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On the cover: In the automotive industry, maintaining the proper equipment with good preventive maintenance practices as well as standardizing inventory can streamline production. (Photo courtesy of Motoman Robotics.)

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The Rewards of Volunteerism

I am a volunteer.

As you know, the American Welding Society is an individual member-based organization that now has more than 67,000 members worldwide. As impressive as that number is, an even more amazing fact is that there are several thousand members who volunteer their time in support of the Society’s activities. While we have an excellent staff working at headquarters in Miami, it is the volunteer leadership who define the objectives and mission of the Society. As you can see, volunteers are essential for the American Welding Society’s operation.

As expected, many members volunteer their time supporting AWS. They fill the leadership positions to manage the volunteer operations of the organization. They play important roles at the Section, District, and national levels. Hundreds of volunteers work on the numerous committees that provide the products and services of AWS. There are approximately 30 Standing Committees that provide the top tier framework of the committee structure. These committees coordinate the activities of working committees responsible for accomplishing the more specific tasks to create the products; for example, technical documents, conferences, certification programs, and services such as educational scholarships and awards.

Even more revealing about the nature of AWS volunteers is the vast number of members who give their time and energy to help their communities. I know of members who are volunteer firemen and emergency medical technicians, or who participate in heart walks or support organizations such as the Special Olympics.

Let me share a recent volunteer activity my wife, Leslie, and I took part of this past December with our church. We went to Terre Noir, Haiti, to work with an elementary school and a church in Repatriot that was destroyed by the January 12, 2010, earthquake. Neither of us had volunteered for a trip like this before. There was plenty of apprehension as the time to leave for Haiti grew closer, but with the support of the other 14 team members, we traveled to Haiti for one of the most memorable and rewarding weeks of our lives. The feeling of satisfaction gained from being able to help those affected by this disaster, and to see the joy in the faces of the children and the expressions of appreciation from the adults for our being there, was more than sufficient compensation for our time and efforts. In fact, we are considering a return trip this winter.

Upon my return from Haiti, I talked about the experience with several AWS members, and was not surprised to learn how many people and corporations in the welding community have also volunteered to assist the Haitian people.

I have always been proud to be an AWS member, but when I think about the impact the membership is making to improve the lives of so many, it makes me even prouder to say that I am an AWS volunteer.

I invite you to also become an active volunteer in AWS, or your community, church, or civic organizations. For every hour you serve, you will reap the many rewards of volunteerism a hundredfold.

Lee G. Kvidahl
Chair, AWS Membership Committee
Hodgson services a wide variety of industries in the ENERGY SECTORS of hydro, petro chemical, atomic, gas, oil, wind, etc., in addition to those in heavy manufacturing, steel, pulp and paper, mining, marine, forestry, offshore projects, etc. Hodgson's commitment to providing customers superior products and personalized professional service has earned itself a reputation for excellence, making the name HODGSON synonymous with quality workmanship.

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For Hodgson Custom Rolling's complete line of products and services, contact Hodgson Custom Rolling Inc. at 5580 Kalar Road, Niagara Falls, Ontario, Canada L2H 3L1.
AWS Releases Statement on Japan Disaster

In the aftermath of the Tōhoku 9.0-magnitude earthquake and tsunami that occurred on March 11, American Welding Society (AWS) President John Mendoza has sent messages of support and condolence to Akira Baba, president of Sanpo Publications and organizer of the biennial Japan International Welding & Cutting Show, and Hiroshi Hasegawa, chief executive of the Japan Welding Engineering Society.

The following statement available at www.aws.org/wa/japan.html, has been issued:

“Speaking for its members, staff, and volunteers, the American Welding Society would like to express its deepest concern and support in the aftermath of the recent earthquake and tsunami that continue to have such a devastating effect on Japan. We offer our sincerest condolences for the tragic loss of life in Japan, as well as the destruction of critical infrastructure, basic shelter, and personal property. AWS stands with those affected in this time of great trial, as they struggle with personal grief and the urgent need to restore essential resources and services.

“Welding, of course, will play a vital role in the rebuilding of the areas of Japan damaged by this natural disaster, including the Fukushima Daiichi nuclear power station. We are confident that the knowledge and leadership demonstrated by Japanese welding experts will play a major role in the rebuilding effort that the country now faces.

“In this most difficult of times, friends and colleagues at the American Welding Society are keeping the people of Japan in their thoughts and prayers. Additional supportive efforts by welding users and equipment manufacturers worldwide are very much appreciated.”

Northrop Grumman Completes Huntington Ingalls Spin-Off

Northrop Grumman Corp. completed the spin-off of its subsidiary Huntington Ingalls Industries, Inc. (HII). Northrop Grumman stockholders of record, at the close of business of the New York Stock Exchange on March 30, received one share of Huntington common stock for every six shares of Northrop Grumman common stock held. Also, Northrop Grumman will report shipbuilding financial results as discontinued operations for the 2011 first quarter and all prior periods.

“We thank HII for their many contributions to our company and the defense of our nation, and wish them the best as an independent company,” said Wes Bush, Northrop Grumman chief executive officer and president.

Also, the Department of the Navy recently announced it’s in a position to support Northrop’s shipbuilding spin-off. The Navy finds Huntington is responsible for the award of amphibious transport dock ship LPD 26 and guided missile destroyer DDG 113 contracts. The Navy’s concern with Huntington’s credit rating, driven by its initial debt, has been offset by Northrop’s agreement to relieve Huntington of first-quarter 2011 debts, provide a starting cash balance of $300 million, and not to recoup retentions, performance incentives, and economic price adjustment payments the Navy might owe under current shipbuilding contracts with Northrop Grumman Ship Building from HII.

Olympus Launches Instrument Rental Program

Olympus NDT, Waltham, Mass., a manufacturer of nondestructive examination equipment, is launching its instrument rental program in the United States. The company’s rental inventory includes flaw detectors, videoscopes, thickness gauges, high-speed video cameras, and X-ray fluorescence analyzers. Users can receive the newest equipment with the latest software for their application; rent the instrument they are familiar with; and be assured the rental is in the best possible condition and tested by experts before delivery. Rentals can be as short as a day or as long as many months. For more information, email rentals@olympusndt.com.

Outside Processors Council Merges with FMA

The Outside Processors Council (OPC), an independent industrial association to serve parties interested in the metal processing business, merged with the Fabricators & Manufacturers Association, Intl’l (FMA). Active OPC members will be grandfathered in as FMA company members and comprise the newly formed Outside Processors special interest group within the FMA membership. Also, the OPC established an endowment fund with Nuts, Bolts & Thingamajigs®, the Foundation of the FMA, to support annual scholarship awards.
Looking for a welding machine that’s as portable as it is productive? Meet the Caddy line of portable MIG welders by ESAB. Weighing only 26 pounds, these machines offer superior arc performance similar to machines three times their size. The CaddyMig 160i is capable of welds over $\frac{1}{6}$ inch thick, while the CaddyMig 220i welds up to $\frac{1}{4}$ inch thick. Plus, both machines are incredibly easy to set up – meaning you’ll be ready to weld in minutes, no matter where the job takes you.

Take a look at this powerful new line of portable welding machines today.

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Waterjet Cuts 55-in. Access Hole in Nuclear Waste Storage Tank

Waterjet contractor AK Services, Everett, Mass., recently cut the largest-ever access hole in an active U.S. Department of Energy (DOE) radioactive waste storage tank at the DOE’s Hanford Site in southeastern Washington.

A 55-in.-diameter hole was cut in the top of the underground tank to allow installing a robotic system that will remove 247,000 gal of radioactive and chemical waste stored there during the Manhattan Project and Cold War.

The company used a specially engineered abrasive waterjet cutting machine to make the cut through 15 in. of concrete and steel rebar in 22 h. It performed the cut at 8 in./h using an abrasive jet of garnet grit mixed with 3 gal/min of water pressurized to 48,000 lb/in.² with a Jet Edge waterjet intensifier pump.

According to Kent Smith, Washington River Protection Solutions (WRPS) deputy manager of retrieval and closure operations, the finished cut represents more than a year of planning and preparation by AK Services and Hanford Site Tank Farms prime contractor, WRPS. Also, according to Carl Franson, AK Services vice president of operations, the company spent a year developing the waterjet cutting system.

“The biggest challenge was running the equipment from 300 feet away,” Franson said. “The tank top is in a radiation area, and entry to the area is regulated to the extent that anything that enters the tank farm must be scanned and cleared prior to being released out of the fenced-in restricted area. The pumps and control systems had to be outside of the restricted area to ensure they did not become contaminated with radiation and then become the property of the DOE. We also had the added challenge of winter weather, so we installed air dryers and used air line antifreeze to keep the system from freezing up.”

After the concrete plug was lifted from the tank, it was wrapped in a plastic sleeve and placed in an isolated area, where it’s being staged for disposal at the Hanford Site. A large riser was placed in the hole to support the robotic retrieval system. The DOE plans to begin retrieving waste from the tank this summer.

Marinette Marine Breaks Ground for New Facility to Enhance Littoral Combat Ships

Marinette Marine Corp., Marinette, Wis., a member of the Lockheed Martin-led Littoral Combat Ship (LCS) industry team, recently broke ground for a new panel-line fabrication building to support construction of the U.S. Navy’s LCS.

The building will improve the first stage of ship construction at Marinette Marine, decrease ship module travel distance throughout the construction process, feature automation to increase efficiency, and provide the capacity for steel storage and other raw materials.

In addition to this groundbreaking, the company marked the opening of its professional center and the completion of a project to expand its main indoor ship construction building to provide enough indoor space to simultaneously house two complete LCS hulls and parts for two additional ships.

These investments are part of a five-year, $100-million plan by the shipyard’s parent company, Fincantieri, to modernize its U.S. shipbuilding operations.

Marinette Marine and Lockheed Martin constructed and
launched the nation’s first LCS, USS Freedom. Currently, the team is constructing the Navy’s third LCS, Fort Worth, which remains on cost/schedule for delivery in 2012.

AMECO USA Opens New Manufacturing Facility, Offers Custom Metal Fabricating

AMECO USA fabricated and machined this stay cable bridge component pylon anchor for a CALTRANS project (12,000 lb weight, 4-in. TASTM A572-50 plate, 2205 duplex stainless steel sleeves, design by T. Y. Lin).

AMECO USA Metal Fabrication Solutions, LLC, a metal fabricator of engineered products and welding service provider, opened a new manufacturing facility in Cleveland, Ohio, that increases manufacturing space to 62,000 sq ft. This includes its sister company, ArcAlloy Metal Fabrication Solutions, operating at an existing 12,000-sq-ft facility in Elyria, Ohio.

The expansion enables an enhanced and broader service range, including heavy custom fabricating, CNC punching, and forming. The plant also has a 50-ton, in-house lifting capacity with more than 30 ft under the hook and oversized factory doors.

Currently, the company employs a total of 20 people at both facilities. This includes 11 employees for newly created positions at the facility with plans to hire additional staff.

“This new facility enables us to offer our customers integrated problem solving through an expanded range of metalworking processes and welding technologies,” said Mike Perkins, president and chief engineer.

Contract Awarded for Platform Project

At Frank’s Casing Crew & Rental Tools facility in the Port of Iberia, La. (pictured), tendons for the Olympus (Mars B) Tension Leg Platform project will be fabricated.

Frank’s Casing Crew & Rental Tools, Inc., an equipment and personnel provider for oilfield projects, has been awarded a contract by Shell Exploration & Production Co. It will fabricate tendons for the Olympus (Mars B) Tension Leg Platform project in the Gulf of Mexico at Mississippi Canyon Block 807 in approxi-
mately 3000 ft of water 95 miles south of New Orleans, La.

These tendons, at 290 ft long and 170,000 lb each, will be critical components holding the tension leg platform in place by connecting its hull to piles driven on the bottom of the sea floor. The platform has 16 tendons total. Also, the contract includes fabricating 184 individual tendon segments, qualification of welding procedures, and fatigue testing.

Frank’s deepwater fabrication department will manage the project. Tendon fabrication will take place at the company’s New Iberia, La., deepwater fabrication facility.

Las Positas College’s Welding Dept. Gets Laser Engineered Net Shaping Machine

Las Positas College, a few miles away from the Sandia/California National Laboratory, recently received from Sandia its original LENS® (laser engineered net shaping) machine for use in the college’s welding department. The machine can fabricate three-dimensional, prototype metallic parts out of virtually any metal alloy.

Sandia’s John Smukey Say is a codeveloper of the device along with former Sandian David Keicher. The serial number of the transferred unit is 001, signifying it is the first one manufactured. Despite being manufactured in 1994, the inaugural LENS machine uses the same technology as present-day machines.

For years, Smugeresky said, the LENS machine was used for the lab’s nuclear weapons mission to help designers create prototype parts for safety and security upgrades, and to manufacture replacement parts for existing nuclear weapons systems.

It features a glove box, high-powered laser, mirrors, and powder feeders. The process fabricates metal parts directly from the computer-aided design models using metal powder injected into a molten pool created by the focused, high-powered laser beam. The technology was licensed by Albuquerque-based company Optomec.

Las Positas welding instructor Scott Minor plans to utilize the LENS machine to introduce students to metal joining techniques.

“We look forward to seeing the equipment being used to inspire future welders, technicians, and engineers for the careers of tomorrow,” said Minor.

LEADERS & INNOVATORS

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Weiler Corp. recently participated in the Veterans in Piping program for returning military veterans. Company representatives Scott Calkins (far left) and David Jescovitch (far right) pose with students at Camp Pendleton, Calif.

Weiler Corp. has found a way to help returning veterans by donating wire and hand brushes, grinding wheels, and tools for a veterans’ training program run by the United Association of Journeymen and Apprentices of the Plumbing and Pipe Fitting Industry. The association partnered with the U.S. military to create the Veterans in Piping program that provides returning vets with 16 weeks of free, accelerated welding training offered to 16 veterans in each course. For more details, visit www.uavip.org.

Weiler representatives recently attended one of the training classes at Camp Pendleton, Calif. U.S. Secretary of Labor Hilda Solis also attended the open house and met with veterans attending the current program. A second training school is under development for 2011 at Camp Lejeune, N.C. The company plans to support this school as well.

North American Robot Suppliers Post Best Year Since 2007

North American-based robotics companies reported strong growth in 2010, posting the best year since 2007, according to statistics by Robotic Industries Association (RIA), Ann Arbor, Mich.

North American suppliers reported orders of 13,174 robots valued at $845.6 million from North American-based companies, increases of 39% in units and 49% in dollars. When orders from customers outside North America are included, the totals are 15,860 robots valued at $993.2 million, gains of 52% in units and 58% in dollars. The automotive industry accounted for 51% of the North American orders in 2010. Orders to this sector were up 34% in units. Nonautomotive orders also jumped 46%.

“The acceleration of orders to customers in all sectors, particularly nonautomotive industries, is great news for the robotics industry,” said John Dulchinos, chair of RIA’s statistics committee and president/CEO at Adept Technology.

Community College Receives Grant to Fund Welding Program

The Community Foundation for the Ohio Valley has made a $40,000 grant to West Virginia Northern Community College for funding a new welding program at the New Martinsville campus. It will offer basic training in shielded metal arc, gas tungsten arc, and gas metal arc welding. In addition to welding units, the college will purchase ventilation systems; both will be portable.

Currently, Wetzel County has an unemployment rate of 11.6%. At the same time, natural gas producers are becoming active, with 290 Marcellus Shale permits from the county received by the state Department of Environmental Protection in the past
year. Studies performed on the workforce needs of the gas industry indicate high-priority occupations in the initial stages of production are deckhand, welder, and truck driver.

Lincoln Electric to Assemble Wind Turbine

Work has started in Euclid on what will soon be the largest wind turbine in northeastern Ohio. It’s financed, in part, by a $350,000 loan from Cuyahoga County government. The Lincoln Electric Co. will use the loan to help pay for assembling a 2.5-MW wind turbine on its Euclid property. Officials indicated the new turbine will help grow its tower-related welding business, reduce its carbon footprint, and save the company approximately $500,000 annually in energy costs. The turbine will stand about 443 ft tall when measured to the blade’s tip.

The county loan represents about 6% of the financing of a $5.9 million project. The state of Ohio has committed about $1.12 million from the American Recovery and Reinvestment Act State Energy Program toward the turbine. The balance of the cost, about 75%, will be covered by Lincoln.

Industry Celebrates 125 Years of Commercial Aluminum Production

One hundred and twenty-five years ago this past February, Charles Martin Hall discovered a method by which to produce aluminum commercially, transforming it from a precious metal to an everyday material. Today, among many other benefits, aluminum makes commercial aviation and space exploration possible; revolutionizes food/beverage packaging; and transforms the modern construction industry.

Hall set about a series of experiments in a woodshed behind his parents’ rural Ohio house, culminating in his discovery nine months later of the electrolytic reduction method for producing primary aluminum. By passing an electric current through a carbon crucible filled with a cryolite bath containing alumina — producing a congealed mass that contained pure aluminum — the 22-year-old achieved what had eluded scientists for decades. To this day, that same process, which Hall patented, is used by aluminum companies to produce aluminum from ore.

“Aluminum’s utility across a wide swath of product applications is, by now, well understood by the American consumer,” said Aluminum Association President Steve Larkin. “What consumers may not be aware of are the sustainable characteristics of this remarkable metal. In particular, its light weight, durability, and recyclability make it a crucial part of the solution to our society’s growing concerns over the environment, energy security, and resource management.”

Wabash National® to Manufacture Bulk Liquid Storage Containers

Wabash National Corp. recently announced an exclusive, 5-year agreement to manufacture frac tanks, which are bulk liquid storage containers used in the environmental services, plus oil and gas industries, for Indiana-based Sabre Manufacturing. The company will be investing approximately $2.5 million and adding up to 200 jobs, including welding positions, to support the new manufacturing initiative. For current openings, visit www.wabashnational.com/careers/careers.htm.

Approximately 300 units this year are expected to be manufactured at Wabash National’s South facility in Lafayette, Ind. Production is expected to commence soon with upwards of 2500 units being produced over the next 5 years.

— continued on page 119
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PEMA to Build Large Robotic Heavy Welding Station in Europe

An artist’s rendering of the robotic welding station Pemamek Oy Ltd. is building for Norwegian winch manufacturer I. P. Huse AS.

Pemamek Oy Ltd. (PEMA) has taken on the job of designing, constructing, and delivering a heavy robotic welding station for the Norwegian heavy winch manufacturer I. P. Huse AS. Once installed in October, I. P. Huse will own and operate what is believed to be the largest heavy robotic welding station in Europe.

The welding station will include two Yaskawa-Motoman welding robots both on three-axis robot positioners, a heavy PEMA two-axis positioner for the drum assemblies, and two sets of Lincoln Electric PowerWave welding power sources. The maximum diameter of the workpieces is 6 m, and the maximum weight is 35,000 kg. PEMA WeldControl programming will control the station; I. P. Huse’s existing off-line programming software can also be used, if necessary. Also included is a safety system, operator training package, and commission and start-up of the station.

I. P. Huse AS, which is located on the island of Harøy, Norway, designs and builds large winches for anchor handling vessels, as well as winches and mooring equipment for FPSOs and other vessels.

Atlas Copco to Increase Ownership in Indian Subsidiary

Atlas Copco AB, Stockholm, Sweden, plans to acquire at least 50% of all shares it does not already own of its subsidiary Atlas Copco (India) Ltd., and will also apply for delisting of its shares from Indian exchanges. The company will initially acquire about 1.8 million shares at approximately $62 per share.

“This investment is in line with the group’s policy of having wholly owned foreign subsidiaries, and offers us greater operational flexibility in India,” said Hans Ola Meyer, chief financial officer of Atlas Copco AB.

Atlas Copco is an industrial group that produces compressors, construction and mining equipment, power tools, and assembly systems. Financial market regulations in India require publicly listed companies to have a public shareholding of at least 25% by June 2015, or apply for delisting. A delisting requires the purchase of at least 50% of outstanding shares, and at least 90% ownership.

Magna to Build New Plant in Mexico

Magna International, Inc., Aurora, Ont., Canada, plans to build a state-of-the-art facility in San Luis Potosi, Mexico. The plant will be a division of Cosma International, a unit of Magna and a leading global automotive body and chassis system supplier. The plant will employ approximately 700 people and will produce stamped and welded assemblies for a variety of automakers. It is expected to be about 300,000 sq ft with the ability to expand to up to 450,000 sq ft.

The company plans to invest more than $100 million to build the new facility, which is expected to open in June 2012.

Company Plans to Set Up Mobile Spiral SAW Pipe Mill in India

Zenith Birla (India) Ltd., part of the Yash Birla Group, plans to set up a manufacturing unit for large-diameter spiral submerged arc welded (SAW) pipes. The company plans to import a mobile spiral mill from Australia that is capable of producing pipes in sizes from 18 to 100 in.

“Once commissioned, it will be the first mobile spiral mill that can move from one location to another location and manufacture pipes at site, thus reducing transportation cost and wastage of materials,” a company spokesperson said. “The move will enable Zenith Birla to become the leading enterprise that can manufacture products from half an inch to 100 in. of steel pipes in the country.”

The company’s current production capacity is 210,000 tons per year of up to 8-in. steel pipes at its facility in Khopoli, near Mumbai. After the expansion, it will have the potential of delivering 360,000 tons per year of up to 14-in. steel pipes.

Praxair to Supply Oxygen to Steel Plant in Brazil

White Martins, the Brazil-based subsidiary of Praxair, Inc., recently signed an agreement to supply oxygen to ArcelorMittal’s steel production facility in João Monlevade, in southeast Brazil. The company will build a new air-separation unit with a capacity of 780 tons per day that will be equipped with advanced process controls and energy-efficient process cycles. It is expected to start operation in early 2013.

The oxygen is used to improve furnace efficiency and environmental performance. White Martins has supplied ArcelorMittal at different locations in Brazil for 20 years.

Fluor Awarded Contract for LNG Project in Australia

Fluor Corp., Irving, Tex., was recently awarded a contract for engineering, procurement, and construction services by Santos Ltd. for its Gladstone liquefied natural gas project in Queensland, Australia. The contract, valued at $3.5 billion, includes upstream facilities associated with the 7.8 million ton/year liquefied natural gas project.

“Fluor shares Santos’ and the partners’ commitment to build this landmark clean-energy project with the highest performance in safety and project execution while maintaining world-class environmental standards and close engagement with the local communities,” said Peter Oosterveer, president of Fluor’s Energy & Chemicals Group.
Here’s to the heroes and their loyal sidekicks.

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No weld job is too difficult, too daring, or too daunting for this dynamic duo!
Friends and Colleagues:

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 Fellows. In particular, I would make a special request that you look to the most senior members of your Section or District in considering members for nomination. 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 take the extra effort required to make sure that those truly worthy are not overlooked because no obvious individual was available to start the nomination process.

