.

“Trying to accomplish these welds using semiautomatic flux cored arc welding just wasn’t going to cut it,” Feil affirmed. “We quickly came to the conclusion that we needed a sub-



Fig. 3 — The side-beam mounted SAW system can weld joints up to 25 ft long, increasing Patriot Erectors' competitiveness when bidding on structural steel projects.



Fig. 4 — An operator controls SAW parameters using a digital controller and handheld pendant.

merged arc welding system.”

To begin production quickly, Patriot Erectors rented a SAW tractor. However, the company wanted a fully automated solution, so Puckett and Feil worked with ESAB Welding & Cutting Products Account Manager Ryan Rummel, Automation Specialist Shane Searels, and SAW/Filler Metal Expert Phil Formento, as well as the Houston-based welding lab of Arc Specialties, a welding automation specialist.

Ultimately, the team settled on a side-beam mounted SAW system that allowed Patriot Erectors to weld joints up to 25 ft long as the entire wire drive, flux hopper, control assembly, and drive motors rode on what is basically an I-beam with a 12-in.-wide flange. The system's configurable torch allowed the company to create butt joints (1G) and fillet welds (1F and 2F) — Fig. 3.

The SAW system components included ESAB's LAF 1000-A direct current (DC) power source and TAF 800-A alternating current (AC) power source, configured in a DC lead/AC trail setting for tandem arc welding; both power sources could be used independently. The system also provided two PEK controllers that regulate welding parameters, store up to 225 different programs, and set parameter limits — Fig. 4. Overall, the system enabled Patriot Erectors to make joints in one pass using a tandem arc process or in two passes with a single electrode.

The SAW tandem arc process melts two electrodes into one weld at the same time. Each electrode is fed via electrically isolated contact tips so they can be controlled independently while still being precisely coordinated.

Tandem arc reduces cycle time; however, it is a more complex process, and the cross-sectional area of the joint needs to remain consistent. Two passes with a single-wire process takes more time, but it allows the operator to more easily manage the total reinforcement level to meet AWS D1.1 requirements. As a result, the company largely opted for the single-wire process on the canopy project.

“With a $\frac{1}{2}$ -in.-diameter electrode and the parameters selected for the canopy, the SAW system can deposit approximately 20 lb per hour with a single wire and 39 lb of weld metal per hour using the tandem arc process,” Rummel said. “At a minimum, Patriot Erectors would improve productivity by 300% with the single-wire process, but it turned out to be more than that” — Fig. 5.

New WPS Saves on Weld Metal

Instead of an AWS EM12K SAW solid electrode, a typical choice for structural steel, Formento recommended ESAB Alloy Shield 70S, a metal-cored electrode with an AWS A5.17:EC1 classification. The metal-cored electrode is paired with OK.71 neutral, bonded flux, which is suitable for use with DC and AC single- and multiple-wire systems at currents up to 1000 A.

Metal-cored electrodes concentrate the current in their outer sheath, creating a higher current density than a solid wire. Higher current densities increase burn-off rate, depositing 15 to 30% more filler into the weld puddle

for a given amperage. Thus, metal-cored wires increase productivity while preserving the mechanical properties needed to pass the Charpy V-notch tests required in structural steel. They also meet Buy America requirements.

The Patriot Erectors/ESAB team also reconfigured the WPS to a B-L2a-S-type joint (a single-V-groove with a 30-deg angle, 0.25-in. root opening, and 0.5-in.-thick A36 steel backing plate). Moving from a 45- to 30-deg groove angle reduced the amount of weld metal required from 1.18 to 0.98 lb/ft, a 17% decrease — Fig. 6. With a total of 15,200 ft of joint to fill, using SAW saved 0.2 lb of deposited metal per foot, thus reducing the total deposit requirements by 3040 lb.

“By using the SAW system, our deposition rates increased dramatically. Instead of completing one or two canopy members per day, we were able to jump up from eight to 12 canopies per day depending on how many shifts we ran,” Feil explained. “The SAW system will shape our future by giving us a leg up on our competition. We're able to do much longer joints. We have a much higher rate of deposition and our efficiency goes through the roof while using this machine.”

For the canopy wing, SAW welding travel speeds averaged 18.5 to 20 in./min. Coupled with setup and repositioning time, total cycle time to join the tubes was about 3 h for a single-wire SAW process and even less for the tandem arc process.

Conclusion

Switching from FCAW to SAW allowed Patriot Erectors to use less weld

metal and complete the ABIA project four months ahead of schedule. The investment also allowed the company to better control costs while expediting project delivery times.

"Integrating a submerged arc system into our operation required us to invest significant capital and human resources," said Ted Turner, senior vice president/general manager, Patriot Erectors. "However, the submerged arc welding investment will pay dividends and let us better serve customers with even more competitive bids or faster delivery times."

Moving forward, the investment will also allow the company to take on more projects.

"In the past, projects with large structural members like plate girders or similar components with long, large continuous welds were not something we would bid on; we wouldn't be profitable," Puckett said. "Now that we have SAW capabilities, that opens up new doors for Patriot Erectors." **WI**



Fig. 5 — In a single-wire configuration on a 0.625-in. steel tube, the SAW system can deposit up to 20 lb of weld metal per hour with a 5/32-in.-diameter metal-cored electrode.



Fig. 6 — Switching to a narrow groove angle for the canopies reduced filler metal use by 17% and boosted SAW productivity.

Doug Zoller (dzoller@esab.com), engineering excellence director, ESAB Welding & Cutting Products, Cleveland, Ohio.

Automated Doesn't Mean Automatic



Submerged Arc Welding Operator Justin Montemayor centers the electrode within the joint and adjusts the torch height.

Just because equipment is automated doesn't mean operators will automatically know how to use it. Patriot Erectors Inc., Dripping Springs, Tex., a provider of steel fabrication and erection services, discovered this fact when it purchased an automated submerged arc welding (SAW) system.

"When we were installing our first automated system, we learned about the importance of training," said Bobby

Feil, quality manager, Patriot Erectors.

To support the company during this transition, ESAB Welding & Cutting Products Automation Specialist Shane Searels developed a written set of operator-oriented instructions for the system. The instructions covered joint preparation, torch angle, electrode extension, the gap between wires, welding parameters, travel speed, and more. Operators had to

sign off on the sheet to confirm they had received proper instruction.

"We held a lunch-and-learn event, then Shane provided a day of intensive hands-on training so operators would understand all the details they needed to pay attention to," Feil explained.

This training made all the difference.

"The training fully helped me.

Shane did a really great job explaining, step by step, how you go about running the machine. Keeping up machine maintenance is very important as well," said Justin Montemayor, one of the SAW system operators who participated in the training.

The experience drove home the importance of training, especially when dealing with automated equipment and machinery.

"Automated does not mean automatic," Feil affirmed. "You can't just put anybody on a submerged arc system. Operators need to be very cognizant of what they're doing and how the equipment works. However, once they're trained, we know we can make welds all day long with 100% consistent results."

Note: Due to COVID-19, these events/opportunities are subject to change.

AWS-SPONSORED EVENTS

Qualification of Welding Procedures Conference. June 2, 3. Lincoln Electric, Cleveland, Ohio. This workshop will explore the role and guide the participants through the process of writing and qualifying a welding procedure specification (WPS) that is ASME Section IX compliant. This includes live demonstrations on the welding of the coupon; test specimen location and preparation; tension, bend, and Charpy testing; evaluation of the test results; and generation of the procedure qualification record(s) and WPS. Each attendee will receive a hard copy of the 2019 edition of ASME's *Section IX Welding, Brazing, and Fusing Qualifications*. Visit aws.org.

Aluminum Conference — Back to Basics. Sept. 16, 17. ITW Technical Center, Houston, Tex. This conference is designed to provide a basic understanding of aluminum welding and will include various topics, including basic aluminum metallurgy; metal preparation and storage; weld discontinuities; AWS D1.2, *Structural Welding Code — Aluminum*; and more. Visit aws.org.

Sheet Metal Welding Conference XIX. Oct. 21, 22. Laurel

Manor, Livonia, Mich. This technical conference brings experts together to discuss welding and joining technologies for the automotive, transportation, and light manufacturing industries. It also provides important opportunities for engineers and researchers from manufacturers, suppliers, universities, and research institutes to network and meet experts in the field of welding. The conference will be preceded by a one-day workshop on Oct. 20. Visit awsdetroit.org.

FABTECH 2020. Nov. 18–20. Las Vegas Convention Center, Las Vegas, Nev. This event provides a one-stop shop venue where attendees can meet with world-class suppliers; see the latest industry products and developments; and find the tools to improve productivity, increase profits, and discover new solutions to all of their metal forming, fabricating, welding, and finishing needs. Visit fabtechexpo.com.

International Brazing and Soldering Conference (IBSC). April 25–28, 2021. Denver, Colo. Attend IBSC to learn about the innovative brazing and soldering processes of today. Included will be education, plenary, and technical sessions; exhibitors; an awards reception; and more. Visit aws.org.

U.S., CANADA, MEXICO EVENTS

ICPIIT 2020 — International Chemical & Petroleum Industry Inspection Technology Conference. June 17–19.

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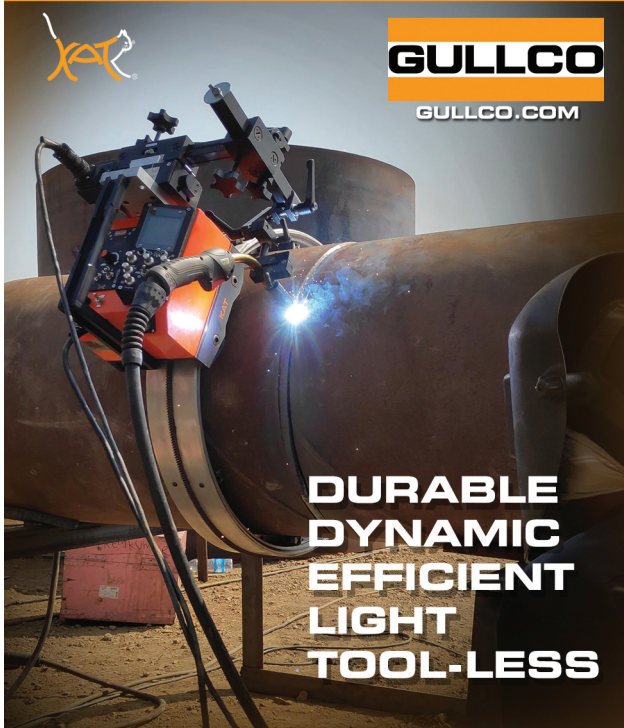
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Sugar Land Marriott Town Square, Sugar Land, Tex. This conference will provide a forum for the exchange of theoretical and scientific information on the nondestructive examination (NDE) of pipeline and piping, pressure vessels, storage tanks, chemical and refinery plants, and equipment for transportation. It will also cover inspector certifications, codes, standards, regulations, risk-based inspections and evaluations, and general NDE. Visit asnt.org.

INTERNATIONAL EVENTS

EuroBLECH 2020 — 26th International Sheet Metal Working Technology Exhibition. Oct. 27–30. Hanover Exhibition Grounds, Hanover, Germany. This event covers the sheet metal working technology chain and offers a marketplace for knowledge transfer, individual manufacturing solutions, and worldwide business contacts. Featured topics include digitalization of manufacturing processes, e-mobility, and sustainable production, as well as innovative materials. Visit euroblech.com.

EDUCATIONAL OPPORTUNITIES

Advanced Fundamentals & Brazing by Design. Philadelphia, Pa. Two-day course covering the essential theoretical aspects of brazing technology combined with real-life applications and case studies. Visit lucasmilhaupt.com.

Amada Miyachi Educational Resources/Training. Personalized training services on resistance and laser welding fundamentals, laser marking, custom programs, material selection, joint design, and more. Visit amadamiyachi.com, or call (626) 303-5676.

ASME Section IX Seminar. Learn how to use ASME Section IX quickly and cost effectively. This ASME-sponsored course is scheduled for Houston, Tex., June 15–17. Contact Marion Hess, hessm@asme.org, (212) 591-7161, or register at asme.org/products/courses/bpv-code-section-ix-welding-brazing-fusing.

Business Electronics Soldering Technology. Certification and training classes held in Rolling Meadows, Ill.; Auburn Hills, Mich.; Rosemount, Minn.; and Cleveland, Ohio, or can be coordinated onsite at your facility. Training schedule is available at solder.net. Contact BEST at (847) 797-9250.

CWB Online/Classroom Courses. Courses in NDE disciplines to meet certifications to the Canadian General Standards Board or Canadian Nuclear Safety Commission. The Canadian Welding Bureau; (800) 844-6790; cwbgroup.org; info@cwbgroup.org.

CWI Exam Prep Course. American Institute of Nondestructive Testing offers a 40-h online CWI exam prep course. Part A covers the fundamentals of welding technology; part B consists of extensive, practical hands-on techniques, and

— continued on page 67

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Note: The 2020 schedules for all certifications are posted online at aws.aws.org/instructor-led-seminars/seminar-exam-schedule/.

Certified Welding Inspector (CWI)

Seminar covers Parts A, B, and C of the CWI exam. Only Part B of the exam is taken following the conclusion of the seminar. Parts A and C are given at Prometric testing centers.

Location	Seminar Dates	Part B Exam Date
Hartford, CT	June 14-19	June 20
Beaumont, TX	June 14-19	June 20
Seattle, WA	June 14-19	June 20
Savannah, GA	June 21-26	June 27
Omaha, NE	June 21-26	June 27
Farmingdale, NJ	June 21-26	June 27
Mobile, AL	July 12-17	July 18
Phoenix, AZ	July 12-17	July 18
Miami, FL	July 12-17	July 18
Louisville, KY	July 12-17	July 18
Nashville, TN	July 12-17	July 18
Cleveland, OH	July 19-24	July 25
Oklahoma City, OK	July 19-24	July 25
Corpus Christie, TX	July 19-24	July 25
Norfolk, VA	July 19-24	July 25
Orlando, FL	July 26-31	Aug. 1
Manchester, NH	July 26-31	Aug. 1
Portland, OR	July 26-31	Aug. 1
Milwaukee, WI	July 26-31	Aug. 1
Los Angeles, CA	Aug. 2-7	Aug. 8
Hutchinson, KS	Aug. 2-7	Aug. 8
Beaumont, TX	Aug. 2-7	Aug. 8
Denver, CO	Aug. 9-14	Aug. 15
Philadelphia, PA	Aug. 9-14	Aug. 15
Salt Lake City, UT	Aug. 9-14	Aug. 15
San Diego, CA	Aug. 16-21	Aug. 22
Miami, FL	Aug. 16-21	Aug. 22
Chicago, IL	Aug. 16-21	Aug. 22
Charlotte, NC	Aug. 16-21	Aug. 22
Sacramento, CA	Aug. 23-28	Aug. 29
Des Moines, IA	Aug. 23-28	Aug. 29
Miami, FL	Sept. 13-18	Sept. 19
Springfield, MO	Sept. 13-18	Sept. 19
Houston, TX	Sept. 13-18	Sept. 19
Seattle, WA	Sept. 13-18	Sept. 19

Certified Welding Inspector (CWI) Part B

Course covers only Part B of the CWI exam. The Part B exam follows the conclusion of the three-day course.

Location	Seminar Dates	Part B Exam Date
Dallas, TX	June 17-19	June 20
Houston, TX	Aug. 5-7	Aug. 8
Minneapolis, MN	Oct. 21-23	Oct. 24
Louisville, KY	Dec. 9-11	Dec. 12

9-Year Recertification Seminar for CWI/SCWI

For current CWIs and SCWIs needing to meet education requirements without taking the exam.

Location	Seminar Dates
Salt Lake City, UT	June 7-12
Pittsburgh, PA	June 21-26
Charlotte, NC	July 19-24
Albuquerque, NM	July 26-31
Houston, TX	Aug. 9-14
Indianapolis, IN	Aug. 16-21

Certified Welding Educator (CWE)

Seminar and exam are given at all sites listed under Certified Welding Inspector. Seminar attendees will not attend the Code Clinic portion of the seminar (usually the first two days).

Certified Welding Sales Representative (CWSR)

CWSR exams are given at Prometric testing centers. More information at aws.org/certification/detail/certified-welding-sales-representative.

Certified Welding Supervisor (CWS)

CWS exams are given at Prometric testing centers. More information at aws.org/certification/detail/certified-welding-supervisor.

Location	Seminar Dates
Cleveland, OH	July 12-17
Atlanta, GA	Dec. 6-11

Certified Radiographic Interpreter (CRI)

The CRI certification can be a stand-alone credential or can exempt you from your next 9-Year Recertification. More information at aws.org/certification/detail/certified-radiographic-interpreter.

Location	Seminar Dates	Exam Date
Las Vegas, NV	June 1-5	June 6
Pittsburgh, PA	Aug. 3-7	Aug. 8
Houston, TX	Oct. 5-9	Oct. 10

Certified Robotic Arc Welding (CRAW)

OTC Daihen Inc., Tipp City, OH; (937) 667-0800, ext. 218
 Lincoln Electric Co., Cleveland, OH; (216) 383-4723
 Wolf Robotics, Fort Collins, CO; (970) 225-7667
 Milwaukee Area Technical College, Milwaukee, WI; (414) 456-5454
 College of the Canyons, Santa Clarita, CA; (661) 259-7800, ext. 3062
 Ogden-Weber Applied Technology College, Ogden, UT; (801) 627-8448
 Genesis Systems IPG Photonics Co., Davenport, IA; (563) 445-5688

IMPORTANT: This schedule is subject to change without notice. Please verify your event dates with the Certification Dept. to confirm your course status before making travel plans. Applications are to be received at least **six weeks** prior to the seminar/exam or exam. Applications received after that time will be assessed a \$395 Fast Track fee. Please verify application deadline dates by visiting our website at aws.org/certification/docs/schedules.html. For information on AWS seminars and certification programs, or to register online, visit aws.org/certification or call (800/305) 443-9353, ext. 273 for Certification; or ext. 455 for Seminars.

WEMCO and RWMA Come Together in the Lone Star State



Fig. 1 — The WEMCO and RWMA annual meetings, which were co-located in San Antonio, Tex., from February 26 to 28, heralded 95 professionals from throughout the United States. Pictured is guest speaker Richard Marini updating a packed house on the Praxair/Linde merger.

From February 26 to 28, the Lone Star State played host to the Welding Equipment Manufacturers Committee (WEMCO) and Resistance Welding Manufacturing Alliance (RWMA) annual meetings, which were co-located in the Omni La Mansión del Rio hotel, San Antonio, Tex.

WEMCO, an American Welding Society (AWS) Standing Committee and Industry Partner, represents manufacturers who make products for welding processes and applications. It aims to provide a common voice to the welding industry, government bodies, and technical organizations worldwide.

RWMA, an AWS Standing Committee and Industry Partner, is a network of industry professionals dedicated to the advancement of resistance welding standards and processes. It supports the industry's highest technical standards, shares best practices, and prepares future generations for success.

Uniting 95 professionals from throughout the United States, the three-day event provided attendees a platform for sharing ideas, networking, and learning from the best minds in the industry.

WEMCO

For WEMCO, the first day of the event was dedicated to its Executive

Committee meeting. The second and last days were carved out for keynote and guest speakers.

"The committee members had their sales and management representatives gather for a few days of important networking opportunities and exchange of best practices amongst this group of welding equipment manufacturers," said WEMCO Vice Chair Shawn Toops. "The ability to gather with peers in the welding equipment manufacturing space is a proven value for WEMCO members who share a common position in the welding supply channel."

The five experts who presented were Chris Kuehl, managing director, Armada Corporate Intelligence; Richard Marini, president, Praxair Distribution Inc.; Mike Lang, global director of corporate welding services, Fluor Corp.; Jenny Levy, vice president of people,

community, and environment, Hypertherm Inc.; and Justin Morse, director of field technical service, Kiewit Corp.

Giving attendees an economic perspective, Kuehl delivered his keynote speech titled "2020 — The Year of Living Dangerously (Economically Speaking)." His presentation centered on the next predicted recession, which experts forecast will occur this year. He also uncovered several factors that could plunge the country into a recession, including the COVID-19 pandemic, a sinking Purchasing Managers' Index, lost jobs and higher costs due to tariffs, and reduced industrial production.

During his presentation, Marini updated attendees on the merger between Praxair, an industrial gases company based in the United States, and Linde AG, a Germany-based supplier of industrial, process, and specialty gases — Fig. 1.

Focusing on the welding economy, Lang delivered a speech about some of the obstacles faced by the construction industry, including the labor shortage. He encouraged industry to adapt to these challenges by maximizing and improving processes. To do so, Lang emphasized that allied processes must be synced to avoid holding up other processes; nondestructive examination should be properly coordinated to prevent delays; and execution planning is vital.

Levy's presentation, titled "Practical Insights to Address the Talent Challenge," discussed issues and solutions related to attracting, retaining, and developing talent. Some of the tips she offered included connecting your business to the shared purposes and values of the workforce; approach-



Fig. 2 — WEMCO panelists (from left) Richard Marini, president, Praxair Distribution Inc.; Jenny Levy, vice president of people, community, and environment, Hypertherm Inc.; Justin Morse, director of field technical service, Kiewit Corp.; and Mike Lang, global director of corporate welding services, Fluor Corp., answered audience questions.



Fig. 3 — RWMA members toured the TMMTX facility in San Antonio, Tex. (Photo credit: Toyota.)

ing recruiting as an ongoing experience; focusing on retention by keeping the talent you have and respecting them as individuals; and creating clear paths to advancement as well as encouraging ongoing learning.

Morse's speech was titled "Value Chain Approach to Welding Improvement: How Leveraging New Technology Can Add to Your Bottom Line." He highlighted the need to improve welding productivity through technology to combat some of the challenges faced by the construction industry, including the labor shortage, reduced margins, and increased project complexity. He also stressed the need to perform value chain analysis/LEAN analysis, vet all changes before making them, and develop stakeholder buy-in.

After the presentations, a discussion panel was held with Lang, Levy, Marini, and Morse to address audience questions and exchange ideas — Fig. 2.

RWMA

For RWMA, the three days were filled with meetings, as well as networking and educational outings.

RWMA held meetings for its Governance, Education, Membership, and Certified Resistance Welding Technician (CRWT) Committees, plus two full-member meetings. This allowed RWMA to highlight the CRWT exam and program it co-developed with AWS (see Don DeCorte's editorial on page 6 of this issue for more information on the new CRWT certification).

"In addition to great networking

opportunities, the recent RWMA meeting in San Antonio allowed attendees to coordinate our efforts related to rolling out the new CRWT program. RWMA Chair Don DeCorte set the pace by meeting with senior managers from General Motors," affirmed RWMA Past Chairman Tom Snow. "With additional emphasis due to the new certification, resistance welding is on a roll."

Additionally, the group enjoyed a tour of Toyota Motor Mfg., Texas Inc. (TMMTX) — Fig. 3. Covering TMMTX's 2.2 million sq-ft facility, the tour gave attendees the opportunity to learn what goes into the manufacturing of the Toyota Tundra and Tacoma pickup trucks that roll off the line each day. Attendees saw the body weld

shop, where a team of computer-controlled robots weld stamp steel pieces; the plastics shop, which features critical components, including the vehicle bumpers and instrument panels; and the overhead conveyors that transport the trucks from paint to assembly. Throughout the tour, attendees were provided with insight into the processes being conducted by TMMTX workers.

WEMCO and RWMA: Shared Networking

To pay homage to their host city, WEMCO and RWMA held a joint reception at The Buckhorn Saloon and Museum — a historic, Western-themed institution located in the heart of downtown San Antonio — Fig. 4. The occasion gave attendees the opportunity to network while they enjoyed the taxidermy on the walls, authentic Texas Ranger Division artifacts, and wildlife exhibits. Some attendees got into the Old West spirit by donning cowboy attire.

WEMCO and RWMA also shared a welcome reception in the hotel on the first day of the event.

Save the Date

The next WEMCO and RWMA co-located meetings are slated for February 24–26 at the Silverado Resort in Napa Valley, Calif. [WJ](#)



Fig. 4 — Attendees of the WEMCO and RWMA annual meetings network at The Buckhorn Saloon and Museum, a historic institution located in the heart of downtown San Antonio, Tex.

TECH TOPICS

Opportunities to Contribute to AWS Technical Committees

The following committees welcome new members. Some committees are recruiting members with specific interests in regard to the committee's scope, as marked below: Producers (P), General Interest (G), Educators (E), Consultants (C), and Users (U). For more information, contact the staff member listed or visit aws.org/library/doclib/Technical-Committee-Application.pdf.

S. Borrero, sborrero@aws.org, ext. 334. **Definitions and symbols**, A2 Committee (E). **Titanium and zirconium filler metals**, A5K Subcommittee. **Piping and tubing**, D10 Committee (C, E, U). **Welding practices and procedures for austenitic steels**, D10C Subcommittee. **Aluminum piping**, D10H Subcommittee. **Chromium molybdenum steel piping**, D10I Subcommittee. **Welding of titanium piping**, D10K Subcommittee. **Purging and root pass welding**, D10S Subcommittee. **Low-carbon steel pipe**, D10T Subcommittee. **Orbital pipe welding**, D10U Subcommittee. **Duplex pipe welding**, D10Y Subcommittee. **Joining metals and alloys**, G2 Committee (E, G, U). **Reactive alloys**, G2D Subcommittee (G).

R. Gupta, gupta@aws.org, ext. 301. **Filler metals and allied materials**, A5 Committee (E). **Magnesium alloy filler metals**, A5L Subcommittee.

P. Portela, pportela@aws.org, ext. 311. **Additive manufacturing**, D20

Committee (C, E, G). The D1N Subcommittee on Titanium Welding is recruiting all interest groups.

J. Molin, jmolin@aws.org, ext. 304. **Structural welding**, D1 Committee (E). **Sheet metal welding**, D9 Committee (C, G). The D1 Committee is recruiting educators. The D9 Committee is recruiting producers, consultants, and general interest members.

K. Bulger, kbulger@aws.org, ext. 306. **Methods of weld inspection**, B1 Committee (C, E). **Brazing and soldering**, C3 Committee (C, E, G). **Welding in marine construction**, D3 Committee (C, E, G, U). **High energy beam welding and cutting**, C7 Committee (C, E, G). **Hybrid welding**, C7D Subcommittee (G). **Welding of machinery and equipment**, D14 Committee (C, E, G, U).

M. Diaz, mdiaz@aws.org, ext. 310. **Resistance welding**, C1 Committee (C, E, G, U). **Friction welding**, C6 Committee (C, E). **Automotive welding**, D8 Committee (C, E, G, U). **Resistance welding equipment**, J1 Committee (C, E, G, U). **Welding in the aircraft and aerospace industry**, D17 Subcommittee (C, E, G).

S. Hedrick, steveh@aws.org, ext. 305. **Metric practice**, A1 Committee (C, E). **Mechanical testing of welds**, B4 Committee (E, G, P). **Joining of plastics and composites**, G1 Committee (C, E, G). **Safety and health committee**, SHC Committee (E, G). **Welding in sanitary applications**, D18 Committee.

J. Rosario, jrosario@aws.org, ext. 308. **Procedure and performance qualifi-**

RWMA Past Chair Recognized



Matt Post was presented with a captain's chronometer clock in honor of his service as the 2018–2019 chairman of the Resistance Welding Manufacturing Alliance (RWMA) during the co-located WEMCO and RWMA annual meetings held February 26–28 in San Antonio, Tex.

cation, B2 Committee (E, G). **Thermal spraying**, C2 Committee (C, E, G, U). **Oxyfuel gas welding and cutting**, C4 Committee (C, E, G). **Welding iron castings**, D11 (C, E, G, P, U). **Railroad welding**, D15 (C, E, G, U). **Robotic and automatic welding**, D16 Committee (C, E).

ISO Subcommittee Created for Underwater Welding Standard

A new U.S. Technical Advisory Group (TAG) for the ISO/TC 44/SC 15 standard on underwater welding has been created. The scope of the new subcommittee is standardization of all aspects of underwater welding, including procedure and performance qualification in wet and dry hyperbaric environments as well as classification of welding elec-

trodes for underwater welding.

The American Welding Society is actively looking for TAG members to participate and review ISO draft standards for underwater welding.

For more information, contact U.S. TAG Secretary Andrew Davis at adavis@aws.org.

ISO Draft Standards for Public Review

Copies of the following Draft International Standards are available for review and comment through your national standards body, which in the United States is ANSI, 25 W. 43 St., Fourth Floor, New York, NY, 10036; telephone (212) 642-4900. Any comments regarding ISO documents should be sent to your national standards body.

In the United States, if you wish to participate in the development of international standards for welding, contact Andrew Davis at AWS, 8669 NW 36 St., #130, Miami, FL 33166-6672; telephone (305) 443-9353, ext. 466; email: adavis@aws.org. Otherwise, contact your national standards body.

ISO/DIS 13585 — *Brazing — Qualification test of brazers and brazing operators*.

ISO/DIS 13919-2 — *Electron and laser-beam welded joints — Requirements and recommendations on quality levels for imperfections — Part 2: Aluminium, magnesium and their alloys and*

pure copper.

ISO/DIS 15614-12 — *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 12: Spot, seam and projection welding*.

ISO/DIS 15614-13 — *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 13: Upset (resistance butt) and flash welding*.

ISO/DIS 17779 — *Brazing — Specification and qualification of brazing procedures for metallic materials*.

New Standards Approved by ANSI

D18.1/D18.1M:2020, *Specification for Welding of Austenitic Stainless Steel Tube and Pipe Systems in Sanitary (Hygienic) Applications*. Approval Date: 3/5/2020.

D18.2/D18.2M:2020, *Guide to Weld Discoloration Levels on Inside of Austenitic Stainless Steel Tube*. Approval Date: 3/5/2020.

Revised Standard Approved by ANSI

A4.2M-2020 (ISO 8249-2018 MOD), *Standard Procedures for Calibrating Magnetic Instruments to Measure the Delta Ferrite Content of Austenitic and Duplex Ferritic-Austenitic Stainless Steel Weld Metal*. Approval Date: 2/27/2020.

Follow AWS on Social Media

Facebook: Find us at facebook.com/americanweldingsociety.

Instagram: Look at our photos [@americanweldingsociety](https://instagram.com/americanweldingsociety).

Twitter: Tweet us @AWSHQ.

YouTube: Watch our videos at youtube.com/awsorg.