For specifics on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Fellow nomination form in this issue of the Welding Journal. 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, 2011. The Committee looks forward to receiving numerous Fellow nominations for 2012 consideration.

Sincerely,

Thomas M. Mustaleski
Chair, AWS Fellows Selection Committee
CLASS OF 2012
FELLOW NOMINATION FORM

DATE ___________________ NAME OF CANDIDATE ____________________________

AWS MEMBER NO._____________________________ YEARS OF AWS MEMBERSHIP ____________________________

HOME ADDRESS _____________________________________________________________

CITY________________________ STATE ______ ZIP CODE ______ PHONE ______

PRESENT COMPANY/INSTITUTION AFFILIATION: _______________________________________

TITLE/POSITION: _______________________________________________________________

BUSINESS ADDRESS _____________________________________________________________

CITY________________________ STATE ______ ZIP CODE ______ PHONE ______

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION _________________________________________________________________

MAJOR & MINOR ______________________________________________________________

DEGREES OR CERTIFICATES/YEAR _______________________________________________

LICENSED PROFESSIONAL ENGINEER: YES ______ NO ______ STATE ______________

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE __________________________________________________________________

POSITION ________________________ YEARS ________________________

COMPANY/CITY/STATE __________________________________________________________________

POSITION ________________________ YEARS ________________________

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:

______________________________________________________________________________

______________________________________________________________________________

IT IS MANDATORY THAT A CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE
SELECTED AS AN AWS FELLOW ACCOMPANY NOMINATION PACKET. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE IN-
CORPORATED WITHIN THE CITATION CERTIFICATE.

SEE GUIDELINES ON REVERSE SIDE

SUBMITTED BY: PROPOSER _________________________ AWS Member No. _________________________

Print Name __________________________

The Proposer will serve as the contact if the Selection Committee requires further information. Signatures on this nominating form, or
supporting letters from each nominator, are required from four AWS members in addition to the Proposer. Signatures may be acquired
by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should
be submitted.

NOMINATING MEMBER: _____________________________________________________________

Print Name _________________________ AWS Member No. _________________________

NOMINATING MEMBER: _____________________________________________________________

Print Name _________________________ AWS Member No. _________________________

NOMINATING MEMBER: _____________________________________________________________

Print Name _________________________ AWS Member No. _________________________

SUBMISSION DEADLINE July 1, 2011
Fellow Description

DEFINITION AND HISTORY
The American Welding Society, in 1990, established the honor of Fellow of the Society 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 the outstanding accomplishments and technical impact of the individual. Such accomplishments will have advanced the science, technology and application of welding, as evidenced by:
- Sustained service and performance in the advancement of welding science and technology
- Publication of papers, articles and books which enhance knowledge of welding
- Innovative development of welding technology
- Society and chapter contributions
- Professional recognition

RULES
1. Candidates shall have 10 years of membership in AWS
2. Candidates shall be nominated by any five members of the Society
3. Nominations shall be submitted on the official form available from AWS Headquarters
4. Nominations must be submitted to AWS Headquarters no later than July 1 of the year prior to that in which the award is to be presented
5. Nominations will remain valid for three years
6. All information on nominees will be held in strict confidence
7. No more than two posthumous Fellows may be elected each year

NUMBER OF FELLOWS
Maximum of 10 Fellows selected each year.

AWS Fellow Application Guidelines

Nomination packages for AWS Fellow should clearly demonstrate the candidates outstanding contributions to the advancement of welding science and technology. In order for the Fellows Selection Committee to fairly assess the candidates qualifications, the nomination package must list and clearly describe the candidates specific technical accomplishments, how they contributed to the advancement of welding technology, and that these contributions were sustained. Essential in demonstrating the candidates impact are the following (in approximate order of importance).

1. Description of significant technical advancements. This should be a brief summary of the candidates most significant contributions to the advancement of welding science and technology.
2. Publications of books, papers, articles or other significant scholarly works that demonstrate the contributions cited in (1). Where possible, papers and articles should be designated as to whether they were published in peer-reviewed journals.
3. Inventions and patents.
4. Professional recognition including awards and honors from AWS and other professional societies.
5. Meaningful participation in technical committees. Indicate the number of years served on these committees and any leadership roles (chair, vice-chair, subcommittee responsibilities, etc.).
6. Contributions to handbooks and standards.
7. Presentations made at technical conferences and section meetings.
8. Consultancy — particularly as it impacts technology advancement.
9. Leadership at the technical society or corporate level, particularly as it impacts advancement of welding technology.
10. Participation on organizing committees for technical programming.
11. Advocacy — support of the society and its technical advancement through institutional, political or other means.

Note: Application packages that do not support the candidate using the metrics listed above will have a very low probability of success.

Supporting Letters
Letters of support from individuals knowledgeable of the candidate and his/her contributions are encouraged. These letters should address the metrics listed above and provide personal insight into the contributions and stature of the candidate. Letters of support that simply endorse the candidate will have little impact on the selection process.

Return completed Fellow nomination package to:

Wendy S. Reeve
American Welding Society
Senior Manager
Award Programs and Administrative Support
550 N.W. LeJeune Road
Miami, FL 33126

Telephone: 800-443-9353, extension 293

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Committee proposal of the time (Ref. 3). Three austenitic stainless steel electrode compositions were proposed, as shown in Table 1. AWS later abandoned the nominal composition type designations in favor of the AISI steel type designations for stainless steel welding electrodes. Of these proposed classifications, the composition limits changed somewhat over time: the 18-8 Mn evolved into 307, the 18-8 Mo evolved into 308Mo, and the 25-20 is the same as 310.

Subsequently, consumable manufacturers succeeded in reducing diffusible hydrogen in weld metal from ferritic low-alloy steel welding consumables so that the cold cracking problems were mitigated with ferritic electrodes for welding armor, and as a result demand for austenitic stainless steel welding consumables for welding armor continually decreased. Consequently, these austenitic stainless steel electrodes for welding armor have largely disappeared in the United States, except that 310 has other uses. However, Germany in particular, and Europe in general, has retained the prewar high-manganese 18-8 composition for welding a host of steels that have severe tendencies to suffer from hydrogen-induced cracking. The GMA wire electrode, which you are finding on the Internet under trade names that reduce than the AWS ER307. With higher manganese than AWS ER307, it is more stable as regards transformation of diluted weld metal.

<table>
<thead>
<tr>
<th>Class Designation</th>
<th>Chemical Composition (wt-%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>18-8 Mn</td>
<td>C  0.20 max</td>
</tr>
<tr>
<td></td>
<td>Mn 2.0 to 5.0</td>
</tr>
<tr>
<td></td>
<td>Cr 18.0 min</td>
</tr>
<tr>
<td></td>
<td>Ni 8.0 min</td>
</tr>
<tr>
<td></td>
<td>Mo 1.25 max</td>
</tr>
<tr>
<td>18-8 Mo</td>
<td>C  0.20 max</td>
</tr>
<tr>
<td></td>
<td>Mn 3.0 max</td>
</tr>
<tr>
<td></td>
<td>Cr 18.0 min</td>
</tr>
<tr>
<td></td>
<td>Ni 8.0 min</td>
</tr>
<tr>
<td></td>
<td>Mo 1.0 to 4.0</td>
</tr>
<tr>
<td>25-20</td>
<td>C  0.20 max</td>
</tr>
<tr>
<td></td>
<td>Mn 3.0 max</td>
</tr>
<tr>
<td></td>
<td>Cr 24.0 min</td>
</tr>
<tr>
<td></td>
<td>Ni 19.0 min</td>
</tr>
<tr>
<td></td>
<td>Mo —</td>
</tr>
</tbody>
</table>

Table 2 — Composition Limits for G 18 8 Mn vs. ER307

<table>
<thead>
<tr>
<th>Class</th>
<th>C (wt-%)</th>
<th>Mn (wt-%)</th>
<th>P (wt-%)</th>
<th>S (wt-%)</th>
<th>Si (wt-%)</th>
<th>Cr (wt-%)</th>
<th>Ni (wt-%)</th>
<th>Mo (wt-%)</th>
<th>Cu (wt-%)</th>
<th>Other, total (wt-%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>EN 12072, G 18 8 Mn</td>
<td>0.20</td>
<td>5.0 to 8.0</td>
<td>0.03</td>
<td>0.03</td>
<td>1.2</td>
<td>17.0 to 20.0</td>
<td>7.0 to 10.0</td>
<td>0.3</td>
<td>0.3</td>
<td>NS</td>
</tr>
<tr>
<td>ISO 14343, G 18 8 Mn</td>
<td>0.20</td>
<td>5.0 to 8.0</td>
<td>0.03</td>
<td>0.03</td>
<td>1.2</td>
<td>17.0 to 20.0</td>
<td>7.0 to 10.0</td>
<td>0.5</td>
<td>0.5</td>
<td>NS</td>
</tr>
<tr>
<td>AWS A5.9, ER307</td>
<td>0.04 to 0.14</td>
<td>3.30 to 4.75</td>
<td>0.03</td>
<td>0.03</td>
<td>0.30 to 0.65</td>
<td>19.5 to 22.0</td>
<td>8.0 to 10.7</td>
<td>0.75</td>
<td>0.75</td>
<td>0.50</td>
</tr>
</tbody>
</table>

Q: I have a 40-year-old WPS that calls for GMA welding of armor with AWS A5.9 Class ER307 filler metal. When I go online to find a source of ER307, I find many suppliers of a product carrying a trade name that includes 307, but the composition is not ER307 — the product contains no molybdenum, but more manganese, vs. ER307. The product literature indicates that ER307 is the nearest equivalent to an American Welding Society (AWS) classification. What is going on here?

A: It appears to me that the traditional AWS A5.9 ER307 classification has largely disappeared from the marketplace. It has an interesting history that links it to the products you are finding online. The story begins in the armaments buildup leading up to, and during, World War II, years before the gas metal arc (GMA) welding process was invented. The welding was done mainly with the shielded metal arc welding (SMAW) process. The armor of the day was medium carbon (e.g., 0.4% C), low-alloy steel of quite high hardenability. Welds made with ferritic electrodes had severe hydrogen-induced cracking problems, so austenitic stainless steel covered electrodes were much used for armor.

In the United States, armor was initially welded with E310-XX covered electrodes (25% Cr, 20% Ni). But the Germans experienced nickel shortages more quickly than the United States did, so that German armor welding with austenitic stainless steel electrodes tended toward lower nickel content. Ritchie (Ref. 1) reports from studies of recovered German armor that electrodes of 18% Cr, 8% Ni were used. He doesn’t state this, but it seems clear that high manganese was necessary to obtain austenite stability in the diluted weld metal. This was later confirmed by Thielsch (Ref. 2). The shortage of nickel caused the United States to also tend in this alloy direction, as can be seen in an AWS Filler Metal Specifications Table.
metal to martensite than is ER307, and it has higher resistance to solidification cracking.

The G 18 8 Mn wire electrode is appearing more and more in North America due to its numerous applications. The AWS ASD Subcommittee members have decided that after the currently underway revision of AWS A5.9 is published, it will take up the matter of adoption of ISO 14343 to replace AWS A5.9. If this effort comes to fruition, then the G 18 8 Mn classification will become an AWS classification.

References

DAMIAN J. KOTECKI is president, Damian Kotecki Welding Consultants, Inc. He is a past president of the American Welding Society, currently treasurer and a past vice president of the International Institute of Welding, and a member of the AWS ASD Subcommittee on Stainless Steel Filler Metals, and the AWS D1K Subcommittee on Stainless Steel Structural Welding. Dr. Kotecki is a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel-Base Alloys, and a past chair of the A5 Committee on Filler Metals and Allied Materials. E-mail your questions to damian@damiankotecki.com or mail to Damian Kotecki, c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126.
Q: I am trying to join sintered silver contacts to copper bars. These are used in the manufacture of circuit breakers and other switch gear. We are presently using a soldering process, but we find that it is very slow, requires extensive part cleanup, and the final product is pretty much dependent on operator skill. Is there a better and faster process for this production part?

A: Joining of metals with very dissimilar melting points can be difficult. Copper melts at just under 2000°F while silver at about 1750°F. However, there is a little-known process called percussion welding that works well and produces extremely strong parts at good production speeds.

Percussion welding uses a special resistance welding machine. This machine has the traditional welding cylinder and welding transformer, but it additionally includes a strong doughnut-shaped electromagnet that is powered by a second resistance welding transformer. The machine's air-cylinder shaft that pushes the electrode closed passes through the center of this doughnut-shaped electromagnet. A "T" formation fastened to this shaft rests just above the top of the electromagnet when the electrode touches the part being welded with a spacing of about \( \frac{1}{4} \) in.

The sintered silver contact has a projection point on the side that touches the copper bar.

The process is as follows:
1. The copper part is installed on the lower electrode and clamped in place.
2. The sintered silver contact is pushed up into the upper electrode where it is held in place by a vacuum line connected to this hollow electrode.
3. After the start button is pushed, a door closes to protect the operator. In some machines, water is displaced to place the parts being welded underwater for the percussion welding sequence to eliminate the need for a moving door.
4. The upper electrode comes down under very low force, usually under 100 lb, with the projection now touching the top of the copper bar.
5. The welding control fires one-half line cycle of power. Because the parts are under very low force, this explodes the projection and produces an extremely hot arc at the contact point to the copper bar.
6. At some point during this same one-half line cycle before the molten metal has blown out of the weld zone, the second welding transformer is fired to power the doughnut-shaped electromagnet. This pulls the upper electrode down on the sintered silver contact to extinguish the arc and forge the molten projection metal into the hot copper bar.
7. The whole process is over in one line cycle (\( \frac{1}{4} \)th of a second) and sounds just like a gun shot.
8. The expulsion (flash) that flows out of the weld area is typically removed using a rotary cutting tool to dress the surface and also shape the top of the sintered-silver contact. This takes only a second or less to do and produces a complete joint. Some companies tumble the welded pieces to produce a polished finish on all surfaces.

The joint produced between the sintered-silver contact and the copper bar is strong enough to pull metal out of both parts when subjected to destructive testing, and the electrical resistance between the two parts approaches the electrical resistance of the base copper bar.

ROGER HIRSCH is immediate past chair of the RWMA, a standing committee of the American Welding Society. He is also president of Unitrol Electronics, Inc., Northbrook, Ill. Send your comments and questions to Roger Hirsch at roger@unitrol-electronics.com, or mail to Roger Hirsch, c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126.
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Electrode Dressing Makes a Better Spot Weld

Outlined are why the electrode face changes during welding, strategies for cutting blade selection, advantages of using tip dressers, and future methods

BY HIRO KUSANO

It's essential in automobile body production to perform resistance welding, including nut and bolt, spot, and stud welding. Thousands of spot welds support the quality and reliability of an automobile's body structure.

Technology continues to progress for preventing rust, along with making the auto body's structure lighter and stronger, through better materials. The demand for thin-coated steel has been steadily increasing for the past 20 years. Recently, the demand for high-tension material with rust-preventive coating has increased. Although there have been improvements to these materials, many new obstacles have arisen in spot welding.

This article is not intended to tell you how to weld these new materials, but rather to explain the changing of electrode management when using these materials to achieve better welding quality.

Why the Electrode Face Changes

During the process of resistance welding, two copper electrodes press down and create joule heat inside the steel material to be welded. This process creates a nugget that bonds together the steel material. In the case of galvanized steel, the galvanized coat melts and permeates on the electrode causing buildup on the electrode face. During this resistance welding process, a layer of alloy, Cu-Zn (copper and zinc), builds up on the electrode due to high pressure and temperature.

After repeating this phenomenon multiple times, the electrodes will be covered with buildup that eventually causes damage to the electrode, possibly causing the electrode to crack. Some of the alloy layer may come off the electrode and stick to the metal, which can cause cosmetic problems to the automobile body. Even though some of the layer may come off, the majority of the alloy layer remains on the electrode surface. This also causes less current to pass, which leads to weak welding conditions and possibly cold welds. Something has to be done to clean the electrode face so proper welding conditions can be maintained.

In addition to the galvanized material buildup problem, the electrode shape, cooling condition, steel material, coating, or welding gun may cause a deformed or cracked electrode. Current step-up programs are not good for the electrode because higher current softens the cap tip and causes the galvanized material to spread out more on the electrode causing greater buildup on the electrode face.

Analysis of the Electrode Face

To analyze the electrode's alloy layer, the following equipment was used:

- Electrode: CuCrZr material, 16-mm-diameter cap tip (female cap)
- Robot: 150 kg
- Welding gun: C gun
- Steel material: galvanized coated material (t = 1.0 mm, t = 1.2 mm)
- Welding specification: optimal for welding quality
- Weld time: 100, 300, 400, and 500

Because the dissolved Zn and steel permeated on the cap tip surface, there was a layer of alloy that formed. The alloy layer consisted of 79% Fe, 13% Zn, 6% Cu, 0.8% Cr, and 0.8% Al.

Results

In Fig. 1, the alloy layer steadily increases in size as the number of welds increase. There was a direct correlation found between larger alloy layer sizes and an increasing number of welds. In addition, it was found that with the increase in the number of welds, the alloy layer can cause indentation of the electrode surface. Based on fatigue testing, as the number of welds increase, the nugget can become more oval shaped, which can cause bad or cold welds.

Table 1 explains the correlation between the number of welds with the diameter of the weld nugget if no tip dressing occurs.

In Fig. 2, the black line represents non-coated steel, and the red line represents galvanized steel. The dotted black line represents the standard nugget size wanted when welding. Anything above the dotted line represents a good nugget/weld, and anything below the dotted line represents a bad nugget/weld. When the welds

HIRO KUSANO (hiro@changer-dresser.com) is a sales manager at Changer & Dresser, Inc., Anniston, Ala.

Table 1 — Correlation Table between Numbers of Welds to Alloy Layer Thickness

<table>
<thead>
<tr>
<th>No.</th>
<th>No. of Welds</th>
<th>Alloy Layer Thickness (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100</td>
<td>11</td>
</tr>
<tr>
<td>2</td>
<td>300</td>
<td>87</td>
</tr>
<tr>
<td>3</td>
<td>400</td>
<td>101</td>
</tr>
<tr>
<td>4</td>
<td>500</td>
<td>140</td>
</tr>
</tbody>
</table>

As you can see, 1800 welds ($t = 1.2$ mm) is the limit of good welds an electrode can make without tip dressing. Therefore, it’s essential to remove the alloy layer well before the 1800 weld limit.

What Is the Tip Dresser?

There are several types of tip dressers, but this article focuses on the in-line auto electric motor tip dresser. The unit is used for milling the face of an electrode operated by robotic programming — Fig. 3.

Tip dresser components include a geared motor, floating unit, holder and cutting blade, stand, and switching box (power supply). Additional options consist of an air blower, chip collection and tip verification devices, and a rotation sensor.

Tip Dressing Details

The main purpose of tip dressing is to extend electrode life by milling the electrode’s face to its original shape by removing the layer of alloy that has built up on the electrode surface from welding galvanized steel — Figs. 4, 5. This is the most efficient and effective method of electrode management. The quality and economical savings of resistance welding depends on the extension of the electrode’s life.

Dressing Time and Amount

The dressing time and amount depends on torque, rev/min of the dressing unit, and the cutting blade. Figure 6 shows the correlation between the dressing amount and gun pressure with 1 s of tip dressing. The most effective condition for tip dressing is also based on the steel thickness, number of welds, current, cycle time, and electrode material. The best condition for tip dressing should be decided under the worst conditions of alloy buildup. Some auto manufacturers use the in-cycle dress method that the manufacturer tip dresses after each job (approximately 25 welds). Because of this method, the manufacturer
may only have to dress for 0.3 to 0.5 s because the alloy layer didn’t build up due to the small number of welds.

This dressing method not only keeps welding quality high, but it also increases the electrode and cutting blade life. The method only removes hundredths of a millimeter each dress depending on the short dressing time. In comparing the in-cycle dress method to not dressing at all (step up), one must look at not only the first weld but also the last weld.

If welding is performed without using a tip dresser, the first weld would have good quality, but weld number 400 will not be the same quality and continually get worse. When using a tip dresser and the in-cycle method, the first weld will have the same quality as the 400th, and the quality stays the same because the electrode face keeps the original form and cleanliness. This allows you to not have to step up nearly as much, which saves time and money as the use of oversized transformers will not be needed.

The Importance of Cutting Blade Selection

Electrodes come in many different shapes and sizes. Therefore, cutting blades must be designed to fit each electrode — Fig. 7. These can come in many blade variations as well, including single, double, four, and reversible. They also come in various materials such as high-speed and carbide steel.

If a manufacturer uses the wrong cutting blade that doesn’t match the correct electrode, the electrode’s surface could resemble the photos in Fig. 8 (excluding the first image).

Guidelines for Tip Dressing

Following is useful information for tip dressing, including the number of welds and dresses along with optimal conditions, weld parameters, cutting blade life, verification devices, and chips/shavings management.

Number of Welds between Tip Dressing

The number of welds between tip dressing depends on the welding parameters and type of steel. For example, if the steel thickness is 1.0 mm, the maximum number of welds between tip dressing is 400 welds.

Optimal Tip Dressing Condition

The conditions that affect tip dressing are cutting blade shape, rev/min of the tip dresser, gun pressure, and tip dressing
The target result for tip dressing is one second of dress time while removing 0.1 mm of material. Choose the correct cutting blade shape, rev/min, gun pressure, and time to achieve this result. If results are unstable, it’s recommended you ask your tip dresser manufacturer for the best tip dressing condition for your program.

**Weld Parameters**

Some users follow a step-up program (2–5% increase) without using tip dressers. With tip dressing, there is no need to increase current.

**Number of Tip Dressings**

The number of dresses depends on tip dressing parameters. A user can dress up to 50–100 times per cap (depends on weld conditions, including weld gun, electrode shape, dress time, etc.).

**Cutting Life**

Cutting life is difficult to determine because of welding parameters such as weld gun type, material, gun pressure, and dress time. However, there are two ways to determine this factor. First, change your cutting blade on a periodic basis. For example, some users determined from experience what the shortest life a cutting blade has on an application and then changed these based on the shortest time. The second way is by using a weld face verification device. This allows a user to know if the cutting blade is dressing the electrode properly, and if it’s not, it alerts the user that a blade change is needed. Cutting life has steadily improved over the past few years due to new materials and technology in designing the cutting blades.

**Verification Devices**

There has been new technology introduced over the past few years to help the user with tip dressing. One of the new products is the rotation sensor that allows a user to be sure the motor of their dressing unit is turning. The second is the tip verification device that allows you to know whether or not you are getting a good tip dress.

**Chips/Shavings Management**

Over the past few years, society has seen a movement to keep the environment clean. Auto manufacturers have also followed in this movement. In the past, manufacturers used air blower units, and copper chips were blown all over manufacturing floors. Now, many manufacturers use devices that allow chips/shavings to be collected into containers for recycling. This keeps manufacturing floors clean and is also eco-friendly by recycling the copper shavings.

**What’s the Advantage of Using Tip Dressers?**

Here’s a breakdown of various tip dressing factors, including cost analysis, cap tip cost, and spatter reduction benefits.

**Cost Analysis without Tip Dressing**

- Number of welding robots: 50
- Time of manual cap tip change: 3 min per robot
- Cost per min: $0.80
- Number of welds between tip change: 1000
- Cost of cap tip: $0.50
- Usage of cap tips: 4000 per month
- Number of manual tip changes per month per robot: 40 times (4000/50/2)
- Cost of tip changing: $57,600 (40 times × 3 min × $0.80 × 50 robots × 12 months)
Cost Analysis with Tip Dressing

- Frequency of tip dressing: every 200 welds
- Number of tip dresses per cap: 40 dresses
- Number of welds per cap: 8000 welds (200 welds x 40 dresses)
- Usage of cap tips per month: 500 (based on above calculation, using tip dresser makes cap last 8 times longer)
- Number of tip changes per month per robot: (500/50 robots/2) = 5 times per robot
- Cost of cap tip change: $7200 (5 times x 3 min x $0.80 x 50 robots x 12 months)
- Result: $50,400 savings

Cap Tip Cost

- 4000 – 500 = 3500, 3500 caps x $0.50 = $1750 x 12 months = $21,000
- Result: $21,000 savings

From the above analysis, you can save $71,400 yearly and $5950 monthly.

Reduce Spattering

Tip dressing reduces spatter by not having to step up the current. When a manufacturer does not tip dress, it has to step up the current many times, causing massive spatter showers that can lead to cosmetic and weld quality problems. Tip dressing is not only cost effective, it’s also a good controller of spatter issues.

Future Method of Electrode Management

The future looks bright for tip dressing in automobile manufacturing as manufacturers continue to cut costs wherever possible all while being eco-friendly. Demand for tip dressers is at an all-time high, and new technology continues to increase daily.

Some of the new technology includes a servo dresser that uses an eighth axis of the robot servo motor. This next-generation tip dresser synchronizes with the robot and servo motor welding gun — Fig. 9. The advantage of this tip dresser allows manufacturers to use dressers in various welding conditions. The servo dresser can adjust motor rev/min while tip dressing, adjust the milling amount, and manage how the electrode is wearing as the electrode becomes smaller. This dresser is cost effective for new projects because there is no control box needed — only the dresser and stand.

Another technological breakthrough is the hybrid dresser that’s a combination of milling and forming the electrode. This device reforms the side by a roller and mills only the electrode’s face — Fig. 10. The amount of milling is 0.01 mm for the hybrid dresser. Test results show that one electrode was able to weld 40,000 times. This hybrid dresser works well, but it needs to have good maintenance and learned to be used. If this takes place, the hybrid dresser can produce good welding conditions with little spatter and long electrode life.

Conclusion

The importance of electrode management in modern body shops is at an all-time high. The uncertain climate that manufacturers are in today cause many engineers to look for ways to save money without risking quality.

Tip dressing is important and necessary because it helps improve economic impacts and provides better welding quality across the automotive manufacturing board. With the new technology previously mentioned, it’s felt that tip dressing will be something every automobile manufacturer will have in the near future, and it will dramatically impact costs as well as the environment for years to come. 

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Many HVAC shops are relying on their welding capabilities to bring in work and help them succeed in a down economy.

Pop culture attributes “keep your friends close, but your enemies closer” to Michael Corleone in The Godfather II, but throughout the centuries, leaders, from philosophers to generals, have expressed the same idea — know your competition. In the heating, ventilation, and air-conditioning (HVAC) world today, contractors not only need to know the competition, they need to understand their own company and its limits on what it can offer customers.

The down economy has pushed many HVAC contractors into becoming creative business strategists. The more they think outside the norm of everyday business, the better chance they have to survive. Whether it is partnering with another contractor to complete a job or mining the talents of the workers in the shop, some contractors see it necessary to expand the way they think about HVAC projects.

In Pueblo, Colo., where heavy plate work is common, Vision Mechanical’s leadership decided in 2001 to begin estimating jobs in that arena to add to their business opportunities. At the time, the events of Sept. 11 took its toll on the economy and contractors were just beginning to open their thinking to save their businesses. For Vision Mechanical, larger industrial jobs with additional welding was the way to go — Fig. 1.

When company Vice President Reggie Garcia says, “The work was out there; you just had to go and get it,” it sounds easy. But there was a learning curve on every front and a transition period.

“It takes time, and it’s an art,” he added. “You have to know your limits as a shop, too.”

Cooperating with the Competition

With this knowledge, a truce between competitors spelled success for Vision Mechanical, Pueblo, Colo. They made friends along the way and parts of the projects they worked on with others.

TIFFANIE BOND is a media relations specialist working on behalf of the International Training Institute, Alexandria, Va., www.sheetmetal-iti.org.
Mechanical. Sheet metal companies could get together to complement each other's talents and shop capabilities, keeping the industry, and their businesses, moving forward.

"You can get a little work. It keeps you busy. I can get a little work. It keeps me busy. A little work is better than no work. Part of a job is better than no job," Garcia said. "Right now, in this economy, something is better than nothing."

A decade after the change, Vision Mechanical wrapped up a power plant project in Wyoming (Figs. 2-4) and is ready to begin work on a $50 million power plant in Colorado. Neither job, Garcia said, would have belonged to Vision Mechanical without the extra components, such as welding, the company added to its business — Figs. 5, 6.

Garcia said he learned, as an apprentice, that sheet metal workers can do anything, but he thinks sometimes they forget about all the options available to them. The traditional way of doing things isn't always the most successful.

"You have to know your limits, but you have to look outside the box. The key is looking outside the box," Garcia said. "Our contractors have to get in that mindset. We have to start thinking, 'How are we going to grow our businesses and grow the industry?'"

A drastic change, such as the one demonstrated by Vision Mechanical a decade ago, isn't always feasible and it's never easy, said Mike Harris, program administrator for the International Training Institute (ITI) for the unionized sheet metal and air-conditioning industry.

In HVAC, as opposed to other applications, welding isn't risky and doesn't hold as many liability concerns because it's all about air flow. If a component fails, it's easily fixed and no one gets hurt. When HVAC
Fig. 4 — Keagan Singleton, a third-generation sheet metal worker, does some cleanup on a section of pipe destined for the Wyoming steam header project.

companies expand to provide industrial services, liability skyrockets. On larger projects, smaller companies run the risk of bidding themselves out of business if the project is delayed or is overdue. However, large-scale risks aren’t excuses for small-scale business decisions, Harris added.

“Many companies will only pull out all the stops if a loyal customer comes to them and asks for something outside their comfort zone,” he said. “Why not do this with a majority of customers on those smaller jobs?”

Utilizing Your Workers’ Talents

In Portland, Ore., Carol Duncan understands how difficult it can be to change. Her company, General Sheet Metal, was established in 1932. She has seen the economy shift many times in her nearly 30-year career with the company, but when change will mean whether the company stays open or closes, it has to happen.

A little more than a year ago, Duncan knew an expansion was needed in order to keep her HVAC shop viable. When Ric Olander, a Certified Welding Inspector and former Joint Apprentice Training Center (JATC) instructor, walked through the door with architectural experience, Duncan knew she’d found a way to expand her company. In 2010, architectural contracts made up 32% of all business for General Sheet Metal.

“In a market where everyone else’s numbers were dropping by 30%, ours increased by 30%. We actually did better in a bad economy,” she said. To put the numbers in perspective, however, because bids are lower, the increase just kept the doors open. “We kept up on our bills. We kept the guys working. The market’s improved, but we’re not out of the woods yet.”

It’s not the first time Duncan has locked into an employee’s talents and made them work for the company. Adam Kriss began working for the firm 11 years ago, and when Duncan found out he had a passion for AutoCAD and building information modeling software, she encouraged him and invested in his talent.

“It’s a conscientious investment,” she said. “It takes time to pay it back, and it has. I could see we could be more efficient (because of this software). To be able to draw it, download it, and build it made everything more efficient.”

Using the talents of employees is something any HVAC contractor can do, no matter how large or small, Duncan said. When work is slow, she scans government bids and puts in the footwork to network jobs they wouldn’t normally do such as photo booths and garbage cans and covers to keep employees working.

HVAC shops are going to be forced to diversify and include welding before long because, as Duncan has observed, more projects are requiring certified welders in addition to the HVAC work. Companies without a welding shop, the talent to run it, or the forethought to subcontract work could lose out on valuable projects.

“If I can’t do it, I’ll find someone who can,” Duncan said. “I never tell a customer, ‘no.’ I might know a guy down the street who does it. It’s networking with your competitors and anybody else.”

Taking Advantage of Welding Capabilities

Steve Kowats, welding quality assurance manager and industrial specialist for ITI, pushes contractors to bid on welding projects. If the workers have to come from a competitor, the equipment they’ll need can be rented. If a contractor has welders and no shop, one can be found.

“Welding is part of every HVAC project,” Kowats said. “If you think of a unit sitting on top of a building, it’s not just sitting there. There are fittings and supports.

Fig. 5 — A worker welds on a coal chute made from ½-in. plate on its way to a mine in Wyoming.
If more of the HVAC contractors were more diverse, took welding jobs, and invested in machinery, they'd keep guys working. They could do more welding jobs when the big HVAC jobs weren’t there. There is a 3 to 5% profit margin for large HVAC jobs, whereas welding can bring in a 30 to 40% profit margin. Contractors don’t realize they have the resources with sheet metal workers to do the welding part of the job” — Fig. 7.

The investment in a shop isn’t a stagnant entity that is only used when a project is under way. Duncan constantly thinks of ways to use the equipment and talent she has to move the company forward and keep her employees working.

“Some HVAC contractors have made a conscious decision not to have a shop,” Duncan said. “We have a shop, but you’ve got to get the most out of that equipment as you can.”

Duncan is proof of how looking outside her expertise saved a nearly 80-year-old company. When HVAC jobs started to dwindle, Duncan knew change was coming.

“We did come to a crossroads. You have to constantly figure out your next move and be ahead of the curve,” she said. “We couldn’t have survived doing straight HVAC the last two years.”

In 2001, the average tenure at General Sheet Metal was 18 years. Today, it’s only three years. Welcoming younger employees and encouraging older ones to make changes isn’t easy. When Duncan decided to expand the company beyond HVAC, she and her husband, Dave, were hesitant. They questioned whether they should risk their nest egg. “We borrowed money. Contractors are gamblers,” she said.

Having a new perspective on the company and individual projects brought change to General Sheet Metal all on its own. To Duncan, the next generation holds the future of her company, and if new workers don’t recognize themselves in the company, it won’t survive when owners like her reach retirement age. Bringing in fresh ideas keeps that forward movement continuous, she said.

Duncan admitted change isn’t comfortable, but if the world stayed continuously comfortable, it wouldn’t have modern advances such as the ability to decode DNA, the Internet, digital photography, space travel, and three-dimensional ultrasounds.

“Some of the best ideas have come from the newest guy on the job. They come in with fresh eyes. They just see it different. I have to keep reminding myself, ‘don’t get stuck in your ways,’” she added. “If you get some young blood and enthusiasm, it’s easier to think outside that box. Getting younger folks involved in the business gives you an edge.”

Many HVAC contractors can make their own opportunities just as Duncan and Garcia have, Kowats said. There are 86 American Welding Society Accredited Test Facilities in JATCs around the country with resources and classes, including certified welding and welding inspector classes, to help companies expand. In fact, welding shops are included in most centers nationwide.

“Training is always available,” Kowats said. “Just as companies are trying to diversify, sheet metal workers can do the same on an individual level. By taking classes and earning certifications, workers can make themselves more employable and bring ideas to the table to help further individual businesses and the industry. Success begins at every level, from the individual worker to the contractor. The more diverse you are, the further you’ll go.”

Fig. 6 — Shop Foreman Ken Bartmass stands next to a ¼-in. stainless steel water duct fabricated for a local steel mill. The ductwork will be installed at the furnace deck area and will need to withstand very high temperatures.

Fig. 7 — Steve Kowats, welding quality assurance manager and industrial specialist for the International Training Institute, demonstrates a technique during a welding instructor course in Las Vegas.
Welding Challenges in Today’s Automotive Industry

The automotive industry has certainly begun to show signs of rebounding from the economic downturn; however, companies are now being asked to “do more with less” as production volumes approach the levels of several years ago. More than ever, companies require operational efficiencies to maintain process flow and avoid unscheduled downtime of automated equipment.

Commonly, arc welding process challenges have a significant impact on achieving production goals and maintaining efficiency. Typical contributors to arc welding process inefficiencies include poor part fitup, tool center point (TCP) repeatability, and the ability to manage consumable changes, as well as spatter. Effectively managing these elements are essential if companies are to meet their quality requirements and fulfill a high-volume production demand.

As the automotive industry continues to experience an upswing in production...
Standardizing GMAW guns and consumables can help to avoid unscheduled downtime for changing out incorrect consumables or reworking quality issues.

BY ROBERT RYAN AND DAVID BELLAMY

Well-Managed Inventory Equals Greater Uptime

In recent years, the consolidation of automotive suppliers and facilities has resulted in welding operations made up of multiple brands of welding equipment, including power sources, robotic controllers, robotic manipulators, and gas metal arc welding (GMAW) guns. The outcome is often a wide breadth of products to manage and, with fewer resources, an increased potential for costly errors and unscheduled downtime.

Not surprisingly, in an industry that requires repeatable, high-volume welds — some up to 500 parts in a single shift — consistency is critical and any deviation in quality could result in downtime, scrap, or rework.

Ideally, standardizing on a single GMAW gun brand can help companies in the automotive industry avoid unscheduled downtime for changing out incorrect consumables or reworking quality issues. It can also reduce the amount of time spent managing inventory and provide a built-in poka yoke (mistake-proofing) system by eliminating (or significantly reducing) the opportunities for incorrect installation. Some companies have found that such standardization, along with a vendor-managed consumable system, works well and contributes positively to their goal of maintaining process efficiency and equipment utilization. The process of standardization may take time — replacing older GMAW guns as they wear, for example — but in the long term it can yield positive results in quality, performance, and cost. It also allows the production team to have one point of contact for technical support should questions arise about the performance of a GMAW gun or consumable, as opposed to having to contact multiple manufacturers.

To help with the transition to one
GMAW equipment supplier, front-end conversion kits are widely available and allow companies to standardize on a single brand of consumables, regardless of the type of GMAW gun being used. These kits are a good alternative to replacing an entire fleet of GMAW guns, while still offering the benefits of standardized inventory. In some cases, there is an opportunity to maximize the value of welding consumables by using the same contact tips and nozzles for semiautomatic applications (such as those for repairs or rework) after they are too worn for the robotic application, which further reduces inventory.

The Right Equipment Maintained Properly

Most welding technicians, supervisors, and operators in the automotive industry will attest to the fact that proper part fit-up is a constant concern. But not only do the parts that move into the weld cell need to be of the proper dimension and fit, the welding gun and consumables being used also need to provide accurate, repeatable, and durable performance.

Robotic GMAW guns are intended to weld at the same location every cycle by providing a consistent tool center point. Some products are more durable than others, but they all require preventive maintenance to optimize performance and prevent unscheduled downtime for replacing items like contact tips or liners.

Air-cooled robotic GMAW guns are among the most durable products available. Many applications in the automotive industry, such as suspension components, use thin materials (2 to 4 mm) that are ideal for an air-cooled robotic GMAW gun since the typical operating range is approximately 200–300 A at an average 60% duty cycle.

Water-cooled products improve performance at higher duty cycles, yet they are inferior to air-cooled products from a durability perspective. This is primarily due to the addition of water channels and other mechanical requirements of a water-cooled design. In the automotive industry, it is rare to experience applications that truly require a water-cooled GMAW gun. Even for end users welding thicker base metals (truck frames, for example), they are still likely to be within the comfort range of an air-cooled GMAW gun. In some cases, however, the addition of water cooling will help manage excessive heat and prolong the life of welding consumables (e.g., nozzles and contact tips). In these instances, there exists an opportunity to use a hybrid air-cooled/water-cooled gun. This type of product has the underlying construction and durability of an air-cooled robotic GMAW gun while offering some of the benefits of water-cooling.

Regardless of the welding application, it is important for companies to use the most appropriate type of GMAW gun for the job and properly maintain the equipment to ensure a maximum return on investment.

Good preventive maintenance procedures include inspection of all connections in the entire system: GMAW gun, wire feeder, ground cables, etc. Also include regular inspections for proper wire feeding and proactively replacing worn components during scheduled downtimes. Preventive maintenance procedures can be performed at the beginning of the shift to avoid interruptions to production.

Meeting the Demands

As the automotive industry returns to the production levels of several years ago, taking steps to standardize inventory, implement good preventive maintenance techniques, and select the right product will help companies become more efficient and do more with less.
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This double-barreled two-day conference in Charlotte will be something a little different in AWS conferences.

Day one will be all about the newer corrosion-resistant alloys and will cover such materials as the growing body of duplex stainless steels, the nickel-base alloys, and titanium. The duplex grades are beginning to replace the austenitic stainless steels in some instances, so there is much to learn in terms of how to weld these grades. Newer is the introduction of less expensive duplex alloys, so much needs to be learned here as well. There’s a new titanium alloy which could very well replace the popular 6Al-4V grade. It, too, will be on the program. Cladding is also playing an increasingly important role in the whole matter.

Day two will be devoted to another hot topic in welding, the new chrome-moly steels such as the 91, 92, and 911 grades. There are benefits here, but there is still much to learn. It’s a market cut out for the low-hydrogen consumables. Fabrication is tricky. Great attention must be paid to heat treat and dissimilar metal welding. Although not new but still a problem to many, there will even be discussion on that old nemesis, to some, 4130.

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Stud Welding Improves Kitchen Ventilation Systems

Switching to an automated system helped a manufacturer save labor and improve the appearance of its product

CaptiveAire, Raleigh, N.C., a leading manufacturer of commercial kitchen ventilation systems (Fig. 1), uses stud welding to attach fasteners without penetrating the system’s walls. This eliminates leakage and the possibility for bacteria or other impurities to build up in any area. The manual stud welding process the company used previously was labor intensive and made it difficult to maintain the vertical position of the studs. CaptiveAire contracted Spectrum Design LLC, Franklin, N.J., to develop a custom computer numerical control (CNC) stud welding system that automatically positions the studs and makes the welds — Fig. 2. International Welding Technologies, Inc., Lindenwold, N.J., manufactured the stud welding components. The resulting automated weld system is based upon a CNC gantry system (Fig. 3) from Techno, Inc., New Hyde Park, N.Y., that provides the input/output (I/O), automated operation, accuracy, and speed the application requires. Now, every stud is perfectly positioned before welding and the only labor required is to load the machine and turn it on.

CaptiveAire’s integrated kitchen ventilation packages include hoods, exhaust fans, electrical controls, direct-fired heaters, grease duct systems, fire-suppression systems, grease filters, and utility distribution systems. The company’s clients include independent restaurants, national chains, and other public and private institutions. In 2008, its sales reached $224 million. CaptiveAire has been recognized as one of the 100 largest private companies in North Carolina by Business North Carolina magazine and one of the top 50 fastest growing private companies in the Raleigh Triangle (Triangle Business Journal).

Advantages of Stud Welding

CaptiveAire has long used stud welding to produce stainless steel restaurant oven hoods — Fig. 4. Stud welding fasteners have a small tip extending from the base. Upon triggering, energy stored in capacitors is discharged to produce the weld. Peak currents vaporize the tip, drawing a precisely timed arc. The arc melts the full diameter of the stud and the same area of the base metal. Spring loading forces the molten fastener against the surface of the workpiece and the weld is completed in about 3 ms.

Stud welding improves food safety by eliminating potential sources of contamination. The elimination of holes also avoids the potential for leaks and improves

the strength of the base material. Appearance of the product is improved because studs are surface mounted to one side of the piece with no holes or reverse side marking. Stud welds won’t shake loose because they are fused to the base metal. Products made with stud welding include cookware, ovens, buffet heaters, hand rails used in elevators, slot machines, and signs.

Converting from a Manual to Automated Process

“We were very pleased with the benefits that stud welding provides to our customers but had concerns with the previous manual welding process,” said Luke Wilson, quality process engineer for CaptiveAire. “One problem with the manual process was the difficulty involved in positioning the studs against the 18-gauge base material. The welder eyeballed the stud to put it into position, and it was easy to place it at an angle. If the stud is not perpendicular to the material, then the nut that is fastened to the stud can put a dimple in the mating material. Another concern with the previous process was that it took a considerable amount of labor.”

The company approached Spectrum Design, LLC, Franklinville, Tenn., to discuss automating this application. Spectrum Design has 15 years of experience manufacturing custom process equipment including robotics and CNC-based systems. Spectrum Design offers state-of-the-art 3-D design software and in-house manufacturing capabilities. Its products include automated assembly, conveyors, robotic welding systems, and material handling systems. For this project, Spectrum Design partnered with IWT, a manufacturer of capacitor discharge stud welding products including both hand-held and fully automatic systems. The company makes both manual and automated stud welding equipment as well as a complete line of fasteners. The high-quality auto-feed fasteners are critical to controlling the quality of the finished product.

“Several years ago, we recognized the benefits of automating the stud welding process,” said Neil Wilkinson, IWT general manager. “Originally, we built our own CNC machines in house. But, as demand increased, we needed an off-the-shelf reliable positioning base that could easily support the stud welding application. An important consideration in selecting a supplier was the ability to provide the multiple I/Os needed to drive our capacitor-discharge power supplies. We make everything from very simple machines with a single feeder bowl and one head to machines with three weld heads supported by six feeder bowls. Each weld head and feeder bowl needs a signal from the control system to make it work.”

Gantry System Key to Successful Application

The supplier IWT selected was Techno, Inc. “Techno met our challenge by providing a breakout board with their gantry systems that provides either 16 or 32 I/Os,” Wilkinson said. “We connect these I/Os to the various devices on our machine and control them through commands in the CNC program. For example, one command tells the gantry to bring the head into position to make the weld, another command advances the weld head, another command fires the head, another turns off the weld head, and so on.

Techno’s ability to control all of our equipment was an enormous advantage and one of the main reasons that we selected their gantry systems.”

The Techno LCT gantry system is equipped with ball screws on all three axes with closed-loop servo motor drives that provide an accuracy of ± 100 microns per
300 millimeters (mm) and a repeatability of ± 100 microns. The machine also provides a speed of 152 mm or 6 in. per second, which is fast enough to achieve high production rates. Off-the-shelf CNC programming software is used to control the motion of the gantry and issue commands to the welding system — Fig. 5.