MEMBERSHIP ACTIVITIES

New AWS Supporters

Educational Institution Members

Agencia de Examinacion en Tecnologia de Soldadura
Av. Saracho #1317
La Paz, El Alto
Bolivia

B&R Welder Repair Service Inc.
4412 Southern Business Park
White Plains, MD 20695

Chippewa Falls Senior High School
735 Terrill St.
Chippewa Falls, WI 54729

Crown School of Trades & Technology
2307 W. Beaver Creek Dr.
Powell, TN 37849

Hancock County School District — Board of Education
P.O. Box 629
Sneedville, TN 37869

Korean Register
36 Myeongji Ocean City 9-ro,
Gangseo District
Busan 46762 Republic of Korea

Lexington High School
8783 N. Highway 77
Lexington, TX 78947

Maryland Welding Technology Inc.
4341 Charles Crossing Dr.
Unit 4B
White Plains, MD 20695

Minnesota State Community and Technical College
900 Highway 34 E.
Detroit Lakes, MN 56501

Rocky Mountain College of Art and Design
1600 S. Pierce St.
Lakewood, CO 80214

Rogers High School
12801 86 Ave. E.
Phyllup, WA 98323

Rushville-Industry High School
740 Maple Ave.
Rushville, IL 62681

Tecnisoldar Construcción e Inspección SAS
Carrera 78 K. No. 40, 93 S. Torre 15
Apt. 302
Bogotá, Cundinamarca 110851
Colombia

TIVA Certified Welding and Testing
13421 Belscher Rd.
Springville, NY 14141

Treasure Coast Technical College
4680 28 Ct.
Vero Beach, FL 32967

Sustaining Members

Integrity Aero Service
14829 Bristol Park Blvd.
Edmond, OK 73013

NRTC Automation
4700 Pinson Valley Pkwy.
Birmingham, AL 35215

StrongBox, a Division of MUM Industries
2320 Meyers Ave.
Escondido, CA 92029

Affiliate Corporate Members

Avoiding Mediocrity
4071 N. Valentine, Unit 105
Fresno, CA 93722

Custom Fabricators & Repairs Inc.
1379 N. Harvey Mitchell Pkwy.
Bryan, TX 77803

E-Z Line Pipe Support Co. LLC
21340 Hwy. 6
Manvel, TX 77578

Gulf Coast Welding
20589 County Rd. 24
Foley, AL 36535

Heavy Metal Supply LLC
141 Spring Cove Dr.
Cary, NC 27511

High Rise Maintenance Systems Inc.
3313 May St.
Fort Worth, TX 76110

Murphy Engineering
5870 N. Country Rd. 500 E.
Bainbridge, IN 46105

NSC
Carr. 1 Km 98.4 Bo. Lapa
Salinas, PR 00751

Offshore Energy Services
5900 E. Hwy. 90
Broussard, LA 70517

Palmer Machine Works Inc.
P.O. Box 359
Amory, MS 38821

Paragon D & E Co.
5225 33 St. SE
Grand Rapids, MI 49512

Scott Metals Inc.
730 Superior St.
Carnegie, PA 15106

Worth Inspections LLC
1407 Nottingham Rd.
Raleigh, NC 27607

Supporting Company Members

Barton Consulting Services LLC
9249 S. Broadway #200-102
Highlands Ranch, CO 80129

USF Fabrication
2382 Rulon White Blvd.
Ogden, UT 84404

Welding Distributor Member

Grupo Brumich SA de CV
Ave. Lopez Mateos #290 Col. Lagrange
San Nicolas de los Garza 66490
Nuevo León, Mexico

2020 Membership Challenge

Listed here are the members participating in the 2020 Membership Challenge — point standings as of March 19. The campaign runs from Jan. 1 to Dec. 31, 2020. Members receive 5 points for each Individual Member and 1 point for every Student Member they recruit. For more information, please see page 65 of this *Welding Journal* or call the AWS Membership Dept. at (800) 443-9353, ext. 480.

A. D. Dillon, Detroit — 38
B. J. Cain, Los Angeles/Inland Empire — 34
J. P. Theberge, Boston — 31
J. C. Durbin, Tri-River — 30
D. P. Thompson, SW Virginia — 29
A. P. Duris, Northwest Ohio — 26
R. Young, Iowa — 24
T. Edwards, Tulsa — 20
H. J. Merrill II, Louisville — 20
W. H. Wilson, New Orleans — 17
B. A. Cheatham, Columbia — 17
O. Ortiz, Los Angeles/Inland Empire — 16
G. J. Smith, Lehigh Valley — 16
C. W. Gilbertson, Northern Plains — 14
V. O. Harthun, Northern Plains — 13
S. Silverstein, Milwaukee — 12

AWS Member Counts April 1, 2020

Sustaining.....	586
Supporting	363
Educational.....	842
Affiliate	615
Welding Distributor	64
Total Corporate	2470
Individual	57,149
Student + Transitional	10,819
Total Members.....	67,968

Nominate AWS Members to be Profiled

The *Welding Journal* is celebrating the diversity of its membership by profiling AWS members each month in its Society News section. Nicole Sulzer and Trevor Hofman are profiled on the following pages.

To nominate an AWS member, submit a short statement

about what makes the nominee a noteworthy member, along with the nominee's contact information, to Katie Pacheco, kpacheco@aws.org.

To see member profiles from previous issues, visit aws.org/about/page/diversity-inclusion.

AWS Member Profile



Nicole Sulzer

At the tender age of eight, when most kids are preoccupied with coloring and playing with toys, Nicole Sulzer was helping her dad complete repair projects around their cattle farm. As the fifth generation living on Sulzer Beef Farms, she describes welding as an inherent part of farm life in Wisconsin.

"I would go down to the shop where he worked on our farm and watch him fix the old Oliver tractors," she recalled. "I would help with stick [shielded metal arc welding] and TIG [gas tungsten arc welding] on the industrial tractors, and I'd do small projects."

Ready to weld with other students, Sulzer was met with disappointment the year she entered Monroe High School and learned it had suddenly retired its long-time welding program. She had been looking forward to enrolling in the welding program for years because her father completed it when he was a high-school student. According to Sulzer, the program allowed her father to sharpen his skills as well as compete at local welding competitions, where he received high marks. Although she continued to weld on the family farm, Sulzer regrets not being able to further develop her welding knowledge and abilities as a teenager.

"Back then, I wasn't the best be-

cause I wasn't able to weld at my high school. Only my dad had showed me how to weld," she said.

The unexpected change in plans didn't deter Sulzer from pursuing a welding education, and she is currently a freshman at Blackhawk Technical College (BTC), where she is working toward a technical diploma in welding. Thus far, the school has helped her hone her skills in flux cored arc welding (FCAW), gas metal arc welding (GMAW), and gas tungsten arc welding (GTAW). She is currently learning shielded metal arc welding.

"I really like TIG [GTAW]; my teacher said I have a real skill for it. And I like flux [FCAW] because I like plug welding, and you use a lot of it during plug welding and more industrial welding, like pipe; it's very versatile," she explained. "MIG [GMAW] is a pretty simple process; you can go anywhere and do stuff with it."

Sulzer's goal is to reach a high level of proficiency so that she may take part in local competitions and SkillsUSA.

However, what Sulzer values most about her school's welding program is the opportunity to be a part of the American Welding Society (AWS) BTC Student Chapter. She hopes to be its student leader in the future.

"Going into school and being new to the process of welding, they all came together and showed me so much. I've made a lifetime of friends," she said. "AWS is a great thing to join, and when new students come in, I tell them to join."

Through the student chapter, Sulzer gets to make welded art projects, which she loves doing. She is currently helping with the welding of a large metal hawk sculpture, nicknamed Hank the Hawk, which will sit outside the college's Milton, Wis., campus. The student chapter is also working on two outdoor lending libraries — one for a local library and one for the college.

Sulzer uses social media to show others the process involved with making pieces of welded art. Sharing the student chapter's work, as well as her own, with the world has helped her make friends and feel connected to the welding community. It has also connected her to some of welding's most popular social media influencers, like

Barbara Parsons, who goes by "Barbie the Welder," and Sean Flottmann, known as "Dabswellington" (to learn more about these metal artists, see page 32 of this issue).

"They're a great inspiration to me, especially Barbie. I got to meet her at FABTECH, and I chat with her on social media. I'm trying to get her to visit our school when we finish Hank," she said. "They've gotten me a lot more into welding and shown me the flexibility of welding."

As she continues to develop her skills, Sulzer is interested in venturing more deeply into the world of welded art. She has been making metal hearts using a process inspired by Dabswellington, and she is toying with the idea of taking apart older tractors and transforming them into metal sculptures.

"From making welded art to helping people, or just fixing an old tractor to keep it working, I like the possibilities of what you can make with welding and the endless possibilities of where it can take you," she affirmed.

Slated to graduate in 2021, Sulzer has various career plans. Although she enjoys working on the family farm, she also harbors the desire to branch out into something new, such as structural welding. Sulzer is interested in building homes, such as earth homes (i.e., a type of shelter that is built with the surrounding terrain or other natural elements for sustainable living). Referring to the recent tornado that hit Tennessee, Sulzer also wants to use her welding skills to aid communities impacted by natural disasters.

"I want to be able to do structural welding anywhere in the world to help people rebuild," she affirmed.

Additionally, Sulzer wants to have a positive influence on the next generation of welders. She hopes to one day launch an outreach program geared toward helping teens see the many opportunities in the welding industry. She also plans to continue her education after she graduates from BTC so that she may become a welding teacher.

"I want to give back to the youth. I want to teach them the skill, and teach them to get their anger out by beating up some metal," she said with a laugh. "I want to help give them a career and a good future."

AWS Member Profile



Trevor Hofman

For Trevor Hofman, welding is a family matter. He is the third generation to enlist in the family business, RoMan Mfg. Inc., a Michigan-based manufacturer of water-cooled, high-current, and low-voltage power sources. Born into a family where conversations centered on manufacturing, Hofman admits that thinking about how things are built came naturally to him.

"Growing up around engineering, it has a way of naturally rubbing off on you," he said. "As a kid, 'How It's Made' was the show we watched while eating dinner every night. I was always playing with LEGO, rebuilding go-karts, or making gadgets. This sparked a love in me for mechanics and creating machines to solve problems."

In high school, Hofman took as many technical classes as he could, including computer-aided design (CAD) and machining. He credits his high-school teacher, Lary Shoemaker, for encouraging him to take on a leadership role in the school's Electric Car team, where Hofman helped build the electric-powered vehicle that won the final race that year. These early experiences had a great influence on Hofman's future career choices.

"This solidified my love for engineering and led me to pursue mechanical engineering in specific," he recalled. "I began looking into the worlds of

manufacturing, automation, and electric vehicles, all of which interested me greatly."

As a 15 year old, Hofman also began working at the family business during the summers. He described feeling "enamored by the many manufacturing jobs and operations." He especially found the experience of working alongside his father, Kurt Hofman, and cousin, Chad Schondelmayer, as well as RoMan Mfg.'s president and CEO, Bob Roth, to be invaluable.

Two years later, Hofman began attending the company's stockholder meetings, which allowed him to learn about the business side of things. His interest in both the manufacturing and business aspects of RoMan Mfg. led him to pursue a bachelor's in mechanical engineering, coupled with two minors in economics and entrepreneurship, from Michigan State University (MSU), East Lansing, Mich.

"These classes provided me the lens to understand the in-depth conversations around me, realizing how important this industry is, not only from a technical perspective but a business perspective as well," he said. "This all led me to develop a deep passion for the inner workings of manufacturing industry."

While in college, Hofman decided to follow in his father and grandfather's footsteps by becoming a member of the American Welding Society (AWS) and attending local AWS Section events. Hofman's grandfather is an AWS Lifetime Member, serving as Director-at-Large and officer of the West Michigan Section. Becoming a member has helped Hofman learn more about the welding industry and be able to take part in meaningful conversations with other professionals.

"It gave me an opportunity to read the *Welding Journal* and discuss the welding industry and how it impacts the family business, RoMan, with both my father and Bob Roth," he explained. "Through these discussions, I have gained much understanding of what AWS is doing to keep the welding industry growing and contribute to the American manufacturing sector."

Additionally, Hofman continued to develop his engineering acumen at the family business, where he has worked

as an inventory database manager/failure analysis engineer as well as an assistant shipping supervisor/Auto-CAD engineer.

"Working at RoMan provided a great experience for me as a young engineer," he said. "As a CAD designer, I had the chance to analyze and get my hands on parts for a broad range of applications," he said. "This not only kept me from getting bored, but allowed me to get an idea of many aspects of the operation and the thought that goes into a part from start to finish."

Hofman has also worked as an engineering intern at Levitate Technologies Inc. in San Diego, Calif., where he inspected and repaired exoskeletons and conducted technical sales.

"Levitate is doing brilliant things, and it was an honor to work for a company that is providing relief and protection for workers," he said. "This showed me the value of working somewhere that is dedicated to the betterment of society, which became one of my most important career goals."

Set to graduate this year, Hofman plans to diversify his skill set by securing a job outside of RoMan Mfg., which has a policy requiring family members to work outside of the company for a few years. He views this rule as an opportunity to try something new. He is hoping to be involved with automation, electric vehicles, and exoskeletons.

"These industries are growing rapidly and seeing great technological leaps forward that make me really excited, and are something I want to be a part of," he said.

However, he doesn't plan to stray from the family business for too long.

"As of this time, my career goals are to be involved in manufacturing, and I hope someday to be in a leadership role at RoMan Manufacturing," he affirmed. "With these goals, I hope to give back to AWS, the manufacturing community, and better the world as a whole through manufacturing."

When he's not working, Hofman enjoys intramural sports at MSU and karate, in which he has a black belt. He is also part of a team, called The Cru, that works on artistic endeavors for clothing, graphic designs, and virtual reality applications.

District 1

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BOSTON March 10

Location: Steel Fab Inc., Fitchburg, Mass.
Presenter: Scott Houle, manufacturing superintendent, Steel Fab
Summary: Houle gave members of the Boston and Central Mass & Rhode Island Sections a tour of the Steel Fab manufacturing facility. The company fabricates operating systems for water control gates and fixed cone valves. The processes used include heavy plate fabrication, submerged arc, flux core gas metal arc welding, and gas tungsten arc welding and they work with carbon, low alloy, high nickel, and stainless steel. The company was presented with a Section appreciation plaque and the members enjoyed food and refreshments after the completion of the tour.

District 2

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District 3

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District 4

Mr. Lynn Showalter, director
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lynneshowalter@gmail.com

District 5

Howard Record, director
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ATLANTA March 1

Location: Winder, Ga.
Summary: Lanier Technical College Winder Campus student Rachel Lee won a student membership in a meeting raffle. When she found out the Section needed a replacement for a student liason she stepped up to fill the role. Lee will now handle the Section's publicity and social media, and work with the local Student Chapter. Lee's instructors Tim Rieger and David Ennis recommended her for the role.

CENTRAL FLORIDA-ORLANDO February 20

Location: Valencia College, Kissimmee, Fla.
Presenter: Rick Harrell, sales manager, Lincoln Electric
Summary: Harrell gave a presentation on the applications and benefits of surface tension transfer (STT) technology on open root pipe and plate applications. Following the presentation, there was a technical demonstration where all attendees were able to use the system themselves. In addition to the presentation, five student memberships were awarded to students who attended the meeting.



ATLANTA — Welding Instructor Tom Rieger (left) and Section Chair René Engeron (right) posed with new Student Liason Rachel Lee. Not shown is Instructor David Ennis.



BOSTON — Members of the Boston and Central Massachusetts/Rhode Island Sections toured Steel Fab Inc.



CENTRAL FLORIDA-ORLANDO — Members gathered for a group photo during their February meeting.



CENTRAL FLORIDA-ORLANDO — Student members tried surface tension transfer technology on open root pipe.



FLORIDA WEST COAST — Brad Wickline (left) accepted the District 5 Educator Award on behalf of Brian Logaglio, from District Director Howard Record.



FLORIDA WEST COAST — District Director Howard Record (right) presented the District 5 CWI of the Year Award to Bill Stoltz.

FLORIDA WEST COAST March 6

Location: Frontier Steak House
Summary: District Director Howard Record presented the District 5 Educator Award to Brian Logaglio from Marchman Technical College, the District 5 CWI of the Year Award to Bill Stoltz from Pierce Mfg., and the District 5 Private Sector Instructor Award to Daryl Peterson from Central Maintenance and Welding. After the award presentations, members were treated to a talk by Floyd Kiel from Midalloy on the differences between a filler



FLORIDA WEST COAST — Guest Speaker Floyd Kiel (left) with Section Chair Daryl Peterson.



FLORIDA WEST COAST — Daryl Peterson (right) received the District 5 Private Sector Instructor Award from District Director Howard Record.

metal Material Test Report and a Certificate of Compliance, and when either are appropriate or acceptable. Certified Welding Inspectors in attendance were issued forms to help claim professional development hours toward their nine-year recertification.

District 6

Ronald Stahura, director

(716) 207-7869

rstahura@esab.com

NORTHERN NEW YORK March 10

Location: Niskayuna, N.Y.
Summary: Section members toured Unilux Advanced Mfg. LLC. The company manufactures commercial-grade bent water tube and fire tube boilers, storage tanks, hot water tanks, and high-temperature hot water units. Much of their product is used in schools, hospitals, manufacturing facilities, breweries, and agricultural growing facilities. David Freedom, operation manager, and his engineering team joined members as they walked through the manufacturing steps. Kamyar Pashayi, quality control engineer, explained the stringent ASME codes they follow. Kyle Kremzier, boiler design engineer, shared a video of the company's products. Raymond Martin, draftsman and equipment engineer, demonstrated plasma table capabilities and rolling of large plate material. Jeetindra Dattarain, lead welder, has been with Unilux for more than 14 years and he and Section Member Doug Tanner spent much of their time discussing and inspecting many different weld details. It was an informative visit in an impec-



NORTHERN NEW YORK — Unilux Mfg. staff is seen with Section tour attendees.

cably clean manufacturing facility. The company has invited the Section and its students to go back for a hands-on day.

District 7

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COLUMBUS

March 12

Location: Crowne Plaza Columbus North, Columbus, Ohio

Presenters: Kristen Hammer, business development manager, Virgin Hyperloop One; and Thea Walsh, director, Mid Ohio Regional Planning Commission

Summary: Walsh did a presentation on the economics of the Virgin Hyperloop One (VHO) and Hammer did a virtual presentation on the technical aspects of it. Virgin Hyperloop One is one of several companies around the world working to commercialize hyperloop technology and change the way that we live and travel. The VHO

system uses magnetically levitated pods to move people or cargo through a low-pressure tube at more than 600 mph – think about getting from Columbus to Chicago in just 41 min. Pods move you directly to your destination, without stopping at other locations along the way. The system is autonomously controlled and entirely electric, with zero direct emissions. The company built the world's first full-system hyperloop test track at its Las Vegas Test Site in 2017, and have since performed over 400 tests of the system. Now, the team is focused on safety certification and obtaining approval to operate hyperloop systems around the country and around the world. The presentation highlighted some of the technical and materials challenges with this new technology, as well as the outlook for building a hyperloop route in the state of Ohio. A question and answer session followed the presentation.

JOHNSTOWN/ALTOONA

February 26

Location: Johnstown, Pa.

Presenters: Austin Wolfe, technical

sales representative; and David McMahn, district manager, The Lincoln Electric Co.

Summary: Wolfe and McMahn presented on submerged arc welding and welding fumes. Members learned what a welding fume is, about understanding the various properties of welding fume for different processes, and how to safely work in a welding fume environment. Additionally, they learned about the submerged arc welding process, its history, and examples of its uses and applications in the field.



COLUMBUS — Section Chair Tom Eckardt (left) presented a speakers gift to Thea Walsh.



JOHNSTOWN/ALTOONA — Members are pictured following their February meeting.



CHATTANOOGA — Winners of the Annual Student Welding Competition included (from left) Nathaniel Clanton, Cameron Banks, Lane Hutcheson, Garrett Griffen, Cade Cox, Jackson Davis, Payton Ervin, and Joey Morrison.

District 8

James Thompson, director

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CHATTANOOGA

February 29

Location: Sequoyah High School, Soddy-Daisy, Tenn.

Summary: More than 60 students participated in the 11th Annual Student Welding Competition. Winners included: 6 G Category — Nathaniel Clanton, 1st place; Cameron Banks, 2nd place; and Lane Hutcheson, 3rd place. In the 4G category, the winners were Cade Cox, 1st place; Garrett Griffen, 2nd place; and Skyler Bunch, 3rd place. In the 3G category the winners were Jackson Davis, 1st place; Payton Ervin, 2nd place; and Joey Morrison, 3rd place.

NASHVILLE

December 20

Location: Lincoln Tech, Nashville, Tenn.

Summary: Curtis Duncan presented a

\$750 Section Scholarship Award to Wes Biggs, a welding student at Lincoln Tech.

February 19

Location: Holston Gases, Nashville, Tenn.

Presenters: Grant Sartain, Nashville branch manager; and Kyle Robertson, Clarksville branch manager, Holston Gases.

Summary: Section members met at Holston Gases for their February



NASHVILLE — Section Chair Curtis Duncan (left) is seen with Tommy Curtis, program director, Lincoln Tech, and Bob Butterworth, president, Lincoln Tech.

meeting. The facility overlooks the foothills of west Nashville and the John C. Tune Airport. After a wonderful barbecue meal provided by the company, Section Chair Curtis Duncan bought the meeting to order. Once Section business concluded, Sartain gave a brief company history followed by a tour of its new state-of-the-art facility. Afterward, members enjoyed shopping on the company's sales floor. The Section is grateful to Sartain, Robertson, and Holston Gases for a great meeting and their hospitality.

District 9

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AUBURN-OPELIKA

February 25

Location: Auburn University, Auburn, Ala.

Presenter: Chris Stiver, Lincoln Electric Co.

Summary: Stiver gave members an



NASHVILLE — February meeting attendees are seen at the Holston Gases facility tour.



AUBURN-OPELIKA — Students viewed a welding demonstration at Auburn University.

SECTION NEWS

overview of the HyperFill twin-wire gas metal arc solution, which was developed to revolutionize heavy fabrication productivity. After the presentation, the equipment was shown and Central Alabama Community College's DJ James showed students how to weld using the equipment.

BATON ROUGE February 20

Location: Emerson, Gonzales, La.
Presenters: Jeremy Whittemore, NDE Level 2 technician, welder, quality assurance/quality control; and Blake Coburn, regional manager, Emerson



AUBURN-OPELIKA — Students viewed several welding demonstrations while visiting Auburn University.



BATON ROUGE — Jeremy Whittemore gives a bore welder explanation.

Summary: Whittemore, with the assistance of Coburn, gave a presentation titled "Addressing Industry Needs Locally and Globally." Following the presentation, there was a brief question and answer session, and an in-depth shop tour where members were able to see the entire process of what takes place at Emerson. The Gonzales location performs valve repairs, refurbishments, and more. Fisher valve bodies and assemblies are brought back to original equipment manufacturer specs at this location for local and global customers.

MOBILE February 13

Location: The Blacksmith Experience, Daphne, Ala.

Summary: Section Chair Jody Heusman opened the meeting by welcoming everyone and provided a brief update on Section news. The Cutting Board catered an excellent dinner for everyone. Small's Smokehouse catered food for all in attendance. Jerry Gardner, owner/instructor of The Blacksmith Experience, gave a brief introduction on how he became a blacksmith. He then gave a brief forging

demonstration with all his industrial blacksmithing tools, including his forge, power hammer, and hydraulic press. In support of the meeting, Gardner invited four additional local blacksmiths to attend and share their diverse experiences and talents with regards to blacksmithing. At the end of the meeting, he turned on all three of his forges and offered anyone interested an opportunity to try blacksmithing. Four attendees elected to participate and each formed a coat hook from square stock material.



MOBILE — Section Chair Jody Heusman (right) presented a speaker appreciation plaque to Jerry Gardner.



MOBILE — Blacksmith instructors are seen with Section Chair Jody Huesman (far right).



BATON ROUGE — February meeting attendees gathered for a group photo.

Gardner was presented with a speaker plaque in appreciation from the Section. Each of the four instructors invited received a pair of kevlar gloves in appreciation for them sharing their blacksmithing knowledge with the group. As this was also Instructors' Night, local welding instructors were recognized for their dedicated work. The Section wants to express a sincere thanks to both Gardner for providing a wonderful opportunity and to ESAB for sponsoring the meeting. Total attendance for the meeting was 62. All in attendance were included in drawings for door prizes.

District 10

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CLEVELAND

February 11

Location: Toscana Party Center, Cleveland, Ohio

Presenter: Mike Barrett, welding engineer, Lincoln Electric

Summary: Barrett discussed advances in stainless steel pipe welds without



CLEVELAND — Guest Speaker Mike Barrett compared welds made with and without the use of backing gas.

the use of backing gas, using different shielding gases for welding stainless steel using modified short arc processes, and pulsed gas metal arc welding. Additionally, the performance of gas metal arc welds made without backing gas were compared to welds made using conventional gas tungsten arc welding processes.

District 11

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DETROIT

March 12

Location: Yaskawa America Inc., Rochester Hills, Mich.

Presenter: Josh Leath, welding robotics project manager, Yaskawa America

Summary: The Section held a technical meeting/Patrons and Old Timer's Appreciation Night at Yaskawa America Inc., Motoman Robotics Division. The host for the event was Anthony Pawlak, general manager of the Great Lakes Region, Yaskawa. Leath presented the latest company tools for en-

hancing welding and analysis with sensor usage, collaborative technology, and data acquisition. His presentation focused on how Industry 4.0 initiatives can enable new practices within the welding industry. The Section also took time to celebrate its Old Timers and Patrons, as well as acknowledge individuals who have long served the Detroit Section and American Welding Society. This year, three members received their AWS 25-Year Silver Member Award. The 22 companies and individuals that make up the Section Patrons were very generous, with dona-



DETROIT — Section Events Chair Eric Lichtfusz (right) is seen with Guest Speaker Josh Leath (left) and Host Anthony Pawlak.



DETROIT — Pictured are the Detroit Section Patrons who generously donated to fund scholarships in the Section and surrounding areas.



CLEVELAND — Section student board members presented the Section Instructor Award to Johnny Napier (center with plaque), welding instructor at Polaris Career Center.

tions exceeding \$10,000. All donations to the Detroit Section Patrons Fund are used solely to fund scholarship activities in the section and surrounding area.



DETROIT — Mike Palko (left) congratulated Old Timers Andre Young, John Pippen Jr., and Mitch Yench.



LAKESHORE — Section Past Chair Adam Witcpalek (right) thanked Tim Steffek from D&S Machine Services.



LAKESHORE — Section Chair Andy Miller (left) thanked Guest Speaker Jeff Somenske.

District 12

Dale Lange, director

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LAKESHORE

January 16

Location: D&S Machine Service Inc., Luxemburg, Wis.

Summary: Section members toured D&S Machine Service, a full-service manufacturer of metal products for welding, machining, burning, and painting. Led by Welding Supervisor Tim Steffek, the tour included a question and answer session. A post-tour dinner was held at Rendezvous Supper Club.

February 13

Location: Suster's Arcade, Denmark, Wis.

Summary: The Section's February meeting was a technical presentation and demonstration of the MetraSCAN 3D laser scanning inspection equipment. Jeff Somenske, account manager, Creaform USA Inc., showcased how the handheld optical scanning system is capable of measurement accuracy up to .0034 in., in parts up to 20 ft in

size. A pre-event dinner was provided by Suster's Arcade.

RACINE-KENOSHA

February 14

Location: Gateway Technical College, Racine, Wis.

Summary: Section Chair Dan Crifase assisted with the Regional High School SkillsUSA Welding Competition hosted by Gateway Technical College. The winners were Evan Bjorge, 1st place; Ethan Schaffer, 2nd place; and Gage Wilson, 3rd place. All three attend Waterford High School.

District 13

Ronald Ashelford, director

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CHICAGO

February 24

Location: Cooper's Hawk Winery & Restaurant, Burr Ridge, Ill.

Summary: Members enjoyed a Section Valentine's Day celebration. Attendees spent time together while enjoying a savory meal.



CHICAGO — Enjoying the Section's Valentine's Day Celebration were (from left) John and Cathy Hesseltine, Kim and Craig Tichelar, and Anghelina and Cliff Iftime.



RACINE-KENOSHA — Welding Instructor Kyle Worzalla (left) and Section Chair Dan Crifase (second from left) are seen with Regional High School SkillsUSA winners (from left) Evan Bjorge, Ethan Schaffer, and Gage Wilson as well as Lincoln Electric's Luke Scheenberg.

District 14

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ST. LOUIS February 20

Location: Red Bud, Ill.
Summary: Section members toured Red Bud Industries, a manufacturer and supplier of coil processing equipment. Led by Brandon Sachtleben, the tour included an overview of the company's 200,000 sq ft facility and the history of how the company went from a small tool and die machine shop to where it is today. Sachtleben also discussed how the engineers who design the equipment are located in the shop and when there is a design issue they are brought to the floor to help determine the fix. The company designs and builds all its own equipment.

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District 17

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District 18

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CORPUS CHRISTI January 10

Location: Corpus Christi, Tex.
Summary: District 18 Director Tom Holt presented two first-place welding competition scholarships during the Nueces County Junior Livestock show.



CORPUS CHRISTI — District 18 Director Tom Holt (left) and Section Chair Ellery Francisco (second from left) are seen with winner Alvin Tagal and Matt Richard.



ST. LOUIS — Section members thanked Red Bud Industries' Brandon Sachtleben (with plaque) for leading them on a facility tour.



ST. LOUIS — Tour guide Brandon Sachtleben explained to members how all of Red Bud Industries products are built in-house.

SECTION NEWS

Alvin Tagal from A. C. Jones High School placed first in the D1.1 3G Plate Contest and Arturo Hernandez from Tuloso-Midway High School placed first in the ASME Section IX Pipe Contest.

HOUSTON February 19

Location: Greer & Lowdermilk Conference Center, Houston, Tex.

Presenter: Dan Jones, COO, Industrial Welding Academy, and manager, Dynamic Industries

Summary: The Section had a combination of more than 300 students and industry members attend its annual Student Night. Jones presented on the essential variables for welding students, which included welder etiquette, information on qualification testing, and an explanation of slang terms common in the industry. A raffle followed the presentation and prizes included welding hoods and other supplies donated by industry sponsors.

District 19

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ALASKA



HOUSTON — Section Chair John Chen (left) thanked Guest Speaker Dan Jones.

FEBRUARY 25

Location: Seward, Alaska

Summary: Section Chair Dennis Long visited the Alaska Vocational Technical Center (AVTEC) welding program students. Long gave an overview of AWS student membership, scholarships, and AWS.org website resources.

BRITISH COLUMBIA



ALASKA — AVTEC's Pipe Welding Instructor Roger Hohl (left) is seen with Dennis Estes (right) and Department Head Bobby Dunno.



CORPUS CHRISTI — Pictured are (from left) Matt Richard, District 18 Director Tom Holt, Section Chair Ellery Francisco, Kyle Villalon, winner Arturo Hernandez, and Jesse Ramirez.



HOUSTON — It was a packed house during the Section's Annual Student Night.

December 13

Location: Fraser Downs Racetrack, Surrey, British Columbia
Summary: Members participated in Sponsors' Night at the Races. Attendees enjoyed dinner at the racetrack.

January 22

Location: UA Piping Industry College (UAPIC) Delta, British Columbia
Summary: The January meeting consisted of a catered dinner at UAPIC, followed by a presentation by Joe Goodings of Applus+RTD entitled "Ultrasonic Testing."

February 19

Location: Silver City Galvanizing, Delta, British Columbia
Summary: Members were treated to pizza and a plant tour of Silver City Galvanizing hosted by General Manager and Owner Jeff Boychuk.



BRITISH COLUMBIA — Members enjoyed dinner at the Fraser Downs Racetrack. Pictured are (from left) Joe Calla, Al Sumal, Kyle Bramhoff, Steve Curr, Section Chair Bernard Booth, and Danielle and Tom Foote.

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BRITISH COLUMBIA — Section Chair Bernard Booth (right) thanked Guest Speaker Joe Goodings.



BRITISH COLUMBIA — Section Chair Bernard Booth (right) presented a speaker gift to Jeff Boychuk.



ALASKA — Structural Welding Students are pictured with AVTEC Structural Welding Instructor Robert Frasher.

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MEMBERSHIP



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Renewing Member

☐ 1 Year - Digital *Welding Journal* \$88 ☐ 2 Year - Digital *Welding Journal* \$163
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NEWS OF THE INDUSTRY

— continued from page 13

“Construction makes up an impressive 13 percent of the employment in our region and the projected demand for skilled craft professionals is up in our area,” said David Helveston, president and CEO of the Pelican Chapter of the Associated Builders and Contractors. “ABC Pelican proudly prepares craft students like these 156 graduates with both book knowledge and hands-on experience to ensure the workforce meets the demand of our industry.”

Applications Sought for Harbor Freight Tools for Schools Contest Offering \$1 Million in Prizes

At hftforschoolsprize.org, applications are due on May 13 for the 2020 Harbor Freight Tools for Schools Prize for Teaching Excellence. The endeavor will award cash prizes totaling \$1 million to 18 of America's best public high school skilled trades teachers or teacher teams and their programs.

“At a challenging time for all Americans as we work to prevent further spread of COVID-19, and especially for educators as they try to keep students learning online or remotely, teachers deserve our thanks and an extra-bright spotlight for their contribution to students, communities, and to our country,” said Danny Corwin, executive director of Harbor Freight Tools for Schools.

Three grand prize winners and 15 additional prize winners will be announced in October.

COMING EVENTS

— continued from page 45

will be held at the Houston Marriott North in Houston, Tex.; and part C provides in-depth training to the welding code portion of the exam. Contact Jeff LeTourneau, instructor@trainingndt.com, (855) 313-0325, or visit trainingndt.com.

E-Courses in Destructive and Nondestructive Testing of Welds and Other Welding-Related Topics. Online video courses taken at one's own pace offer certificates of completion and continuing education units. Contact Hobart Institute of Welding Technology; (800) 332-9448; welding.org/product-category/online-courses/.

ESAB Welding and Cutting Instructor-Led Training. Year-round training at Denton, Tex.; West Lebanon, N.H.; Traverse City, Mich.; Hanover, Pa.; and Salt Lake City, Utah. Online e-Learning training is available. Email trainingteam@esab.com or visit training.victortechologies.com.

Gas Tungsten Arc Welding Aerospace Course. Hobart Institute of Welding Technology, Troy, Ohio. This 70-h course will develop the skills necessary for entrance into the aerospace industry, including working with typical materials, weld joint configurations, and tools involved in production and testing within aerospace manufacturing and repair. For information, contact (937) 332-9500 or visit welding.org.

Industry Notes

• The **Federal Emergency Management Agency** released an update late last year to its Recovery Interim Policy FP-104-009-11, Consensus-Based Codes, Specifications and Standards for Public Assistance (Policy), Version 2.1, adding several International Codes developed by the International Code Council to the list of required Consensus-Based Codes, Specifications and Standards. The policy's updates will require, for the first time, construction adhere to the latest International Wildland Urban Interface Code; the International Mechanical Code and International Fuel Gas Code; and the International Plumbing Code. Visit fema.gov/media-library/assets/documents/184615.

• While the construction industry navigates these uncertain times, the **ALL Family of Companies**, one of the largest privately held crane rental and sales enterprise in North America, will continue to support essential business activities/provide customer service. It has asked teams to work with users through digital platforms, postpone nonessential in-person meetings, and follow health/safety best practices. Also, it's adapting to support the needs of businesses in each of its communities and will remain open to all essential business activities not subject to the Stay at Home order in that state/province.

• **Touchplan**, Boston, Mass., a construction management and collaboration technology provider, recently revealed its global expansion into Canada. After seeing success on more than 1200 jobs in the United States, this expansion is a next step toward meeting the international demand for digitized construction collaboration and planning tools. **WJ**

Hypertherm Cutting Institute Online. Includes video tutorials, interactive e-Learning courses, discussion forums, webinars, and blogs. Visit hypertherm.com; hyperthermcuttinginstitute.com.

Industrial Laser Training. Technical training and support offered for users of industrial lasers in manufacturing, education, and research. Regularly scheduled classes in laser welding, laser cutting, and drilling. HDE Technologies Inc.; (916) 714-4944; laserweldtraining.com.

Laser Safety Training Courses. Laser training courses for personnel in research, industrial, and medical laser facilities. Courses based on ANSI Z136.1, *Safe Use of Lasers*. Orlando, Fla., or customer's site. Laser Institute of America; (800) 345-2737; lia.org.

Laser Vision Training Seminars. Two-day classes, offered monthly and on request, include tutorials and practical training. Presented at Servo-Robot Inc., St. Bruno, QC, Canada. For schedule, cost, and availability, email info@servorobot.com.

Machine Safeguarding Seminar. Rockford, Ill. Two-and-a-half-day seminar teaches how to properly safeguard machinery for OSHA/ANSI standards. Also included will be discussion of the upcoming release of ANSI B11.0-2020 and ANSI B11.19-2019 standards. Go to rockfordsystems.com/seminar. **WJ**

Phillips Screw Promotes CEO



S. Filion

Scott Filion has been appointed CEO of The Phillips Screw Co., Wakefield, Mass., a supplier of fasteners and licensed technologies for the construction, automotive, and aerospace industries. He succeeds Ken Hurley, who has transitioned to chairman of the board of directors. Filion started with the company in February 2019 as president. He brings more than 30 years of industry experience, including a background in developing and marketing industrial and consumer products. He started his career in engineering, where he developed products and processes for the automotive industry. He currently holds 22 patents. Prior to joining Phillips, Filion spent more than 20 years with Velcro USA Inc., most recently serving as president.

MEC Announces Chief Operating Officer



R. Stille

Mayville Engineering Co. (MEC), Mayville, Wis., a manufacturer that provides a range of prototyping and tooling, production fabrication, coating, and assembly, has promoted Rand Stille to chief operating officer. Stille joined the company in April 2019 as vice president of performance structures operations. He was then promoted to executive vice president of DMP & performance structures operations, where he was responsible for eight MEC facilities across four states. Prior, he served as senior vice president of operations at Universal Logistics Holdings from 2017 to 2019, where he ran interna-

tional operations in Bogota, Colombia, and San Luis Potosi, Mexico, as well as overseeing its Westport Axle Corp. entities in Virginia, Kentucky, and Pennsylvania. He also served as vice president and executive director of Westport Axle from 2014 to 2017 and as vice president of Mexican operations from 2012 to 2014. From 2011 to 2012, he served as COO of JayTec LLC at L&W Engineering. Earlier in his career, from 2004 to 2011, Stille held executive roles at Shape Corp., including vice president of Mexican operations, vice president of Asian operations, and vice president of Shape's General Motors Business Unit. From 1994 to 2003, he held various managerial roles at Johnson Controls.

HGG Profiling Equipment Adds Customer Account Manager



M. Cooper

HGG Profiling Equipment, Medina, Ohio, a subsidiary of HGG, a global supplier of pipe cutting machines, robotic profile cutting lines, and cutting equipment solutions, has hired Michelle Cooper as customer account manager for the Americas. She will support the company's U.S. regional managers with quotations, purchase order processing, and invoicing. She will also support its customers with inventory management, spare parts acquisition, and will be another liaison for customers to the company's headquarters in Holland.

Guardair Appoints Leadership Positions

Guardair Corp., Chicopee, Mass., a manufacturer of safety air guns and pneumatic vacuums, has hired Scott Burkins as senior director of operations. Burkins brings 35 years of experience in the industrial maintenance, repair, and operations space. Most recently, he was the director of operations and engineering for Lenox, Stan-



S. Burkins



T. Ferraro

ley Black & Decker. He will oversee all manufacturing operations, including optimizing production through strategic planning, continuous process improvement, high quality control, and safety procedures.

Additionally, the company has promoted Thomas Ferraro as marketing manager. Ferraro joined the company in October 2017 with a background in marketing technology and digital advertising. Since that time, he has held the position of digital marketing specialist and has been instrumental in the company's online success. In his new role, he will develop and manage strategic marketing programs, and optimize omnichannel opportunities in parallel with continuous company growth.

Obituaries

Michael "Mike" Ludwig

American Welding Society (AWS) Staff Member and Welding Engineer Michael "Mike" Ludwig passed away on March 16, 2020. Ludwig initially intended to study law, but ultimately graduated with a degree in welding engineering from Millikin University in Decatur, Ill. Throughout his life, he approached his work strategically and mindfully.

Over the course of his 35-year engineering career, he worked at Fronius USA, Cianbro, Bath Iron Works, and Newport News Shipbuilding in the areas of quality engineering, welding engineering, sales, marketing, business development, project management, R&D, and direct supervisory management.

In April 2019, he moved from Maine to Miami to serve as a staff welding engineer at AWS. He was re-



M. Ludwig

sponsible for responding to member and customer technical inquiries. He also served as an internal technical subject matter expert to the company's business units; established technical liaisons with other organizations; and supported

new product development, project management, and other work within the Society. His connection with AWS started in 1976 when he first became an AWS member. In 1999, he became a contributing technical volunteer member and served on various AWS technical committees over the past two decades. He will be posthumously honored as an AWS Life Member.

Additionally, Ludwig was active on ASME technical committees, the Navy Joining Center steering committee, and the National Shipbuilding Research Program Welding Technical Panel. He published articles and gave presentations on gas metal arc welding, hybrid laser arc welding, portable weld inspection management systems, aluminum welding, cladding, digitization of welding data, and double-sided arc welding processes.

He enjoyed working with school vocational programs, community outreach programs, judging science fairs, and coaching track and field as a USTAF certified coach. He also coached basketball and football, and was involved with Special Olympics events. Ludwig is survived by his wife, Debbie, two sons, mother-in-law, and numerous family members and friends.

Daniel John Roland



D. J. Roland

Daniel John Roland passed away on Feb. 21, 2020. He was 49. Born in Norfolk, Va., Roland had a love of music, the outdoors, and welding. He was a welding instructor at Northwest Technical School. He joined the

American Welding Society (AWS) in 1996. He became an AWS Certified Welding Inspector and a Certified Welding Supervisor in 2009. He was also an AWS District Director. He is survived by his wife, Michelle, daughter, grandson, brother, and nieces. **WJ**



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Job Shop Manufacturers Benefit from 5-Axis Laser Cutting

Explore the array of advantages this process provides

BY PIERSON CHENG

With its inherent accuracy and recent developments on fast cutting speed, short cycle time, and lower running cost, 3D laser-cutting technology has been proven as a viable solution in high-volume production. For example, this is the case in cutting ultra-high strength steel, where the top priorities are repetition, continuity, and low cost per part.

Job shop manufacturers are an important segment of the U.S. industry, and can be defined by uncertainty and uniqueness. They deal with small batch sizes of a large variety of custom products, not high volume and standardization. Because economies of scale are usually not a part of a job shop's competitive edge, other than on price per part, they usually compete on quality and lead time.

3D laser-cutting technology has also found use in this segment due to its lower initial investment, development in software capabilities, and smart functions to produce parts at a high quality and short turnaround time. This meets challenges for job shop manufacturers and is the focus of this article, with an emphasis on 5-axis laser cutting.

Secondary Processing of Metal-Forming Parts at Job Shops

Forming is a common manufacturing process in today's metal fabrication world. The most well-known forming technologies include hot stamping, deep-draw stamping, hydro-forming, metal spinning, and tube bending. At its core, forming is a



High-quality laser cutting results from the optimal combination of a series of cutting parameters, including laser power, focus, speed, gas pressure, and piercing strategy.

method of turning raw materials into 3D shapes. Before final assembly, however, it's usually required to cut out holes and trim flanges on the 3D parts. Given the complexity of the metal-forming process, sometimes it's difficult, if not impossible, to incorporate these functions into the forming process. As a result, secondary processing of the metal formed parts is often required. For job shops, given the nature of low volume and high variety, this process is usually done by a traditional process, which often involves custom dies/punches or band saws. A typical process is shown in Fig. 1.

This process requires skilled work-

ers and is labor intensive because high quality and process repeatability are hard to achieve. More importantly, the design, build, and inventory of custom fixtures and dies; high rate of scrap parts; and multiple steps increase fabrication time and costs.

5-Axis Laser Cutting: Streamlined Process with Transparent Cost

While it is often easy to bid on jobs the shop has manufactured before, new jobs require accurate costs of labor, materials, and equipment, as well as accurate assigning of overhead.

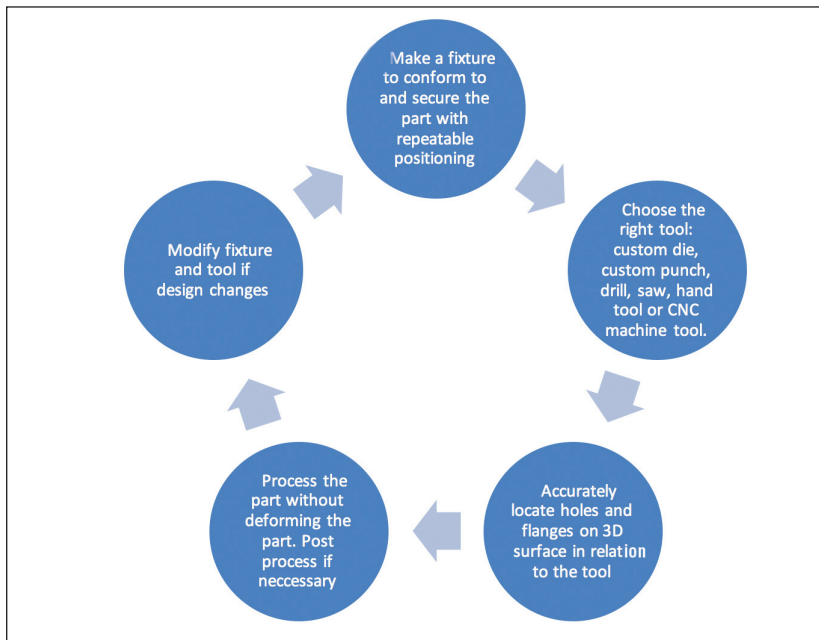


Fig. 1 — Traditional process for secondary processing of metal-forming parts.

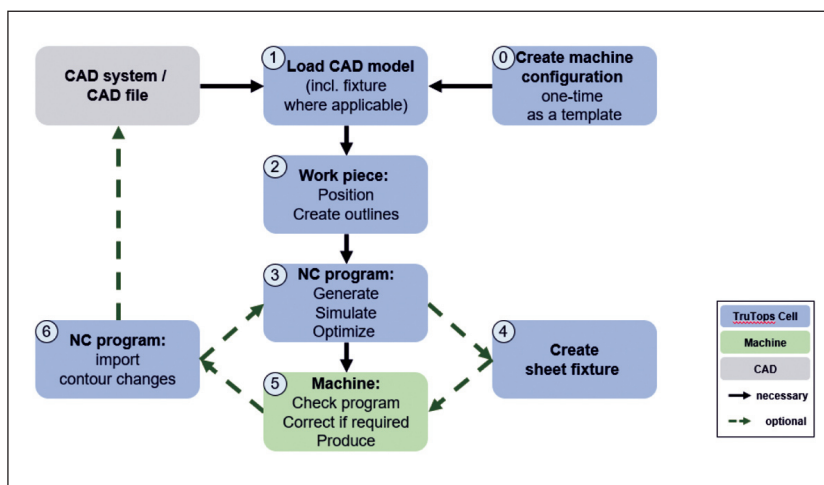


Fig. 2 — 5-axis laser-cutting procedures with aid from offline programming software. (NC stands for numerically controlled. CAD is computer-aided design.)

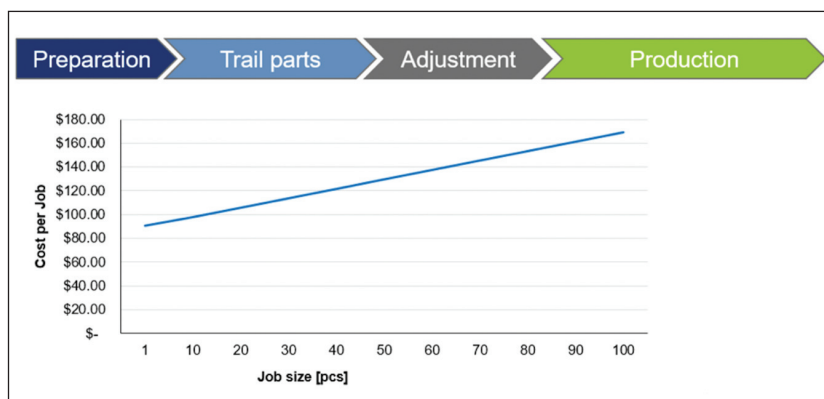


Fig. 3 — Cost per job vs. job size with the TruLaser Cell 5030 (based on certain conditions and constraints).

With 5-axis laser cutting, this becomes a streamlined manufacturing process with fewer manufacturing steps and manual labor involved. Such streamlined processes make it possible to have an accurate grasp on cost. A typical 3D laser-cutting process is shown in Fig. 2.

When bidding for a job, shop manufacturers usually quote their customers based on their cost per job. Typically, the preparation time, trial parts, adjustment, and production costs are taken into consideration.

With 3D laser cutting, it is relatively straightforward to calculate the cost given the streamlined process. Figure 3 shows the cost per job vs. job size for a TRUMPF TruLaser Cell 5030 5-axis cutting machine with a 3-kW laser source.

Offline Programming Software

Job shops constantly work on getting existing orders done and bidding for new ones, a balance that requires the utmost lead time efficiency to stay competitive. With some of today's offline programming software, job shops can generate numerically controlled programs for 3D parts, design a sheet metal fixture, perform cutting simulations with interference checks, and optimize cutting parameters in as little as a half hour. Such activities used to take hours, if not days.

The TruTops Cell, also from the company, is an offline programming system for 3D machining and the interface between the computer-aided design system and multiaxis laser machine — Fig. 4. The process-reliable, numerically controlled program is generated offline while the machine is in production.

Compatibility is important so that offline programming software not only knows the correct tool path, but also the technology and machine-unique features to access extensive process rules. Also important to fabricators is the capability to make a simple and low-cost fixture. When generating the fixture, the offline programming system uses the cutting path, defined in X and Y directions, to generate the entire 3D fixture and the 2D unfolding for the supports. These fixture plates can be cut on the same machine, or the fixture parts can be exported as drawing eXchange format files to cut with a TruTops 2D laser.

Smart Functions for Quick Setup, Adjustment

Prototype and low-volume manufacturers are facing the challenge of constant parts changeover every day, so quick setup and adjustment are the keys for success.

Many of the smart functions have been transferred from the TruLaser Cell series to

the newly designed 5030 machine to reduce setup time. Also, to verify the machine is in ideal condition before cutting, operators can benefit from the ObserveLine Professional function. This verifies optical alignment within a few seconds. But should misalignment be detected, operators can use the Smart Optics Setup. This swivel device, mounted on the machine body, allows automatic optics orientation.

Visualize the Fine Tuning

If an operator has already performed a simulation on the software, even the first cutting of the part will likely proceed without problems. However, if fine tuning is needed, sequences can be edited on-the-fly in a visualized way. TruTops Cell Basic, an online tool that allows operators to make quick adjustments, such as moving contours, changing points/diameters, and inserting micro joints with a few mouse clicks, is visualized with the process path and cutting head shown on the machine control panel.

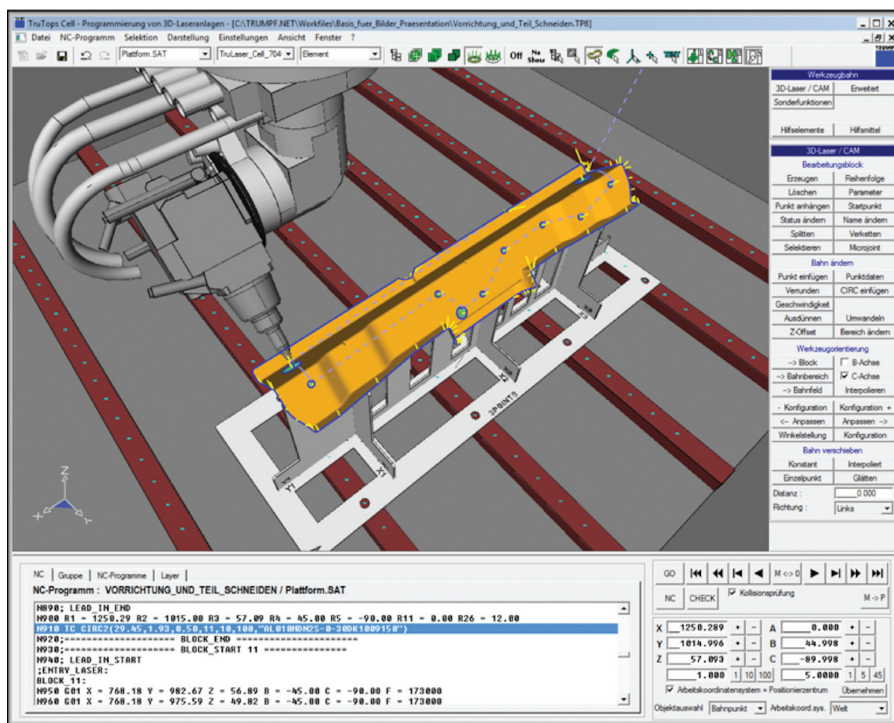


Fig. 4 — The 3D laser offline programming software TruTops Cell.

Automatic Focus Adjustment and Laser Technology Table

High-quality laser cutting results from the optimal combination of a series of cutting parameters, including laser power, focus, speed, gas pressure, and piercing strategy (see lead photo). Company experts have integrated optimized laser cutting parameters in the machine control system. Operators just need to select the material and thickness, and the machine will choose the right parameters. The TruLaser Cell series is equipped with FocusLine technology, a function to adjust laser focus position automatically. With it, the machine can set a laser focus point to achieve burr-free cutting for different materials of varied thickness, without manual adjustment.

Eliminate Burrs on the Corner

Another feature, X-Blast technology, allows operators to double the working distance between the nozzle and workpiece while doubling the bandwidth — Fig. 5. This reduces the chance of nozzle collision and, thus, reduces interruption to the production

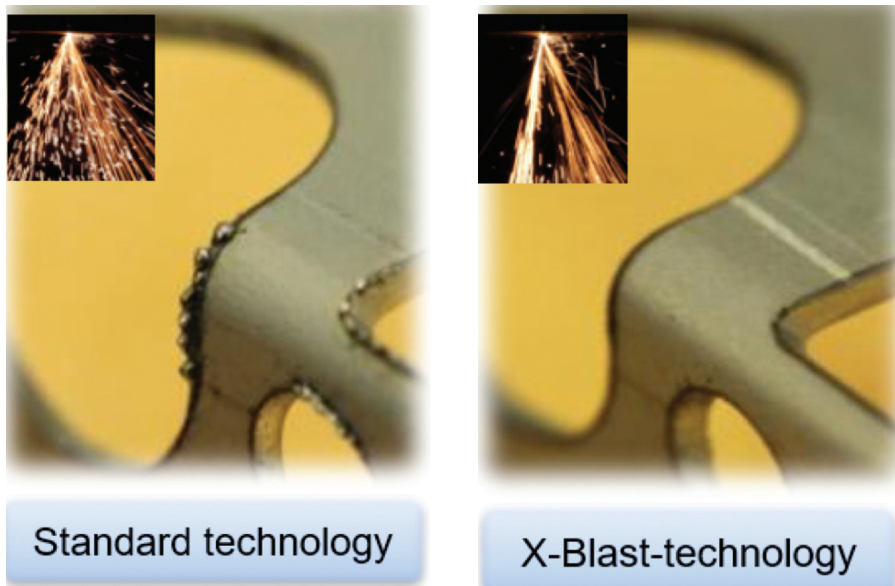


Fig. 5 — Side-by-side comparisons with burr-free cutting quality achieved on a corner section (right).

process. At the same time, the machine can cut complicated shapes, resulting in stable and reproducible parts quality, as well as eliminating post processing.

Conclusion

As a secondary processing on pre-formed metal parts, 3D laser cutting provides many advantages to job shop manufacturers. It not only allows for

improvement in lead time but also quality and cut cost. This is made possible due to the inherent characteristics of laser cutting, as well as recent developments in software capabilities and smart machine functions. [WJ](mailto:pierson.cheng@trumpf.com)

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Tips for Improving Cutting Performance with Angle Grinders

Best practices optimize metal-cutting performance and results

BY RICK HOPKINS

Maximizing productivity and quality when cutting metal with a right-angle grinder depends on many factors, including choosing the right abrasive and using it properly — Fig. 1.

While every operator is different in terms of skill level and technique, there are some common pitfalls that can arise when using cutting wheels.

This can negatively impact wheel performance and life.

Consider these tips to help improve productivity and save time and money in metal-cutting applications.

Tools for Cutting Metal

When an operator needs to make multiple cuts to a piece of metal with

an offhand cutting tool, they are likely using a right-angle grinder or, in certain specialized cases, a die grinder.

When choosing a cutting wheel, there are two profiles most commonly found in general fabrication and cutting applications. A Type 27 cutting wheel, sometimes called a depressed center wheel, has a raised hub at the center. While this feature provides



Fig. 1 — Maximizing productivity and quality when cutting metal with a right-angle grinder depends on many factors, including choosing the right abrasive and using it properly.

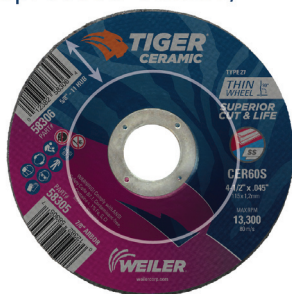
CUTTING

Type 1 (Flat)



Flat profile allows for deep cuts

Type 27 (Depressed Center)



Added clearance when working at a constrained angle

Fig. 2 — Type 27 cutting wheels are limited when working around extrusions, corners, or profiles. In comparison, a Type 1 cutting wheel has a flat profile and increased cutting surface, allowing the operator to complete more cuts per wheel.

additional offset or clearance between the wheel and the tool, it reduces the amount of cutting surface, especially with wheels that are 4½ in., or smaller, in diameter. This limits the number of cuts the operator will get out of each wheel. The raised hub can also be an interference point, especially when the operator is cutting thicker material or is plunging the wheel too deeply into the workpiece. Type 27 wheels are also limited when working around extrusions, corners, or profiles. In comparison, a Type 1 cutting wheel has a flat profile and increased cutting surface, allowing the operator to complete more cuts per wheel — Fig. 2.

Two specific applications for a Type 27 cutting wheel are flush cutting and rip cutting. For most general-purpose cutting operations and materials, a Type 1 wheel is suggested.

Type 1 cutting wheels are available in diameters of 2 to 9 in. Type 27 wheels are typically not available in sizes smaller than 4 in.



Fig. 3 — Understanding how the cutting wheel is designed to be used and following some best practices for technique can help extend operator safety and product life, as well as maximize performance and results.

Tips to Maximize Productivity in Cutting

There are several best practices that operators can follow to maximize performance and efficiency of their cutting wheels. Here are six tips:

1. Use motion through the cut.

Cutting abrasives are like knife blades. Downward pressure results in the blade dulling much faster compared to a slicing motion. Abrasive grains are similar. Using a sliding or rocking motion in the direction of the cut is recommended — moving the wheel into and through the workpiece rather than straight down. Allow the wheel to pull itself through the workpiece rather than trying to force it through. This minimizes friction and force, and helps extend the life of the cutting grains.

2. Don't push too hard. Pressure and heat are the biggest enemies of abrasive cutting products. Pushing too hard is a common pitfall because it's human nature to think pushing harder on the wheel will make it perform better. But pressure doesn't provide better cutting speed and only builds heat and friction, potentially binding or damaging the wheel. Increased heat and friction shortens wheel life considerably. Let the wheel do as much of the work as possible in the cut.

3. Clamp the workpiece properly. When the workpiece isn't properly clamped to a work surface, the metal can move and slide around as the operator is cutting it. A clamp that's too far away from the cut line of the workpiece can also result in greater vibration, which can bind or damage the wheel. It's important to clamp the workpiece properly and for the operator to consider how he or she can best see the piece to control it. The clamp can be oriented differently depending on operator preference and comfort. Never attempt to make a cut of any length or depth without properly and securely clamping the workpiece.

4. Approach from the proper angle. Cutting wheels are designed to make straight, in-line cuts. They should be used at a 90-deg angle perpendicular to the work surface; an improper angle can cause binding. The thinner the wheel, the more critical it is to use a 90-deg orientation to ap-

Never attempt to make a cut of any length or depth without properly and securely clamping the workpiece.

proach the part. Thicker wheels are more tolerant and will generally last longer. Thinner cutting wheels cut faster and leave a cleaner cut line with smaller burrs. Operators should find an ergonomic position for their body that allows them to actually see the wheel entering the cut line — whatever is most comfortable for them to follow proper technique. Always enter the cut from the point of least resistance. When cutting corners or square profiles, this means entering from the sharp corner for the least amount of surface contact to start the cut.

5. Follow the direction of rotation. Every right-angle grinder is marked with a directional arrow on the head of the grinder that indicates the direction the wheel is rotating when in use. For optimal performance, it's important to orient the cutting wheel so it rotates into and pulls itself into the workpiece rather than rotating away from the workpiece. This allows the wheel to cut more efficiently and with less effort from the operator. A wheel that rotates away from the workpiece also presents a safety hazard for the operator because any kick-back will throw the wheel back toward the operator. Be aware that die grinders typically do not have a directional arrow, so operators using a die grinder with a cutting wheel should pay close attention to what direction the wheel is spinning. Anytime an operator feels the wheel binding in the cut (hearing the RPMs drop can be a sign of binding), it's important to come to a complete stop and take the wheel out of the cut line to assess the problem. After inspecting the wheel for cracks or damage, allow the wheel to come up to full free-speed before re-entering the cut. Never restart a cutting wheel while it is inside a cut.