The gantry system also features an x-y travel of up to 60 x 120 in. All axes are provided with a home reference switch and far end limit switch. Each axis is provided with two double slide linear rails and four double bearing blocks. The x-axis bearings and drive screw are mounted below the work surface to protect them from dust and debris. The x-axis is provided with an aluminum dust cover and plastic lip seals to provide protection against contaminants. Heavy cast aluminum side plates support the y-axis and provide increased stiffness for positioning and cutting applications. The machine comes complete with electronics, cabling, motors, and software so the end user has a complete solution from a single source. This eliminates the cost and frustration of dealing with multiple vendors.

**Substantial Performance Improvements**

Spectrum Design worked with IWT’s engineers to design a special fastener to address the concerns with reverse marking on the application. International Welding Technologies’ cold heading division enabled rapid development of various fastener tip configurations that could then be tested for weld strength and reverse side marking. They researched the customer’s requirements and tailored the material properties of the fastener to provide optimal performance. The first machine delivered to CaptiveAire uses both a bottom load head in which the fastener is loaded into the bottom of the welding head and an auto-feed head. The machine has two heads for different types of studs. The machine program moves the head to a point, moves either the first or second head into position and then fires the head.

“We have seen substantial improvements by automating stud welding with the CNC machines,” Wilson concluded. “Our operators simply load a workpiece and run the program. Then while the machine is running, they can move to another task. The quality has been consistently excellent with studs positioned exactly perpendicular and no blemishes on the opposite side of the base material.”

The company was so pleased with the system that it recently purchased four more automated welding machines to install in each of its four other manufacturing facilities.
Collision Welding of Sheet Metals: A Practical and ‘Green’ Technology

Three geometric configurations for magnetic pulse welding and one configuration for laser impact welding are described that provide metallurgical bonds between like and dissimilar metal pairs

BY YUAN ZHANG, HUIMIN WANG, SURESH BABU, JOHN C. LIPPOLD, JOHN KWASEGROCH, MIKE LAHA, AND GLENN S. DAEHN

There’s growing recognition that optimal lightweight structures for automobiles, aircraft, and even bicycles are often created from multimaterial assemblies. Joining dissimilar high-strength light alloys has, therefore, been of significant and growing interest. One of the most elegant ways to accomplish dissimilar metal welding is by collision welding.

The advantages of collision welding include handling materials with dissimilar melting temperatures, and the low temperatures and brief times involved minimize the formation of continuous intermetallic phases while chemically bonding dissimilar metals (Ref. 1). Collision welding does not result in heat-affected zone or distortion near the welded region. One variant of collision welding that’s well accepted is explosion welding. This has been widely applied, but it can only be practiced in special and usually remote facilities.

This article explores two solid-state collision welding processes that can be integrated into most factory environments—magnetic pulse welding (MPW) and laser impact welding (LIW). Since 1969, MPW has been successfully applied for tube-to-tube impulse welding but typically employs relatively high discharge energies, usually in the range of 20~100 kJ (Ref. 2). While most studies have focused on circularly symmetric geometries (Ref. 3), much recent work has focused on lower symmetry sheet-to-sheet collision welding (Refs. 4–6). These methods tend to use much less energy than earlier tube welding experiments. For example, the reported energy to weld aluminum alloy plate about 1 mm in thickness to a mild steel plate is about 1.4 kJ for a 50 mm length (Ref. 6). Low primary circuit inductance and rapid rise times (time for actuator to reach maximum primary current) in the capacitor discharge circuit are largely responsible for this efficiency.

This article’s objective is to explain the MPW application’s flexibility in that many configurations are possible, and to introduce LIW. Both processes complete within microseconds, and both can be practiced in conventional manufacturing environments without unusual safety hazards. Four configurations for plate-to-plate welding are introduced and methods for instrumenting the collision process are described. Preliminary mechanical property data are also shown.

Principles of Magnetic Pulse Welding

Magnetic pulse welding is closely analogous to explosion welding, and it’s necessary to have a collision angle to form a jet along the mating surface (Ref. 6). However, rather than explosives, MPW uses electromagnetic force to accelerate the flyer plate. Therefore, MPW can be safely and reproducibly used in production environments controlled by an electric power supply. The fine adjustments to parameters are straightforward. With proper design, the process has high-energy efficiency because heating or melting of the metals to be joined is not required.

As shown in Fig. 1, the MPW system includes a capacitor bank, an actuator, and workpieces.

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The capacitor bank uses low-inductance buswork to connect a group of capacitors to an actuator that has significant inductance and generates a magnetic field. A chosen standoff distance provides a distance for acceleration. When capacitors are discharged, an intense current that typically peaks in the tens of thousands of amps, with a time to peak current on the order of 10 μs flows through the actuator. This is the primary circuit.

With proper design of the actuator, the associated electromagnetic field induces a strong secondary (eddy) current through the nearby metal workpiece (flyer plate). Therefore, the flyer plate carries current and produces its own magnetic field. Since the primary current and the secondary current generally travel in opposite directions, their interactions result in a strong repulsive force, which is the Lorentz force. Launch velocities well in excess of 100 m/s are possible for sheet metals of practical interest (i.e., on the order of 1-mm-thick aluminum or steel). The magnetic launch process can be effectively modeled with appropriate finite element software; for example, LS-DYNA has been adapted to accurately model electromagnetic forming with elastic and plastic deformation (Ref. 7).

Examples of Magnetic Pulse Welding Using Sheet Metal

Lap collision welds can be produced using simple actuators. These are typically created from a high-strength, high-conductivity copper alloy backed by a glass-reinforced phenolic and insulating tape. The example shown in Fig. 2 has a primary actuator fabricated from the copper alloy C18150. The geometry creates a nearly complete eddy current path, and the narrow leg of the actuator has a much greater current density (and therefore magnetic pressure) than the wide leg. It also has a somewhat higher inductance than the wide leg.

To study the collision angle and velocity effects for lap joints, a second-generation flat bar actuator was designed that offers different initial launch angles — Fig. 3. Figure 3A presents the actuator that’s assembled into the die. The narrow leg has a chamfered angle and four through holes with a 2.54 mm diameter. The holes are used for laser velocimetry measurements of sheet velocity and position. The sheet velocity and acceleration can be measured at multiple locations using photon doppler velocimetry. Implementation at The Ohio State University is described elsewhere (Ref. 8), and results are shown later in this article. The chamfered angle determines the initial launch angle as shown in Fig. 3B. The narrow leg has been chamfered into 5, 10, 15, 20, and 30-deg angles. Accordingly, the flyer plates being welded were bent to such angles, providing initial launch angles.

Preflange Lap Joint

Magnetic pulse welding can also elegantly collision weld flanged metal sheet to form a simultaneously hemmed and welded joint. The preflange actuator can be regarded as a bar actuator; however, the inbound leg and outbound leg are not in the same plane. The being welded plate was bent and inserted beneath one of the actuator legs with a chosen preflanged angle. Primary current in the actuator produces a Lorentz force on the thinner leg that can accelerate the flanged flyer against the central target workpiece. The flyer plate undergoes flanging and welding at once. This is shown schematically in Fig. 4.

Lap Joint with Embedded Wires

The uniform pressure (UP) actuator developed by Daehn, Kamal, and Banik (Refs. 9, 10) has been developed for the electromagnetic forming of features in nominally flat sheets. The actuator, shown in Fig. 5A, is an oblong solenoid coil with a secondary circuit that’s made up of a return path and workpiece. Its function is to accelerate a sheet of metal in a nearly planar state to high velocities. Commonly, a 1-mm-thick piece of aluminum can be accelerated to 200 m/s over a 4 mm launch distance.

While normal collision does not cause welding, if features are placed on the tar-
get sheet, the UP actuator can be used for collision welding. In the present example, collision welding was conducted with embedded wires between the flyer and target plates. The embedded wires are attached to the target plate prior to welding. These wires disrupt the normal flight of the flyer plate and force collision between the flyer and target at a significant angle that varies locally.

The overall system setup is shown in Fig. 5B. A clamping pressure of about 5000 lb/in.² is used to couple the workpiece to the return path of the actuator.

One of the welded samples is shown in Fig. 5C. The welded plate materials are AA6061, and the embedded wire is steel. The thickness of the plate is 0.254 mm, and the steel wire diameter is 0.25 mm. The overall performance of the UP actuator is shown in Fig. 6, which shows flyer sheet acceleration as measured by photon doppler velocimetry over a distance of 2 mm before it collides with the target. The measured current is also shown. It’s advantageous for impact to happen near peak current as this minimizes rebound and encourages impact welding.

**Principle and Configuration of Laser Impact Welding**

Magnetic pulse welding is efficient so long as an eddy current can be carried along a closed path. However, this is difficult to scale to ‘spot’ type geometries. A new technique, laser impact welding, has recently been proposed and demonstrated (Ref. 11). This method is another variant on collision welding and has some different characteristics than MPW that allow it to couple efficiently with other geometries. Some early results are presented below.

Laser impact welding is also the result of the collision between a flyer and target, both of which are initially at ambient temperature. The essential technique is shown in Fig. 7. The beam from a pulsed laser shines through a transparent substrate and strikes the darkened (with ink) surface of a metal flyer. The optical energy of the laser is absorbed, ablating the ink. The rapidly expanding ink provides pressure both against the flyer and substrate. The ablation generates a plasma-based pressure pulse that accelerates the substrate and flyer away from each other in a manner that’s in rough accord with conservation of momentum. Thus, if the flyer is relatively thin and light, it can accelerate to great velocity. After free flight over a short distance (usually under 100 µm), the plates collide with high velocity. The short duration of the high-pressure pulse causes the surfaces to co-deform, forming a plasma jet if the proper impact conditions are met. When the clean metal surfaces meet under pressure, metallurgical joining is accomplished. Figure 6 also shows that the collision angle and the standoff distance can be adjusted by simple geometric variations. The optical output energies for LIW are in the order of...
a few joules, as opposed to several or tens of kilojoules for MPW and megajoules for explosive welding. Accordingly, the sizes that can be bonded with each technique scale proportionately. Laser impact welding, it seems, can be tuned to produce collision welding for almost arbitrarily small foil thicknesses and length scales.

In the present example, AA1100 plates and low-carbon steel 1010 plates were welded by LIW. The laser beam source was a Continuum Powerlite II YAG laser, which can output a 3-J pulse in the infrared spectrum at a 1064-nm wavelength. The pulse width was about 8 ns, and the beam was focused to a 3-mm spot diameter. In the case of aluminum-to-aluminum joining, the flyer sheet had a thickness of 0.175 mm. The target plate was large in all dimensions relative to the flyer plate and had a 15-deg taper as shown in Fig. 6. For dissimilar welding, the flyer plate was AA1100 and 0.05 mm thick, 3 mm wide, and 20 mm long. The target plate was low-carbon steel 1010, which was again a large block with a 15-deg tapered flat surface. The real impact region on the flyer plate was circular with a 3-mm diameter. The metal surfaces were lightly ground with sand paper prior to welding.

**Collision Weld Structure and Properties**

**Microstructure**

The welded interfaces from MPW and LIW processes indicate wavy morphology as shown in Figs. 8 and 9A, B. For MPW, the wavy structures show both nonsymmetric and symmetric waves, and it's similar for all samples; for LIW, the interface is more nearly flat with smaller and more symmetric waves. The wavelengths and amplitudes increase with both increasing input energy and sample thicknesses. In all cases, the two materials genuinely adhere to each other except at the edges. There is a strong correlation between wave amplitude and input energy. Explosive welding, where energy inputs per unit area are many times that seen in MPW or LIW, have much greater wave amplitudes. This correlation has been examined in detail elsewhere (Ref. 12).

High-velocity collision welding invariably leads to greatly refined interface structures. This is explored in some depth elsewhere (Ref. 13), but one specific example is shown here for a dissimilar metal Cu-Al interface. The welded interface exhibited ultratine grain structure, which was of several tens of nanometers in diameter as shown in Fig. 10. The transmission electron microscopy image was from 5.6 kJ welded Cu-Al interface (using the approach shown in Fig. 2). The grain size decreases to the nanometer range in the impact interface with diffraction pattern changing from spots to rings, indicating a nearly random, nanocrystalline material. High local strengths are expected in accord with the Hall-Petch relationship. The large grain size gradient was caused by high strain rates strain and strain rate gradients from collision welding. The submicron grains near interface were elongated along the impact direction.
Local Hardness

The lap joint samples have been examined by lap shearing, peeling, and nanoindentation tests. For both AA6061 and Cu110 similar metal weldments, the joint region is stronger than the base metal; the fracture of the lap shearing test was out of the welded region and broke at the base metal. For the dissimilar materials joint, the peeling test results exhibited base metal fracture before the joints were fully pulled apart. Lap shearing and peeling tests qualitatively suggested the collision joint was stronger than the base metal. Nanoindentation test quantitatively presents the joint strength as shown in Fig. 11, which shows the local hardness values increased significantly at the interfaces.

Conclusion

This article studies a variety of actuator configurations for magnetic pulse welding for sheet metal lap joint welding. Three types of configurations for magnetic pulse welding — direct, preflange, and embedded wire lap joints — plus one configuration for laser impact welding are described. Further, the electromagnetic acceleration can be predicted by numerical modeling as discussed elsewhere (Ref. 7). Collision welding was applied to both similar and dissimilar materials. The study also shows that high-velocity oblique collision welding is feasible in lab or plant environments and provides metallurgical joining over a range of length scales and sample geometries. These methods can be applied to join similar and dissimilar materials. The wavy interface is observed at all length scales, but wave amplitude and period decrease with decreasing energy. These processes result in the improved microhardness along the interface after high-velocity collision welding. These techniques are significant because they can be easily applied in typical manufacturing environments and offer new opportunities for dissimilar metals welding. Equipment and techniques for these practical collision welding processes are now under active development.

Acknowledgment

The financial support from the American Welding Society for a student fellowship to Yuan Zhang is highly appreciated.

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Remote Laser Beam Welding: A Cost-Effective, High-Productivity Tool for Manufacturing

A production cost model developed for remote laser beam welding was compared to a cost model for spot welding to show the break-point for the more cost-effective method

BY ROBERT MUELLER AND MARIANA FORREST

Laser beam welding is well established in many aspects of automotive production, such as tailor welded blanks and gear welding. Improvements in laser resonator technology over the last decade have improved the quality of high-power laser beams, and enabled the development of remote laser welding. Remote laser welding allows the production of many weld stitches within a large footprint at a much faster rate than is possible with robotic resistance spot welding. Remote laser welding has gained significant acceptance in European automotive assembly operations, at the body shop, and at the subassembly level. In this paper, we describe the technology of laser remote welding, compare the properties of laser remote welds to resistance spot welds (RSW), and introduce a costing model for spot welding to determine when to use remote laser welding and when to use resistance welding.

Remote Laser Beam Welding Technology

Laser beam welding involves focusing a high-power laser beam onto a metal surface, melting and vaporizing the metal under the focus to create a weld keyhole, and translating that keyhole across the material to generate a weld bead. This process is shown schematically in Fig. 1. Traditionally, multitikowatt high-power lasers had poor beam quality, and required fairly short focus lengths to produce sufficient intensity for keyhole welding. Lasers were also not particularly energy efficient. CO2 lasers were among the most efficient systems, with electrical-to-optical conversion efficiencies approaching 10%. A typical weld cell configuration would include an 8-kW CO2 laser focused with a 250-mm parabolic mirror to weld tailored blanks at 6 m/min, with a fusion zone width on the order of 1 mm.

Over the last 10 years, there have been significant developments in laser resonator design for CO2, solid-state fiber, and disk laser configurations. While the technical details of these resonator designs are beyond the scope of this paper, the result of these developments is that it is now possible to produce high-power, high-quality laser beams with better electrical efficiency than ever before. A high-quality laser beam means that it may be focused to a smaller spot at the same focal distance as the older laser resonator design, or that the same spot size can be achieved using a longer focus optic.

Remote laser welding is based on the latter concept: a high-power, high-quality laser beam focused using a long (0.5 to over 1 m) focal length optic is able to achieve sufficient intensity at focus for keyhole welding. The laser beam is directed toward the workpiece by one (Ref. 1) or two (Refs. 2-4) deflecting mirrors (Fig. 2), or by precise robotic pointing of the focus optics (Ref. 5). These laser welding configurations are capable of producing long continuous welds, but are most often used to produce a series of weld stitches. In stitching mode, these systems compete directly with resistance spot welding. Remote welding systems have great flexibility in the size and shape of the weld stitch, as shown in Fig. 3. Instead of a round spot weld nugget of a size determined by the gun tip size, remote weld stitches can vary in size and orientation according to the local strength requirements of the application.

Laser Advantage

The primary advantage of remote laser welding over robotic resistance spot welding is the reduction in cycle time. Resistance spot welding involves a number of mechanical motions (open gun, robot reposition to next weld site, close gun) between each electrical weld pulse cycle. These mechanical motions add considerably to the time for each process cycle. A typical process rate for robotic resistance spot welding is around one spot weld every three seconds. Remote laser welding reduces cycle time in two ways. The laser weld process is very fast, with typical welding speeds of several m/min. A 25-mm weld stitch length at 3 m/min weld speed requires only 0.5 s to complete. Remote laser weld cycles may be less than resist-

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 ance spot weld cycles. The bigger time saving comes between the actual welds. Remote laser welding minimizes the “dead-time” between welds. It takes much less time to re-orient one or two small mirrors to point toward the next weld location than it does to physically move a weld gun to the next location. Time plots for resistance and remote laser weld cycles are shown in Figs. 4 and 5. The remote laser welding system completes 20 weld stitches in the time it takes the resistance weld robot to complete 4 spots.

The one mirror approach (Fig. 2), with a single mirror mounted in a two-axis gimbal, is favored for CO₂ laser systems, as these systems typically have a larger raw beam diameter, and require a larger mirror. By moving the mirror and the focusing lens together along the X-axis, these systems can address a very large working area. The primary limitation of the one-mirror system is that all the weld locations must be visible from the one-axis mirror travel range. If this is not possible, the only option is to rotate the part (and its tooling) to provide line of sight. The single mirror system is best suited for large flat components, such as seatbacks.

The two-mirror design uses galvanometer scanning mirror technology, originally developed for laser marking applications. These heads are functionally identical to laser marker technology, but scaled up to handle the higher beam powers required for laser welding. These systems are usually coupled to near-IR lasers using fiber-optic delivery. The working area footprint of a galvo-head scanner is typically smaller than the single mirror systems, but fiber beam delivery makes mounting of a galvo head onto a robot a relatively straightforward process. Mounting the galvo head on a robot gives access to the entire working envelope of the robot, and the complete range of pointing orientations. Some galvo head systems are very well integrated with the robot motion, permitting coordinated “weld-on-the-fly” motion to process the part, as shown in Fig. 6. Galvo head systems are best suited to large, multifaceted parts that can take advantage of the mobility of the robot.

Another alternative is to use a simple long focus welding optic mounted to an accurate robot, and then use the wrist motion of the robot to draw the weld stitches and move between welds. This solution costs significantly less than the mirror systems, but with a penalty of reduced productivity. With a single robot and weld optic, there is a finite time to point the head at the next weld location, resulting in reduced weld productivity. One option is to use two robots and weld heads, and an optical switch to alternately direct laser power to each head. This allows one robot...
Weld Properties

The process rate advantage of remote laser welding is useful only if the welds produced have acceptable properties. The narrow weld width, and the ability to use a number of weld shapes, makes direct comparison to the performance of resistance spot welds more difficult. We now look at the metallurgical characteristics of remote laser welds, and compare basic mechanical properties with resistance spot welds.

Weld Oxidation

Weld oxidation is minimal and restricted to a surface film over the weld. The weld keyhole is held open by the recoil pressure of metal atoms vaporized from the keyhole wall. The flow of this metal vapor out the keyhole opening prevents the flow of ambient oxygen into the keyhole, and prevents any subsurface oxidation of the weldment.

Results of weld strength measurements for a range of remote welding conditions, and comparable resistance welds, are shown in Fig. 9. The experiment tested linear, staple, and C stitch shapes of several stitch lengths, and compared the measured strengths to a set of resistance spot welds. The test was repeated for two material thickness combinations, all in mild steel. Several trends are apparent. The remote laser weld strengths were quite repeatable, showing low scatter. Remote weld strength is generally linear with weld stitch length. The strengths of the different stitch shapes were similar, with the C shape generally being slightly lower than the others. Comparing the remote weld data to the resistance spot weld, the remote weld strengths were generally higher, and by choosing a remote weld length, one can always find a condition to exceed the strength of the resistance spot weld.

With appropriate selection of welding parameters, remote laser stitch welds should be an acceptable substitute for resistance spot welds.

Cost Model for Spot Welding

Adoption of any new technology requires the demonstration of merit in two areas: technical proficiency and cost. It has been shown that remote laser welding is capable of producing technically superior welds. This section describes a cost model for spot welding.
model and demonstrates the cost-effectiveness of remote welding systems.

This cost model considers four cases: 1) a simple resistance spot welding cell with one robotic spot welding gun, 2) a larger resistance spot welding cell with four robotic spot welding guns, 3) a remote laser welding system using a CO2 laser, and 4) a remote laser welding system using a near-IR fiber-delivered laser, with the remote welding head on a robot. For each case, we considered the following cost elements: capital, manpower, building costs, electricity usage, and process consumables. A spreadsheet was constructed to record and calculate the relevant costs for each case, and calculate the production capacity of each system. For the capital costs, the purchase price was estimated for each machine and its tooling. This cost was amortized over a two-year loan, at a typical commercial interest rate, and the annual cost of these loan payments was added to the annual cost for the system. For manpower, we considered that each system requires one operator per shift, and that all the operators are paid at the same rate. We also factored in maintenance, and the amount of work required to be performed on each type of machine. Resistance spot welding cells require maintenance at regular intervals to dress and change the spot welding tips. The laser cells need to have the protective window on the process head checked and cleaned once per shift. A factory building costs a certain amount per year, to rent or lease, and to keep the lights on and the space heated. This cost should be divided up among all the operations taking place in the building, in proportion to the floor space occupied by each operation. We therefore assumed a reasonable annual building cost of $50/ft², and multiply this by the cell area for each case. The cell area includes space for the equipment and a safety enclosure, operator workspace, and space for racking or other dunnage for incoming and completed parts. Warehousing of incoming and completed parts was not included. For electricity utilization, we list the rated electrical consumption of the major components of each cell, in the usage fraction of each component, derive a total consumption, and multiply by a uniform price for electricity. The consumables category captures all the items, with cost and lifetime, required to keep a system operational for a year. It includes items such as spot welding tips, laser gases, protective windows, even water filter cartridges. The cost of each item is multiplied by the number of service lifetimes in an operating year. The total costs for each system are totaled, along with the production capacity. Table 1 summarizes these results.

Figure 10 shows the cost per spot weld for the four configurations described.

### Table 1 — Production Capacity and Cost Summary for Resistance and Remote Welding Systems

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</table>
above, and running at capacity on two shifts. For all configurations, capital and manpower are the largest contributors to the total cost. The total costs per spot for the remote laser welding systems are significantly less than for the resistance welding systems, due mostly to the increased productivity of the remote welding systems. The remote welding systems have nearly the same annual costs as the four-gun resistance welding cell, but that cost is spread over three times the production capacity of the resistance cell.

Figure 11 shows the result of a calculation of total annual cost (capital and operating) against production volume. We assumed that capital, manpower, and building costs are fixed, and the rest of the costs vary with machine usage. For example, an idle machine does not use consumables or electricity. We also assumed no overtime, and if a system reaches its production capacity, another machine must be purchased in order to increase capacity. The data show that, at low volume, a single robot resistance welding cell is the low-cost option. But as production demand increases, one must add cells (and operators), and the single robot cell becomes uncompetitive. At low volumes, the four-robot resistance cell and the two remote welding cases have nearly identical costs. This remains true until the four-robot resistance cell reaches capacity, and a second cell is required. At that point, the cost of the resistance system takes a step increase, and is no longer competitive with remote welding. This defines the production volume threshold for cost-effective remote laser welding. In this case, remote laser welding would be the more cost effective production method if you require more than 15 million spots to be produced per year.

This cost model uses values for individual costs deemed appropriate and representative. Each user’s actual costs may vary, and prospective users should perform this type of study using their own data before selecting the appropriate manufacturing method for a specific situation.

Discussion

Remote laser welding has been shown to be technically capable of producing sound welds with mechanical properties at least as good as resistance spot welds, and shown to be cost effective in moderate-to-high-volume usage.

Remote laser welding is a high-productivity process capable of making several (typically two to five) spot welds per second. This rate is substantially faster than for robotic resistance spot welding systems, and several changes in system design and work flow may be required to fully utilize the productivity available with remote welding. Traditional resistance spot welding cells often use a two-station dial table with two geo-tools to introduce parts to one or several RSW robots for processing. The processing time of the RSW process matches the capability of an operator to unload a completed assembly and load fresh parts. The rotation time of the dial table is also relatively fast compared to the RSW process rate, so that no more than two spot welds per gun are lost per cycle. With remote laser welding, an assembly is completed much faster, and an operator would have great difficulty in keeping up with a two-station dial configuration. It is preferable to configure the remote weld cell so that the remote welding head can address more than one tool, thus allowing operators more time to unload and load parts, or an automatic unload capability must be provided to reduce operator work load. The dead time during the rotation of a single dial table also loses many possible welding cycles. A 5-s dial rotation in a remote weld system doing 3 spots/s loses 15 weld cycles, enough to complete a small assembly.

Few applications would completely fill the capacity of a remote welding system. It should be common practice to treat remote welding systems as flexible manufacturing cells, with multiple tools introduced to the cell, either in batch mode, or interleaved. One goal in system design of remote welding cells should be to minimize the transition time between tools or processes, to keep the remote welding machine operating, while at the same time allowing the safe movement of parts into and out of the processing zone.

In an interleaved flexible production system, each assembly type may only need a single tool. Remote welding tools are typically more complex (and costly) than RSW tools, as the tool must provide all part clamping, as well as part positioning. The need for only one single tool partially offsets the increased tool cost, and the fact that all production comes off a single tool increases product uniformity.

Problems with Coated Steel

Lap welding of galvanized and other coated steels is a general problem in manufacturing. The trapped coating layers between the steel sheets melt and boil before the steel layers melt. Once the steel melts, the trapped vapor can explode, ejecting a significant portion of the weld metal, and leaving a crater or similar defect in the part. RSW addresses this issue with a preheat cycle to give the coating vapor time to escape. In laser lap welding, including remote laser welding, the heating cycle is very fast, and the weld blowout problem can become quite serious. One accepted method to overcome this issue is to provide a small (0.1–0.2 mm) gap be-
between the layers, to give the vapor a path to escape without building up pressure. Consistently creating a controlled, small gap in a production situation is not easy, but several methods have been proposed and developed. Mechanically creating dimples or ridges in stamped parts is an effective method, but there is resistance in the die shop to include small wear features in stamping dies. Mechanical knurling of one surface in the area to be joined is effective in creating a path for vapor to escape, but this introduces another operation to the production process. The high productivity of remote welding may offer a solution. It is well known that a bead-on-plate weld can produce a raised weld bead, due to surface tension and thermal expansion. The crown height of this bead for narrow laser welds is in the range of 0.1 mm; and can be used to maintain a gap between the lapped weld sheets. These bead-on-plate welds, or laser dimples (Ref. 6), can be very small, and can be performed very quickly using remote laser welding. In practice, the lower part of the assembly is loaded into the tool, the remote weld system performs bead-on-plate welds in the areas to be joined, the tool comes back out to be loaded with the upper parts, and the tool returned to the remote welding cell to complete the joining operation. The small induced gap between the sheets greatly reduces weld defects, and permits the use of remote laser welding to join galvanized components. With proper system design, the laser dimpling operation is performed in what would otherwise be dead time while parts were cycled in and out of the cell, resulting in no net loss of productivity.

Conclusions

Remote laser welding has been shown to be a viable method for sheet metal joining in automotive applications, from both engineering and cost perspectives. Remote laser weld stitches can be tailored to meet or exceed any given weld strength threshold, simply by adjusting the length of the stitch. Remote laser welding is a cost-effective method for sheet metal joining, at production volumes well within the demand range of automotive production. Remote laser welding is a flexible manufacturing technology, able to handle high-volume production, whether dedicated to a single product, or consisting of a mix of products.

References


Many years ago, welding power supplies used to be easy to understand. You could even make one yourself!

When I first got into the welding game, it was possible to get a tapped transformer, then add a rectifier to construct a workable power supply. When you wanted to reduce spatter, you could add a small inductor of your own design, made by winding some welding cable around an iron bar or pipe. You can still make a workable shielded metal arc welding power supply this way, if you feel ambitious and are careful not to get shocked.

When gas metal arc welding power supplies first came out, they were simple to construct. All you took was a tapped constant potential transformer and a rectifier. Spatter was controlled by adding a homemade inductor. Some manufacturers began to make units with variable voltage and tapped inductance. When you wanted a little extra volt-ampere slope, you used a longer cable or added a resistor (made from a piece of sheet metal strip) to the welding circuit. Then, units were offered with variable everything, including voltage, slope, and inductance.

Afterward, pulse gas metal arc welding came along. If you wanted to try it out experimentally, you connected a couple of power sources together. One was a standard three-phase rectifier, and the other was a single-phase rectifier with one of its diodes disconnected. A little later, manufacturers provided pulse units with variable everything, except frequency. Even then, you could get 60 and 120 pulses/s. Eventually, even frequency became adjustable.

Next came the era of solid-state, silicon-controlled rectifiers, transistors, and other electrical materials. Instead of changing taps or moving something inside the power source, you now could tweak a dial on the unit and get all sorts of magical changes in output. However, you could still get a soldering iron, plus some capacitors and resistors, to make repairs.

Eventually, the era of printed circuits, microprocessors, and digital controls was here. These power sources only do whatever the designer has built into them. A new term, synergic welding, was coined to describe these systems with built-in, one-knob welding programs that matched the electrode feed rate and power. They are smaller and lighter than previous units. However, it isn’t possible to pull out your trusted soldering iron and modify the output characteristics as in the past. It’s a sign of the times. The name of the game today is remove and replace or get a new one.

Do you think this digital processor microchip revolution might have anything to do with the decline in our mechanical aptitudes and skills?

August F. Manz
AWS Fellow
The **BRAZIL WELDING SHOW 2011** is the first specialized trade show dedicated to welding technology in Brazil. It joins forces with the Corte & Conformação de Metais, the largest trade show for metal forming and fabricating in South America, which is being held concurrently with the **BRAZIL WELDING SHOW**. Show organizers Messe Essen and Aranda Eventos are supported by DVS - German Welding Society and the AWS - American Welding Society. AWS and Essen Trade Shows USA are jointly organizing a US Pavilion. For further information, please contact:

**Essen Trade Shows**, Karen Vogelsang, Tel. 001-914-962-1310, karen@essentradeshows.com or

**AWS**, Joe Krall, Tel. 001-305-443-9353 ext. 297, jkrall@aws.org

For info go to www.aws.org/ad-index
Conference on Welding in Shipbuilding
May 10, 11
Seattle, Wash.

Welding is the most vital and fundamental manufacturing process in the construction of ships and metal hull boats. Attendees will learn the progress of new and innovative developments, as well as how their potential value and impact to the industry is essential for those in the shipbuilding community. The conference will also address the critical importance of welding in the shipbuilding industry by providing current information on new and emerging technologies being developed for shipbuilding applications.

Conference on Preventing Weld Failures
June 14, 15
New Orleans, La.

Management continues to point fingers at the engineers in the weld shop: “How come that weld failed? What are you going to do to prevent it from happening again?” Finding the answers to the questions is not as easy as it might seem. For help on this matter, come to this conference. There will be presentations on two of the most critical problems: postweld heat treating and dissimilar metal welding. It will be a useful mix of the valuable existing technologies and some of the new technologies coming on the scene. Topics like Six Sigma, lean manufacturing, several of the newer NDE inspection methods, and new software that can be put to practical use will be discussed.

Corrosion-Resistant Alloys and the New Chrome-Moly Steels
August 16, 17
Charlotte, N.C.

This double-barreled two-day conference in Charlotte will be something a little different in AWS conferences. Day one will be all about the newer corrosion-resistant alloys and will cover such materials as the growing body of duplex stainless steels, the nickel-based alloys, and titanium. The duplex grades are beginning to replace the austenitic stainless steels in some applications and there is much to learn about welding them. Even newer is the introduction of less-expensive duplex alloys, so much needs to be learned about those as well. There’s also a new titanium alloy that could replace the popular 6Al-4V grade. It too will be on the program. Cladding is also playing an increasingly important role in the industry.

Day two will be devoted to another hot topic in welding, the new chrome-moly steels such as the 91, 92, and 911 grades. There are benefits with those, but there is still much to learn. It’s a market cut out for the low-hydrogen consumables. Fabrication is tricky. Great attention must be paid to heat treating and dissimilar metal welding. Also discussed will be the material that to some is an old nemesis, 4130 chrome-moly steel.

14th Annual Aluminum Welding Conference
September 20, 21
Ft. Lauderdale, Fla.

Aluminum lends itself to a wide variety of industrial applications because of its light weight, high strength-to-weight ratio, corrosion resistance, and other attributes. However, because its chemical and physical properties are different from those of steel, welding aluminum requires special processes, techniques, and expertise.

A distinguished panel of aluminum-industry experts will survey the state of the art in aluminum welding technology and practice. The conference will also provide opportunities for you to network informally with speakers and other participants, as well as visit an exhibition showcasing products and services specifically for the aluminum welding industry.

2011 FABTECH Conference Schedule
Chicago, Ill.

National Welding Education Conference
November 13

Presented by the National Center for Welding Education and Training (Weld-Ed), this conference is designed to bring together educators for professional development and networking opportunities. Weld-Ed’s focus is on the preparation of welders, welding technicians, and welding engineers to meet the needs of industry. This conference will include presentations on topics such as Weld-Ed accomplishments in the last year, the partnership between Weld-Ed and AWS, welding industry workforce needs, recruitment tips and tools for educators, competency models, externship programs for educators, tips on partnering with other secondary and postsecondary schools, welding education trends, curriculums, materials science education and applications, distance learning updates, new technology applications, and presentations from welding educators who will share their best practices.

ABCs of Welding Engineering
November 14

8th Conference on Weld Cracking
November 15

The most perplexing problem in the welding industry has to be weld cracking. This conference is for those who want to get a handle on controlling weld cracking situations.

Understanding Power Sources Conference
November 16

For more information, please contact the AWS Conferences and Seminars Business Unit at (800) 443-9353, ext. 264, or e-mail zoliva@aws.org. You can also visit the Conference Department Web site at www.aws.org/conferences for upcoming conferences and registration information.
“C” is for Certified.
The “W” stands for Welding.
“S” is not just for Supervisor.

Studies have shown that having an AWS Certified Welding Supervisor on staff can save thousands of dollars a year per welder. This certification—which establishes that a CWS has the knowledge to improve a welding operation’s quality, cost, productivity, and safety—is not just for supervisors. The training has been designed to enhance the value of anyone involved in welding design, quoting, purchasing, detailing, inspecting, instructing, or management.

Beneficiaries of the program include CEOs, lead welders, design engineers, CWIs, and others. In fact, we can train an entire team right at your location, saving you time and money on a program that is proven to improve profitability.

The “S” stands for Supervisor, but for non-supervisors at your company, it can mean “savings,” “superior quality,” “safety,” and more. To find out more about sending employees for six-day CWS training and certification, or having a program presented at your company, visit www.aws.org/certification/CWS or call (800) 443-9353 ext 273.

American Welding Society®

New Orleans 4/4-4/9 • Minneapolis 7/18-7/23 • Miami 9/12-9/17 • Norfolk 10/17-10/22
**COMING EVENTS**

**NOTE: A DIAMOND (♦) DENOTES AN AWS-SPONSORED EVENT.**


**JOM-16, Int'l Conf. on the Joining of Materials and ICEW-7, 7th Int'l Conf. on Education in Welding.** May 10–13, Sankt Helene Centre, Tisvildeleje, Denmark. Contact JOM Institute, Gilleleje, Denmark. Phone +45 48 35 54 58; jom_aws@post10.tele.dk.

♦ **AWS WELDMEX.** May 11–13, Cintermex, Monterrey, Mexico. Colocated with FABTECH Mexico and MetalForm Mexico. See the latest welding and cutting products, thermal spray, metal finishing and safety equipment, metalforming products, tool and die, metal stamping, forming and assembly, and a variety of bending and fabrication products, including laser and plasma cutting, coil processing, roll forming, plate and structural fabricating, saws and cut-off machines, tooling, press brakes, shears, punching, and tube and pipe equipment; www.awsweldmex.com.


Weld India 2011, Int'l Expo on Joining, Cutting, and Surfacing.


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♦ FABTECH. Nov. 14–17. McCormick Place, Chicago, Ill. This exhibition is the largest event in North America dedicated to showcasing the full spectrum of metal forming, fabricating, tube and pipe, welding equipment, and myriad manufacturing technologies. Contact American Welding Society, (800/305) 443-9353, ext. 264; www.fabtechexpo.com or www.aws.org.


♦ 5th Int’l Brazing and Soldering Conf. April 22–25. Red Rock Casino Resort Spa, Las Vegas, Nev. The American Welding Society and ASM International® jointly organize this event. It brings together scientists and engineers from around the world who are involved in the research, development, and application of brazing and soldering. www.asminternational.org/IBSC.


Educational Opportunities


Certified Welding Supervisor Preparation with Exam. Two-week-long class beginning Sept. 1. Hobart Institute of Welding Technology, Troy, Ohio; www.welding.org; hiwt@welding.org; (800) 332-9448.


Lyncole Grounding Courses. May 5, 6, Atlanta, Ga.; June 23, 24, St. Louis, Mo.; Aug. 18, 19, Washington, D.C.; Oct. 20, 21, Chicago, Ill. Instruction on how to protect equipment against lightning strikes and power surges. Lyncole XIT Grounding; www.lyncole.com; (800) 962-2610.


Art Using Welding Technology Classes and Workshops. Miami, Fla. With artist and sculptor Sandra Garcia-Pardo. Meet the artist at www.sandragarciaart.com; (786) 547-8681.

ASM Int’l Courses. Numerous classes on welding, corrosion, failure analysis, metallography, heat treating, etc., presented in Materials Park, Ohio, online, webinars, on-site, videos, and DVDs; www.asminternational.org. search for “courses.”


Basics of Nonferrous Surface Preparation. Online course, six hours includes exam. Offered on the 15th of every month by The Society for Protective Coatings. Register at www.sspc.org/training.

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Columbus, Ohio; www.nationalboard.org; (614) 888-8320.


CWI/CWE Prep Course and Exam and NDT Inspector Training. Courses. An AWS Accredited Testing Facility. Courses held year-round in Allentown, Pa., and at customers’ facilities. Welder Training & Testing Institute; (800) 223-9884; info@wtti.edu; www.wtti.edu.

CWI Preparatory and Visual Weld Inspection Courses. Classes presented in Pascagoula, Miss., Houston, Tex., and Houma and Sulphur, La. Real Educational Services, Inc. (800) 489-2890; info@realeducational.com.

Consumables: Care and Optimization. Free online e-courses on the basics of plasma consumables for plasma operators, sales, and service personnel; www.hyperthermcuttinginstitute.com.

Crane and Hoist Training for Operators. Konecranes Training Institute, Springfield, Ohio; www.konecranesamericas.com; (262) 821-4001.

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### Seminars, Code Clinics, and Examinations

Application deadlines are six weeks before the scheduled seminar or exam. Late applications will be assessed a $250 fee.

#### Certified Welding Inspector (CWI)

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#### 9-Year Recertification Seminar for CWI/SCWI

For current CWIs and SCWIs needing to meet education requirements without taking the exam. The exam can be taken at any site listed under Certified Welding Inspector.

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<tr>
<td>New Orleans, LA</td>
<td>Nov. 7–12</td>
<td>No exam</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Dec. 11–17</td>
<td>No exam</td>
</tr>
</tbody>
</table>

#### Certified Welding Supervisor (CWS)

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minneapolis, MN</td>
<td>July 18–22</td>
<td>July 23</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Sept. 12–16</td>
<td>Sept. 17</td>
</tr>
<tr>
<td>Norfolk, VA</td>
<td>Oct. 17–21</td>
<td>Oct. 22</td>
</tr>
</tbody>
</table>

CWS exams are also given at all CWI exam sites.

#### Certified Radiographic Interpreter (CRI)

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Miami, FL</td>
<td>June 6–10</td>
<td>June 11</td>
</tr>
<tr>
<td>Dallas, TX</td>
<td>July 18–22</td>
<td>July 23</td>
</tr>
<tr>
<td>Chicago, IL</td>
<td>Sept. 12–16</td>
<td>Sept. 17</td>
</tr>
<tr>
<td>Pittsburgh, PA</td>
<td>Oct. 17–21</td>
<td>Oct. 22</td>
</tr>
<tr>
<td>Allentown, PA</td>
<td>Nov. 7–11</td>
<td>Nov. 12</td>
</tr>
</tbody>
</table>

The CRI certification can be a stand-alone credential or can exempt you from your next 9-Year Recertification.

#### Certified Welding Sales Representative (CWSR)

<table>
<thead>
<tr>
<th>Location</th>
<th>Seminar Dates</th>
<th>Exam Date</th>
</tr>
</thead>
<tbody>
<tr>
<td>Atlanta, GA</td>
<td>June 8–10</td>
<td>June 10</td>
</tr>
<tr>
<td>Miami, FL</td>
<td>Aug. 24–26</td>
<td>Aug. 26</td>
</tr>
<tr>
<td>Indianapolis, IN</td>
<td>Sept. 21–23</td>
<td>Sept. 23</td>
</tr>
</tbody>
</table>

CWSR exams will also be given at CWI exam sites.

#### 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 Robotic Arc Welding (CRAW)

<table>
<thead>
<tr>
<th>Week of</th>
<th>Location</th>
<th>Contact</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aug. 1</td>
<td>Wolf Robotics, Ft. Collins, CO (970) 225–7736</td>
<td></td>
</tr>
<tr>
<td>Aug. 1</td>
<td>ABB, Inc., Auburn Hills, MI (248) 391–8421</td>
<td></td>
</tr>
<tr>
<td>Sept. 19</td>
<td>Wolf Robotics, Ft. Collins, CO (970) 225–7736</td>
<td></td>
</tr>
<tr>
<td>Oct. 24</td>
<td>The Lincoln Electric Co. (216) 383–8542</td>
<td></td>
</tr>
<tr>
<td>Nov. 7</td>
<td>ABB, Inc., Auburn Hills, MI (248) 391–8421</td>
<td></td>
</tr>
</tbody>
</table>

Personalized schedules, call Larry Gross (414) 297–6996

#### Certified Welding Engineer (CWE)

Exam can be taken at any site listed under Certified Welding Inspector. No preparatory seminar is offered.

#### Senior Certified Welding Inspector (SCWI)

Exam can be taken at any site listed under Certified Welding Inspector. No preparatory seminar is offered.

#### International CWI Courses and Exams

Visit www.aws.org/certification/inter_contact.html.
WEMCO and RWMA Hold Joint Annual Event

BY NATALIE TAPLEY

The Welding Equipment Manufacturers Committee (WEMCO) and the Resistance Welding Manufacturing Alliance (RWMA) held their second annual colocated meetings Feb. 24–26, at the PGA National Resort and Spa, Palm Beach Gardens, Fla.

The theme for these meetings was “Opportunities in the Energy Sector.” Highlighting the program were insightful presentations by Joe F. Colvin, Andrew Masterman, and Bill Kroll.

Colvin is president and CEO of the Nuclear Energy Institute (NEI) that represents nearly 300 United States and international corporations. He touched on specific opportunities in the nuclear, solar, and cold energy sectors.

Masterman is president and CEO of ESAB North America, Florence, S.C. He addressed global trends in the welding industry and the anticipated effects on his company.

Kroll is president, chair, and CEO of Matheson Tri-Gas, Inc., Basking Ridge, N.J. His talk centered on business opportunities worldwide from a gas provider’s view.

During the reception held Feb. 25, Hector Villarreal, president of Weldcoa, was named the 2011–2012 WEMCO chair, and Wade Burnett, vice president — sales and marketing at NSRW, Inc., was named the 2011–2013 RWMA chair.

Concluding the annual event was the renowned Economist Alan Beaulieu, president of the Institute for Trend Research (ITR). Beaulieu has become an all-time favorite speaker of WEMCO, and his whimsical style helps to make a straightforward economic forecast entertaining.

Based on the recent annual survey results, the 2012 WEMCO and RWMA annual meetings will be held on the west coast. The date and location will be announced later. Contact the WEMCO or RWMA office at (800) 443-9353, ext. 295, or ext. 444, for more information about the 2012 annual meetings.

NATALIE TAPLEY (tapley@aws.org) is manager, Welding Equipment Manufacturers Committee.

How to Order Journal Article Reprints and AWS Publications

To order custom reprints of Welding Journal articles in quantities of 100 or more, or electronic posting of articles, contact Rhonda Brown, Foster Printing Services, rhondab@fosterprinting.com; (866) 879-9144, ext. 194; www.marketingreprints.com.

To order individual copies of Welding Journal articles, contact Sandra Muñoz, smunoz@aws.org, or Ruben Lara, rlara@aws.org.