6. Choose the right wheel thickness. The thinner the face of the cutting wheel, the smoother and faster it will track in the cut. A thicker wheel will cut slower but last longer, particularly when cutting harder or thicker workpieces, and provide more abrasive, in-direct contact with the base material. This increased surface contact, however, also increases friction and heat. A .045-in. wheel is common in many cutting applications. When cutting sheet metal or thinner-gauge material, thinner wheels, such as a 1-mm wheel, may be a better option. Thicker base material holds more heat and will generate more surface contact and friction. When thinner wheels are used on thicker material, heat and friction will affect wheel life and durability.

Improving Performance in Metal Cutting

Choosing the right cutting wheel for the job often depends on the goals of the operation. If cut speed is most important, the operation will likely have to compromise a little on product life — and vice versa.

No matter what type and style of cutting wheel an operator selects, understanding how that product is designed to be used and following some best practices for technique can help extend operator safety and product life, as well as maximize performance and results — Fig 3. [WJ](#)

RICK HOPKINS
(rhopkins@weilerabrasives.com) is a senior product manager for welding and fabrication at Weiler Abrasives, Cresco, Pa.

Motivated Millennial Creates a Successful Fab Shop

How school, welding, and a plasma cutting machine helped drive a young business owner to expand his company

BY ANN THOMPSON

Meet Justin Sly, a hardworking, 24-year-old millennial who defies the stereotypes given to his generation by proving he's an ambitious and savvy entrepreneur — Fig. 1.

Sly's first job was mowing the lawns and trimming the trees of his neighbors in his hometown of Saline, Mich. (ten miles south of Ann Arbor). As a junior high schooler, he liked the work and appreciated the flexibility the job gave him. As word spread about his services, his customer base naturally grew. More work was great, but practically speaking, it meant more wear and tear on his equipment. Sly wanted to learn how to repair his lawn mower and clippers himself.

"I had the drive to learn how to weld," he explained. "I knew if I could weld then that would give me the freedom to fix things myself and to customize my equipment."

Saline High School offered a beginner's welding class, which Sly signed up for in his freshman year. With his newly earned talent for light welding repairs, the neighbors took notice and hired him to perform these jobs too, along with the landscaping he was already doing for them. When he received his driver's license during sophomore year, his business, JSI Industrial, expanded beyond the neighborhood as word spread in the community. That's when farmers began hiring him for mobile welding services.



Fig. 1 — Justin Sly modifies farm equipment. He is pictured here removing hangers on a rolling basket so rakes can be added to this soil-cultivating machine.



Fig. 2 — Sly on an emergency call; the arm on this backhoe loader split and needed immediate repairs.

Field Work

Sly was always thinking about his future, and his parents were utterly shocked, when at the age of 14, he told them he wanted to buy an 18-year-old Ford F-250 truck. He'd noticed the pickup for sale in a yard while en route to a regional tractor pull with his dad. Sly's parents didn't know what to

make of their son's pronouncement, as he wasn't legally able to drive for a few more years. Recognizing Sly wasn't like most kids, interested in sports or texting on his phone, his parents were supportive.

With money saved up from Christmas and birthday gifts, along with earnings he had saved from his yardwork, Sly had the \$1000 needed to

purchase the truck. The maroon-colored Ford sat in his parents' driveway for at least a year. When he was eligible for a temporary operator's permit, he used it to chauffeur his mother around town on errands, right up until the day he was ready for the state's driving test.

Once of legal age, Sly loaded his vehicle with basic hand tools. He had a hammer, pliers, chisels, a welding helmet, gloves, and a refurbished Lincoln Electric Outback® 185 engine-driven shielded metal arc welding machine he purchased, at age 13, from Ann Arbor Welding Supply. It was a bare-bones operation in the beginning, but he was on his way — Fig. 2.

Love What You Do

Sly loved welding, and as his business grew, his thoughts turned to college. He heard about Michigan's Ferris State University from Jerry O'Donnell, Saline High School's metals technology teacher. O'Donnell had told Sly and his high school classmates about Ferris' nationally recognized welding program.

During his junior year in high school, Sly convinced his father to take him to see the Big Rapids campus, and together they toured the university's facilities with Program Coordinator and Associate Professor Jeffrey Carney. Sly visited the campus on two more occasions, going both times with his advanced metals' teacher, Steve Hasselbach, when Sly represented Saline High School in the State Secondary Welding Competition's Fabrication Division in 2012 and 2013.

By the time his high school graduation came along, Sly was sold on Ferris' program. He headed to Big Rapids in the fall of 2013, joining 50 students in the Welding Engineering Technology's freshman class. Now a 3-h drive from his parents' house, Sly was set up in a dorm room and enrolled in classes from Monday to Thursday. On weekends, he'd jump in his truck and returned home to run JSI Industrial.

Getting Schooled

Lots of hands-on opportunities meant Sly could immediately practice what he was being taught at school. He machined and finished high-precision parts using the school's milling machines, and fabricated metal with the



Fig. 3 — Sly's three-point skid steer attachment.



Fig. 4 — Sly (left) and Stith lean on the new 5 × 10 in. cutting table they're building for Stith's CNC machine.

school's welding and plasma cutting machines. Some of the tools were familiar, while others were not.

Ferris has a Hypertherm XPR300™ X-Definition plasma system and nearly a dozen light industrial Powermax® air plasma systems. Sly used the school's Powermax85®.

New Prospects

Associate Professor Brent Williams told his introductory welding class about Hypertherm's student rebate program, and Sly saw an opportunity to expand his business into fabrication services. He bought a Powermax45® XP and immediately took on more complex projects. Most of these jobs included modifying farm equipment and fabricating custom attachments. Demand for Sly's services increased, especially during the spring planting season and fall harvest, when farm machinery is in heavy use.

"Farmers are the lifeline of my business and by far the finest customers anyone could ever ask for. Farmers don't ask when something will be done, they ask what they can do to help and are always beyond generous, supportive, and loyal," Sly said.

It was this encouraging spirit from his customers that allowed Sly to gain more and more experience over time. He worked on anything and everything and has repaired and rebuilt it all, from haying equipment to planters and harvesters. In addition to the farm equipment, his customers have hired him to make construction equip-

ment attachments; fabricate metal staircases, scaffolding, and walkways; and even create decorative railings for their homes.

Beyond School

With all the work Sly had, he made enough money to cover his college costs. He graduated in 2018 with an associate's degree in heavy equipment service and a bachelor's degree in welding engineering technology. The solid education he received at Ferris, combined with the energy he put into his own studies, resulted in Sly receiving a job offer from General Motors (GM) before graduation. He moved 330 miles from home to Bedford, Ind. He currently works as a project engineer, writing company procedures for tool steels used to make hard-wearing production tools.

Bedford is a 5-h drive from Saline, so JSI Industrial entered a new phase. Before moving, Sly made sure his loyal farmers had the support they needed by finding a good welder to replace him. He also saw the move as an opportunity to expand JSI Industrial into product manufacturing. He had an idea. What if farmers could use tractor attachments on a skid steer?

Product development and production take effort. In addition to working full-time for GM, Sly spends an additional 40 to 50 h on JSI Industrial projects. He's currently learning how to run a computer numerical control (CNC) plasma system from another young entrepreneur, John Stith, co-

owner of Force Designs. Stith teaches Sly about CNC operation and electronics, while Sly lends him his plasma cutting machine. Currently, Sly is cutting parts for his skid steer attachments on Stith's CNC, but he hopes to have his own system soon — Figs. 3 and 4.

Earned Wisdom

Sly has now been in business for ten years and is excited to think about how he will continue to evolve and grow professionally. The inspirational millennial has a way of making things look easy at his young age, but he'll be the first to admit there have been hardships and setbacks, and even a crisis of confidence from time to time. However, these experiences have forged him into a leader, and he has great advice for anyone who wants to be a business owner.

"Trust your gut and take chances," he said. "Blaze your own path because the real opportunity is in writing your own story, rather than following behind someone else. People will doubt you, but you don't have to doubt yourself." 

ANN THOMPSON (ann.thompson@hypertherm.com) is the marketing specialist at Hypertherm, Hanover, N.H.

Oxyfuel Gas Cutting

Oxyfuel gas cutting (OFC) processes cut or remove metal by means of the chemical reaction of oxygen with the metal at elevated temperatures. The necessary heat is provided by a flame of fuel gas burning with oxygen. These cutting processes are often referred to by various other names, including burning, flame cutting, and flame machining, but the standard term designated by the American Welding Society is oxyfuel gas cutting.

Oxyfuel gas cutting and its variations are important processes commonly used in structural fabrication, shipbuilding, the manufacture of heavy machinery, and the fabrication, repair, and maintenance of pressure vessels and storage tanks.

Oxyfuel gas cutting processes can be used to cut structural shapes, pipe, rod, similar materials for construction and maintenance, and scrap in salvage operations. In a steel mill or foundry, extraneous projections can be quickly severed from billets and castings using OFC processes. In disassembly operations, these processes can also rapidly sever bolts, rivets, and pins.

Mechanized and automated OFC processes are used in steel warehouses and many other industrial settings to cut steel to size and pierce or cut holes, as well as to cut various shapes from plate. An important application is preparing plate edges for welding. The processes are also used in the fabrication of machine parts such as gears, clevises, frames, and tools.

Oxyfuel Gas Cutting Operations

The OFC operation begins by using a fuel gas flame to heat the area of the workpiece to be cut to the ignition temperature of approximately 870°C (1600°F). The actual cutting is performed by an oxygen stream that is directed at the preheated location on the workpiece, resulting in the oxidation of the heated metal and the generation of heat. This

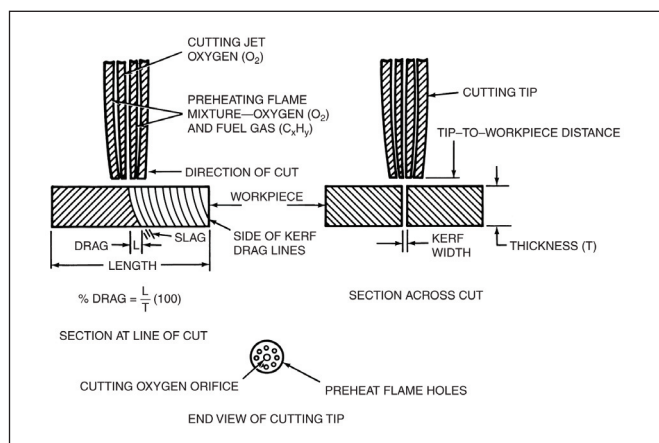


Fig. 1 — Schematic view of the oxyfuel gas cutting process.

heat sustains the continued oxidation of the metal throughout the cut. The oxygen stream and combusted gas transport the molten oxide away, and the metal in the path of the stream burns, producing a narrow cut known as a kerf.

The torch directs the preheat flame produced by the controlled combustion of fuel gases and controls the cutting oxygen. Because the cutting oxygen jet has a 360-deg cutting edge, it provides a rapid means of cutting straight edges or curved shapes to required dimensions without expensive handling equipment. The cutting direction can be continuously changed during operation.

The oxyfuel gas cutting process is illustrated in Fig. 1.

Advantages of Oxyfuel Gas Cutting

A comparison of OFC to other metal-cutting methods such as sawing, milling, and arc cutting reveals a number of process advantages and disadvantages. The following are several advantages of OFC:

1. Steels can generally be cut faster with OFC than by mechanical chip removal processes;
2. Section shapes and thicknesses that are difficult to cut by mechanical means can be severed economically by OFC;
3. Basic manual OFC equipment costs are low compared to machine tools or the equipment used in other cutting processes;
4. Manual OFC equipment is portable and easily deployed in the field;
5. Cutting direction can be changed rapidly on a small radius during operation;
6. Large metal plate sections can be rapidly cut in place by moving the OFC torch rather than the plate; and
7. Oxyfuel cutting is an economical method of plate-edge preparation for bevel and groove weld joint designs.

Disadvantages of Oxyfuel Gas Cutting

The following limitations are inherent to the OFC of metals:

1. Dimensional tolerances achieved may be greater than those attained with mechanical cutting;
2. The process is essentially limited to the cutting of steels and cast iron, although other readily oxidized metals such as titanium can be cut;
3. Preheat flames and expelled red-hot slag constitute fire and burn hazards;
4. Fuel combustion and oxidation of the metal require proper fume control and adequate ventilation;
5. Hardenable steels may require preheat or postheat, or both, to control their metallurgical structures and mechanical properties adjacent to the cut edges; and
6. Special process modifications are required for the cutting of high-alloy steels and cast irons. [WJ](#)

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Through relationships with many job boards and distributors, it offers direct access to more than 88% of the welding-related jobs posted on the Internet.

Users may search various openings for welders, Certified Welding Inspectors, engineers, technicians, and managers/supervisors.

In addition, the website contains the following highlights:

- The home page displays featured welding jobs along with the companies looking to fill them and city/state locations.
- The job seeker section connects individuals to new career opportunities by allowing them to post an anonymous résumé, view jobs, and make personal job alerts. This area has résumé tips, certification information, and a school locator.
- The employer area enables association with qualified applicants. Résumés, job postings, and products/pricing options may be viewed here.

Visit the website to create or access job seeker and employer accounts.



Underwater Pulse-Current FCAW — Part 1: Waveform and Process Features

*Regulating metal transfer using pulse current
improved welding process stability*

BY C. JIA, J. WU, Y. HAN, Y. ZHANG, Q. YANG, AND C. WU

ABSTRACT

The typical metal transfer mode in conventional underwater wet flux cored arc welding (FCAW) delivers large droplet repulsive transfer with low frequency. The process stability and the weld quality are seriously deteriorated with significant spatter and frequent arc extinctions. It is thought the repulsive forces applied on droplets can be reduced by rapidly decreasing the welding current, making the droplets sag and oscillate. A novel underwater pulse-current FCAW was proposed to periodically regulate the forces applied on droplets. The experimental system was developed with specially designed pulse current and reliable arc length control. Visual and electrical signals were collected simultaneously to study the process features. It was found that the maximum droplet diameter decreased to less than 5 mm; the temporary arc-extinguishing frequency decreased significantly; there was almost no short-circuit transfer and surface-tension transfer; and the stability of the welding process was significantly improved.

KEYWORDS

- Underwater Wet Welding • Metal Transfer
- Pulse Current • Flux Cored Arc Welding
- Process Control

Introduction

Underwater welding technology is one of the indispensable technologies in modern offshore engineering, such as offshore platform construction, submarine pipeline laying and maintenance, bridge construction and maintenance, and nuclear power plant maintenance (Refs. 1–4). The self-shielded underwater flux cored arc welding (FCAW) process does not need special drainage equipment and an evacuated chamber for underwater dry welding methods. Compared to manual welding, automated welding has many advantages, including easy operation, high efficiency, and low cost (Ref. 2). Due to the special and complex underwater environment, the quality of underwater wet welding is influenced

by many factors, such as arc plasma characteristics, metal transfer, and bubble behaviors. Many studies have proved that metal transfer plays an important role in weld formation, process stability, heat input, and arc burning (Refs. 5–8). Scholars have also conducted a great deal of research on metal transfer control schemes (Refs. 9, 10). Some have reduced the surface tension of droplets by adjusting the type of shielding gas, wire material, and wire feeding methods, thus reducing the size of droplets when they detach from the tip of the wire and decreasing the production of spatter (Refs. 11, 12).

With the performance improvements of the welding power supply (digital, inverters, and controlled waveform), more and more scholars use current waveform to control metal transfer in various welding processes. According to the different characteristics of each phase of metal transfer, corresponding welding current and voltage waveforms were input to ensure a more stable metal transfer and to reduce generated spatter. Among these methods, the most representative one was surface tension metal transfer (Ref. 13). This method is mainly applied in low-current welding. It ensures smooth metal transfer under the effect of surface tension by reducing welding current at the initial stage of short circuit and increasing short-circuit welding current at the later stage of short-circuit transfer. The welding current is significantly reduced at the moment when the droplet contacts the molten pool to form a short circuit; the welding arc is reignited after the metal is transferred to the molten pool, so as to avoid the liquid “bridge” being heated sharply to form a burst resulting in significant spatter. In the process of smooth short-circuit transfer by means of surface tension, the pinch current will be raised again; the electromagnetic contraction force at the neck of the shrunken droplet will be greatly increased, which will have a squeezing effect on the droplet, promoting the metal transfer and shortening the transfer time.

Y. M. Zhang et al. proposed an active control method for pulsed gas metal arc welding (GMAW-P) based on the synergistic use of droplet oscillation momentum and electromagnetic force (Ref. 7). The droplet oscillates when the welding current changes from peak to base. When droplets grow to

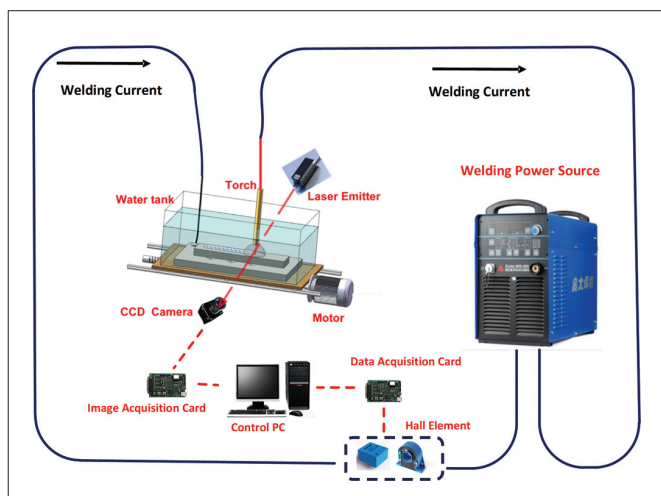


Fig. 1 — Experimental platform and signal acquisition system.

the appropriate size, the pulse current is switched to the valley current, and then the welding current is switched to the excitation current with higher amplitude when droplets oscillate downward. The droplet's downward momentum and the sudden increase of electromagnetic force were used to produce sufficient force to make the droplet detach from the tip of the wire. As a result, the smooth and regulated metal transfer was achieved. In recent years, G. J. Zhang et al. proposed the application of pulsed-laser and negative-pulse current to achieve the free transfer of droplets using low welding current (Ref. 14). On one hand, the evaporative reaction force caused by the laser beam was used to promote droplet dropping; on the other hand, the resistant arc force to droplet falling was reduced by rapidly reducing the welding current. The electromagnetic spot resistance of droplets decreased instantaneously with the decrease of the welding current. The droplets changed from a repelled state to a natural sagging state, and returned to the axial position of the wire flexibly (in about 7 ms).

The above research provides a theoretical basis for improving the metal transfer in underwater wet FCAW. In conventional wet FCAW, droplets are mainly repelled by complex upward forces in bubbles, which makes it difficult for them to drop freely. They are forced to grow to a large size and even be excluded from the wire axis. According to the analysis of the forces applied on droplets under water (Ref. 15), it is known that the drag force of gas in bubbles mainly comes from the decomposition of flux cores, the decomposition or evaporation of water, and the irregular flow of metal vapor in the molten pool. Therefore, arc heat is the fundamental reason for the repulsive forces. The arc force mainly includes spot pressure, the axial component of electromagnetic force. The repulsive force magnitudes depend mainly on the welding current.

Considering the aforementioned research, merely increasing welding current or voltage can theoretically reduce surface tension and improve plasma flow force, but it will inevitably intensify flux-core decomposition and water decomposition or evaporation, and increase the drag force of gas flow on droplets. At the same time, the arc spot pressure under the droplet increases with the increasing welding cur-

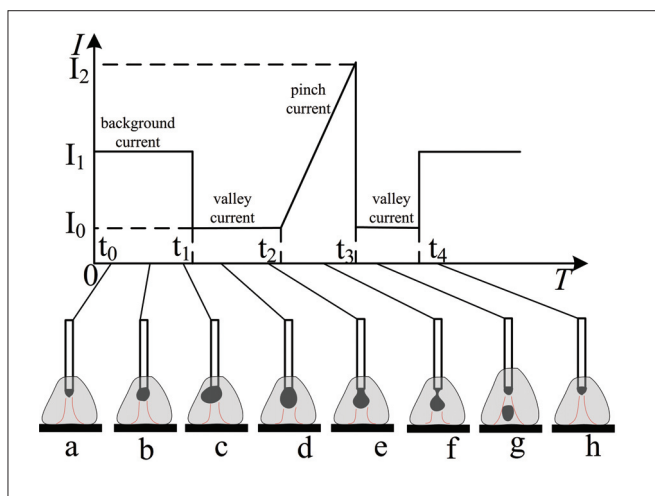


Fig. 2 — Schematic of the pulse-current waveform and assumed metal transfer.

rent. The droplet is still subject to large upward repulsive forces and cannot transfer freely. It is difficult to obtain higher frequency and smaller size metal transfer.

To improve metal transfer stability and weld formation, it was proposed to use pulse current to regulate the metal transfer during underwater wet welding. A novel underwater wet pulse-current FCAW process and its features were investigated. The waveform design, arc length control, and metal transfer processes were comprehensively studied and discussed. The control mechanism, based on pulse current, provided important data and theoretical basis for further optimization of this technology.

Experimental Procedure

To analyze the relationship between the metal transfer processes and the electrical parameters, a data acquisition and control system was built based on LabVIEW, as shown in Fig. 1. All the experiments were conducted at the water depth of 0.5 m in a water tank. The data acquisition system included a data acquisition card, terminal board, Hall effect current sensor, voltage sensor, and computer. The sampling acquisition frequency was 100 kHz. The range of the voltage sensor was 0 to 100 V. The range of the current sensor was 5 to 500 A. The acquisition and control system can fulfill the requirement of synchronous analog/digital data acquisition and output.

The employed voltage sensor was also designed according to the Hall effect principle. The sensor first converted the collected voltage signals into current form through the designed electric circuit, then output them to the acquisition card. The base metal was Q235 with 8-mm thickness. Bead-on-plate welding experiments were carried out using a specially designed flux-cored wire for underwater wet welding made by E. O. Paton Electric Welding Institute, Kiev, Ukraine.

In underwater FCAW, the visual signal acquisition is usually disturbed by many factors, such as bubbles and welding fumes. The fluctuation of the water surface would change

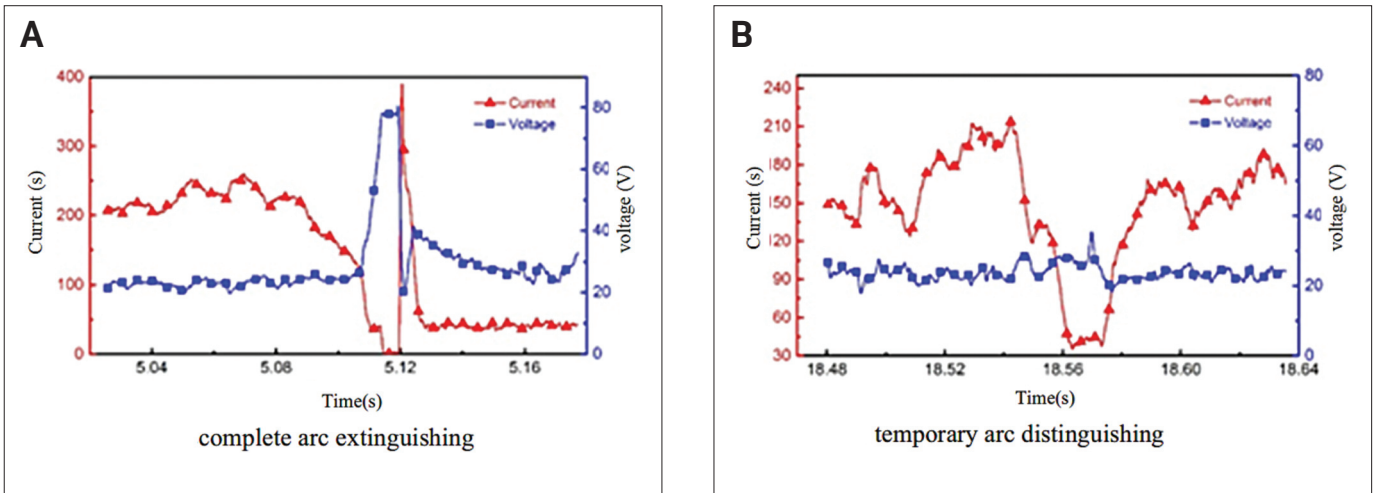


Fig. 3 — Schematic of the closed-loop control system.

the optical path from the welding area to the camera. The x-ray-assisted photography technique could obtain metal transfer images, but would lose important information such as the arc and bubble evolution processes (Ref. 16).

In light of the problems detailed above, a visual sensing system based on a high-speed camera was designed. The resolution of the camera was 640×480 pixels with frame rate up to 2000 fps. Clear images of the underwater wet FCAW process (Ref. 17) were obtained, containing rich and important information, including metal transfer, bubble evolution, and arc behaviors. Experiments were designed with the pulse-current waveform, to explore its control effect on metal transfer behaviors in underwater wet welding. Experimental parameters are shown in Table 1 and Table 2. Please note the experiments under constant voltage were conducted to compare and study the welding process stability in pulse-current FCAW.

Results

Pulse-Current Waveform Design

GMAW using solid wire, increasing the welding current or voltage can reduce the surface tension and improve the plasma flow force, thus the high-frequency free metal trans-

fer or projected transfer can be realized. The free metal transfer mode is the transition form the droplet falls into in the weld pool after falling off from the welding wire end and moving freely through the arc space for a certain distance. However, for underwater wet welding using flux-cored wire, higher current or voltage will inevitably intensify the flux core's decomposition and the water decomposition or evaporation, as well as increase the drag force of gas flow. In addition, the arc spot pressure and electromagnetic force acting upward on the droplets also increase along with the increased welding current. Thus, the repulsive forces are strengthened with a larger extent than the arc forces. The droplets are still subjected to a large upward force and cannot drop freely. As a result, it is difficult to obtain high-frequency droplet transfer with small diameter droplets.

Therefore, the authors proposed that the free metal transfer in underwater wet FCAW can be realized based on pulse-current control and regulation. The drag force and arc force were controlled by adjusting welding current, so as to realize the one drop per pulse free metal transfer mode with higher frequency and smaller droplet size. As shown in Fig. 2, the pulse-current waveform was designed with four sections: background current I_1 , valley current I_0 , pinch current I_2 , and valley current I_0 . The preset function of each section was as follows: The waveform of background current is shown in the t_0 - t_1 period. The wire melted in a short time at a high current,

Table 1 — Experiment Parameters Under Pulse-Current Mode

	Wire Feed Rate	Welding Speed	Average Current	Frequency
Welding Parameters	4.4 m/min	180 mm/min	200 A	20 Hz

Table 2 — Experiment Parameters Under Constant-Voltage Mode

	Arc Voltage	Wire Feed Rate	Welding Speed	Wire Diameter
Welding Parameters	27 V	4.4 m/min	180 mm/min	1.6 mm

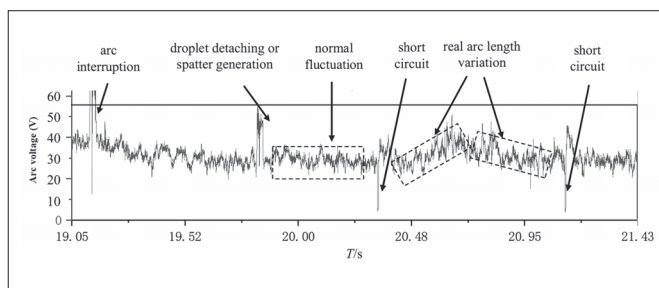


Fig. 4 — Arc voltage fluctuation features and recognition in underwater constant-voltage FCAW.

and the droplet grew to a certain size. At that time, there were large repelling forces consisting of the drag force, electric arc force, and buoyancy. At the “c” moment of metal transfer, the grown droplet was repelled by the complex forces, which stopped the droplet’s downward movement.

The waveform of valley current I_0 is shown in the t_1 – t_2 period. When the droplet grew to a certain size at t_1 , the welding current was sharply decreased to the valley current. In this case, the repulsive forces decreased subsequently, including the arc force and drag force. The force balance of droplets was then destabilized. According to the previous analysis, it was assumed that the sharply decreased welding current would significantly reduce the repulsive forces. Subsequently the repelled droplet moved downward and hung at the end of the wire. This transition produced a certain oscillation. The droplet size grew larger with the ongoing welding process, and the necking occurred due to the gravity and the downward momentum. The characteristics of metal transfer are shown the moments “d” and “e” in the corresponding graphs.

The pinch current I_2 is shown in the t_2 – t_3 period of the figure. Once the droplet grew large enough, the downward forces became higher than the upward forces, as shown at the “e” moment, when the necking phenomenon of the droplet happened. As the welding current was increased sharply from valley current to pinch current, the radial and downward axial components of the electromagnetic contraction forces got much stronger and accelerated the metal transfer process. In addition, the downward inertia momentum offered additional contribution to the droplet detaching process. The detaching and transfer processes are described at moments “f” and “g” in Fig. 2.

Subsequently, the welding current was reduced to valley current I_0 when the droplet was about to detach from the wire end, so as to prevent the excessive heat input, reduce repulsive forces, and avoid spatter. The characteristics of the metal transfer are shown as “g” in the corresponding graph. Stable arc burning and bubbles generation were maintained. Then the welding current was raised to the background current to start the next cycle.

Arc Length Control Strategy

To realize the reliable and accurate output of the preset current waveform, the welding power source was controlled by an external program through an industrial computer. Because the arc self-regulation effect under constant-voltage was not effective in the pulse-current mode, the correspon-

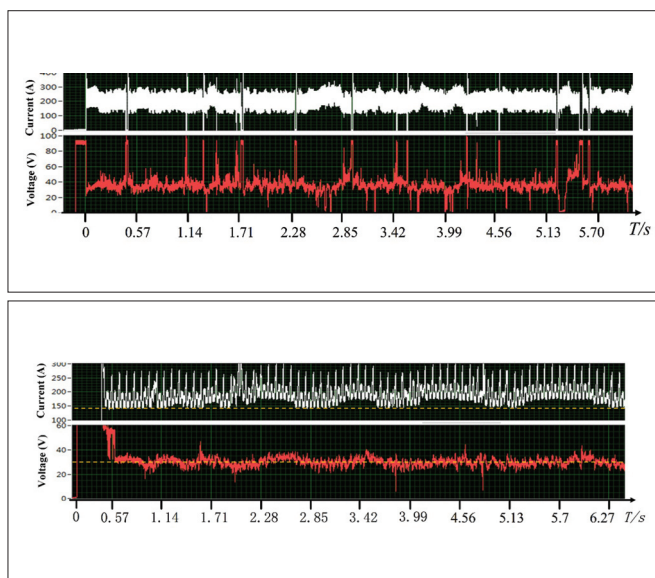


Fig. 5 — Collected welding current and arc voltage signals in pulse-current wet FCAW before (top) and after (bottom) applying the arc length control.

ding control for maintaining a stable arc length was critical for FCAW process.