To order AWS standards, books, and other publications, contact World Engineering Xchange (WEX), www.awspubs.com; call toll-free in the United States (888) 935-3464; elsewhere call (305) 826-6192; or FAX (305) 826-6195.
Tech Topics

Technical Activities Committee Elects Officers for the 2011–2013 Term

Dick Holdren has been elected chairman of the Technical Activities Committee (TAC). Allen Sindel has been named first vice chairman, and Walter Sperko has been elected second vice chairman for the term beginning Jan. 1, 2011, and ending Dec. 31, 2013.

The Technical Activities Committee oversees the development of all AWS standards including AWS D1.1, A2.4, B2.1, and the A5 filler metals standards.

Holdren is a vice president of Engineering and Quality at Applications Technologies Co., LLC. He has been active on AWS technical committees for many years, particularly with the committees responsible for the A2.4 (Weld Symbols) and A3.0 (Definitions) documents.

Allen Sindel

Walter Sperko

New Standards Projects

Development work has begun on the following revised standard. Affected individuals are invited to contribute to its development. For information, call A. Diaz, ext. 304. Participation on AWS technical committees is open to all persons.

B2.2/B2.2M:20XX, Specification for Brazing Procedure and Performance Qualification. This specification provides the requirements for qualification of brazing procedure specifications, brazers, and brazing operators for manual, mechanized, and automatic brazing. The processes included are torch, furnace, diffusion, resistance, dip, infrared, and induction brazing. The base metals, and brazing filler metals, fluxes, atmospheres, and joint clearances are included. Stakeholders: Manufacturers, brazers, and brazing operators.

Standards for Public Review

A5.1/A5.1M:20XX, Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding. Revised. $25. 5/2/11.


A5.35/A5.35M:20XX, Specification for Wet Welding Electrodes for Shielded Metal Arc Welding. New. $25. 5/21/11.

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. The above standards’ review expiration dates are shown. To order draft copies, contact R. O’Neill, roneill@aws.org, (305) 443-9353, ext. 451.

Technical Committee Meetings

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should contact the staff secretary of the committee as listed below at (800/305) 443-9353 at the extension listed.


Nominations Sought for the M.I.T. Prof. Masubuchi Award

The deadline for submitting nominations for the 2012 Prof. Koichi Masubuchi Award is Nov. 2, 2011. Sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology (M.I.T.), this award includes a $5000 honorarium. It is presented each year to one person, 40 years old or younger, who has made significant contributions to the advancement of materials joining through research and development.

Nominations should include the candidate’s experience, publications, honors, and awards, and at least three letters of recommendation from fellow researchers. E-mail your nomination package to Todd A. Palmer, assistant professor, The Pennsylvania State University, tap103@psu.edu.

Errata

D1.1/D1.1M:2010, Structural Welding Code — Steel

The following errata have been identified and will be incorporated into the next reprinting of this document.

Page 8 — 2.4.3.6 Minimum Skewed T-Joint Weld Size. The requirements of 2.3.2.8 shall apply.

The reference should be “…requirements of 2.4.2.8...”.

D1.2/D1.2M:2008, Structural Welding Code — Aluminum

The following errata have been identified and will be incorporated into the next reprinting of this document.

Page 69 — 4.17.5 Craters. Weld craters shall meet the requirements of Table 4.6 or shall be repaired in conformance with 4.19.

The reference should be “...conformance with 4.20.”
D3B Subcommittee Releases First AWS Underwater Welding Code

Recently, the AWS D3B Subcommittee on Underwater Welding in collaboration with the D3 Committee on Marine Construction released the first D3.6, Underwater Welding Code. This new edition has upgraded D3.6 from a specification to a code. By AWS definitions, “A code is intended to be a mandatory document. It includes a set of conditions and requirements relating to a specific subject. A code describes industry-accepted procedures by which it can be determined that the requirements have been met. It is written to make it suitable for adoption by governmental entities and trade groups. Insurance companies, and other authorities as a part of a law or regulation or cited as a normative reference in other standards.” Whereas, “a specification details, using the prescriptive shall, the essential technical requirements for a material, product, system, or service. It specifies the procedures, methods, qualifications, or equipment by which it can be determined that the requirements have been met. A specification is mandatory when cited as a normative reference by a mandatory document or agreed to be mandatory by the concerned individuals or agencies, such as when used for procurement purposes.”

Other recent committee achievements include updating the Welding Handbook, Vol. 4, Chapter 10 on Underwater Welding and Cutting, and initiating, in collaboration with the A5 Committee on Filler Metals and Allied Materials, AWS A5.35/A5.35M, Specification for Welding Electrodes for Shielded Metal Arc Welding. This specification will be the first edition for classification of electrodes developed for shielded metal arc welding underwater, in the wet, with no mechanical barrier between the water and the welding arc. It will cover ferritic, austenitic stainless steel, and nonferrous filler materials, including any auxiliary coating applied over the electrode covering.

Contribute Your Skills to These Technical Committees

It is the volunteers on AWS Technical Committees who provide the expertise to develop the standards, codes, and other technical publications to serve industry’s ever-changing needs for welding and allied processes. Currently, more than 1800 volunteers serve on the 160 AWS technical committees and subcommittees. Membership on AWS technical committees is open to everyone. Review the committee openings outlined here, then contact the committee secretary listed to learn more about the advantages and responsibilities for contributing to this work.

Thermal Spray Protection of Steel

The Tri-Society Subcommittee C2B on Thermal Spray Protection of Steel is beginning the revision cycles for C2.23, Specification for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel, and C2.18, Guide for the Application of Thermal Spray Coatings (Metallizing) of Aluminum, Zinc, and Their Alloys and Composites for the Corrosion Protection of Steel. These standards are revised, approved, and published in coordination with NACE and SSPC. The next planned meeting of C2B will be in Charleston, S.C., on May 19. For more information or to get involved, contact Efram Abrams, eabrams@aws.org; (800/305) 443-9353, ext. 307.

Joining Wrought Nickel Alloys

The G2C Subcommittee on Nickel Alloys seeks volunteers to review G2.1M/G2.1, Guide for the Joining of Wrought Nickel-Based Alloys, and participate in the regular meetings and teleconferences. Steve Borrero, sborrero@aws.org, ext. 334.

Marine Construction

The D3 Committee for Welding in Marine Construction to contribute to the development of D3.5, Guide for Steel Hull Welding; D3.6, Specification for Underwater Welding; D3.7, Guide for Aluminum Hull Welding; and D3.9, Specification for Classification of Weld-Through Paint Primers. Brian McGrath, bmcgrath@aws.org, ext. 311.

Surfacing Industrial Mill Rolls


Magnesium Alloy Filler Metals

ASL Subcommittee on Magnesium Alloy Filler Metals to assist in the updating of AWS A5.19-92 (R2006), Specification for Magnesium Alloy Welding Electrodes and Rods. Contact Rakesh Gupta, gupta@aws.org, ext. 301.

Robotic and Automatic Welding


Thermal Spraying


Labeling and Safe Practices

SH14 Subcommittee on Labeling and Safe Practices to update AWS F2.2, Lens Shade Selector; AWS F4.1, Safe Practices for the Preparation of Containers and Piping for Welding and Cutting; and the AWS Safety and Health Fact Sheets. Steve Hedrick, steveh@aws.org, ext. 305.

Mechanical Testing of Welds

The B4 Committee for Mechanical Testing of Welds to contribute to B4.0, Standard Methods for Mechanical Testing of Welds. Brian McGrath, bmcgrath@aws.org, ext. 311.
Listed below are the March 17, 2011, standings of the members participating in the 2010–2011 Member-Get-A-Member Campaign. For complete campaign rules and prize list, see page 83 of this Welding Journal, or visit www.aws.org/mgm. Call the Membership Department, (800) 443-9353, ext. 480, for questions concerning your member proposer status.

**Winner’s Circle**

AWS Members who have sponsored 20 or more new Individual Members, per year, since June 1, 1999. The superscript denotes the number of years the member earned Winner’s Circle status, if more than once.

- J. Compton, San Fernando Valley
- J. Hopwood, Iowa — 4
- J. Hope, Puget Sound — 4
- J. Dolan, New Jersey — 4
- J. Daubert, Northern New York — 6
- T. Crate, Drake Well — 7
- J. Merzthal, Peru
- J. Compton, San Fernando Valley — 7
- W. Sturge, New York — 3
- W. Sartin, Long Bch./Or. Cty. — 3
- F. Oravets, Inland Empire — 3
- D. McQuaid, Pittsburgh — 3
- M. Haggard, Inland Empire — 3
- R. Ellenbecker, Fox Valley — 3
- M. Haggard, Inland Empire — 3
- A. Syder, Spokane — 18
- J. Shirk, Tidewater — 15
- J. Crate, Drake Well — 15
- C. Hobson, Olympic Section — 15
- T. Shirk, Tidewater — 15
- R. Evans, Siouxland — 14
- K. Karwoski, Racine-Kenosha — 14
- T. Palmer, Columbia — 14
- C. Schiner, Wyoming Section — 14
- M. Arand, Louisville — 13
- C. Donnell, NW Ohio — 13
- G. Watry, Houston — 13
- W. Wilson, New Orleans — 13
- R. Boyer, Nevada — 12
- J. Daughtery, Louisville — 12
- J. Goodson, New Orleans — 12
- R. Wahrman, Triangle — 12
- D. Zabel, SE Nebraska — 12
- J. Boyer, Lancaster — 11
- D. Porter, Nashville — 11
- J. Theberge, Boston — 11
- R. Metheney, Stark Central — 10
- K. Rawlings, Columbus — 10
- D. Wright, Kansas City — 10
- R. Young, Iowa — 10
- A. Badeaux, Washington, D.C. — 9
- C. Kipp, Lehigh Valley — 9
- D. Kowalski, Pittsburgh — 9
- C. Renfro, Chattanooga — 9
- S. Ulrich, St. Louis — 9
- V. Covey, Central Texas — 8
- M. Koehler, Milwaukee — 8
- T. Moore, New Orleans — 8
- R. Belluzzi, New York — 7
- A. Duron, New Orleans — 7
- T. Green, Central Arkansas — 7
- R. Hutchinson, Long Bch./Or. Cty. — 7
- K. Kerns, Northern Michigan — 7
- D. Ketter, Willamette Valley — 7
- J. Kline, Northern New York — 7
- A. Perazzone, Arizona — 7
- G. Siepert, Kansas — 7
- J. Johnson, Madison-Beloit — 6
- J. Gardin, Northwest — 5
- J. Meyer, San Francisco — 5
- T. Smeltzer, San Francisco — 5
- B. Suckow, Northern Plains — 5
- B. Wenzel, Sacramento — 5
- B. Benyon, Drake Well — 4
- S. Colton, Arizona — 4
- W. Galvery, Long Bch./Or. Cty. — 4
- A. Holt, St. Louis — 4
- C. Mackenzie, Northern Michigan — 4
- J. Morash, Boston — 4
- C. Warren, N. Central Florida — 4
- D. Aragon, Puget Sound — 3
- R. Bass, Tulsa — 3
- R. Chase, L.A./Inland Empire — 3
- B. Clark, Iowa — 3
- R. Harris, Spokane — 3
- R. Hilty, Pittsburgh — 3
- C. Lindquist, Central Michigan — 3
- S. Miner, San Francisco — 3
- F. Pruitt, Greater Hunts — 3
- G. Rolla, L.A./Inland Empire — 3
- J. Seitzer, York-Central Pa. — 3
- S. Silverstein, Milwaukee — 3
- J. Sullivan, Mobile — 3

**President’s Club**

Sponsored 3–8 new members

- M. Tryon, Utah — 8
- T. Crate, Drake Well — 7
- J. Daubert, Northern New York — 6
- R. Dawson, Western Carolina — 4
- J. Dolan, New Jersey — 4
- J. Hope, Puget Sound — 4
- J. Hopwood, Iowa — 4
- D. Steyer, Niagara Frontier — 4
- D. Wright, Kansas City — 4
- G. Bish, Atlanta — 3
- H. Cable, Pittsburgh — 3
- C. Crompton, Florida W. Coast — 3
- R. Ellenbecker, Fox Valley — 3
- M. Haggard, Inland Empire — 3
- D. McQuaid, Pittsburgh — 3
- F. Oravets, Inland Empire — 3
- W. Sartin, Long Bch./Or. Cty. — 3
- G. Seese, Johnstown-Altoona — 3
- W. Sturge, New York — 3

**President’s Honor Roll**

Sponsored 2 new members

- M. Allen, Charlotte
- D. Berger, New Orleans
- J. Carney, West Michigan
- R. Fuller, Florida W. Coast
- G. Hamilton, Houston
- J. Hill, Nebraska
- A. Holt, St. Louis
- J. Kline, Northern New York
- A. Laabs, Lakeshore
- F. Nguni, New Jersey
- T. Palmer, Columbia
- B. Severson, Iowa
- W. Wall, Auburn
- D. Wantz, York-Central Pa.
- G. Watry, Houston
- S. Witkowski, Madison-Beloit

**Student Sponsors**

Listed below are the March 17, 2011, standings of the members participating in the 2010–2011 Member-Get-A-Member Campaign. For complete campaign rules and prize list, see page 83 of this Welding Journal, or visit www.aws.org/mgm. Call the Membership Department, (800) 443-9353, ext. 480, for questions concerning your member proposer status.

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- J. Goodson, New Orleans — 12
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- D. Zabel, SE Nebraska — 12
- J. Boyer, Lancaster — 11
- D. Porter, Nashville — 11
- J. Theberge, Boston — 11
- R. Metheney, Stark Central — 10
- K. Rawlings, Columbus — 10
- D. Wright, Kansas City — 10
- R. Young, Iowa — 10
- A. Badeaux, Washington, D.C. — 9
- C. Kipp, Lehigh Valley — 9
- D. Kowalski, Pittsburgh — 9
- C. Renfro, Chattanooga — 9
- S. Ulrich, St. Louis — 9
- V. Covey, Central Texas — 8
- M. Koehler, Milwaukee — 8
- T. Moore, New Orleans — 8
- R. Belluzzi, New York — 7
- A. Duron, New Orleans — 7
- T. Green, Central Arkansas — 7
- R. Hutchinson, Long Bch./Or. Cty. — 7
- K. Kerns, Northern Michigan — 7
- D. Ketter, Willamette Valley — 7
- J. Kline, Northern New York — 7
- A. Perazzone, Arizona — 7
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- A. Holt, St. Louis — 4
- C. Mackenzie, Northern Michigan — 4
- J. Morash, Boston — 4
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- D. Aragon, Puget Sound — 3
- R. Bass, Tulsa — 3
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- B. Clark, Iowa — 3
- R. Harris, Spokane — 3
- R. Hilty, Pittsburgh — 3
- C. Lindquist, Central Michigan — 3
- S. Miner, San Francisco — 3
- F. Pruitt, Greater Hunts — 3
- G. Rolla, L.A./Inland Empire — 3
- J. Seitzer, York-Central Pa. — 3
- S. Silverstein, Milwaukee — 3
- J. Sullivan, Mobile — 3
C3 Committee Meets in New Mexico

The AWS C3 Committee on Brazing and Soldering met March 8, 9, in Santa Fe, N.Mex., as part of its biannual gathering. Newly elected Chair Ron Smith presided over discussion on the next edition of the Brazing Handbook, the 2012 International Brazing and Soldering Conference (IBSC), as well as the expansion of a brazing and soldering course currently taught at the The Ohio State University.

AWS Executives Take a Golf Break

Shown from left are District 18 Director John Bray, Vice President Dean Wilson, Past President Vic Matthews, National Treasurer Robert Pali, District 16 Director David Landon, Past President Ron Pierce, and Leon Cole. They are shown during the AWS executive board meeting held Feb. 3-7 at the PGA National Resort & Spa in Palm Beach Gardens, Fla.

Paschall Receives Student Chapter Member Award

Ryne Paschall, AWS Aiken Technical College Student Chapter, Columbia Section, District 5, has been selected by Jean Palmer, Student Chapter adviser, to receive the AWS Student Chapter Member Award. Paschall currently serves as Chapter Program Committee chair. He participates in the community as a volunteer on several Habitat for Humanity projects and is active in the local United Way program. Paschall currently is assisting in planning for the Student Chapter’s trip to attend this year’s FABTECH expo in Chicago.

The AWS Board of Directors established the Student Chapter Member Award to recognize AWS Student Members whose Student Chapter activities have produced outstanding school, community, or industry achievements. This award also provides an opportunity for Student Chapter advisers, Section officers, and District directors to recognize outstanding students affiliated with AWS Student Chapters, as well as to enhance the image of welding within their communities. To qualify for this certificate award, the individual must be an AWS Student Member affiliated with an AWS Student Chapter. The criteria and nomination form can be downloaded from the AWS Web page www.aws.org/sections/awards/student_chapter.pdf, or call the Membership Dept. at (800/305) 443-9353, ext. 260.

Student Chapter Adviser Jean Palmer (left) is shown with awardee Ryne Paschall.
New AWS Supporters

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IMTES Imalat Teknolojisi  
Baskent Organize Sanayi Bölgesi  
26 Cad No. 10 Malikoy/Temelli  
Ankara 06900, Turkey  
Representative: Harun Resit Pamuk  
www.imtes.com.tr

IMTES provides fabricated parts built to customer and industry standards utilizing welding, sheet metal, machining, cutting, painting, and assembly processes performed by well-trained and qualified personnel. Its projects conform to ISO 9001-2008 and OHSAS 18001-2008 certificates approved by AQA. Its clientele include the defense, aerospace, chemical, medical, transport, and energy industries.

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Ventura, CA 93003

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Flushing, NY 11354

Ground Works, Inc.  
1253 E. 33rd St.  
Edmond, OK 73013

**Supporting Companies**

Heinen Custom Operations, Inc.  
PO Box 182  
Valley Falls, KS 66088

Job Corps  
301 E. Main St., Ste. 950  
Lexington, KY 40507

N C Machine LLC  
PO Box 280  
Casper, WY 82602

United Welding, Inc.  
22 Perchwood Dr., Ste. 207  
Fredericksburg, VA 22405

TTL, Inc.  
3516 Greensboro Ave.  
Tuscaloosa, AL 35401

**Educational Institutions**

Canutillo High School  
6675 S. Desert Blvd.  
El Paso, TX 79932

Dixie County High School  
16077 NE Hwy. 19  
Cross City, FL 32628

**AWS Member Counts**

April 1, 2011  
Grades  
Sustaining.........................507  
Supporting.........................298  
Educational.........................563  
Affiliate ............................466  
Welding Distributor...............43  
Total Corporate ....................1,877  
Individual .........................56,357  
Student + Transitional ..........10,897  
Total Members.....................67,254

**Honorary Meritorious Awards**

The deadline for submitting candidates for these awards is December 31 prior to the year of the awards presentations. Send candidate materials to Wendy Sue Reeve, wreeve@aws.org; 550 NW LeJeune Rd., Miami, FL 33126.

**William Irrgang Memorial Award**  
This award is given to the individual who has done the most over the past five years to enhance the Society’s goal of advancing the science and technology of welding. It includes a $2500 honorarium and a certificate.

**National Meritorious Certificate Award**  
This award recognizes the recipient’s counsel, loyalty, and dedication to AWS affairs, assistance in promoting cordial relations with industry and other organizations, and for contributions of time and effort on behalf of the Society.

**George E. Willis Award**  
This award is given an individual who promoted the advancement of welding internationally by fostering cooperative participation in technology transfer, standards rationalization, and promotion of industrial goodwill. It includes a $2500 honorarium.

**Honorary Membership Award**  
This award acknowledges eminence in the welding profession, or one who is credited with exceptional accomplishments in the development of the welding art. Honorary Members have full rights of membership.

**International Meritorious Certificate Award**  
This honor recognizes recipients’ significant contributions to the welding industry for service to the international welding community in the broadest terms. The award consists of a certificate and a one-year AWS membership.
District 1
Thomas Ferri, director
(508) 527-1884
thomas_ferri@thermadyne.com

BOSTON, CENTRAL MASS., RHODE ISLAND
MARCH 1
Activity: The Sections participated in a tour of the Integrated Process Technologies, Inc., facilities in Devens, Mass. Company founders Christopher Sandusky and James Banks, and Luke Ciarfella, fabrication manager, led the tour. They described how the company started and grew into its present 80-employee, 20,000-sq-ft operation. They also detailed the company’s process control systems, integration services, field installations, and specialty fabrications.

GREEN & WHITE MOUNTAINS
JANUARY 13
Speaker: Bruce Lamarre, P.E.
Affiliation: White Mountain Biodiesel, LLC
Topic: Producing biodiesel fuel from animal fats and vegetable oils
Activity: The program included a tour of the company’s new facility in North Haverhill, N.H.

Shown (from left) are District 1 Director Tom Ferri with presenters James Banks, Christopher Sandusky, and Luke Ciarfella.

Shown at the Long Island Section meeting are (from left) Jesse Prowler, Tom Gartland, Alex Duschere, Ray O’Leary, Chair Brian Cassidy, Joe Kass, and Harland Thompson, District 2 director.
Shown at the New York Section program are (from left) Chair Dominick Colasanto, speaker Bob Waite, and Harland Thompson, District 2 director.

York-Central Pa. Section Chair Jim Henry (left) is shown with speaker John DuPont.

Reading Section Chair Daniel Millan (left) is shown with David Hibshman.

Jim Ladlee addressed the Reading Section.

Shown at the New York Section program are (from left) Chair Dominick Colasanto, speaker Bob Waite, and Harland Thompson, District 2 director. The meeting was held at The Nook Restaurant in Long Island, N.Y.

NEW YORK
FEBRUARY 7
Speaker: Bob Waite, P.E.
Affiliation: Waite Welding Engineer Consultant Co.
Topic: Pros and cons of working with China
Activity: The program was held at Buckley’s Restaurant in Brooklyn, N.Y.

District 2
Harland W. Thompson, director
(631) 546-2903
harland.w.thompson@us.ul.com

LONG ISLAND
MARCH 10
Activity: The Section held a meeting to discuss its Web site development and upcoming District conference headed by Tom Gartland and Harland Thompson, District 2 director. The meeting was held at The Nook Restaurant in Long Island, N.Y.

District 3
Michael Wiswesser, director
(610) 820-9551
mike@welderinstitute.com

LANCASTER, READING, YORK-CENTRAL PA.
MARCH 3
Speaker: John N. DuPont, professor
Affiliation: Lehigh University
Topic: Critical weld failures
Activity: The three Sections convened for this special program held at Heritage Hills Inn in Lancaster, Pa.

District 3
Michael Wiswesser, director
(610) 820-9551
mike@welderinstitute.com

LANCASTER, READING, YORK-CENTRAL PA.
MARCH 3
Speaker: John N. DuPont, professor
Affiliation: Lehigh University
Topic: Critical weld failures
Activity: The three Sections convened for this special program held at Heritage Hills Inn in Lancaster, Pa.