As shown in Fig. 3, a closed-loop control system was developed to avoid arc extinguishing or short circuit caused by arc length variations. The arc length was adjusted by changing the welding current appropriately based on the collected arc voltage signal as feedback. Specifically, when the arc length was too long, the arc voltage was higher than the preset threshold value (≥ 27 V), the output current of welding power source was reduced, thus the melting rate of the welding wire slowed down, and the arc length was shortened, correspondingly. When the arc length was too short, the arc voltage was lower than the threshold value (< 27 V), the output current was increased to accelerate the melting rate of the wire, and the arc length was then increased accordingly.

Once the difference between the collected and preset threshold voltage was obtained, the controller output a control variable, which decides the average welding current level for the next cycle. As shown in Equation 1, a proportional-integral (PI) controller was used to calculate the correct output average current in real time. In other words, the amplitude and directions of the welding current adjustment were determined for eliminating the voltage variation.

$$u_t = K_p \left[e(t) + \frac{1}{T_i} \int_0^t e(t) dt \right] \quad (1)$$

where, u_t is the output value at t moment, K_p is the proportional gain, T_i is the integral time, $e(t)$ is the obtained difference between the collected and preset threshold voltages at t moment, and t represents the current moment for calculation. Based on the employed PI controller, the accumulated controlled variables and the initial waveform parameters both determined the required current waveform for a stable arc length. Note that the gain settings associated with the

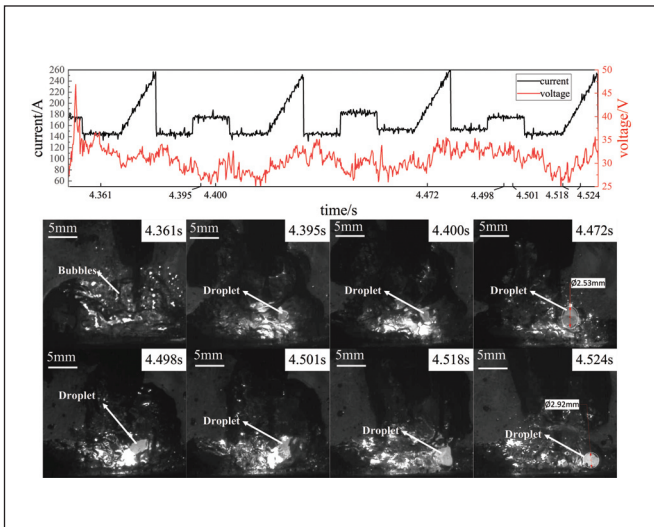


Fig. 6 — Typical metal transfer in pulse-current wet FCAW (No. 1).

controller were tuned manually according to experience and experimental data.

However, because the wet welding process is vulnerable to short arcs and frequent disturbances, the above controller might output inappropriate values. For example, if arc distinguishing happens, the detected arc voltage would show ultra-high values (close to open-circuit voltage) and the controller would produce an ultra-low welding current; if short circuit happens, ultra-high welding current would be output. Therefore, some restrictions were added to the computer program considering possible exceptions. Thus, the controller became a relatively sophisticated hybrid controller that combined a traditional PI controller with an expert system that is responsible for detecting the disturbances and avoiding wrong output.

Figure 4 shows the arc voltage fluctuations and features in underwater constant-voltage FCAW. The features of different signal fluctuation conditions are recognized, including arc interruption, droplet detaching or spatter generation, normal fluctuation, short circuit, and real arc length variation. In the control program, a function of real-time analysis of the signal data was added to the PI controller and acted as an auxiliary expert system. Based on certain judgment conditions, the changing rates of voltage signals in each pulse cycle were calculated for the automatic feature recognition.

When the arc interruption happened, the arc voltage sharply rose to open-circuit voltage (80 V). When the large droplet detached from the wire end and formed a spatter or transferred to the weld pool, a sudden rise of the arc voltage was observed. During the stable wet FCAW, the arc voltage fluctuations still existed due to the complicated arc and metal transfer processes in the water environment. It was not suitable to recognize the “normal” fluctuations as “abnormal.” In other words, the waveform did not need any adjustment. In comparison, the continuously increasing or decreasing arc voltage signals with certain slopes indicated the real changing arc lengths. The control system needs to output the required adjustment of the welding

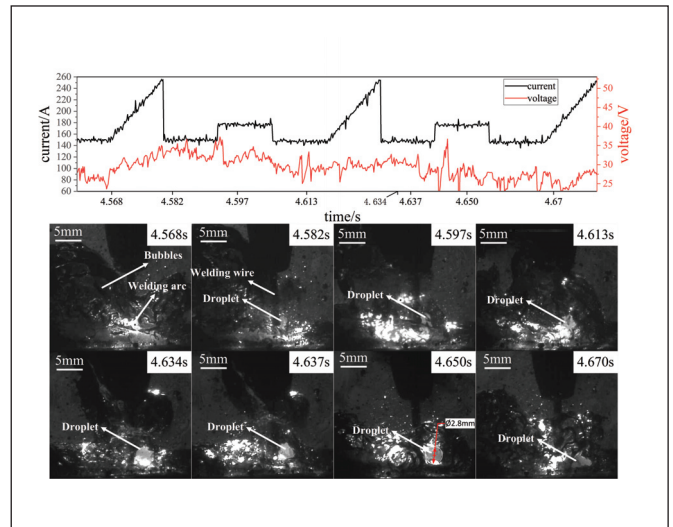


Fig. 7 — Typical metal transfer in pulse-current wet FCAW (No. 2).

current according to Equation 1. In addition, except for the large droplet repulsive transfer, short-circuit transfer happened resulting in the sharply decreased arc voltage (close to 0). Considering the above exceptions, the controller output judged the fluctuation types first and gave an appropriate slight adjustment of the current waveform.

Thus, the controller made the right decisions considering the voltage fluctuation trends and other abnormal disturbances. Please note that the update rate of the controller was actually equal to the pulse-current frequency. That is to say, the average current of each cycle of waveform was determined according to the controller output. Additionally, according to the requirement for different welding processes, the pulse and control frequencies ranged from 10 to 100 Hz.

Figure 5 shows the real welding current and arc voltage signals under the pulse-current mode with arc length control. The two sets of signals represented the processes before and after applying the aforementioned arc length control, respectively. It appeared that arc extinguishing and short circuit happened many times during the welding process without arc length control. In comparison, after applying the arc length control strategy, the arc voltage was maintained in a reasonable range; no arc interruption or long-time arc extinguishing happened; the average level of the pulse current was adjusted by the hybrid PI controller. This indicated the well-controlled arc length in the underwater wet FCAW.

Visualization of the Metal Transfer in Pulse-Current FCAW

Figures 6 and 7 show the synchronously obtained visual and electrical signals in pulse-current underwater wet FCAW. The two selected metal transfer cycles well showed the regulation effect by the pulsed welding current. As shown in Fig. 6, along with the periodically varying welding current, the detailed metal transfer process in a com-

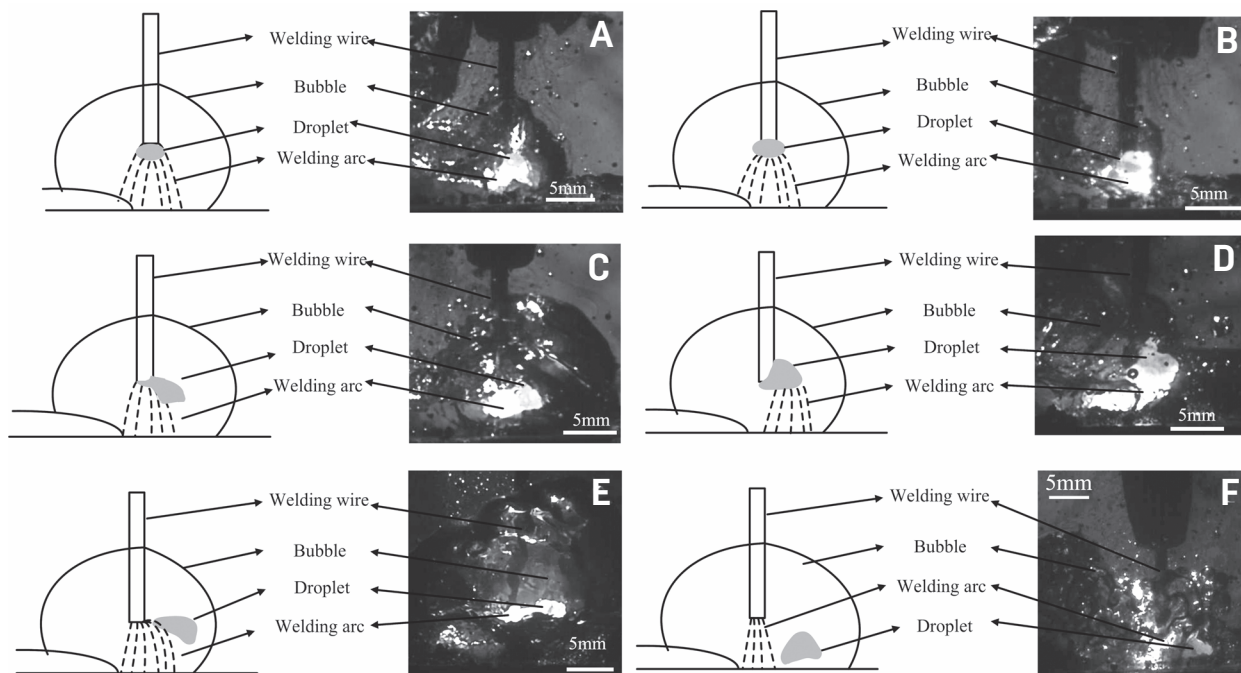


Fig. 8 — Six stages of the typical repelled globular transfer in pulse-current wet FCAW.

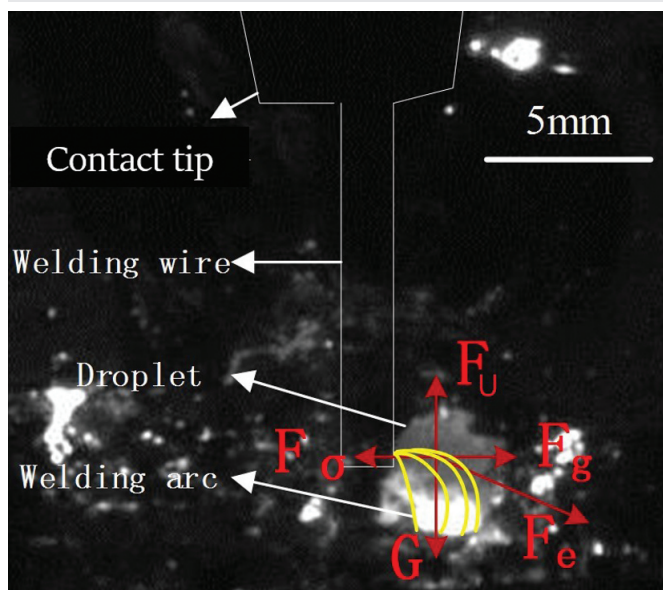


Fig. 9 — Force analysis on the droplet at the deviated large droplet stage.

plete cycle from 4.361 to 4.524 s was clearly observed. Overall, there was only one cycle of metal transfer in three cycles of pulse-current waveform. According to the preset pulse-current frequency (20 Hz), the metal transfer frequency had been increased to 5–6 Hz, which is higher than that in conventional wet FCAW (4.44 Hz) (Ref. 16).

A new liquid droplet was formed at 4.395 s, and the relative positions of the droplet, arc, and wire were clearly seen. Due to the complex situation, the droplet was repelled leav-

ing the wire axis with an offset. Subsequently, at 4.472 s the droplet had grown to an ellipsoid, under the influence from bubbles and welding arc, with a maximum diameter of 2.53 mm as measured in the figure, which was much smaller than the reported 7.2 mm in conventional wet FCAW (Ref. 16). In addition, at the moment of 4.472 s, the pinch current was applied by the preset waveform. The droplet was then repelled, due to the pinching forces to the right side at 4.498 s. From 4.498 to 4.501 s, the droplet detached and dropped into the weld pool. It was calculated that the presented metal transfer happened from 4.361 to 4.518 s, which took 157 ms in total.

Another metal transfer process closely following the finish cycle shown in Fig. 7 was the transfer of the second droplet. The last droplet's detachment time (4.518 s) was set as the starting time of the current metal transfer. A newly formed small droplet was seen at the tip of the wire at 4.582 s. Despite the small volume, the droplet was located on one side of the wire due to the repulsive forces. At 4.613 s, it returned back to below the wire and close to the wire axis. After 119 ms (4.518 to 4.637 s), the droplet grew to a size slightly bigger than the wire diameter. From 4.637 to 4.650 s, the welding current experienced a sudden increase. Accordingly, the arc voltage also increased suddenly and then decreased, and the droplet on the side of the wire detached from the wire end. The droplet maximum diameter was 2.8 mm, and the whole transfer time was 152 ms.

During the two stages, it was noted that the droplet-detaching behaviors of the two droplets were similar. Under the rapidly varying welding current, the droplets were dragged and pushed by complex forces. The oscillation of the liquid droplets was intensified.

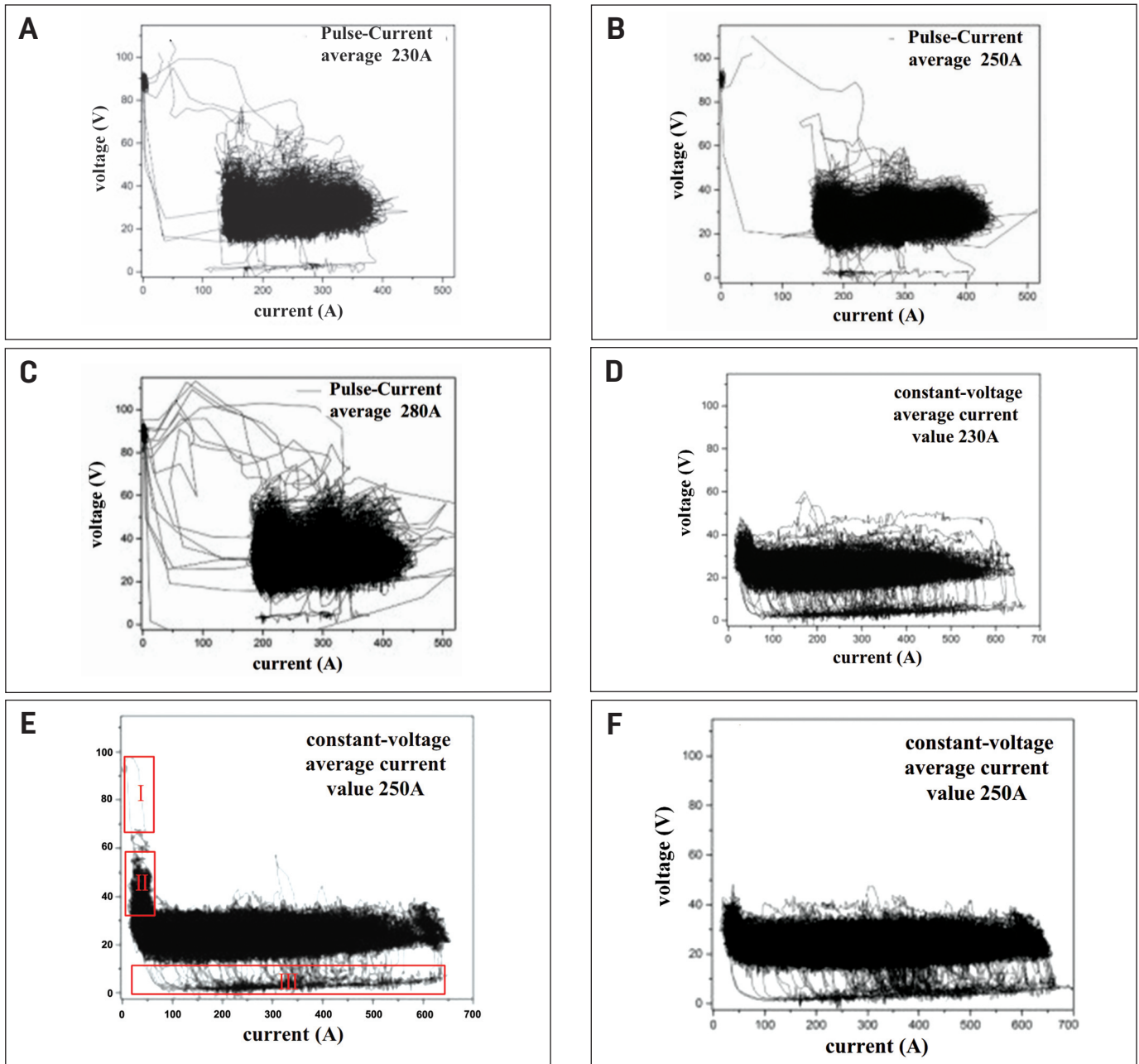


Fig. 10 — Comparison of the U-I diagrams during pulse-current and constant-voltage wet FCAW processes.

Discussion

Metal Transfer under Pulse Current

Based on the observation and statistics results, the metal transfer mode in pulse-current wet FCAW is still categorized as repelled globular transfer. However, it had a smaller droplet size and higher frequency than that in conventional wet FCAW. Compared to the proposed control strategy shown in Fig. 2, the real metal transfer seemed different from the assumed situation. The detailed metal transfer process in pulse-current wet FCAW and its characteristics were discussed in this session.

As shown in Fig. 8, a typical metal transfer cycle in pulse-current wet FCAW can be divided into six stages according to the relative positions of the arc, droplet, and wire. That is initial stage, growing, deviation, deviated large droplet, detaching, and transferring, as shown in Fig. 8A-F, respectively. It can be seen that the relative positions of the droplet, arc, and wire kept varying along with the increasing liquid volume and changing applied forces.

First, in the initial stage of metal transfer (Fig. 8A), the droplet with small volume hung at the end of the wire and was mostly wrapped in the arc. The resistance forces stopping the droplet from detachment played the predominant role. For example, the surface tension exerted a great influence on the liquid metal. Comparatively, the downward pro-

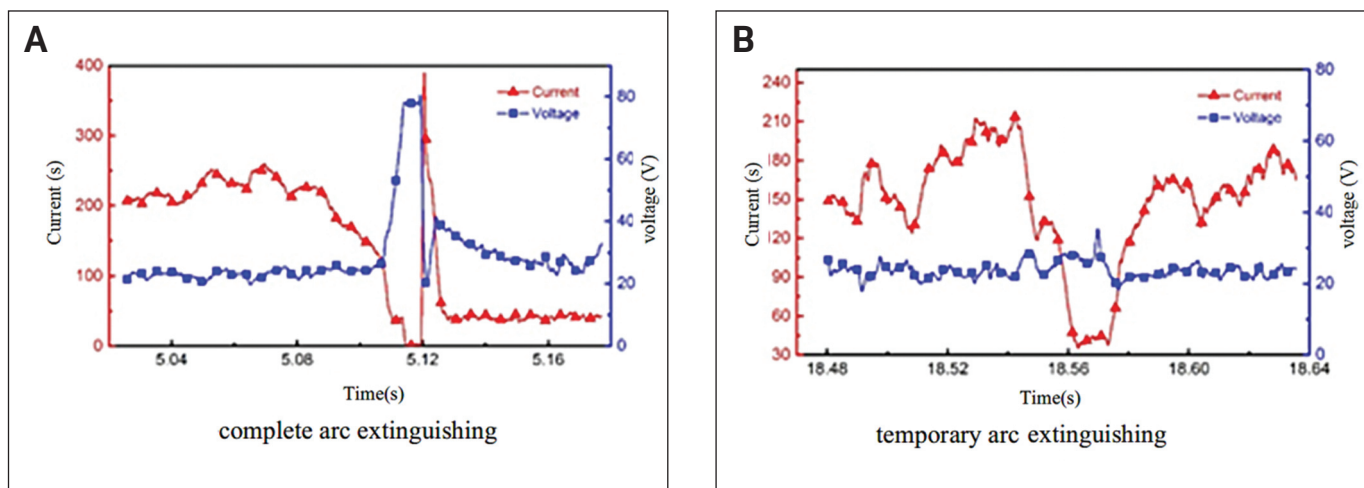


Fig. 11 — Electrical signal fluctuations: A — Complete; B — temporary arc extinguishing under the constant-voltage mode.

motion forces applied on the droplets, such as gravity, electromagnetic force, and plasma flow force, were lower.

As shown in Fig. 8B, the droplet continued to grow until its diameter exceeded that of the wire. The welding arc could not cover the droplet volume anymore. The arc anode spot was located on the surface below the liquid droplet. Therefore, the plasma-flow force did not apply to the droplet. Under the impact of gas flow due to thermal decomposition of the flux core, the inner gas flow of the bubbles, and so forth, the repulsive forces pushed the droplet upward and to the side of the wire, as shown in Fig. 8C.

Note that when the FCAW was carried out in air, the grown droplet also deviated to one side of the wire. However, it soon detached from the wire end and was transferred to the molten pool in a short time. Comparatively, in an underwater environment, due to the special interactions between the bubbles, arc, and droplets, the droplet would be pushed upward and outward by the repulsive forces. Thus, the droplet continued to grow when hanging at the wire end and deviated from the wire axis, as shown in Fig. 8D.

When the droplet continued to grow until the moment shown in Fig. 8E, the downward promotion forces, especially gravity and electromagnetic force, prevailed. The droplet was then forced to detach from the wire end and transferred to the weld pool, as shown in Fig. 8F.

It should be noted that the given ideal six stages are not always in accordance with the real situation. For example, during the first two stages, i.e., the initial stage and the growing stage (Fig. 8A and B), the droplet rotated or deviated from the wire rather than keeping coaxial; however, the surface tension force made it return back in a short time. For the mentioned deviation stage (Fig. 8C), the droplet had a sufficient volume, and the surface tension was offset by the increased gravity; the droplet could not return back anymore. Comparing the conventional constant voltage and the pulse-current FCAW processes under the same average current level, the three stages (Fig. 8A–C) occurred over almost the same length of time, approximately 60–70 ms. Therefore, it could be concluded that shortening the time length of the three stages requires higher heat input, which could be considered for following waveform optimization.

For the deviated large droplet stage (Fig. 8D), the time

length varied in a large range. In conventional constant-voltage wet FCAW, this stage lasted for 150 to 200 ms. Comparatively, in the pulse-current condition, the time length changed from 30 ms to 200 ms. That is to say, the applied pulse current in this stage significantly influenced the droplet detaching behaviors. In the situation of the minimum value of 30 ms, the pulse current decreased the metal transfer cycle in a large amplitude. However, the effect of the present pulse current was not stable and accurate. Further optimization of the current waveform was required.

Force Analysis and Pulse-Current Influence

According to the above analysis, it was found that the long duration of the fourth stage of metal transfer (Fig. 8D), i.e., the deviated large droplet stage, was the main factor causing the long cycle, low frequency, and instability of the metal transfer. It was critical to preliminarily analyze the applied forces on the droplets for precise adjustment and regulation of the behaviors, as shown in Fig. 9.

As can be seen, the droplet was located on one side of the wire, and the welding arc was located right below the droplet. Thus, the droplet and arc were both deviated from the wire axis. The yellow lines represent the main current flow paths. Due to the complex force applications, the liquid droplet was repelled upward and outward. Different forces were discussed based on their orientations.

At this moment, the upward forces (F_U) applied on the droplet mainly included buoyancy, the drag force, arc forces, and so on. The buoyancy was produced because the droplet was immersed in the bubble gases, which was relevant to its volume and density differences. The drag force was due to the rapidly flowing gas inside the bubbles. The arc forces were mainly composed of anode spot forces and evaporation recoil force. Note that the plasma flow force can be neglected because the large-size droplet was completely outside and above the arc plasma flow. Generally, the resultant upward force was expressed as F_U . The downward force was mainly the gravity (G), which increased along with the increasing droplet volume. Please note that the generated electromagnetic pinching force pointed to the welding current paths. Because the droplet was repelled upward and outward, the

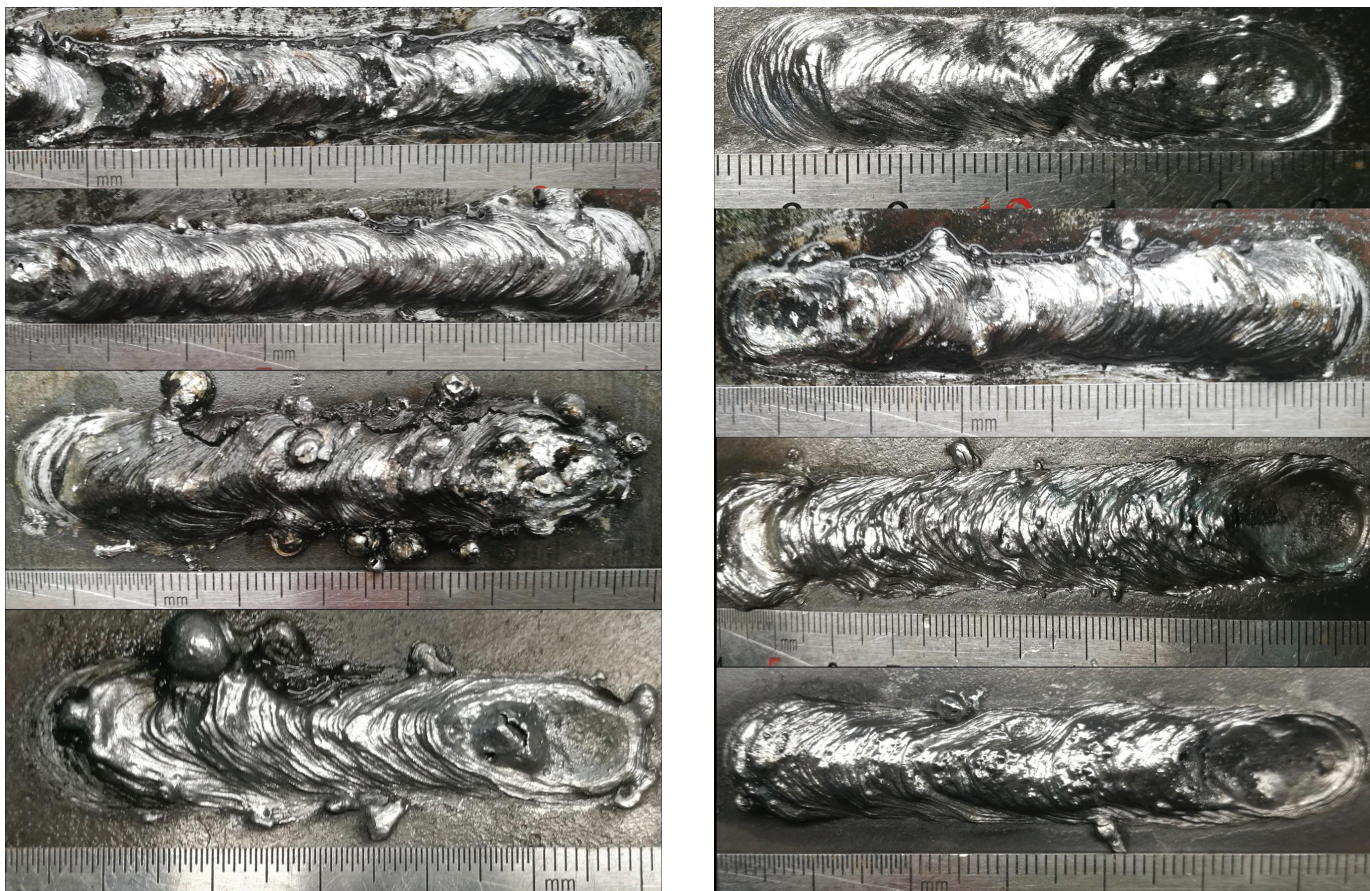


Fig. 12 — Comparison of weld appearance under constant-voltage (left) and pulse-current (right) modes.

dramatically changing shapes at the necking point caused that the resulting pinching force (F_p) direction was slanted downward and outward.

It was thought the rightward forces (pushing the droplet away from the wire) were mainly caused by the complex and turbulent gas flow (marked as F_g). On one side, the thermal decomposition of flux core continuously released an amount of gases not only from the droplet but also from the below weld pool. On the other side, the surrounded water was ionized and generated an amount of H_2 , O_2 , and vapor. The surface tension F_s tried to pull the droplet back to the wire axis; therefore, its direction was approximately towards the left.

Overall, the force equilibrium on the droplet was maintained temporarily under the above condition. Although the droplet volume continued to increase, it would not detach from the tip of the wire until its diameter was three to four times that of the wire diameter, and the gravity (G) was large enough. The special relative positions delayed the droplet necking and detaching processes; large-size droplets were required due to the gas flow influences in the underwater environment.

Under the condition of pulse current, the droplets were forced to oscillate at this stage (the deviated large droplet stage), as shown in Fig. 7 (note that the oscillation can be more easily recognized from the video). It was thought that the rapidly changing welding current resulted in rapidly changing forces. The force equilibrium was frequently disturbed, which caused the droplet to oscillate. The oscillation

kept stretching or shoving the large droplet from time to time. Necking was easier to occur, which further strengthened the electromagnetic pinching force (F_p) and reduced the surface tension (F_s). Thus, for the metal transfer, the resistance force decreased and the promoting force increased. As shown in Figs. 6 and 7, at 4.518 and 4.670 s, respectively, the two droplets detached from the wire end and were transferred along the slant downward and outward trajectories.

The experiments showed that the applied pulse current could accelerate the metal transfer process in wet FCAW. However, the duration of the deviated large droplet stage varied in a large range (from 30 to 200 ms). It was thought that the pulse current waveform did not match the corresponding metal transfer processes very well. The improvement of reducing the metal transfer cycle and increasing its frequency was not stable.

Therefore, according to the experimental data and analysis, the pulse-current waveform needed to be optimized to change the current immediately when the droplet entered the deviation and deviated large droplet stages. Thus, the relevant forces could be changed, promoting the droplet detachment from the wire as soon as possible. The deviated large droplet stage, as well as the whole metal transfer cycle, could be greatly shortened.

Welding Process Stability

The U-I diagrams during conventional constant-voltage

and pulse-current wet FCAW processes were compared to examine the welding process stability as shown in Fig. 10. Experiments were designed using the same level of average welding current. Overall, the U-I distribution in pulse-current welding was more concentrated, as shown in Fig. 10A–C, than in constant-voltage mode, as shown in Fig. 10D–F. That means that most of the time the electrical signals were stable without violent fluctuations; the pulse-current welding process was more stable than the constant-voltage mode. In addition, the proportions of low (< 50 A) or high (> 450 A) welding current areas were apparently much lower than that the constant-voltage mode. It was thought that low the welding-current area meant arc extinguishing, or at least unstable arc burning. Therefore, it can be concluded that the arc-extinguishing frequency in the pulse-current mode was much lower than that in the constant-voltage mode.

Analyzing the typical U-I signals during constant-voltage wet FCAW in Fig. 10D–F, it was found that the U-I signals were gathered in a larger range than the pulse-current conditions. According to the characteristics, three typical disturbance areas were given in Fig. 10E, including the complete arc-extinguishing region (I), the temporary arc extinguishing region (II), and the short-circuit transfer region (III). The three special U-I areas were used to help analyzing the welding stability differences between constant-voltage and pulse-current wet FCAW. According to the authors' observation, there were mainly two types of arc extinguishing in underwater welding, namely complete arc extinguishing and temporary arc extinguishing. The corresponding electrical signals are shown in Fig. 11.

As shown in Fig. 11A, in the complete arc-extinguishing period, the fluctuation of the electrical signals were typical and similar to conventional GMAW in air. Actually, the arc was completely extinguished; the volume of bubbles decreased sharply; and the continuity of welding process was greatly affected. The characteristics of the temporary arc extinguishing were different because the arc was only temporarily extinguished as seen in Fig. 11B. In the short period, a sharply decreased welding current and a slightly increased arc voltage were observed. The surrounding bubble did not shrink much and continued to shield the arc-burning area. In a short time, the arc was reignited without direct contact between the wire and the weld pool.

Through analysis and comparison, the following characteristics were found. Firstly, the performance of the constant-voltage mode and pulse-current mode in the complete arc-extinguishing area (I) was basically the same. The constant-voltage mode had a slightly less complete arc extinguishing, so this mode was better. Secondly, the proportion of the short-circuit metal transfer area (III) was significantly lower in the pulse-current mode than that in the constant-voltage mode. Previous analysis showed that surface-tension transfer or short-circuit transfer was not a perfect transfer mode for underwater wet welding process. In the process of metal transfer, arc extinguishing and bubble production decreased sharply, which directly affected arc reignition after metal transfer, thus deteriorating the stability of the welding process. In the pulse-current mode, the short-circuit transfer area took less proportionally, which made the mode of metal transfer more single and improved the

metal transfer process. It has been demonstrated that the metal transfer modes are complex (usually two to three kinds) under various parameters in constant-voltage wet welding. The experiments in this paper verified that under the pulse-current mode, the metal transfer mode is single, which was more conducive to enhancing the stability of the underwater wet welding process and to improving the metal transfer mode by other means in the follow-up. Finally, the pulse-current mode performed better in the temporary arc extinguishing area than in the constant-voltage mode. In underwater pulse-current wet welding, there were almost no short-circuit transfer and surface-tension transfer; the frequency of temporary arc-extinguishing was greatly reduced, while the stability of the welding process was improved. Therefore, the performance of the pulse-current wet FCAW was much better than the constant-voltage welding. Frequent arc extinguishing, as well as more spatter and deteriorated process stability, were avoided.

Weld Appearance

As shown in Fig. 12, the obtained weld appearances under the constant-voltage mode and pulse-current mode were compared. The more stable welding processes resulted in improved weld formation.

The left set of images of Fig. 12 show that the weld appearance varied significantly even with the exact same welding parameters. It indicated that the metal transfer processes, as well as the bubble evolution and arc burning, were not stable. During the complicated welding processes, the weld formation was influenced randomly by the surrounding water without any regulation. Although good topside appearance was occasionally achieved in the second one, more spatter or interrupted weld was observed in the other three experiments, which led to overlap defects on the surface or discontinuous welds.

Comparatively, as shown in the right set of images of Fig. 12, the obtained welds under the pulse-current mode were generally acceptable. Based on the regulated metal transfer by pulse-current waveform, the generated spatter was significantly reduced, and more uniform welds were acquired. In this case, the pulse current successfully avoided the droplets flying outside the bubbles and changing into spatter.

Conclusions

1. A novel underwater pulse-current wet FCAW was proposed to regulate complicated metal-transfer processes. The corresponding current waveform was preliminarily proposed, designed, and realized. The arc length control strategy was designed to maintain stable arc burning. Acquired electrical signals showed arc voltage was successfully maintained in a reasonable range; no arc interruption or complete arc extinguishing happened; and arc length control was effectively maintained using a hybrid controller.

2. Analyzing the synchronously collected electrical and visual signals in two typical metal transfer cycles, the metal transfer mode in pulse-current FCAW is still categorized as repelled globular transfer. Compared to the initially proposed control strategy, the regulated metal transfer needs

three or four pulse cycles to transfer one droplet, which does not match the assumed situation.

3. According to the relative positions between droplet, arc, and wire, the metal transfer process under pulse current can be divided into six stages, i.e., initial stage, growing, deviation, deviated large droplet, detaching, and transferring. The time length for the deviated large droplet stage varied in a large range. The applied pulse current changed the period from 150 to 200 ms in the constant-voltage mode into 30 to 200 ms. Long duration of the deviated large droplet stage was the main factor causing the long cycle, low frequency, and instability of the metal transfer. The pulse current in this stage significantly influenced the droplet detaching behaviors and decreased the metal transfer cycle in a large amplitude. However, the effect of the present pulse-current was not stable and accurate.

4. Force analysis showed that the special relative position of droplets to the welding wire changed the direction of arc force. The upward forces applied on the droplet mainly included buoyancy, the drag force, and arc force. The rightward forces (pushing the droplet away from the wire) were mainly caused by the complex and disorderly gas flow (F_g). Special relative positions delayed the droplet necking and detaching processes; large-size droplets were required due to the gas flow influences. The rapidly changing welding current resulted in rapidly changing forces; therefore, the applied pulse current forced the droplets to oscillate at the deviated large-droplet stage.

5. Process stability analysis showed that, in pulse-current wet FCAW, there was almost no short-circuit transfer and surface-tension transfer; the frequency of temporary arc extinguishing was greatly reduced while the stability of welding process was improved. The performance of the pulse-current wet FCAW was much better than that of constant-voltage welding, avoiding frequent arc extinguishing, spatter, and deterioration of the process stability.

6. During the constant-voltage welding process, the weld formation was influenced randomly by the surrounding water without any regulation, causing spatter or an interrupted weld. Comparatively, the pulse-current FCAW obtained optimized weld formation by regulating the metal transfer and avoiding the droplets flying outside the bubbles and changing into spatter. Additionally, the effect of the underwater bubbles cannot be neglected and the behavior of the bubbles under pulsed current needs further analysis.

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Interactive Phenomena in Hybrid KPAW–GMAW–P

The interaction of the arc, droplet, keyhole, and weld pool improves weld pool convection in a hybrid KPAW–GMAW–P technique

BY D. WU, S. TASHIRO, Z. WU, K. NOMURA, X. HUA, AND M. TANAKA

ABSTRACT

A hybrid welding technique formed by combining keyhole plasma arc welding (KPAW) and pulsed gas metal arc welding (GMAW–P) is characterized by the complex interactions of the arc, droplet, keyhole, and weld pool. With the help of a high-speed video camera, zirconia particles, and a thermal camera, the complex interactive phenomena of the hybrid KPAW–GMAW–P process was analyzed. Owing to the formation of a direct-current path between the KPAW cathode (tungsten electrode) and the GMAW anode (welding wire), the ionized plasma arc was extended to the GMA side, causing an expansion of the GMA. The current at the GMAW droplet was diverged; thus, the Lorentz force promoted a more stable one pulse one droplet metal transfer mode compared with that of GMAW–P. The strong backward flow from the keyhole was suppressed because of the pull-push flow pattern on the top surface of the weld pool between the two arcs. As the heat and molten metal in the weld pool were transported from the region near the GMA (high temperature) to the region near the plasma arc (low temperature), the weld pool temperature decreased.

KEYWORDS

- Hybrid Welding • Arc Interference
- One Pulse One Drop • Weld Pool Convection
- Pull-Push Flow Pattern

Introduction

To suppress weld defects and improve the weld bead formation of keyhole plasma arc welding (KPAW), the paraxial hybrid KPAW and gas metal arc welding (GMAW) capable of successfully welding 12-mm-thick carbon steel plates in one pass has been proposed by many researchers (Refs. 1, 2). In this welding technique, the plasma torch is located at the leading direction, and the tungsten electrode is the cathode. The GMAW gun is located at the rear direction, and the welding wire is the anode. Therefore, the hybrid KPAW–GMAW technique forms a direct-current path between the KPAW cathode (tungsten electrode) and the

GMAW anode (welding wire) through the plasma arc, and arc interference can be observed. A deeper understanding of the interactive phenomena of the hybrid KPAW–GMAW process can provide guidance to welding engineers in their development of welding procedures to obtain high-quality welds.

Both hybrid gas tungsten arc welding (GTAW) and GMAW and hybrid KPAW–GMAW are characterized by the formation of a direct-current path between the cathode (tungsten electrode) and the GMAW anode (welding wire) (Ref. 3). In the hybrid GTAW–GMAW technique, the cathode spots of the GMA become stable (Ref. 4). The temperature gradients on the top surface at the middle and rear parts of the hybrid weld pool are lower than that in the conventional GMA weld pool, while the heat input is increased (Ref. 5). Owing to the additional heat input and electromagnetic force generated by the GTA, the GMA length increases, and the droplet transfer is easy and stable (Refs. 4, 6). In the hybrid KPAW–GMAW technique, because of the strong impingement of the plasma arc (PA), a large keyhole forms (Ref. 2) that may have a significant influence on the arc and droplet behaviors and weld pool convection. Han et al. (Ref. 7) proposed the electrical conductivity of the GMA increased in the hybrid variable polarity plasma arc (VPPA)–GMAW technique because of the large number of metal ions and electrons provided by the keyhole. Furthermore, the VPPA had a compression effect on the GMA.

Both the hybrid laser-GMAW and hybrid KPAW–GMAW techniques are characterized by complex interactions of the arc, droplet, keyhole, and weld pool. In the hybrid laser-GMAW technique, the metal temperature increases, and intense evaporation occurs because of the irradiation of the laser beam on the base metal surface (Ref. 8). Under the influence of the vaporization-induced recoil pressure, a keyhole with a large depth-to-width ratio is generated (Ref. 9). Shinn et al. (Ref. 10) found a laser can stabilize the arc cathode spots in the hybrid laser-GMAW of a titanium alloy. Zhang et al. (Ref. 11) investigated the plasma and droplet behaviors of a hybrid CO₂ laser-GMAW and proposed the metal vapor jet from the keyhole acted as a resistance force on the droplet and suppressed droplet transfer. Liu et al. (Ref. 12) calculated the forces acting on a droplet in hybrid

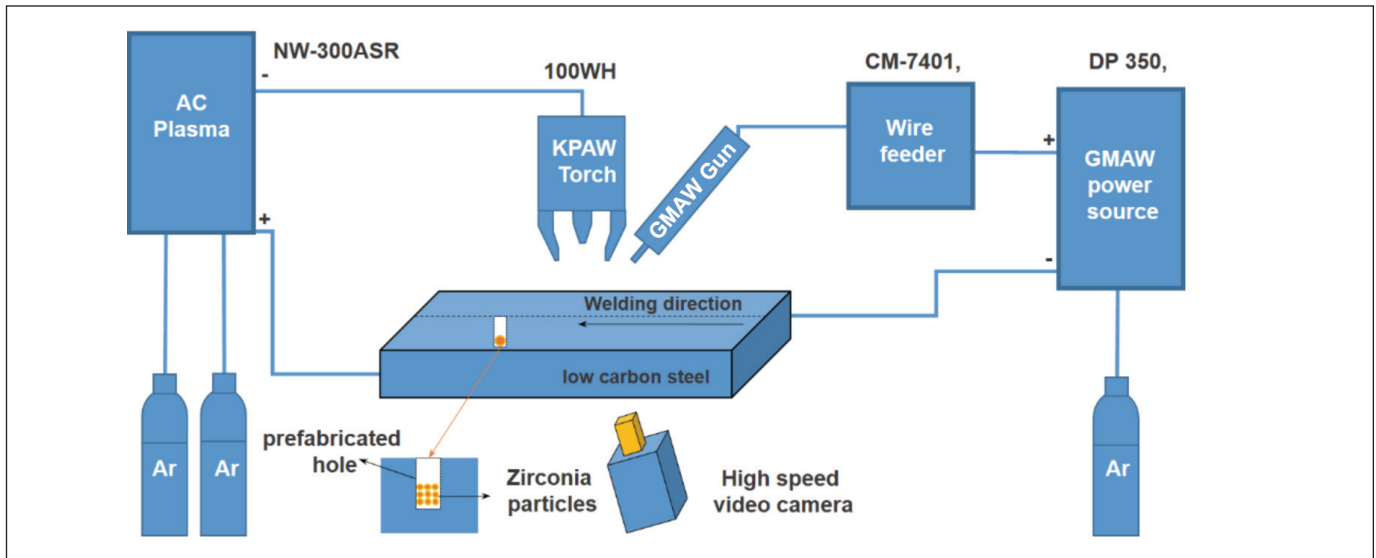


Fig. 1 — Welding experiment setup of hybrid KPAW-GMAW-P.

laser-GMAW and found that the laser plasma compressed the arc and increased the electromagnetic resistance force of the droplet; thus, the droplet shape changed and the droplet transfer frequency decreased. Zhao et al. (Ref. 13) measured the fluid flow of the weld pool of a hybrid laser-GMAW by an advanced x-ray transmission imaging system and found that the arc shear stress and droplet momentum promoted an inward flow in the keyhole. However, in hybrid KPAW-GMAW, the molten-metal temperature near the keyhole was very low (Ref. 14), and the metal evaporation of the weld pool was very weak (Ref. 15); therefore, the metal vapor jet from the keyhole may have a minor influence on droplet transfer. Furthermore, the keyhole size is relatively large, and the action areas of the plasma arc pressure and plasma arc shear stress are very large (Ref. 16); thus, the droplet momentum may have a minor influence on the fluid flow near the keyhole. It can be concluded that the interactive phenomena of the arc, droplet, keyhole, and weld pool in hybrid KPAW-GMAW may differ significantly from those of hybrid laser-GMAW.

Pulsed GMAW (GMAW-P), especially the one pulse one drop (OPOD) metal transfer mode, is capable of reducing spatter and stabilizing the GMA (Ref. 17). However, the

welding parameter range for obtaining a stable OPOD mode is very narrow (Refs. 18, 19). In this study, the paraxial hybrid KPAW-GMAW-P technique was used, and a stable OPOD mode was obtained. During welding, the arc, droplet, keyhole, and weld pool behaviors were captured by a high-speed video camera. The measurement of the fluid flow of the weld pool was aided by zirconia particles. The weld pool temperature was measured with a thermal camera. Based on the observation of the complicated interactive phenomena of the arc, droplet, keyhole, and weld pool in hybrid KPAW-GMAW-P, the influences of arc interference and keyhole behaviors on the droplet transfer are discussed, and the convective patterns in the weld pool and their driving forces are revealed. Even though the heat input was much higher, the maximum temperature of the weld pool in hybrid KPAW-GMAW-P was lower than that of GMAW-P; this thermo-physical phenomenon is also explained.

Experiment Procedures

The welding experiment setup is shown in Fig. 1. A transfer-type plasma arc welding torch (100WH, Nippon

Table 1 — Detailed Welding Parameters

KPAW Torch Orifice Diameter	KPAW Electrode Diameter	KPAW Electrode Setback	KPAW Torch and GMAW Gun Distance	GMAW Gun Angle	Welding Wire Diameter	CTWD (KPAW)
4.0 mm	4.8 mm	3 mm	22 mm	70 deg	1.2 mm	5 mm
CTWD (GMAW)	Welding Speed	Plasma Gas Flow Rate (Ar)	KPAW Shielding Gas Flow Rate (Ar)	GMAW Shielding Gas Flow Rate (Ar)	KPAW Current	Wire Feed Rate
15 mm	3 mm/s	2.5 L/min	10 L/min	15 L/min	DC 280 A	5.8 m/min

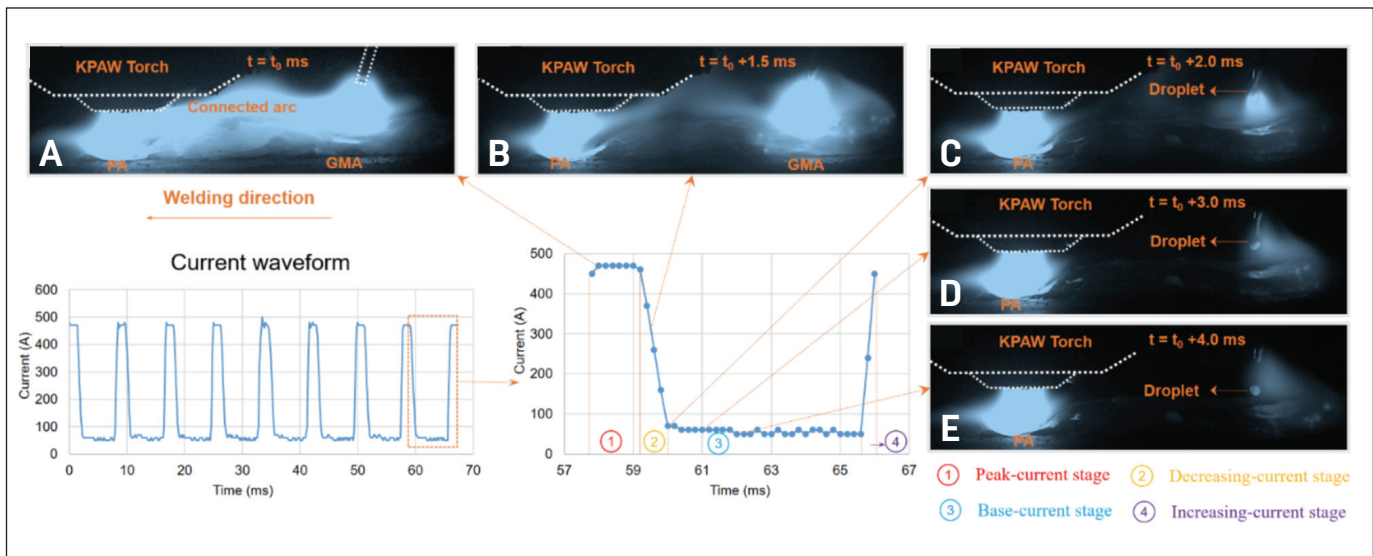


Fig. 2 — Current waveform, arc, and droplet behaviors of hybrid KPAW-GMAW-P.

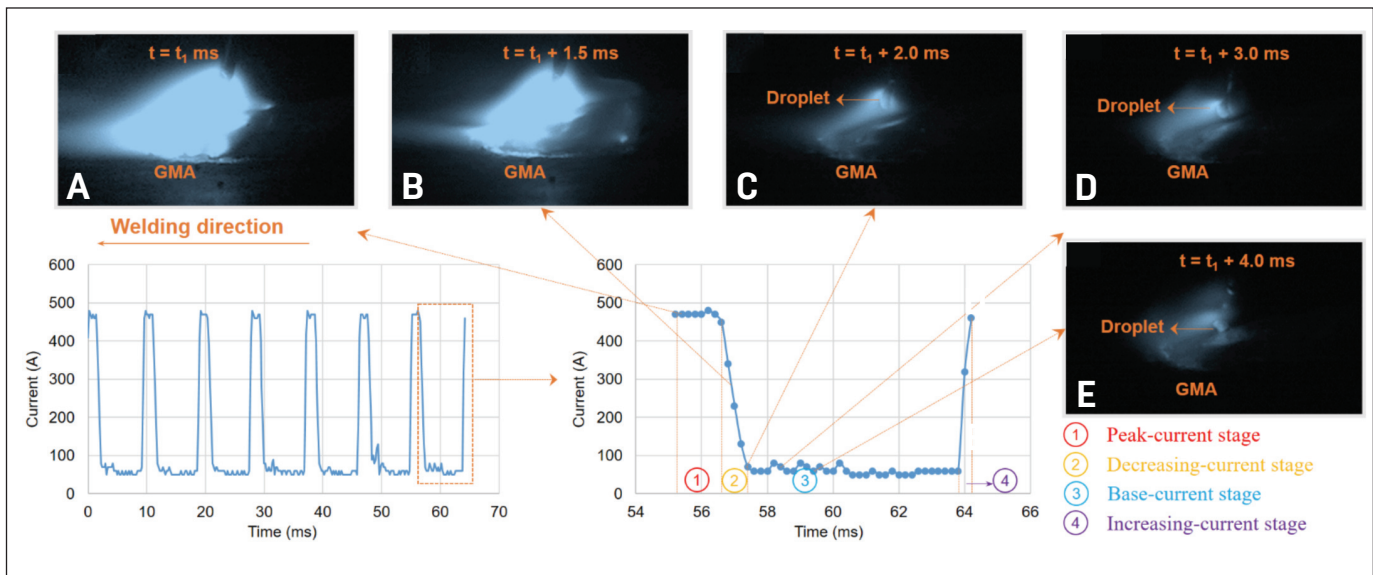


Fig. 3 — Current waveform, arc, and droplet behaviors of GMAW-P.

Steel Welding & Engineering Co. Ltd.), a KPAW power source (NW-300ASR, Nippon Steel Welding & Engineering Co. Ltd.), a GMAW power source (DP 350, Daihen Co. Ltd.), and a wire feeder (CM-7401, Daihen Co. Ltd.) were used as the welding equipment. Carbon steel plates with a thickness of 12 mm (SS400) were used as the base metal. A constant current was adopted for KPAW, and the pulsed mode was adopted for GMAW. Detailed welding parameters are listed in Table 1.

During welding, the current waveform of GMAW was measured by a clamp meter, and the measurement was sent to a datalogger at a frequency of 1 MHz. The arc and droplet behaviors were observed by the high-speed video camera, and the frame rate was 2000 frames/s. To measure the fluid flow of the weld pool before welding, the zirconia particles were placed into prefabricated holes in the base metal. During welding, the movement of the zirconia par-

ticles on the surface of the top weld pool was measured by the high-speed video camera with a frame rate of 2000 frames/s. A thermal camera (Miro Ex4 Phantom, Vision Research Inc.), including three color sensors composed of red (R), green (G), and blue (B) was adopted to obtain the weld pool surface images immediately after switching off the arcs. The weld pool temperatures can be calculated from the ratio of the R to the G sensor signal in the images based on the two-color pyrometry method. The arcs completely disappeared within 1.0 ms after switching off the arcs; therefore, the surface temperature decrease can be ignored (Ref. 20). Detailed descriptions of the observation and measurement methods can be found in our previous work (Ref. 14). For the GMAW-P and hybrid KPAW-GMAW-P, the temperatures of the weld pools were obtained after the droplet transfer in the base current stage.

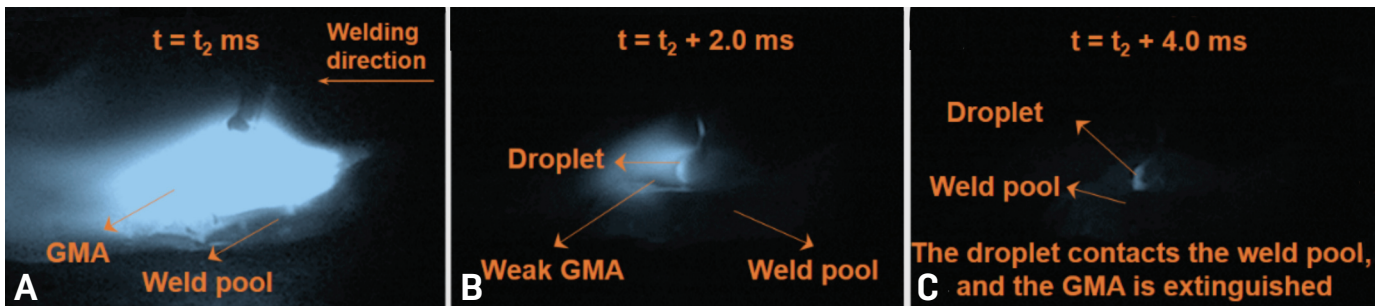


Fig. 4 — Short-circuit transfer mode of GMAW-P.

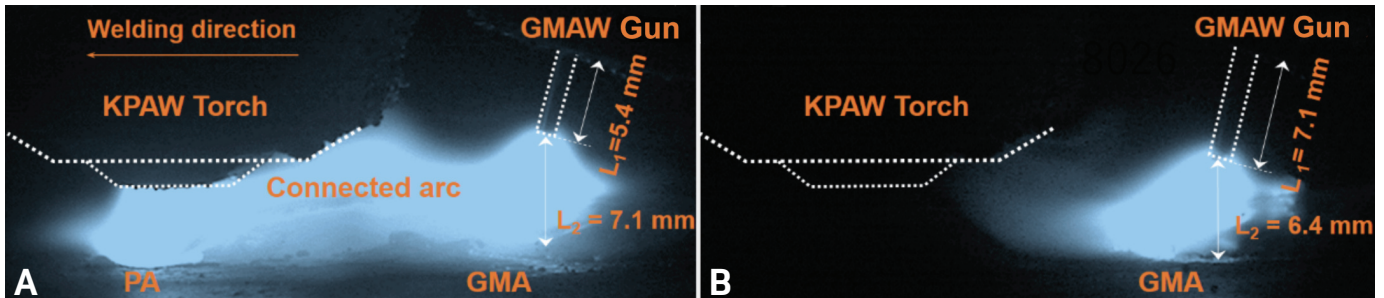


Fig. 5 — Comparison of arcs of hybrid KPAW-GMAW-P and GMAW-P.

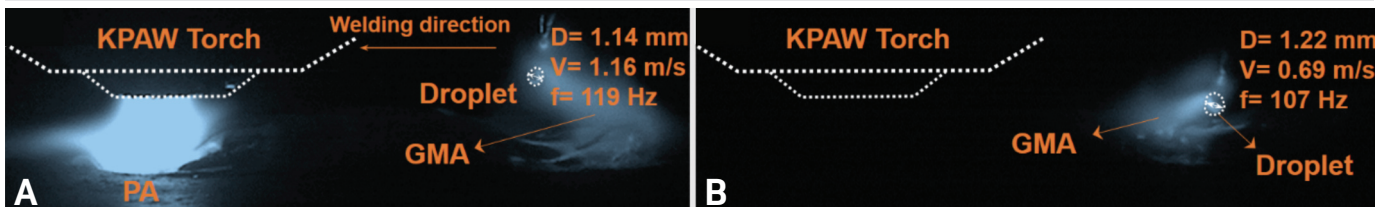


Fig. 6 — Comparison of droplet behaviors of hybrid KPAW-GMAW-P and GMAW-P.

Results

Arc and Droplet Behaviors in the Hybrid Technique

The current waveform, arc, and droplet behaviors of hybrid KPAW-GMAW-P are shown in Fig. 2. In the peak current stage, both the PA and GMA were very bright. The two arcs connected, and a direct-current path formed between the KPAW cathode (tungsten electrode) and the GMAW anode (welding wire) through the plasma arc as shown in Fig. 2A. In the decreasing current stage, the two arcs separated, and the arc interference became weak as shown in Fig. 2B. As shown in Fig. 2C, at the end of the decreasing current stage, the GMA was still bright near the wire axis but very weak and far from the axis. In the base current stage shown in Fig. 2D, the GMA was slightly weak, and a globular droplet detached from the tip of the welding wire. In Fig. 2E, the droplet almost reached the top surface of the weld pool. The average current of hybrid KPAW-GMAW-P was 170.1 A. In summary, the stable OPOD mode was obtained by the hybrid KPAW-GMAW-P technique. The arc interference was strong only during the peak current stage.

The current waveform, arc, and droplet behaviors of GMAW-P are shown in Figs. 3 and 4. Two droplet transfer

modes were observed: globular and short-circuit transfer mode.

As shown in Fig. 3, during the peak current stage, the GMA was very bright, and during the decreasing current stage, the arc length and width decreased. During the base current stage, a globular droplet was transferred. The average current of the GMAW-P was 157 A.

As shown in Fig. 4, the GMA length was short. When a globular droplet was almost detached from the tip of the welding wire, it contacted the weld-pool and extinguished GMA.

Here, the wire extension length (L_1) and arc length (L_2) are presented based on statistics of several pulse periods. As shown in Fig. 5, the wire extension lengths of the hybrid KPAW-GMAW-P and GMAW-P (globular transfer mode) were 5.4 and 7.1 mm, respectively. The arc lengths of the hybrid KPAW-GMAW-P and GMAW-P (globular transfer mode) were 7.1 and 6.4 mm, respectively. In summary, the wire extension length of the hybrid KPAW-GMAW-P technique was shorter, while the average arc length was larger.

The droplet diameter, velocity, and transfer frequency are shown in Fig. 6 based on the statistics of several pulse periods. The droplet diameters (D) of hybrid KPAW-GMAW-P and GMAW-P (globular transfer mode) were 1.14 and 1.22 mm, respectively. The droplet velocities (V) of hybrid

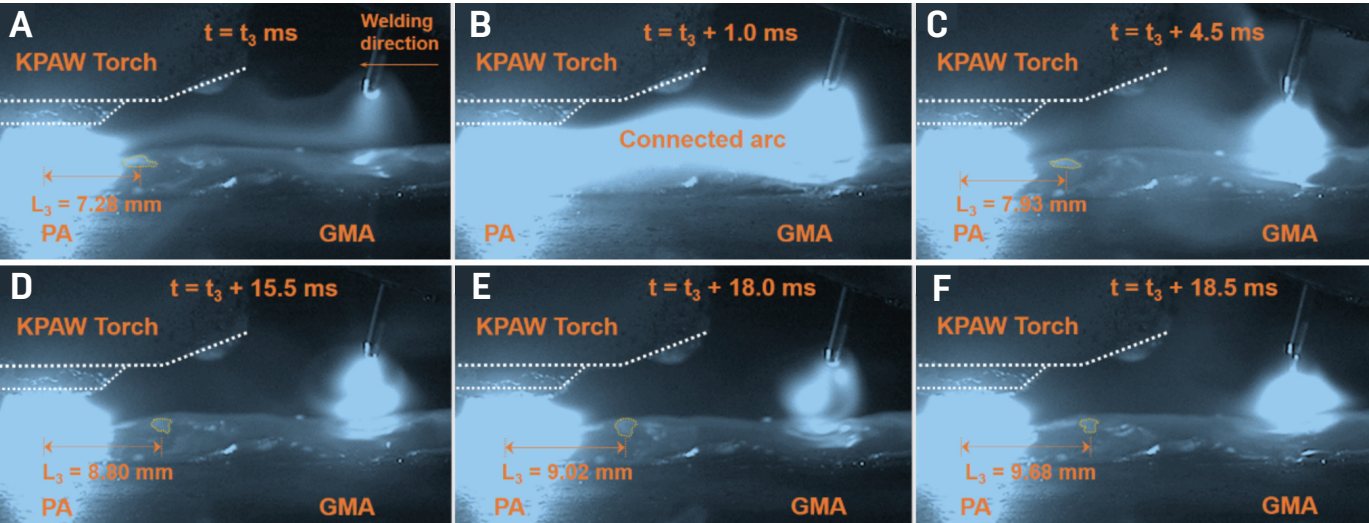


Fig. 7 — Convective patterns on the top surface near the PA.