READING
FEBRUARY 17
Speaker: Jim Ladlee
Affiliation: Penn State University
Topic: The Marcellus Shale 101 project
Activity: David Hibshman received the Silver Membership Certificate for his 25 years of service to the Society. Life Member John Stasik Jr. was recognized for having the longest tenure as Section technical representative and librarian. District 3 Director Mike Wiswesser presented Chris Ochs the District Director Award and cited his work as chair for the Section’s welding contest. Past chairs in attendance included David Hibshman, Chris Ochs, Merilyn McLaughlin, Peter Shaub, Joe Young, and Daniel Millan.

District 4
Roy C. Lanier, director
(252) 321-4285
rlanier@email.pittcc.edu

Jim Ladlee addressed the Reading Section.

John Stasik (right) receives the District Director Award from Mike Wiswesser, District 2 director.

Presenter Raymond Slaughter (left) is shown with David Cash, Southwest Virginia Section treasurer.
SOUTHWEST VIRGINIA
MARCH 16
Activity: The Section members visited Roanoke Cement for a presentation by Raymond Slaughter, mechanical maintenance manager, and a tour of the facilities.

TRIANGLE
FEBRUARY 24
Activity: Russell Wahrman, a past chair, received the Section Meritorious Certificate Award from Roy Lanier, District 4 director. The meeting was held at Bar-B-Q Lodge in Raleigh, N.C.

District 5
Steve Mattson, director
(904) 260-6040
steve.mattson@yahoo.com

FLORIDA WEST COAST
FEBRUARY 26
Activity: The Section hosted its 19th annual golf outing as a fund-raiser for its scholarship program. Colton Murry, Scott Pilger, and Jeremle Spruill each received $500 scholarship funds to continue their welding educations at Pinellas Technical Education Center in Clearwater, Fla. The event was held at Walden Lakes Golf and Country Club in Plant City, Fla.

MARCH 9
Speaker: Glenn Bengert
Affiliation: Tampa Mechanical & Testing
Topic: How the welding codes have changed over the past 40 years
Activity: Steve Mattson, District 5 director, attended this Florida West Coast Section program, held at Frontier Steakhouse in Tampa, Fla.
Top scorers in the Niagara Frontier Section’s weld-off are (from left) Chris Mulkin, Jim Boehnke, Geoff Gies, Beau Babcock, Geoff Feder-spiel, and David Kish.

SkillsUSA contestants in the Northern New York Section-sponsored contest are (from left) Lance Wood, James Denue, Zach Newhart, Cody Unser, Randall Van Wie, Kyle Mogilewski, Nick Guastella, and Jacob Rarick.

Shown at the Syracuse Section program are (back, from left) District 6 Director Ken Phy, Bill Davis, Bob Davis, Al Cruz, Tom Dannible, John Heins, and Burrill Fisher; (front) Gordy McCaffer and Tom Bryant.

District 6
Kenneth Phy, director
(315) 218-5297
KAPhylncc@gmail.com

NIAGARA FRONTIER
February 5
Activity: The Section hosted its 15th an-nual Frank Schweers weld-off competition at Quality Technical Training Institute in Depew, N.Y., for 33 competitors repre-senting eight school districts. The senior division top scorers were Geoff Gies, Jim Boehnke, and Chris Mulkin. The top jun-ior division scorers were Beau Babcock, Geoff Federspiel, and David Kish.

NORTHERN NEW YORK
March 1
Activity: The Section hosted the local SkillsUSA welding competition at Capi-tal Region Career and Technical School in Albany, N.Y. Tying for first place were Nick Guastella and Jacob Rarick. Second place was earned by Kyle Mogilewski, and third-place honors were shared by Cody Unser and Randall Van Wie.

SYRACUSE
March 9
Activity: The Section hosted a round table discussion on welder training in central New York. The event was monitored by Gordy McCaffer, a BOCES instructor, and Tom Bryant, an instructor at Carpenter’s Union and Patriot Resources. The meet-ing was held at Barbagallos Restaurant in Syracuse, N.Y.
**District 7**

Don Howard, director  
(614) 269-2895  
howard@ctc.com

**COLUMBUS**

MARCH 14  
Activity: The Section joined members of the local chapters of SWE, ASME, ASM International, AIAA, and NACE to tour Middle West Spirits in Columbus, Ohio.  
Ryan Lang, an engineer and master distiller, conducted the tour.

**DAYTON, CINCINNATI**

JANUARY 19  
Speaker: Mark James  
Affiliation: Alcoa Research  
Topic: Measuring residual stresses in F-35 fighter plane parts  
Activity: This joint meeting was held at The Engineers Club in Dayton, Ohio.

**DAYTON**

FEBRUARY 8  
Speaker: Dale Reckman  
Affiliation: Great Lakes Wind Network  
Topic: Welding opportunities in the wind power industry  
Activity: The program was held at Bullwinkles Top Hat Bistro in Miamisburg, Ohio.

FEBRUARY 19, 20  
Activity: The Dayton Section members participated with other local professional societies in the annual TechFest held at Sinclair Community College in Dayton, Ohio. The science and technology exhibits attracted about 2700 students.

**JOHNSTOWN / ALTOONA**

NOVEMBER 1, 2010  
Activity: The Section members toured North American Hoganas in Hollsopple, Pa., to study its operations. David Milligan, director of quality, safety, and environment, conducted the program.

FEBRUARY 15  
Activity: The Johnstown/Altoona Section members toured the WyoTech Blairsville, Pa., campus. Paul Dominick, coordinator of street rod and chassis fabrication, and Dan Bracken, an AWS Certified Welding Educator, conducted the program.

FEBRUARY 23  
Activity: The Johnstown/Altoona Section and local ASME chapter members joined to tour New Enterprise Stone & Lime Co., Inc., Concrete Plant in Roaring Spring, Pa.
Johnstown/Altoona Section members are shown at the Feb. 15 tour of the WyoTech campus.

Johnstown/Altoona Section and members of the local ASME chapter are shown during their tour of the New Enterprise facilities Feb. 23.

District 8
Joe Livesay, director
(931) 484-7502, ext. 143
joe.livesay@ttcc.edu

CHATTANOOGA
January 18
Activity: The Section members toured Siag Aerisyn LLC in Chattanooga, Tenn., a manufacturer of wind power generators. The presenters included Andreas Stahr, Joe Kelly, Sam Wells, and Sam Adams.

NORTHEAST TENNESSEE
February 15
Activity: The Northeast Tennessee Section members and guests toured the new welder training facilities at Pellissippi State Community College, Blount Campus, in Friendsville, Tenn.
Northeast Tennessee Section members are from left (front row) Gilbert Cruz, Josh Burgess, Chair Don Combs, and Phil Davis; (back row) David Mosier, Jeff Hankins, AWS Past President Tom Mustaleski, Keith Daniels, Chris Hayes, Paul Pipkin, Chris Harvey, Cecil Yearwood, John Folk, Josh Plum, David Cooper, Jonaaron Jones, and Brad Campbell.

Jackie Morris (left), Mobile Section chair, is shown with speaker Ryan O’Dell.

District 9
George Fairbanks Jr., director
(225) 473-6362
fits@bellsouth.net

Lawson State Community College Student Chapter
FEBRUARY 23
Activity: The students attended a welding seminar at Plumbers and Pipefitters Local 372 in Duncanville, Ala. Exhibiting at the event were ESAB, Lincoln Electric, Miller Electric, Airgas Welding Supply, Profax/Lenco, Atlas Welding Supply, Bosch Tools, and Harris Equipment. The students experienced hands-on training using the latest technology.

MOBILE
FEBRUARY 10
Speaker: Ryan O’Dell
Topic: New trends in pulsed welding equipment
Activity: The program was held at Saucy O Bar B Que in Mobile, Ala.

Presenters at the Chattanooga Section tour included (from left) Andreas Stahr, Joe Kelly, Sam Wells, and Sam Adams.

MARCH 10
Speaker: John Mendoza, AWS president
Affiliation: Lone Star Welding
Topic: What’s happening in AWS
Activity: District 9 Director George Fairbanks presented the Section Meritorious Award to Jerry Betts and Brenda Amos; Section Dalton E. Hamilton CWI of the Year Award to Chair Jackie Morris; District Educator Award to Tim DeVargas; and Section Private Sector Instructor Award to Darryl Bryant. The meeting was held at AIDT Maritime Training Center in Mobile, Ala., for 86 attendees.
Recognized at the Mobile Section March program are (from left) Tim DeVargas, Brenda Amos, Darryl Bryant, Jerry Betts, President John Mendoza, District 9 Director George Fairbanks, and Chair Jackie Morris.

Shown at the New Orleans Section are (from left) Jude Plot, Vice Chair Aldo Duron, Garith Horn, Mike Bertucci, Mike Davis, Percy Price, and Chair D. J. Berger.

Aldo Duron (left), New Orleans Section vice chair, is shown with speaker Mike Davis.

Johnny Fulco (left) accepts the raffle prize from D. J. Berger, New Orleans Section chair.

Speaker Sunniva Collins is shown with Kenny Jones, Mahoning Valley Section chair.

Speaker Marty Siddall (left) is shown with Jesse McIntosh, Northwestern Pennsylvania Section vice chair.

President John Mendoza (right) chats with George Fairbanks, District 9 director, at the Mobile Section program in March.

NEW ORLEANS
FEBRUARY 15
Speaker: Mike Davis
Affiliation: Airgas Southwest
Topic: Safe handling of gas cylinders
Activity: Section sponsors were cited at the program, including Jude Plot, Garith Horn, Mike Bertucci, Mike Davis, and Percy Price. The program was held at Best Western Landmark Hotel in Metairie, La.

District 10
Richard A. Harris, director
(440) 338-5921
richaharris@windstream.net

MAHONING VALLEY
MARCH 10
Speaker: Sunniva Collins, senior research fellow
Affiliation: Swagelock Co.
Topic: Orbital welding for critical applications
Activity: This was a joint meeting with the local ASM International chapter. The meeting was held at Café 422 in Warren, Ohio.
NORTHWESTERN PENNSYLVANIA  
FEBRUARY 20  
Speaker: Marty Siddall  
Affiliation: The Lincoln Electric Co.  
Topic: New technology in robotic welding  
Activity: The program was held at Tri State Business Institute in Erie, Pa., for 50 attendees.

District 11  
Robert P. Wilcox, director  
(734) 721-8272  
rmwilcox@wowway.com

CENTRAL MICHIGAN  
FEBRUARY 21  

District 12  
Daniel J. Roland, director  
(715) 735-9341, ext. 6421  
daniel.roland@us.fincantieri.com

District 13  
W. Richard Polanin, director  
(309) 694-5404  
rpolanin@icc.edu

CHICAGO  
FEBRUARY 23  
Activity: The Section members held a planning meeting at Bohemian Crystal Restaurant in Chicago, Ill. Attending were Hank Sima, Craig Tichelar, Marty Vondra, Jeff Stanczak, Cliff Iftimie, Eric Krauss, and Eric Purkey. Craig Tichelar has been chosen to fulfill the late Chuck Hubbard’s term as chairman.

MARCH 9  
Activity: The Chicago Section hosted its ladies’ night dinner and wine tasting event at Cooper’s Hawk Winery & Restaurant.

District 14  
Robert L. Richwine, director  
(765) 378-5378  
boobrichwine@aol.com

INDIANA  
FEBRUARY 12  
Activity: The Section members conducted the SkillsUSA welding competition at Ivy Tech Community College in Anderson, Ind.
Welding competitors met for the SkillsUSA contests held by the Indiana Section.

Shown at the Tri-River Section program are (from left) AWS Fellow Dorr Doty, Bill Doty, speaker Ken Barry, and Chair John Durbin.

LEXINGTON
February 24
Speaker: James Mattor
Affiliation: Madison Technical School
Topic: American Welding Society
Activity: Chair Tim Pinson presented the Woodrow Scott Memorial Scholarship to Thomas Bailey, a student at Somerset Community College, and the Section Meritorious Award to Coy Hall, an instructor at Clark County Technical School.

TRI-RIVER
February 24
Speaker: Ken Barry, welding automation engineer
Affiliation: Babcock & Wilcox, Nuclear Operations Group
Topic: Careers in nuclear welding
Activity: More than 120 people attended this event held at Ivy Tech Community College in Evansville, Ind. AWS Fellow Dorr Doty, an AWS member since 1946, attended the event.

NORTHWEST
February 23
Activity: The Section hosted its annual Behind the Mask Contest, coordinated by Pam Lesemann, at Dunwoody Institute in Minneapolis, Minn. The event included 96 contestants competing in four processes, OFC, GTAW, GMAW, and SMAW. The event raised about $2000 for the scholarship fund. Sponsors included Advantage Marketing, Airgas North Central, Anoka T. C. alumni, Anoka Supply, Dunwoody Institute, ESAB, Jay Gerding, Pam Lesemann, Mike Hanson, Hobart, Dan Johnson, Matheson Trigas, Metabo, Metro Welding, Miller, Minneapolis Oxygen, Mississippi Sand, Smith Equipment, TBEI–Lake Crystal, Tec Torch, Washington Alloy, Weld-Craft, Simon Wester, Western States Welding, Winnies Supply. The top scorers were OFC: Jeremy Hall, Myles Olson, and Jeremy Kummings; GTAW: Jeremy Hall, Jason Eastling, and Jason Knapp; GMAW: Ryan Suchy, Eric Jacobson, and Joey McAlister; SMAW: Jeremy Hall, Nick Wuertz, and Brett Ford.

District 16
David Landon, director
(641) 621-7576
dlandon@vermeermfg.com

KANSAS CITY
February 24
Speakers: Kellen Petersen, Bryan Johnson
Affiliation: Olsson Associates
Topic: Materials testing and inspection for building construction
Activity: The program was held at Smokehouse BBQ in Overland Park, Kan.

District 15
Mace V. Harris, director
(612) 861-3870
macevh@aol.com

District 17
J. Jones, director
(940) 369-3130
jjones@thermadyne.com
Win Great Prizes in the 2010-2011 AWS Member-Get-A-Member Campaign*

ABOUT: AWS is looking for individuals to become part of an exclusive group of AWS Members who get involved and win. Give back to your profession, strengthen AWS and win great limited-edition prizes by participating in the 2010-2011 Member-Get-A-Member Campaign. By recruiting new members to AWS, you’re adding to the resources necessary to expand your benefits as an AWS Member. Year round, you’ll have the opportunity to recruit new members and be eligible to win special contests and prizes. Referrals are our most successful member recruitment tool. Our Members know first-hand how useful AWS Membership is, and with your help, AWS will continue to be the leading organization in the materials joining industry.

To recruit new Members, use the application on the reverse, or visit www.aws.org/mgm

PRIZE CATEGORIES

resident’s Honor Roll: Recruit 2 new Individual Members and receive an AWS Sportpack bag.

resident’s Club: Recruit 3-8 new Individual Members and receive an AWS hat and an AWS Sportpack bag.

resident’s Roundtable: Recruit 9-19 new Individual Members and receive an AWS polo or denim shirt, hat and an AWS Sportpack bag.

resident’s Guild: Recruit 20 or more new Individual Members and receive an AWS Messenger Bag, an AWS polo or denim shirt, a one-year free AWS Membership, the ”Shelton Hurter Member Proposer Award” certificate and membership in the Winner’s Circle.

Winner’s Circle: All members who recruit 20 or more new Individual Members will receive annual recognition in the Welding Journal and will be honored at the FABTECH show.

SPECIAL PRIZES

Participants will also be eligible to win prizes in specialized categories. Prizes will be awarded at the close of the campaign (June 2011).

Sponsor of the Year: The individual who sponsors the greatest number of new Individual Members during the campaign will receive a plaque, a trip to the 2011 FABTECH Show, and recognition at the AWS Awards Luncheon at the Show.

Student Sponsor Prize: AWS Members who sponsor two or more Student Members will receive an AWS Sportpack bag.

The AWS Member who sponsors the most Student Members will receive a free, one-year AWS Membership, an AWS polo shirt, hat and an AWS Sportpack bag.

International Sponsor Prize: Any member residing outside the United States, Canada and Mexico who sponsors the most new Individual Members will receive a complimentary AWS Membership renewal.

LUCK OF THE DRAW

For every new member you sponsor, your name is entered into a quarterly drawing. The more new members you sponsor, the greater your chances of winning. Prizes will be awarded in November 2010, as well as in February and June 2011.

Prizes Include:
* Complimentary AWS Membership renewal
* AWS t-shirt
* AWS hat

SUPER SECTION CHALLENGE

The AWS Section in each District that achieves the highest net percentage increase in new Individual Members before the June 2011 deadline will receive special recognition in the Welding Journal.

The AWS Sections with the highest numerical increase and greatest net percentage increase in new Individual Members will each receive the Neitzel Membership Award.

The 2010-2011 MGM Campaign runs from June 1, 2010 to May 31, 2011.

American Welding Society
**AWS MEMBERSHIP APPLICATION**

4 Easy Ways to Join or Renew:
- ✔ Mail this form, along with your payment, to AWS
- Call the Membership Department at (800) 443-9353, ext. 480
- ✔ Fax this completed form to (305) 443-5647
- ✔ Join or renew on our website [www.aws.org/membership](http://www.aws.org/membership)

☐ Mr.  ☐ Ms.  ☐ Mrs.  ☐ Dr. Please print • Duplicate this page as needed

Last Name: ____________________________________________________________
First Name: ____________________________________________________________
M.I.: ____________
Title: _________________________________________________________________
Birthdate: ____________

Were you ever an AWS Member?  ☐ YES  ☐ NO  If "YES," give year _______ and Member # _______

Primary Phone ( ) ___________________ Secondary Phone ( ) ___________________

FAX ( ) ______________________________ E-Mail _______________________________

Did you learn of the Society through an AWS Member?  ☐ Yes  ☐ No

If "yes," Member’s name: _________________________________________________ Member’s # (if known):

From time to time, AWS sends out informational emails about programs we offer, new Member benefits, savings opportunities and changes to our website. If you would prefer not to receive these emails, please check here ☐

**ADDRESS**

NOTE: This address will be used for all AWS correspondence.

Company (if applicable): ________________________________________________
Address: _____________________________________________________________
Address Can’t. _____________________________________________________________________________________________

City: ______________ State/Province: __________ Zip/Postal Code: __________ Country: ________________

**PROFILE DATA**

NOTE: This data will be used to develop programs and services to serve you better.

☐ Who pays your dues?  ☐ Company  ☐ Self-paid  ☐ Sex: ☐ Male  ☐ Female

Education level:  ☐ High school diploma  ☐ Associate’s  ☐ Bachelor’s  ☐ Master’s  ☐ Doctoral

**PAYMENT INFORMATION (Required)**

**ONE-YEAR AWS INDIVIDUAL MEMBERSHIP** $80

**TWO-YEAR AWS INDIVIDUAL MEMBERSHIP** $160 $135

New Member?  ☐ Yes  ☐ No

If "YES," add one-time initiation fee of $12 ___________________

International Members add $50 for optional hard copy of Welding Journal (note: digital delivery of WJ is standard) $50 (Optional)

Individual Members add $25 for book selection (up to a $192 value) **$25** (Optional)

(Note: $50 shipping charge applies to members outside of the U.S.)

**TOTAL PAYMENT** ___________________ $ ____________

**AWS STUDENT MEMBERSHIP** $50

Domestic (Canada & Mexico incl.) $15
International $50

**TOTAL PAYMENT** ___________________ $ ____________

Payment can be made (in U.S. dollars) by check or money order (international or foreign), payable to the American Welding Society, or by charge card.

☐ Check  ☐ Money Order  ☐ American Express  ☐ Diners Club  ☐ Carte Blanche  ☐ MasterCard  ☐ Visa  ☐ Discover  ☐ Other

Your Account Number: ___________________ Expiration Date (mm/yy): ___________________

Signature of Applicant: ______________________________________________________________________________________

**Office Use Only**

Check # ___________________ Account # ___________________

Date: ___________________ Amount: ___________________

**BOOK/CD-ROM SELECTION**

(Pay Only $25... up to a $192 value)

**NOTE:** Only New Individual Members are eligible for this selection. Be sure to add $25 to your total payment.

**ONLY ONE SELECTION PLEASE:**

☐ Jefferson’s Welding Encyclopedia (CD-ROM only)
☐ Design & Planning Manual for Cost-Effective Welding
☐ Welding Handbook (9th Ed., Vol. 4)
☐ Welding Handbook (9th Ed., Vol. 3)
☐ Welding Handbook (9th Ed., Vol. 2)
☐ Welding Handbook (9th Ed., Vol. 1)

For more book choices visit [www.aws.org/membership](http://www.aws.org/membership)

Learn more about each publication at [www.awspubs.com](http://www.awspubs.com)

**NEW MEMBER □ RENEWAL **

A free local Section Membership is included with all AWS Memberships.

Section Affiliation Preference (if known): ___________________

**Type of Business**

☐ Contract construction  ☐ Chemicals & allied products  ☐ Petroleum & coal industries
☐ Primary metal industries  ☐ Fabricated metal products  ☐ Machinery except elect. (incl. gas welding)
☐ Electrical equip., supplies, electrodes  ☐ Transportation equip. — air, aerospace
☐ Transportation equip. — automotive  ☐ Transportation equip. — boats, ships
☐ Transportation equip. — railroad  ☐ Utilities
☐ Welding distributors & retail trade  ☐ Misc. repair services (incl. welding shops)
☐ Educational Services (univ., libraries, schools)  ☐ Engineering & architectural services (incl. asns.)
☐ Government (federal, state, local)  ☐ Other

**Job Classification**

☐ President, owner, partner, officer  ☐ Manager, director, superintendent (or assistant)
☐ Sales  ☐ Purchasing  ☐ Engineering — welding  ☐ Engineering — design
☐ Engineering — manufacturing  ☐ Engineer — other  ☐ Architect designer
☐ Metallurgist  ☐ Research & development  ☐ Quality control
☐ Inspector, tester  ☐ Supervisor, foreman  ☐ Technician
☐ Welder, welding or cutting operator  ☐ Consultant
☐ Educator  ☐ Librarian  ☐ Student  ☐ Customer Service
☐ Other

**Technical Interests**

☐ Ferrous metals  ☐ Aluminum  ☐ Nonferrous metals except aluminum  ☐ Advanced materials/Intermetallics
☐ Ceramics  ☐ High energy beam processes  ☐ Arc welding
☐ Brazing and soldering  ☐ Resistance welding  ☐ Thermal spray
☐ Cutting  ☐ LNT  ☐ Safety and health
☐ Bending and shearing  ☐ Roll forming  ☐ Stamping and punching
☐ Aerospace  ☐ Automotive  ☐ Machinery
☐ Marine  ☐ Piping and tubing  ☐ Pressure vessels and tanks
☐ Sheet metal  ☐ Structures  ☐ Other
☐ Automation  ☐ Robotics  ☐ Computerization of Welding
Winners in the Northwest Section weld-off are (from left) OFC: Jeremy Hall, Myles Olson, and Jeremy Kummings; GTAW: Jeremy Hall, Jason Eastling, and Jason Knapp; GMAW: Ryan Suchy, Eric Jacobson, and Joey McAlister; and SMAW: Jeremy Hall, Nick Wuertz, and Brett Ford.