KPAW–GMAW-P and GMAW-P (globular transfer mode) were 1.16 and 0.69 m/s, respectively. The transfer frequencies (f) of hybrid KPAW–GMAW-P and GMAW-P (globular transfer mode) were 119 and 107 Hz, respectively. In summary, the droplet velocity and transfer frequency of the hybrid KPAW–GMAW-P technique increased, while the droplet diameter decreased.

Convective Patterns of Hybrid KPAW–GMAW-P

As shown in Fig. 7A, in the base current stage, a particle cluster existed on the top surface of the weld pool near the PA, and the distance from the PA center was 7.28 mm. In the peak current stage shown in Fig. 7B, the two arcs connected. As shown in Fig. 7C, in the decreasing current stage, the particle cluster flowed away from the PA, and the distance from the PA center was 7.93 mm. With time, as shown in Fig. 7D–F, the distance between the particle cluster and the PA center increased. In summary, the molten metal on the top surface of the weld pool near the plasma arc flowed backwards in hybrid KPAW–GMAW-P.

As shown in Fig. 8A, in the base current stage, a particle cluster existed on the top surface of the weld pool before the GMA, and the distance from the welding wire center was 5.38 mm. After the peak current stage (Fig. 8B), the particle cluster flowed forward, and the distance from the

welding wire center was 7.20 mm — Fig. 8C. In the base current stage shown in Fig. 8D, the particle cluster flowed backwards, and the distance from the welding wire center decreased. After the next two periods, the particle cluster flowed forward as shown in Fig. 8E–I, and the particle cluster finally stopped at the weld-pool side.

As shown in Fig. 9A, in the decreasing current stage, three particles existed on the top surface of the weld pool after the GMA. In the base current stage, the distance between the particles and the welding wire center increased as shown in Fig. 9B. In the next period, the particles flowed backwards as shown in Fig. 9C and D, and then reached the rear part of the weld pool. In conclusion, the molten metal after GMA flowed backwards in hybrid KPAW–GMAW-P.

The convective patterns on the top surface of the GMAW-P weld pool were similar to those shown in Fig. 9 (Ref. 21), and the convective patterns on the top surface of the KPAW weld pool were similar to those in Fig. 7 (Ref. 22).

Temperature Distribution and Weld-Bead Formation of Hybrid KPAW–GMAW-P

As shown in Fig. 10, in hybrid KPAW–GMAW-P, a high-temperature region existed near the GMA, and the maximum temperature was 2489 K. In the GMAW-P, the maxi-

Table 2 — Comparisons of Arc, Droplet, and Keyhole Behaviors between Hybrid Laser-GMAW-P and Hybrid KPAW–GMAW-P

	Keyhole Temperature	Metal Vapor	Metal Vapor Jet Force Effect	Arc Behavior	GMAW Current Density	Lorentz Force Effect
Hybrid laser-GMAW-P	High	Strong	Suppresses droplet transfer	Arc contraction	Converged	Suppresses droplet transfer
Hybrid KPAW-GMAW-P	Low	Weak	Minor influence	Arc expansion	Diverged	Promotes droplet transfer

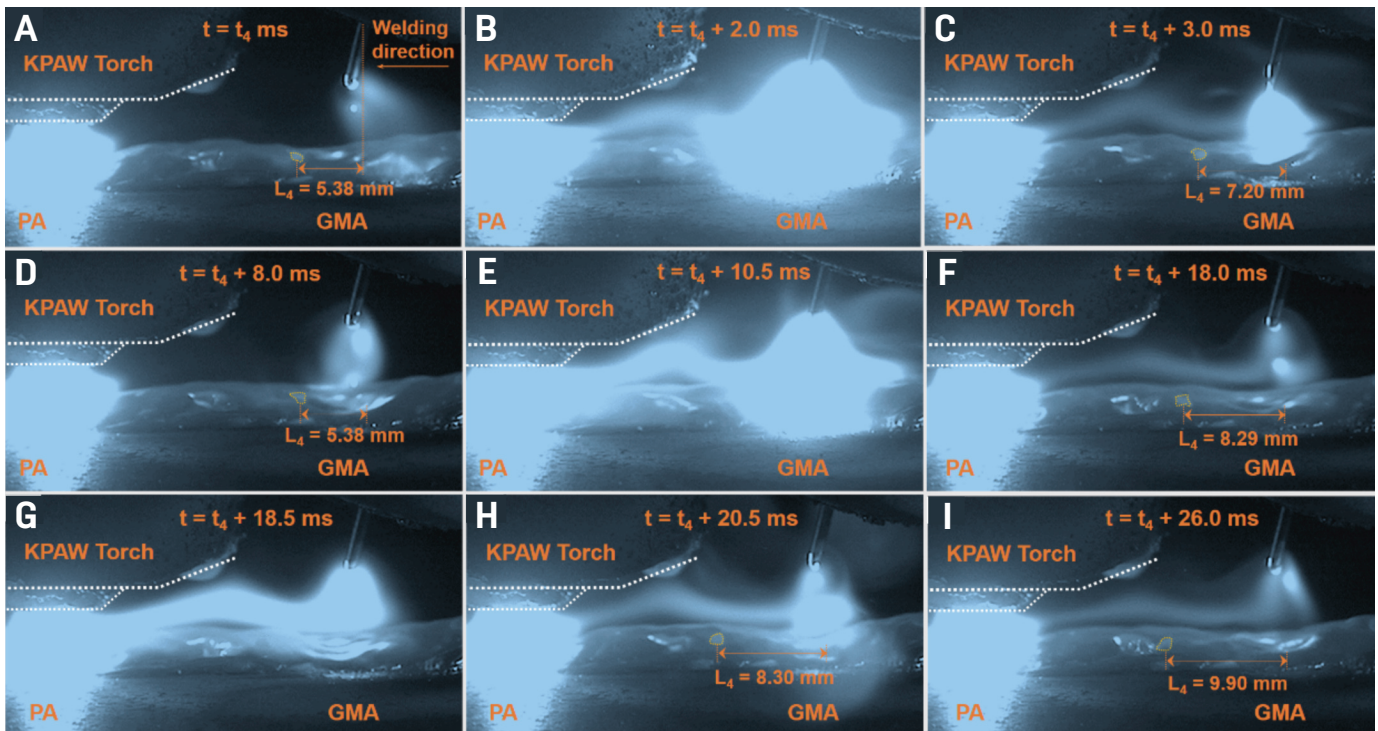


Fig. 8 — Convective patterns on the top surface of the weld pool before the GMA.

imum temperature near the GMA was 2584 K, and high-temperature regions existed at the rear part of the weld pool. As shown in Fig. 10, even though the welding current of KPAW was very high, the maximum temperature of the weld pool was only 2259 K, which is much smaller than that of hybrid KPAW-GMAW-P and GMAW-P.

As shown in Fig. 11A, in hybrid KPAW-GMAW-P, a sound weld bead formation was obtained. In GMAW-P, the weld width was narrow and the reinforcement was high. In KPAW, an undercut formed at the weld toe.

Discussion

Influence of Arc Interference and Keyhole Behavior on Droplet Transfer

Even though both hybrid laser-GMAW-P and hybrid KPAW-GMAW-P are characterized by the complex interaction of the arc, droplet, keyhole, and weld pool, the influence of arc interference and the keyhole behavior on the droplet transfer of these two welding techniques were totally different. In hybrid laser-GMAW-P, the maximum weld pool temperature on the keyhole wall was higher than the boiling temperature of the material, and a large amount of metal vapor was produced. As shown in Fig. 12A, the metal vapor ejected from the keyhole produced a resistance force on the droplet (Ref. 11). Moreover, the current at the droplet converged because of the arc contraction caused by the strong laser plasma. Based on Equation 1 (Ref. 23), the electromagnetic resistance force of the droplet transfer increased (Ref. 12). All of these events contributed to the suppression of the droplet transfer in hybrid laser-GMAW-P.

$$F_{emz} = -\frac{\mu_0 I^2}{4\pi} \left[\frac{1}{4} - \ln \left(\frac{r_d \sin \theta}{r_w} \right) + \frac{1}{1 - \cos \theta} - \frac{2}{(1 - \cos \theta)^2} \ln \left(\frac{2}{1 + \cos \theta} \right) \right] \quad (1)$$

where I is the welding current, r_d is the droplet radius, r_w is the wire radius, θ is the arc hanging angle, and μ_0 is the permeability of free space.

Detailed comparisons of the arc, droplet, and keyhole behaviors between hybrid laser-GMAW-P and hybrid KPAW-GMAW-P are provided in Table 2. In hybrid KPAW-GMAW-P, the maximum weld pool temperature was only 2259 K, which is much lower than the boiling temperature of the material (2900 K); therefore, the metal vapor ejected from the keyhole can be ignored, and the metal vapor jet force had a minor influence on the droplet transfer. The ionized PA was extended to the GMA side because of the formation of a direct-current path between the KPAW cathode (tungsten electrode) and the GMAW anode (welding wire). Based on the minimum voltage principle, an arc has an automatic dropping tendency to drive the electric field intensity E to a minimum value (Ref. 24). As the GMA is heated by the PA, it automatically expands, and the cross-sectional area of the GMA increases. Therefore, the current density decreases, and the electric field intensity E is reduced to a minimum. As shown in Fig. 12B, the current at the GMAW droplet was diverged, and the Lorentz force acted as a detachment force; therefore, the droplet velocity and droplet transfer frequency increased, and the droplet diameter of hybrid KPAW-GMAW-P decreased.

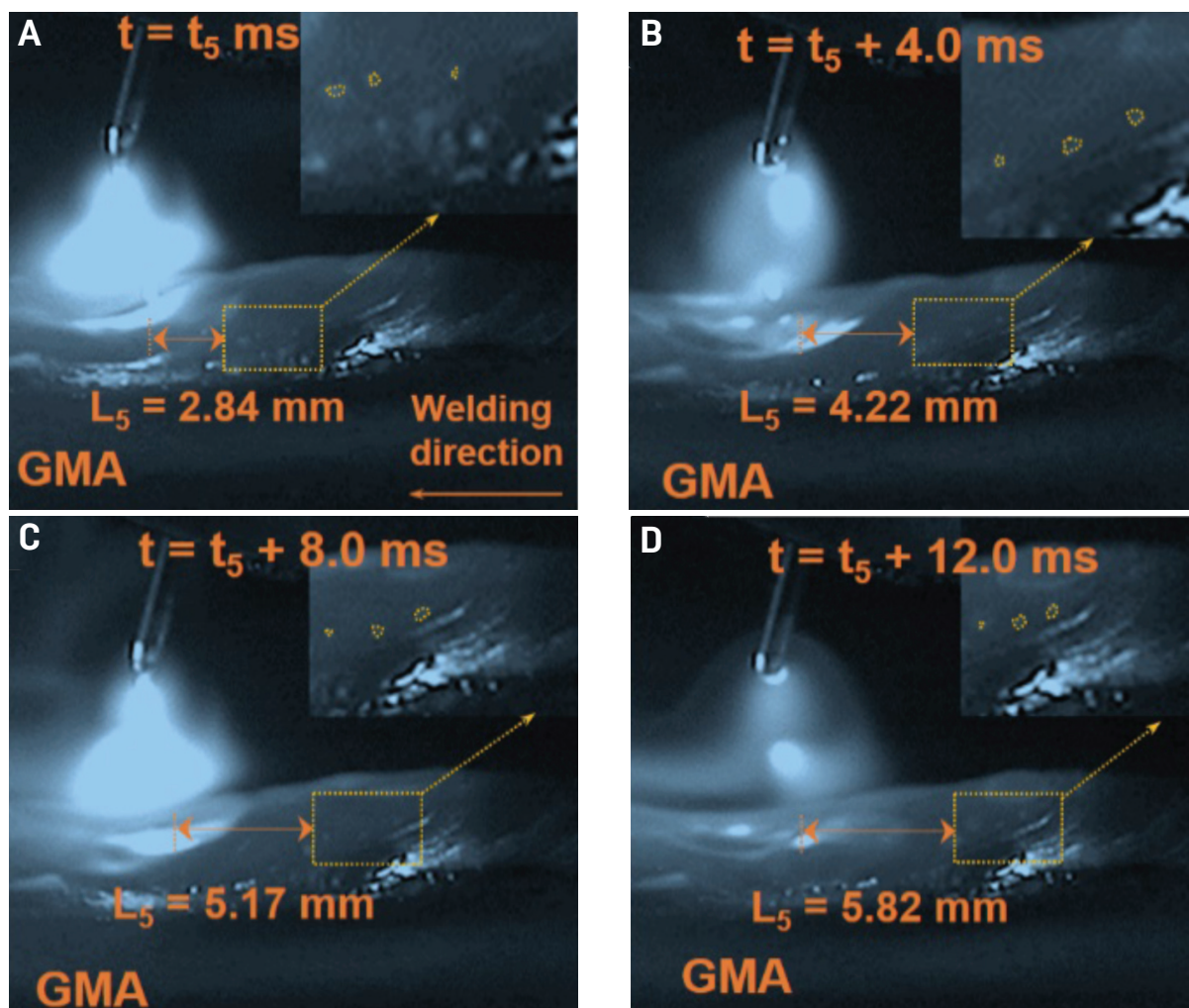


Fig. 9 — Convective patterns on the top surface of the weld pool after the GMA.

more than that of GMAW-P. As a result, the wire extension length was shorter, the arc length longer, and the arc width wider in hybrid KPAW–GMAW-P compared to that of GMAW-P. In summary, the coupled arcs improved the stability of the OPOD metal transfer mode of hybrid KPAW–GMAW-P.

Interaction of the Arc, Droplet, Keyhole, and Weld Pool

Based on the convective patterns of GMAW-P (Ref. 21) and KPAW (Ref. 22) of previous studies and our experimental results, the convective patterns on the weld pool surface and their driving forces in hybrid KPAW–GMAW-P are shown in Fig. 13. Convective pattern 1 (backward flow) on the top surface of the weld pool near the PA was caused by the Marangoni force and the PA shear stress. Convective pattern 2 (forward flow) on the top surface of the transition region was caused by the Marangoni force and the GMA shear stress. Convective pattern 3 (inward flow) on the top surface of the weld pool near the GMA was caused by the arc pressure, Lorentz force, and droplet impingement force. Convective pattern 4 (backward flow) on the

top surface of the weld pool after the GMA was caused by the Marangoni force and the GMA shear stress.

In the peak current stage shown in Fig. 13A, the GMA shear stress was large, and convective pattern 2 (forward flow) on the top surface of the weld pool was strong, while convective pattern 3 (inward flow) was relatively weak. If a particle P_1 is located in the action area of convective pattern 2, it will flow forward as shown in Fig. 8A–C. In the base-current stage shown in Fig. 13B, the GMA shear stress, arc pressure, and Lorentz force were all very small, and convective pattern 2 became weaker. However, the strong droplet impingement caused a strong inward flow, and convective pattern 3 became stronger. If a particle P_2 is located in the active area of convective pattern 3, it will flow inward as shown in Fig. 8C and D. If a particle P_3 is located in the action area of convective pattern 2, it will also flow forward as shown in Fig. 8H and I.

Here, convective pattern 1 (backward flow) is defined as a “pull” flow, and convective pattern 2 (forward flow) as a “push” flow. This pull-push flow pattern on the top surface of a weld pool between the two arcs of hybrid KPAW–GMAW-P is caused by the Marangoni force and the arc shear stress. This flow pattern was also found in tandem GMAW-P

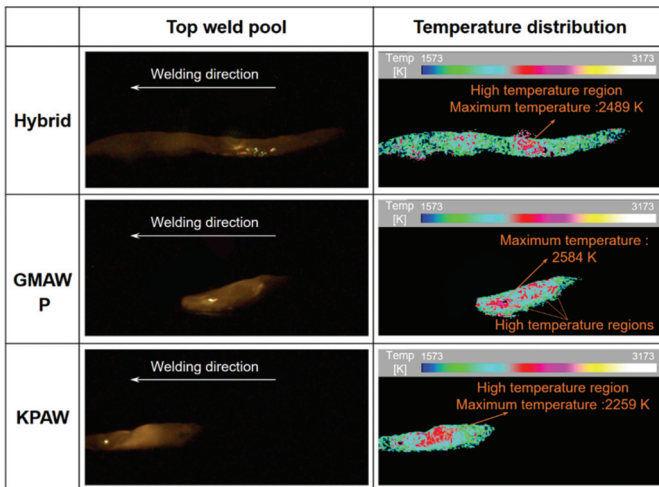


Fig. 10 — Weld pool temperature distributions of hybrid KPAW-GMAW-P, GMAW-P, and KPAW.

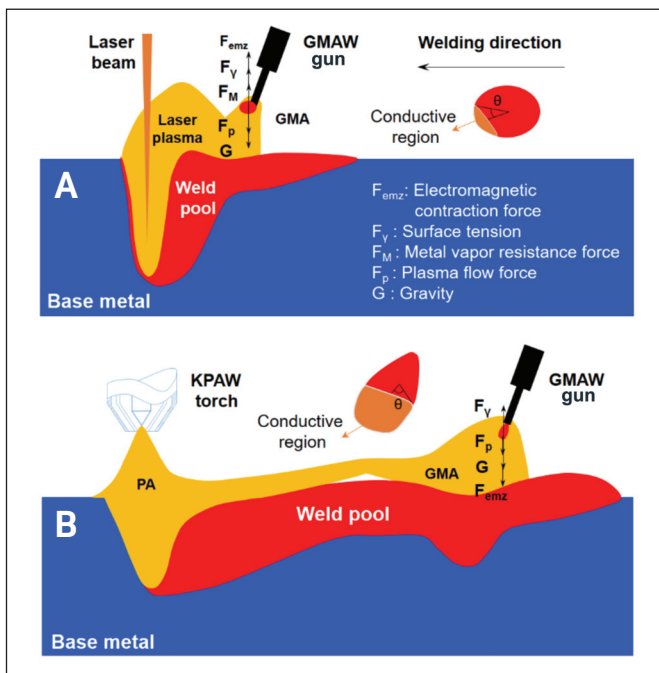


Fig. 12 — Droplet transfer: A — Hybrid laser-GMAW-P; B — hybrid KPAW-GMAW-P.

(Ref. 25), which prevented the irregular backward flow of molten metal and facilitated sound weld bead formation. As revealed in a previous study, the strong backward flow is one of the most important factors for undercut formation in GTAW (Ref. 26). Owing to the pull-push flow pattern of hybrid KPAW-GMAW-P, the strong backward flow from the keyhole is suppressed and prevents undercut formation as shown in Fig. 11.

Even though the heat input was much higher, the maximum weld pool temperatures of hybrid KPAW-GMAW-P (2489 K) and KPAW (2259 K) were lower than that of GMAW-P (2584 K). As revealed in our previous studies, the heat convection of KPAW caused by the fluid flow was the dominant mechanism for heat propagation in the weld pool. Owing to the much higher PA pressure and PA shear

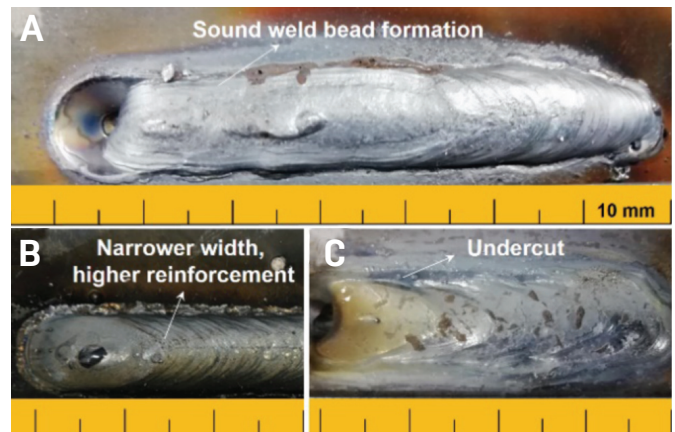


Fig. 11 — Weld bead formation: A — Hybrid KPAW-GMAW-P; B — GMAW-P; C — KPAW.

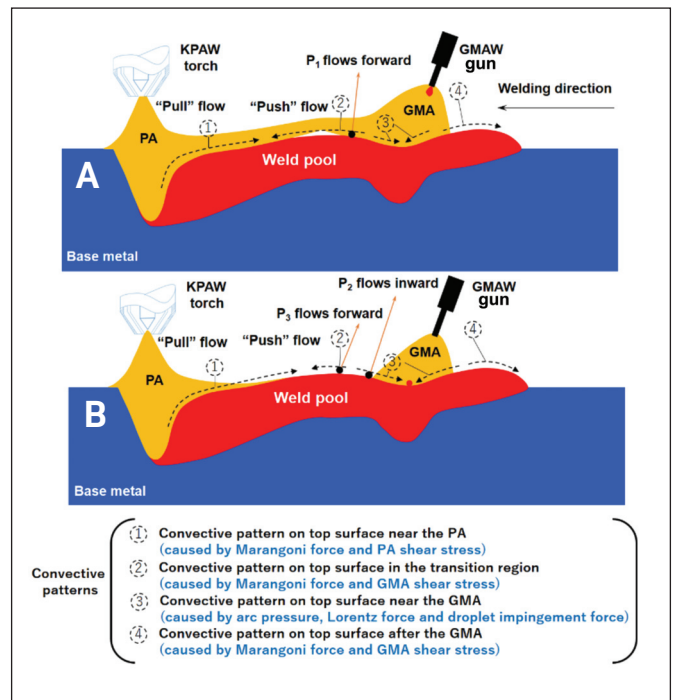


Fig. 13 — Convective patterns on the top surface of the weld pool and their driving forces in hybrid KPAW-GMAW-P: A — Peak current stage; B — base current stage.

stress, the fluid flow and heat propagation in the weld pool were strong. Heat does not accumulate in a keyhole but is transported to the entire weld pool together with the molten metal, causing a relatively low-temperature distribution near the PA (Refs. 14, 16). As shown in Fig. 14, in hybrid KPAW-GMAW-P, the weld pool temperature was lower in the region near the PA and higher in the region near the GMA. The molten metal in the region near the GMA was transported to the region near the PA because of the pull-push flow pattern on the top surface of the weld pool between the two arcs. As the heat in the weld pool was transported from the high-temperature region to the low-temperature region, the molten metal temperature near the GMA decreased. Moreover, the GMA expanded and the current density decreased because of the forma-

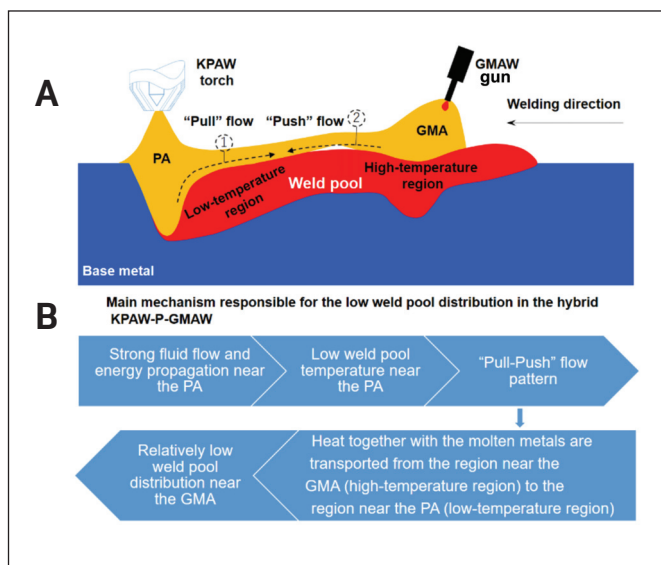


Fig. 14 — A — Convective patterns and energy propagation on the top surface of the weld pool between two arcs; B — main mechanism responsible for low weld pool distribution of hybrid KPAW-GMAW-P.

tion of the direct-current path between the KPAW cathode and the GMAW anode. Therefore, the GMA heat transported to the weld pool decreased. All of these mechanisms contributed to a lower weld pool temperature in hybrid KPAW-GMAW-P compared to that of GMAW-P, and the weld pool convection mechanism was especially important because the arc interference was strong only in the peak current stage.

Usually, multilayer and multipass GMAW with grooves should be adopted to join thick plates, and the welding efficiency is low (Ref. 27). Compared with GMAW, hybrid KPAW-GMAW-P has a higher energy density, deeper weld penetration, and higher welding efficiency. KPAW can be used to join thick plates with only one pass. However, undercut weld defects can easily form with a low welding current and low welding speed (Ref. 22). Compared with KPAW, hybrid KPAW-GMAW has a wider range of process parameters and better weld quality. Hybrid laser-GMAW can join thick plates with high efficiency and quality, but the laser equipment cost is high, and the joint tolerance is relatively low because the laser focus radius is small. Compared with hybrid laser-GMAW, hybrid KPAW-GMAW has lower equipment costs and higher joint tolerance. In summary, hybrid KPAW-GMAW has a promising future in the welding of thick plates.

Conclusion

In this study, the complex interactive phenomena of the arc, droplet, keyhole, and weld pool in a hybrid KPAW-GMAW-P were analyzed with the help of a high-speed video camera, zirconia particles, and a thermal camera. The conclusions are summarized as follows:

1) An ionized PA was extended to the GMA side by the formation of a direct-current path between the KPAW cathode (tungsten electrode) and GMAW anode (welding wire)

in the peak current stage. The wire extension length of hybrid KPAW-GMAW-P was shorter, and the arc length longer than that of GMAW-P.

2) The metal vapor from a keyhole had a minor influence on the droplet transfer, while the Lorentz force promoted the droplet transfer. The hybrid KPAW-GMAW-P process obtained a stable OPOD mode.

3) The pull-push flow pattern on the top surface of a weld pool between two arcs caused by the Marangoni force and arc shear stress suppressed the strong backward flow from the keyhole.

4) The interaction of the arc, droplet, keyhole, and weld pool in hybrid KPAW-GMAW-P promoted the fluid flow and heat transfer in a weld pool and decreased the weld pool temperature.

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Effect of Galvannealed Coating Evolution during Press Hardening on RSW Weldability

This research revealed increasing heat-treatment time shifted the process window toward lower current

BY X. HAN, M. H. RAZMPOOSH, A. MACWAN, E. BIRO, AND Y. ZHOU

ABSTRACT

Press-hardening steels (PHSs) are used in modern passenger vehicles to increase part strength while reducing vehicle weight to meet both environmental and safety regulations. To prevent oxidization and decarburization during heat treatment, some PHSs are coated with Zn (galvanized or galvannealed). Heating during the press-hardening process drives interdiffusion of Zn from the coating and the Fe from the steel substrate, forming a diffusion layer composed of α -Fe phase (a Zn-Fe solid solution). The electrical resistance of the diffusion layer is a function of its thickness and Zn-Fe composition. Both the diffusion layer thickness and the Zn-Fe composition are dependent on the initial coating thickness and heat-treatment time/temperature conditions. Changes to the heat-treatment process shift the resistance spot welding process window by altering the resistance behavior of the material. If the shift in the process window is not accounted for during assembly welding, the welds produced may either be too small or exhibit expulsion, both of which will reduce the strength of the weld. This study showed increasing heat-treatment time shifted the process window toward lower current. A final combined processing window of 1.5 kA, which is suitable for industrial application, was obtained when taking into account the variation in heat-treatment time. The tensile shear performance was not affected by the heat treatment, as increased softening in the heat-affected zone at longer heat-treatment time canceled the strength gain from increasing nugget size.

KEYWORDS

- Resistance Spot Welding • Press-Hardening Steel
- Zn Coating • Tensile Strength • Microstructure

Introduction

Lightweighting has been regarded as a key strategy in the automotive industries to meet increasingly strict emission standards while achieving higher safety performance (Ref. 1). Lightweighting is mainly achieved by reducing the thickness of the sheet steels used to produce automotive

parts for the body-in-white (BIW). By using higher strength steels, part strength may be retained while material thickness is reduced. Press-hardening steel (PHS) has emerged as a suitable candidate for lightweighting applications, where its fully martensitic structure provides extremely high strength and a similar level of passenger protection, allowing thinner steel gauges to be used (Refs. 2, 3).

A PHS undergoes a press-hardening process, where it is formed at a high temperature to achieve the final martensitic structure. During press hardening, a PHS sheet is first heated above the austenitization temperature and held for a set time to ensure full austenitization. While hot, the PHS is transferred into a water-cooled forming die for the in-die quenching process. In-die quenching forms and cools the PHS sheet, allowing high formability during this process and a high cooling rate to transform austenite into the desired martensitic microstructure (Refs. 2, 3). During press hardening, surface coatings are necessary to protect the steel from severe oxidation and decarburization. Zinc-based coatings provide effective protection during press hardening as well as further in-service corrosion protection (Refs. 4–6). During heat treatment, long holding time at the austenitization temperature results in Zn-Fe interdiffusion between the coating and steel substrate, and oxides formation from interaction with the ambient atmosphere of the furnace. The interdiffusion and the oxidation depend both on the temperature and time of the heat-treatment stage of press hardening (Ref. 7). Considering that, heat-treatment time and temperature are varied due to sheet thickness and manufacturing requirements to ensure a full austenitization of the materials, the final thickness, and Fe-Zn composition of the diffusion layer may vary depending on the specific heat-treatment conditions used (Refs. 8, 9).

Variation in the diffusion layer affects the resistivity of the material and consequently changes its resistance spot welding (RSW) behavior. This poses concerns with respect to the robustness of the RSW process when joining GA-coated PHS. Therefore, it is important to understand the Zn diffusion layer effects on RSW to ensure process robustness. The current study investigated the relationship of heat-treatment conditions to the diffusion layer growth,

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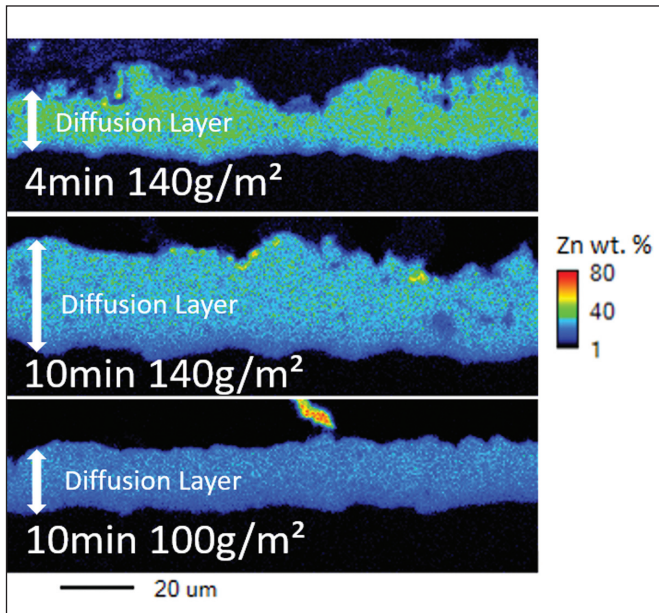


Fig. 1 — EPMA scan in the surface layer of a treated and sand-blasted cross section showing distributions of Zn content.

and their effect on the RSW process window of Zn-coated PHS and its subsequent effect on mechanical properties.

Material and Experimental Procedure

Material Preparation

In this study, 2-mm-thick GA-coated 22MnB5 steel sheets (Table 1) with two different total coating weights of 100 and 120 g/m² were used. The as-received sheets were heat treated in an open-air environment at 860°C for 4, 7, and 10 min. After the heating stage, the sheets were rapidly transferred (< 5 s) into a water-chilled quenching die set with a surface temperature less than 50°C to achieve high cooling rate and final martensitic microstructure. The processed sheets were laser cut into 25 × 25 mm (1 × 1 in.) coupons for welds that were to be analyzed metallographically, and 25 × 100 mm (1 × 4 in.) strips for welds to be mechanically tested in tensile shear. Before welding, all coupons were sandblasted to remove the top oxide layer created during press hardening. The metallographic examination confirmed sandblasting did not disrupt the integrity of the diffusion layer (Ref. 10).

Table 1 — Chemical Composition (wt-%) of the Experimental 22MnB5 Press-Hardening Steel

C	Mn	Si	P	S	Al	Cr	Ti	B	Fe
0.23	1.19	0.25	0.016	0.002	0.05	0.20	0.03	0.003	Bal.

Table 2 — Modified Welding Schedule Adapted from AWS Standard D8.9 (Ref. 11)

Sheet Thickness	Electrode Diameter	Force	Cooling	Weld Sequence (ms)	Hold Time (ms)
2 mm (1/16 in.)	6 mm (1/4 in.)	5.4 kN (1200 lbf)	6 L/min (1.6 gal/min)	167-33-167-33-167	167

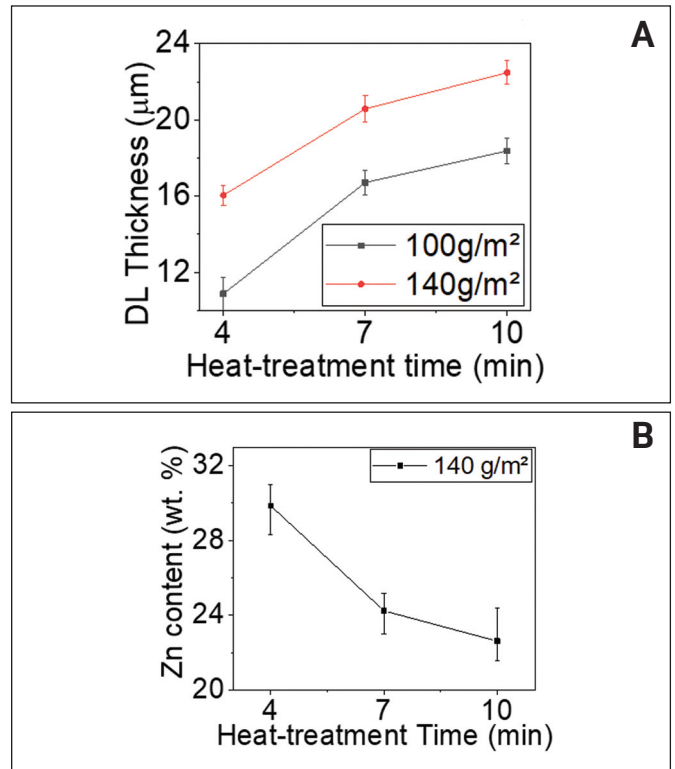


Fig. 2 — A — The diffusion layer thickness; B — EPMA Zn content at different heat-treatment conditions.

Resistance Spot Welding (RSW)

Resistance spot welding was performed using medium-frequency direct current welding equipment with a Rexroth weld controller operating under the constant current mode. Welding parameters were chosen based on the AWS D8.9 Standard (Ref. 11) (Table 2). While the AWS D8.9 Standard is based on alternating current power supply, its specified parameter can also be applicable in the case of direct current welding machines. Due to machine set-up limitations, an electrode face diameter of 6 mm (1/4 in.) and electrode force of 5.4 kN (1200 lbf) was used instead of the 8 mm (5/16 in.) diameter and 7.2 kN (1600 lbf) force required by the AWS D8.9 Standard (Ref. 11). Welding time was converted and rounded from the 60-Hz cycles to milliseconds (ms) used by the weld controller. The weld schedule consists of three welding pulses of 167 ms separated by two cooling pulses of 33 ms (Table 2).

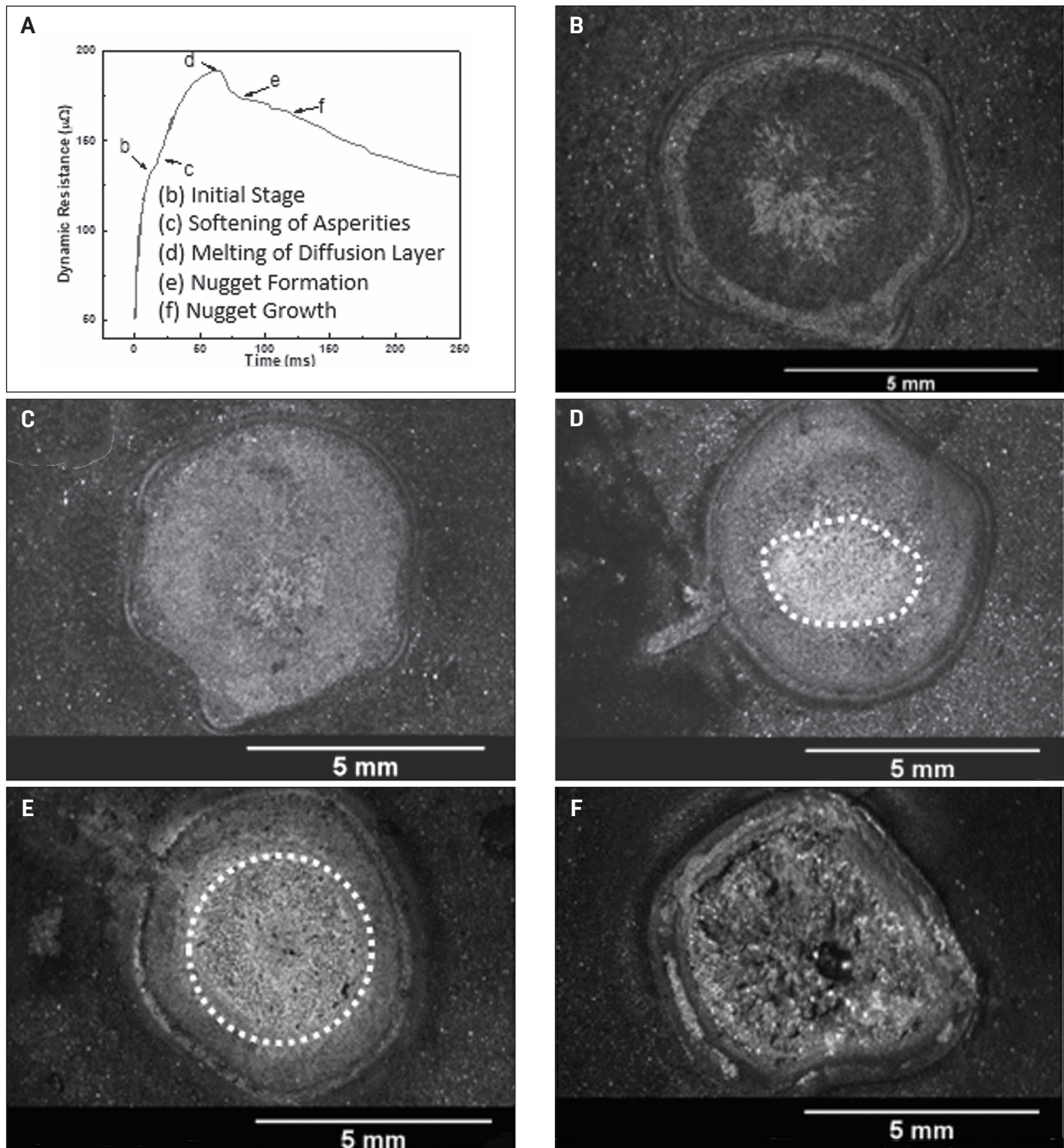


Fig. 3 — A — Interrupted tests correspond to the dynamic resistance curve; B—F — its interfacial condition.

The dynamic resistance measurements were calculated using real-time voltage and current value acquired using the weld control timer. Interrupted tests were performed by reducing welding time to study the evolution of the contact surface and the effects of the diffusion layer on welding behavior. Weld size was measured by peel test and cross-sectional metallographic examination to measure the nugget size.

Microstructure Characterization and Mechanical Testing

To evaluate the microstructure and nugget size, welds were cross sectioned, mounted, polished, and etched using 5% nital. The microstructure was investigated using an Olympus optical microscope and Zeiss Leo 1530 field emission scanning elec-

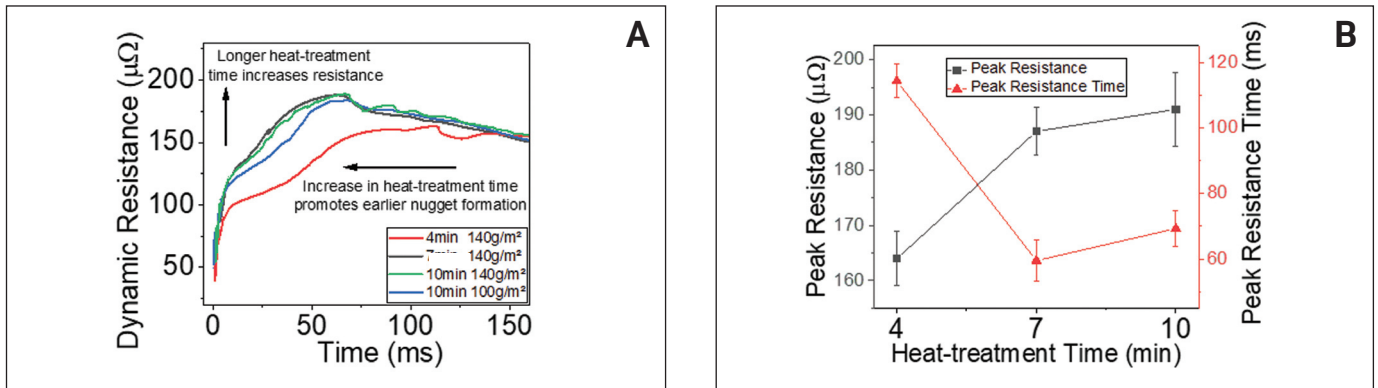


Fig. 4 — A — Dynamic resistance measurement for different heat-treatment conditions; B — the peak resistance (black) and the time when the peak resistance was reached (red) for different heat-treatment times.

tron microscopy (FE-SEM). To characterize the coating evolution after the heat-treatment process, electron probe microanalyzer (EPMA) characterization was performed on the diffusion layer to identify element mapping. Hardness testing was performed using a Clemex-JS2000 Vickers indenter with digital stage control. Indentations were made using a load of 300 g (0.67 lbf) and a dwell time of 15 s. Shear tension testing was performed using an Instron tensile frame with a cross-head speed of 5 mm/min.

Results and Discussion

Fe-Zn Diffusion Layer Evolution

After heat treatment, the δ and Γ - Γ_1 phases of the as-received GA coating (Ref. 12) evolved into a Fe-Zn diffusion layer (uniform solid solution of Zn in α -Fe), as shown in Fig. 1.

The diffusion layer thickness increased with increasing heat-treatment time and GA-coating weight (see Fig. 2). As heat-treatment time increased, the Zn had more time to diffuse deeper into the steel matrix, forming a thicker diffusion layer. However, it should be noted the thickness increase was not linear with respect to heat-treatment time. Larger growth of the diffusion layer was observed between samples treated for 4 and 7 min compared to the growth between samples heat treated for 7 and 10 min. The observed progression of the diffusion layer with respect to time confirms this was a diffusion driven process, as diffusion distance increased as a function of the square root of time (Ref. 7). In addition to the diffusion kinetics, the effective time over which the diffusion occurred was not the whole heat-treatment time. After entering the furnace, the sample needed time to heat to a temperature where significant diffusion began, further showing why a larger difference was observed at a shorter heat-treatment time. Similarly, additional Zn was available for diffusion when increasing the coating weight, resulting in a thicker diffusion layer.

It was also observed, as shown in Fig. 2B, that the concentration of Zn in the diffusion layer decreased with increasing heat-treatment time. With the increase in diffusion depth at longer heat-treatment time, Zn was naturally dispersed in the diffusion layer, causing a decrease in Zn concentration. Furthermore, the total Zn content of the layer decreased as a result of the growth of a ZnO layer that formed during heat

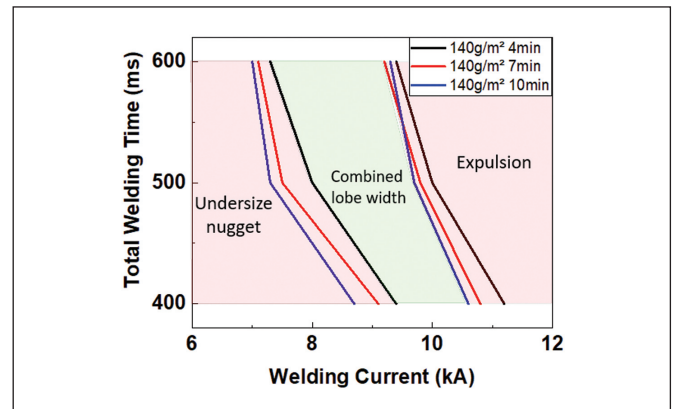


Fig. 5 — Resistance spot weld lobe indicating the range of acceptable welding current and total time of the three welding pulses (in green) and expulsion/undersize nugget region (in red) for different heat-treatment conditions.

treating. The formations of the ZnO layer reduced the availability of Zn in the diffusion layer, further reducing the concentration of Zn in prolonged heat-treated samples. It should be noted that the ZnO layer will not contribute to the welding behavior, as the oxide layer was removed by sandblasting prior to welding in the present study.

Dynamic and Resistive Measurement, Correlation

There are two components that make up dynamic resistance during spot welding: contact resistance at the faying surface and bulk resistance through the material (Ref. 13). Contact resistance is mainly governed by contact surface conditions, while bulk resistance is governed by the material properties and temperature (Ref. 13). Using the interrupted test, different stages of the RSW process can be linked to features in the dynamic resistance curve, which are labeled with time stamps from b to f — Fig. 3.

Since the instantaneous resistance measurement was based on electric current and voltage measurement, resistance readings sampled before time stamp b were affected by the current change and were not representative of the actual sample condition. At point b in the cycle, asperity softening began as temperature at the interface started to increase —

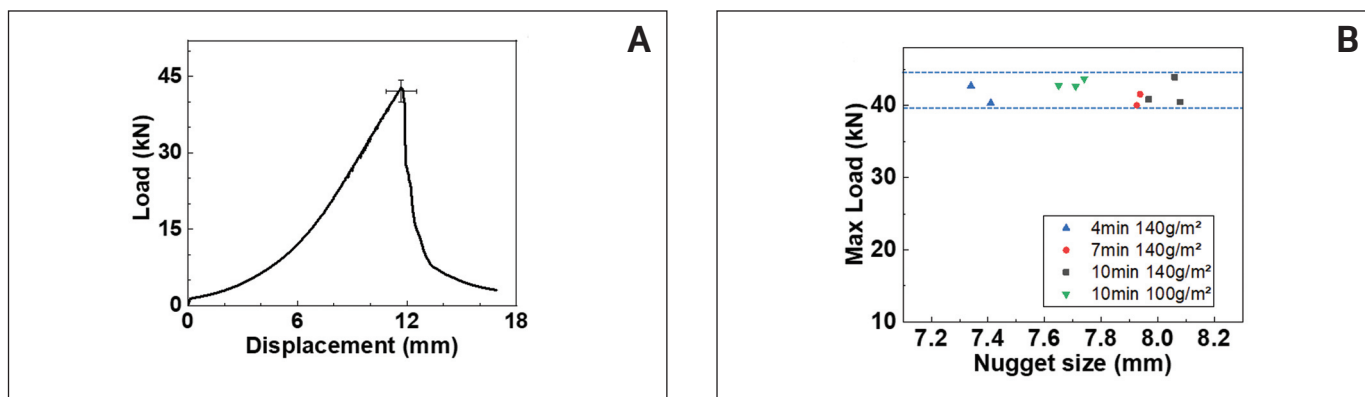


Fig. 6 — A — A representative load-displacement curve; B — comparison of the maximum load based on the nugget size obtained under the same welding parameters.

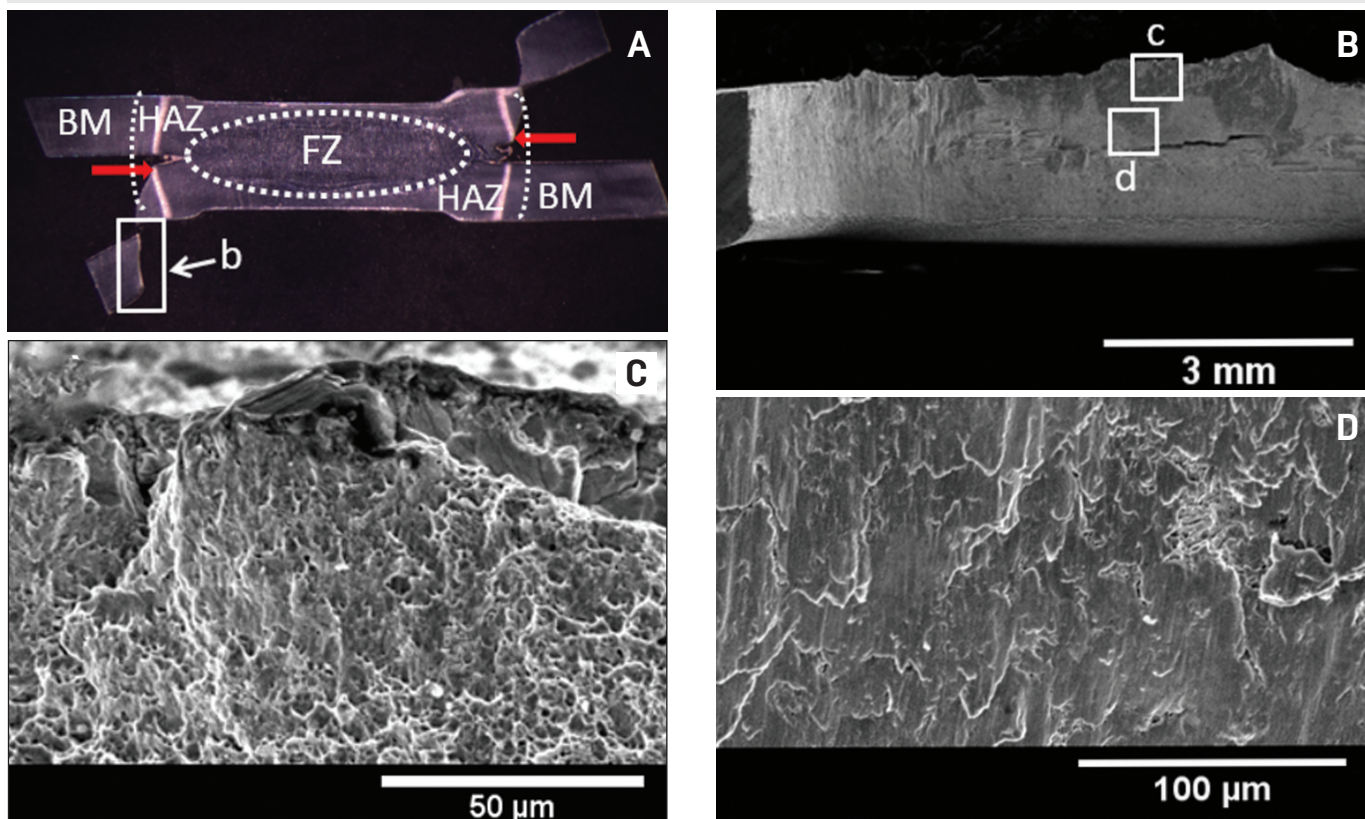


Fig. 7 — A — Macroscopic cross-sectional view of the button pull-out failure with the red arrows indicating the failure initiation points; B — fracture surface under SEM; C — ductile failure at the crack initiation; D — failure transition into the brittle mode as it propagates.

Fig. 3B. The change in dynamic resistance was primarily due to the reduction in contacting surface asperities and heating of the bulk material. When heated, asperities on the contact surface soften, flattened by the electrode and contributing to a decrease in dynamic resistance (Ref. 13). However, increasing temperature increased the bulk resistance, resulting in a continued overall increase in dynamic resistance. At point c, asperity softening was completed (Fig. 3C), which resulted in a change of slope as shown in Fig. 3A. Immediately before reaching point d, the faying surface started to melt — Fig. 3D. Due to the presence of Zn, the diffusion layer had a lower melting temperature compared to the steel substrate (Ref. 14), which resulted in the earlier melting.

Presence of liquid phase reduced dynamic resistance at time d, resulting in the resistance peak. In addition to the melting, the electrode force further spread the liquid across the faying surface, effectively increasing the contact surface — Fig. 3D. Time point d was also referred to as the peak resistance time, as it was the time required for the weld to reach its resistance peak. After the diffusion layer starts to melt at point d, steel substrate melting occurs at the interface, forming the molten nugget. As the area of molten surface increased, dynamic resistance further decreased — Fig. 3E. Beyond time point f, dynamic resistance reduced as the nugget grew (Fig. 3F), until either the welding cycle was completed or expulsion occurred. The occurrence of expul-

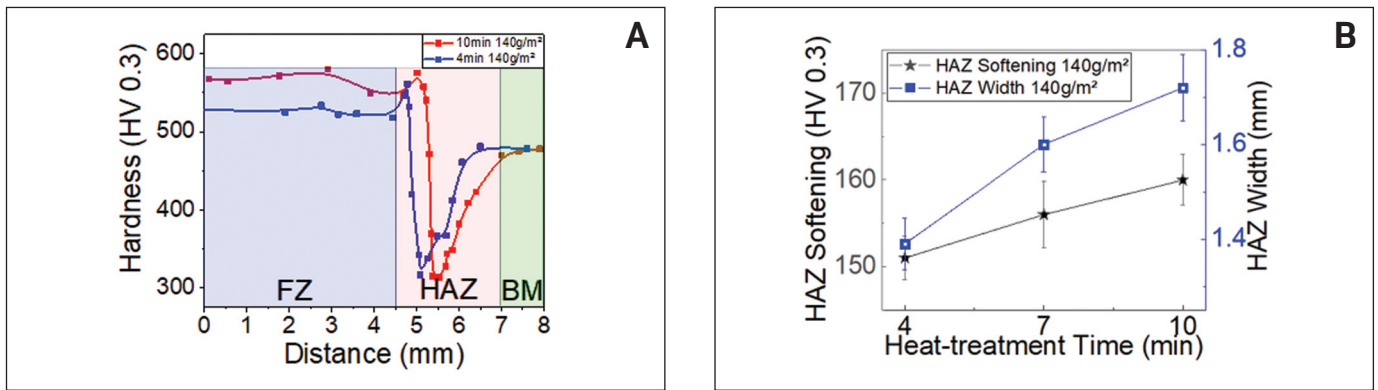


Fig. 8 — A — Hardness profile showing the fusion zone, HAZ, and the base material; B — hardness drop in the HAZ region compared to the base material strength and the HAZ width in different heat-treatment conditions.

sion was due to excessive amounts of heat introduced into the system. When the weld nugget grew beyond the electrode's capability to retain it, liquid metal was ejected from the nugget pool. Ejected metal forms a shunting pass around the nugget area, preventing further growth of the nugget. Since nugget growth was stopped, minimal changes to the dynamic curve were observed post expulsion.

With an understanding of the correlation between dynamic resistance and surface condition, the dynamic resistance curve can be used to compare the difference between welding behavior in the different heat-treatment conditions, as shown in Fig. 4. Higher initial and peak resistances were observed in samples with a longer heat-treatment time — Fig. 4. Higher resistance indicates there will be more heat-generation due to Joule heating, which accelerates melting at the contact surface. As shown in Fig. 3, nugget formation starts right after the peak resistance was reached. Therefore, the earlier peak resistance observed with longer heat treatment time indicated an earlier nugget formation. It is worth noting a similar peak resistance was measured for the heat-treatment time of 7 and 10 min — Fig. 4B. This similarity came from the minimal difference in the diffusion layer thickness and Zn-Fe composition between the two heat-treatment times — Fig. 2. Once the nugget growth started, the dynamic resistance between different diffusion layer conditions became similar because the diffusion layer was consumed by the nugget and could no longer contribute to the resistivity increase.

Change in Weld Size and Weld Lobe

The processing window in RSW can be described using the weld lobe. The minimum nugget curves (Fig. 5) indicated the required parameters to achieve the minimum nugget diameter $d = t^* \sqrt{c/t}$, where c is a constant and t is the sheet thickness. While AWS D8.9 (Ref. 11) requires the c value of 4.0, other studies have suggested 4.0 is not enough for higher strength materials such as PHS (Ref. 15). Hence, the c value of 4.5 was used in this study due to the high strength of PHS. The expulsion curve indicates the parameters where three consecutive expulsions were observed, which is considered the maximum current — Fig. 5.

Weld lobe curve width and locations were both affected by different heat treatment, as shown in Fig. 5. It was observed that material heat treated for longer times had weld lobes that

were shifted to the left of materials heat treated for shorter times. When the weld lobe was farther left, it indicated less current was required to achieve the minimum nugget size. Similarly, this increase in resistance lowered the expulsion current limit. This observation agreed with the dynamic resistance results, showing longer heat-treated samples had higher resistance and reached their peak resistance earlier in the weld cycle — Fig. 4B. The lobe shifting is less severe at a longer welding time. As heat generation from contact resistance was greatly reduced after the nugget growth started, longer welding time reduced the impact of surface conditions as a proportion of heat generated from bulk heating increased. The width of the weld lobe also increased by 0.5 kA when heat treatment was increased from 4 to 10 min; however, it should be noted all the conditions had a lobe width above 2 kA at the suggested total welding time of 500 ms — Fig. 5. To take into consideration the change in diffusion layer because of varied heat-treatment condition, a combined lobe with the extreme conditions (highest minimum nugget and lowest expulsion limits) was constructed. From the combined lobe, an effective operating window above 1.5 kA was observed at a 500-ms welding time when heat treating time was not controlled. This lobe width was commonly reported for a robust RSW process in a manufacturing environment (Refs. 16, 17).

Difference in Mechanical Performance and Hardness Measurement

Under tensile shear loading, all loads exceeded 40 kN. A representative load-displacement curve is shown in Fig. 6A and all samples failed in button pull-out mode — Fig. 7A. When welded using the same welding parameters, no difference in the maximum load was observed, despite the difference in nugget size due to the different heat-treating schedule and zinc thickness — Fig. 6B. To investigate this, a detailed analysis of the fracture surface after tensile testing was performed. It was found fracture initiated in the heat-affected zone (HAZ) and outside of the nugget area — Fig. 7A. The fracture surface was further characterized using SEM — Fig. 7B. A closer inspection of the crack initiation area (Fig. 7C) revealed fracture occurred in a ductile fashion. As the crack propagated during loading, the failure mode became increasingly brittle with signs of cleavage cracking as the load direction is constantly changing — Fig. 7D. This initial ductile fracture in-

dicates microstructural changes in the HAZ are indeed the fracture initiation point. Further analysis of the HAZ can help understanding why increasing nugget size did not increase the joint strength.

The hardness profiles across the welds were measured to understand how heat-treatment conditions affect the HAZ when welded with consistent parameters — Fig. 8A. The fusion zone and base metal both had a high hardness due to their martensitic structure. However, significant softening was observed over the HAZ, which is associated with tempering of martensite that consequently affects the strength of the joint (Refs. 18, 19). Figure 8B shows that with increasing heat-treatment time, both the width of HAZ and degree of softening increased, resulting in a higher loss in strength at a longer heat-treatment time. Therefore, higher heat introduced to the weld should have reduced the mechanical strength of the joints. However, with higher resistance at the higher heat-treatment time, increased heat input also created a larger nugget, which increased the joint strength. The effect of increasing nugget size was compensated by the decrease in HAZ strength, explaining the similar tensile shear strength obtained from the different heat-treatment conditions — Fig. 6B.

Conclusions

Changing the heat-treatment condition of press-hardening varied both the thickness and chemical composition of the Zn-Fe diffusion layer at the sample surface. The processing window for these different conditions had been measured and their mechanical performance compared using a conventional welding schedule with the following conclusions:

1) Prolonged heat-treating time and higher initial coating weight both increased the thickness of the diffusion layer. The Zn content increased with higher initial coating weight and reduced with prolonged heat-treatment. Longer heat-treatment time shifted the weld lobe curve toward lower welding current.

2) Weld lobe shift resulted from the change in resistance profile. Under the constant current mode, higher dynamic resistance measured in prolonged heat-treatment conditions led to higher heat-generation during welding and larger final nugget diameters.

3) An individual weld lobe of at least 2 kA was observed for resistance spot welding of press-hardened steel heat-treated between 4 and 10 min at 860°C. With increasing heat-treatment time, the lobe curve shifts toward the left. A combined overall weld lobe width of 1.5 kA was observed at 500-ms weld time.

4) Button pull-out failure was obtained when welding in the acceptable range of the processing window where softened HAZ being the failure initiation point. Consistent tensile shear strength was observed in different conditions.

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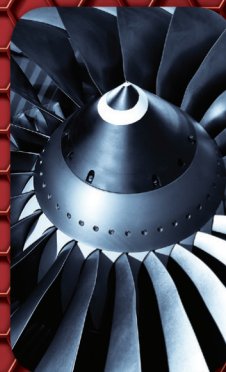
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