SkillsUSA representative Darren Gibson (left) is shown with Cary Reeves, Oklahoma City Section chair.

EAST TEXAS
FEBRUARY 24
Speaker: Robert Warke, professor
Affiliation: LeTourneau University
Topic: Materials joining and engineering programs at the university
Activity: The meeting was held at Tyler Jr. College in Tyler, Tex.

OKLAHOMA CITY
MARCH 10
Speaker: Darren Gibson, state director
Affiliation: SkillsUSA
Topic: How SkillsUSA can benefit local industry
Activity: Following the talk, the attendees toured the newly commissioned welding shop at Francis Tuttle Technology Center in Oklahoma City.

TULSA
MARCH 10
Speaker: John Mendoza, AWS president
Affiliation: Lone Star Welding
Topic: AWS activities
Activity: District 17 Director Jay Jones and AWS President John Mendoza presented Ray Wilsdorf the Section CWI of the Year Award; Shane Steffen the District Educator of the Year Award; and Ralph Johnson and Ron Fogle their Silver Member Certificates for 25 years of service to the Society. This ladies’ night program was held at Ti Amo’s Italian Ristorante in Tulsa, Okla.
Shown at the Tulsa Section program are (from left) District 17 Director J. Jones, Ray Wilsdorf, Shane Steffen, Ralph Johnson, Ron Fogle, AWS President John Mendoza, and Chair Adam Ensinger.

Shown at the Houston Section January program are past Chairs (from left) Dennis Eck, Robert Hunt, Ron Theiss, Larry Wilmesmeier, John Bray, John Husfeld, John Stoll, Robert Anderson, Jim Appledorn, Haskell Ray, Roy Morton, and Asif Lail.

Shown at the Houston Section's fall social are from left (seated) George Fairbanks, John Mendoza, John Bruskotter, and J. Jones, (standing) Glenda Fairbanks, John Bray, Nora Mendoza, Donna Bruskotter, Luanne Bray, and Teresa Jones.

Ron Theiss (left) receives his Silver Member Certificate from John Husfeld, Houston Section chair.

Houston Chair John Husfeld (left) is shown with speaker Jean-Marc Tétevuide at the March 17 program.

District 18
John Bray, director
(281) 997-7273
sales@affiliatedmachinery.com

HOUSTON
DECEMBER 11, 2010
Activity: The Section hosted its fall social at Willie G’s Steak House and Seafood in Houston, Tex. Among the attendees were AWS 2010 President John Bruskotter, 2011 President John Mendoza, District 9 Director George Fairbanks, District 17 Director J. Jones, and District 18 Director John Bray.

JANUARY 19
Speaker: Lennon Evans, deputy sheriff
Affiliation: Harris County Sheriff Dept.
Topic: Home safety and crime statistics
Activity: Twelve Houston Section past chairs attended this event, held at Brady’s Landing Restaurant in Houston, Tex.

FEBRUARY 16
Speaker: Bryan Willingham, welding and cutting consultant
Topic: Safety and gases for oxyfuel cutting
Activity: Houston Section Chair John Husfeld presented Ron Theiss his Silver Member Certificate for 25 years of service to the Society. District 18 Director John Bray presented autodarkening welding helmets to the winners of the recent District weld-
Presenter Dave Brazell (right) is shown with Rob Rothbauer, Olympic Section chair.

ing skills contest. Ryan Plaisance received the Level 1 Award and Erick Mata took first place in Level 2. Both students attend LP Card Skill Center.

**March 17**
**Speaker:** Jean-Marc Tetevuide, sales manager  
**Affiliation:** Durum USA  
**Topic:** Plasma transfer arc for surfacing  
**Activity:** The Houston Section’s many Titanium Sponsors were recognized for their support.

**RIO GRANDE VALLEY**
**February 9**  
**Activity:** Section Treasurer Richard Salinas received the District Director Certificate Award from District 18 Director John Bray. The presentation took place at South Texas Community College in McAllen, Tex.

**SABINE**
**February 15**  
**Speaker:** Ron Theiss, president  
**Affiliation:** Theiss & Associates  
**Topic:** Value of AWS membership  
**Activity:** The Section held its ladies’ night program at La Cantina Mexican Grill near Beaumont, Tex. Twenty-four Lamar Institute of Technology Student Chapter members attended the program.

**SAN ANTONIO**
**February 8**  
**Speaker:** John Mendoza, AWS president  
**Affiliation:** Lone Star Welding  
**Topic:** CWI certification, past and present  
**Activity:** John Bray, District 18 director, presented Clifton Rogers the District Meritorious Certificate Award and the District Educator of the Year Award. Rachel Marin received the District Director Award and Howard Thomas received the Dalton E. Hamilton District CWI of the Year Award.

**District 19**
**Neil Shannon, director**  
(503) 201-5142  
neilshnn@msn.com

**OLYMPIC**
**March 15**  
**Speaker:** Dave Brazell  
**Affiliation:** Hypertherm  
**Topic:** Plasma cutting principles and safety  
**Activity:** Following the talk, the attendees had an opportunity to try plasma cutting equipment. The program was held at Bates Technical College in Tacoma, Wash.

John Mendoza (left), AWS president, receives a speaker gift from Cornelio Ontiveros, San Antonio Section vice chair.
Montana Tech Student Chapter members met with Bill Komlos (third from left), District 20 director, in February.

Speakers Philip Doaninh (right) chats with Ken Johnson, Puget Sound Section chair.

Idaho/Montana Section members are shown during their inspection seminar.
Sheridan College Student Chapter members are shown with Bill Komlos (front), District 20 director, February 24.

PUGET SOUND
March 6
Speaker: Philip Dovinh, marine chemist
Affiliation: Sound Testing, Inc.
Topic: Review of hot work performed in confined spaces on marine vessels
Activity: The program was held at Rock Salt Steak House in Seattle, Wash.

District 20
William A. Komlos, director
(801) 560-2353
bkoz@arctechllc.com

ALBUQUERQUE
February 24
Speaker: Dave Drake, project manager
Affiliation: Array Technologies
Topic: Solar tracker technology
Activity: The program was held at Array Technologies in Albuquerque, N.Mex.

IDAHO/MONTANA
March 4
Activity: The Section hosted a special inspection seminar on structural steel, conducted by Bill Komlos, District 20 director. Attendees received certificates for two professional development hours. Paul Tremblay, Section chair, received a certificate of appreciation for serving two terms as chair (2008–2010). City of Idaho Falls inspector Brian Tomset made a presentation on current local structural steel inspection issues.

Montana Tech Student Chapter
February 28
Speaker: Bill Komlos, District 20 director
Affiliation: Arc Tech LLC
Topic: Job opportunities for welders and update on AWS activities
Activity: Chapter leaders Joe Stavinoha and Shane Krause arranged the program.

Sheridan College Student Chapter
February 24
Speaker: Bill Komlos, District 20 director
Affiliation: ArcTech LLC
Topic: Opportunities for welders in indus-
Sacramento Section members are shown during their tour of Airgas.

Jim Gindt addressed the Sacramento Section members in March.

Activity and update on AWS activities

Activity: Sheridan College Student Chapter Adviser Carl Schiner arranged the program for his students. Don Pindell from the Plumbers & Pipefitters UA Local Union 192 discussed local job opportunities for welders.

District 21
Nanette Samanich, director
(702) 429-5017
nan07@aol.com

NEVADA
FEBRUARY 23
Speaker: Tom Moessner
Affiliation: Southwest Gas Co.
Topic: Magnetic arc blow in gas pipelines
Activity: Following the talk, Jason Corder, an instructor at Ironworkers Local 416/433, led the group on a tour of the Ironworkers facility and presented demonstrations of flux core arc and shielded metal arc welding. District 21 Director Nanette Samanich attended the program.

District 22
Dale Flood, director
(916) 288-6100, ext. 172
d.flood@tritool.com

SACRAMENTO
MARCH 16
Activity: The Section members toured the Airgas NCN cylinder fill plant in Sacramento, Calif., to study its operations. Jim Gindt, vice president of operations, discussed how gas is extracted and treated before being injected into the 60,000 cylinders it fills each month.

SAN FRANCISCO
MARCH 2
Activity: Mike Lampley, systems and solutions manager, conducted the members on a tour of the ConXtech® facilities in Hayward, Calif. The company produces mass customizable, and sustainable structural steel and concrete building systems and components for use in mid- to high-rise residential structures.
Guide to AWS Services

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Structural Welding, Machinery and Equipment

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**Automotive Welding Standards**

Establishes acceptance criteria for resistance spot welds in autos fabricated from steels, including Advanced High Strength Steels. 38 pages, 24 figures, 4 tables, (2007).

**D8.6:2005, Specification for Automotive Resistance Spot Welding Electrodes**  
Supplement to RWMA Bulletin 16, Resistance Welding Equipment Standards. Specifies chemical composition, physical requirements, dimensions, and identification of various shapes and nose configurations of electrodes, electrode caps, and cap-adaptor shanks used in the automotive industry. Annexes describe recommended electrode material for spot welding similar and dissimilar metals, and standard gauges for confirmation of RWMA electrode taps. 98 pages, 8 annexes, 47 figures, 37 tables, (2006).

Presents recommended practices and criteria for evaluating resistance spot welds typical of automotive sheet steel applications. Contains weld characteristics, metrics, and testing methods useful in evaluating spot welding quality on coated and uncoated automotive sheet steels of all strength levels and compositions. The test methods are designed to assess static and dynamic properties of automotive sheet steel welds. 26 pages, 18 figures, 3 tables, (2005).

**D8.8M:2007, Specification for Automotive Weld Quality – Arc Welding of Steel**  
Provides the minimum quality requirements for arc welding of various types of automotive and light truck components. Covers the arc and hybrid arc welding of coated and uncoated steels. 26 pages, 17 figures, (2007).

Helps predict performance of sheet steel that is resistance spot welded for use in auto manufacturing. Also addresses equipment setup, electrode installation and dressing, electrode endurance testing, and current level and range assessment. 78 pages, 3 annexes, 36 figures, 12 tables, (2002).

Governs the arc welding of automotive and light truck components that are manufactured from aluminum alloys. 32 pages, 18 figures, 3 tables, (2008).

Covers low-carbon steels and chromium-molybdenum steel tubing and components with a maximum wall thickness of 3 mm intended for limited production tubular frame vehicles such as race cars.

For self-propelled, on- and off-highway machinery and agricultural equipment. Specifies requirements for structural welds used in the manufacture and repair of crawlers, tractors, graders, loaders, off-highway trucks, power shovels, backhoes, mobile cranes, draglines, and other heavy earthmoving, construction, and agricultural equipment. Provides exhaustive illustrations of qualified complete and partial penetration welds joints (butt, corner, T, or combination) for shielded metal arc welding, submerged arc welding, gas metal arc welding, and flux cored arc welding. Includes variables for prequalified fillet welds. Annexes include “Recommended Practices for Treatment of Shielded Metal Arc and Flux Cored Arc Electrodes.” Tables include “Weldability Classification—Typical Steel Products” and “Minimum Preheat and Interpass Temperatures.” 94 pages, 22 figures, 13 tables, (2011).

**D14.4**


**D14.5**

**D14.5M:2010, Bridge Welding Code**  
Get the facts and code requirements for bridge building with carbon and low-alloy construction steels. Covers welding requirements of the American Association of State Highway and Transportation Officials (AASHTO) for welded highway bridges made from carbon and low-alloy construction steels. Chapters cover design of welded connections, workmanship, technique, procedure and performance qualification, inspection, and stud welding. Features the latest AASHTO revisions and nondestructive examination requirements, as well as a section providing a “Fracture Control Plan for Nonredundant Bridge Members.” Revisions include:
- Revised procedure, personnel, and test equipment inspection requirements
- New materials and hybrid joint provisions
- New guidance on electrical arc and narrow-gap ESW

**RWMA Resistance Welding Manual, Revised Fourth Edition**  
The latest and most complete compilation of basic information on resistance welding available anywhere. 468 pages, 25 chapters, 2 appendices (including an index), 306 figures, 85 tables, 8.5" x 11". (2005).

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D1.6/D1.6M:2007, Structural Welding Code – Stainless Steel
Covers requirements for welding stainless steel structural assemblies/components (including pressure vessels or pressure piping) using gas metal arc welding, shielded metal arc welding, flux cored arc welding, submerged arc welding, and stud welding. Allows prequalified Welding Procedure Specifications for the martensitic stainless steels based on considerable experience with the most widely used stainless steels. Sections include design, procedure and performance qualification, fabrication, inspection, and stud welding. 292 pages, 14 annexes, 80 figs., 29 tables, (2007). 
D1.6 $200/$150

D1.7/D1.7M:2010, Guide for Strengthening and Repairing Existing Structures
Provides engineers and contractors with general direction and guidance on weld repairs, weld strengthening, and other procedures to correct problematic issues with existing structures made of steel (minimum yield strength of 100 ksi and minimum thickness of 1/8 inch), cast iron, and wrought iron. 52 pages, 4 tables, (2009). 
D1.7 $108/$81

D1.8/D1.8M:2009, Structural Welding Code – Seismic Supplement
A supplement to D1.1, applicable to welded joints in seismic load resisting systems designed in accordance with the Seismic Provisions of AISC. Covers additional controls on detailing, materials, workmanship, testing, and inspection necessary to achieve adequate performance of welded steel structures under conditions of severe earthquake-induced inelastic straining. Commentary offers guidance on interpreting and applying this supplement. 124 pages, 9 annexes, commentary, 22 figures, 8 tables, (2009). 
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WHB-1.9 $192/$144

Presents comprehensive information on welding and related processes. Contains detailed information on arc welding power sources; shielded metal arc, gas tungsten arc, gas metal arc, flux cored arc, submerged arc, and plasma arc welding processes. Includes chapters on electrodes, welding, stud welding, oxyfuel gas welding, brazing, soldering, oxygen cutting, arc cutting and gouging, 736 pages, 15 chapters, 260 line drawings, 100 photographs, 148 tables, hardbound. 8"x10", (2004). 
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B2.1 $216/$162

B4.0:2007, Standard Methods for Mechanical Testing of Welds
Describes the most common mechanical test methods applicable to welds and welded joints. Each test method gives details concerning specimen preparation, test parameters, testing procedures, and suggested report forms. Acceptance criteria are not included. Three new weldability tests (WIC, trough, and G6OP) and resistance weld tests have been included in this new edition. U.S. Customary Units. 152 pages, 97 figures, (2007).

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NEW EDITION: C7.2M:2010, Recommended Practices for Laser Beam Welding, Cutting, and Allied Processes
Covers common applications of the process, including drilling and transformation hardening. Describes equipment and procedures. Practical information, including figures and tables, should prove useful in determining capabilities in the processing of various materials. 142 pages, 85 figures, 8 tables, (2010).

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Covers arc and braze welding requirements for nonstructural sheet metal fabrications using commonly welded metals available in sheet form up to and including 3 gauge, or 6.4 mm (0.250 in.). Applications of the code include heating, ventilating, and air conditioning systems, food processing equipment, architectural sheet metal, and other nonstructural sheet metal applications. Sections include procedure and performance qualification, workmanship, and inspection. Nonmandatory annexes provide useful information on materials and processes. Not applicable when negative or positive pressure exceeds 30 kPa (5 psi). 70 pages, 29 figures, 10 tables, (2006).

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D17.1 $160/$120

This invaluable reference tool helps inspectors, engineers, and welders evaluate the difference between discontinuities and rejectable defects. 254 pages, 18 chapters, index, 106 figures, 16 tables, 64/12” x 9”, (2000), third edition.

W1 $76/$57

WIT-T:2008, Welding Inspection Technology
For at-home study, this official reference textbook for the three-day AWS core seminar for CWI exam preparation is readable, informative, and comprehensive. 320 pages, 10 chapters, 379 figures and photographs, (2008).

WIT-T $272/$204

NEW EDITION: AWS User's Guide to Filler Metals
Contains user information on the filler materials contained in the A5 Filler metal classification standards. Provides guidance on welding considerations and applications for the consumables covered. 178 pages, 22 tables, 7 figures (2010).

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The Practical Reference Guide to Positioning
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Future of Materials Joining Detailed in Report


Issued Feb. 2, Strengthening Manufacturing Competitiveness, is the 38-page report from the 2010 Conference on the Future of Materials Joining in North America sponsored by Edison Welding Institute, American Welding Society, and Praxair. The full-color, well-illustrated document discusses this complex topic in clear terms and graphics. Topics include alarming trends, trends in industrial and academic research, paradigm shift in U.S. industries, issues impacting materials joining and manufacturing, technical innovation, workforce development, influencing government priorities, approaches to advancing competitiveness, technology innovation infrastructure, barriers to collaboration, improving workforce competitiveness, and next steps. This is good reading for manufacturing executives and others interested in the nation’s future manufacturing outlook. The report can be downloaded from the Web site below.

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(614) 688-5000

e-Newsletter Offered for Heavy Equipment Builders

The company has initiated a new electronic newsletter written to help heavy equipment manufacturers improve their welding operations and receive news of the latest industry advances. The publication, delivered quarterly to subscribers, is free of charge. It features educational articles that offer tips on improving weld quality and productivity, as well as information about the latest filler metal technologies developed for heavy equipment applications. Other details provided in the e-newsletter include updates on trade shows and seminars, and news items affecting the industry. Subscribers may also use this e-newsletter program to submit technical questions and receive answers from the company’s engineering staff. To subscribe to the newsletter, e-mail your full name, company name, and e-mail address to the address shown below.

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Fire Resistance Design Guide Published

The 264-page Fire Resistance Design Guide for Metal Building Systems offers a complete reference for fire-protection issues related to metal building systems. The book includes fire test standards, shape properties for fire resistance, repair/replacement after fire damage, protection practices related to occupancy and construction options, construction elements, fire walls, exterior walls, joints, sprinklers, and thermal barriers. Other topics are fire protection involving columns, roofs, walls, and joints; and an industry resource listing for fire resistant design. The book lists for $96.

Metal Building Manufacturers Assn.
www.mbmamanual.com
(216) 241-7333

Laser Applications Journal Goes Online-Only

The Institute has made its official publication, Journal of Laser Applications®, an online-only publication. The change will permit the addition of new features and reach a broader audience. The enhanced online format includes full-text HTML rendering that features in-line reference links and the ability to enlarge tables and figures by clicking on them. Among the new features are enhanced search functions with more options and better controls to explore content. Subscriptions to the Journal of Laser Applications are free for Institute members. Non-members may subscribe to the online publication by calling the phone number shown.

The Laser Institute of America
www.lia.org
(407) 380-1553

Canadian Aluminum Welding Standard Issued

The CSA Standard W47.2-2011 specifies requirements for certification of companies engaged in fusion welding of aluminum. The scope has been changed to allow the standard to be applied to many types of components. It no longer applies just to “structures.” Numerous other changes affect exemptions from the re-
quirements, basic duties of engineers and welding supervisors, welding procedures, and welding personnel performance evaluations and bend test criteria. The requirement for submitting a Welding Engineering Standard has been removed and replaced with a new document, Operational Control Procedure. Available online and printed copy, the list price is $190 plus taxes.

Canadian Welding Bureau
www.cwbstore.org
(800) 844-6790

Aluminum Reference Library Available on DVD

Just released, the Aluminum Reference Library DVD provides a complete guide to the selection, designations, processing, properties, and performance of aluminum and aluminum alloys, including all commercial and standard grades. The fully searchable disc features 50 chapters from the ASM Handbook series, and the complete contents of the texts Aluminum Alloy Castings: Properties, Processes, and Applications; Aluminum Extrusion Technology; Aluminum: Properties and Physical Metallurgy; and Aluminum Recycling and Processing for Energy Conservation and Sustainability. Included are hundreds of alloy data sheets, heat treating data sheets, engineering diagrams, and more than 5000 binary and ternary phase diagrams. The list price for the DVD is $895, $795 for ASM members. Visit the Web site and search for Aluminum DVD.

ASM International
www.asminternational.org
(800) 336-5152

Metal Fabrication Hazards Brochure Offered

An informational brochure is available to help manufacturers understand and comply with the new EPA regulation, Metal Fabrication Hazardous Air Pollutants (MFHAP). Under this regulation, which covers nine metal fabricating and finishing source categories, companies that exhaust welding fumes and other process contaminants outside the plant will no longer be permitted to do so, and will be required to prove “zero opacity.” The brochure pinpoints the most important aspects of the MFHAP regulation, including upcoming deadlines, the processes impacted by the regulation, and monitoring and test methods required for compliance. It also discusses the role of high-efficiency dust and fume collectors in maintaining compliance while also reducing energy costs. The brochure can be downloaded from the Web site listed.

Camfil Farr Air Pollution Control
www.farrapc.com/regulations/mfhap
(800) 479-6801

Vacuum Furnace Reference for Metallurgists Updated

A free booklet, Critical Melting Points and Reference Data for Vacuum Heat Treating, provides data on various metals and alloys to be processed in a vacuum environment. Included are a number of tables defining the melting points of elements and many alloys of stainless steel, aluminum, copper, magnesium, nickel, titanium, and others. Included are data on eutectic, emissivity, and vapor pressures when operating at certain temperatures and/or under vacuum. Visit the Web site to order a copy or to download the PDF.

Solar Atmospheres
www.solaratmospheres.com
(800) 347-3236

Do You Have Some News to Tell Us?

If you have a news item that might interest the readers of the Welding Journal, send it to the following address:

Welding Journal Dept.
Attn: Mary Ruth Johnsen
550 NW LeJeune Rd.
Miami, FL 33126

Items can also be sent via FAX to (305) 443-7404 or by e-mail to mjohnsen@aws.org.

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Wall Colmonoy Taps CFO

Wall Colmonoy Corp., Madison Heights, Wis., has named Dan Reilly chief financial officer. Reilly, a CPA in Michigan and Texas, has ten years of experience with a Texas-based tool manufacturer and financial supervisory positions at several Michigan corporations.

Noble Gas Names Branch Manager for Kingston

Noble Gas Solutions (formerly AWESCO), Albany, N.Y., has promoted Jim Bonestell to branch manager of the Kingston, N.Y., division. With the company since 1991, Bonestell previously served as territory sales manager.

President and VP Posts Filled at Airgas

Airgas, Inc., Radnor, Pa., has named Tony Simonetta president of Airgas East, replacing Frederick E. Manley who joined the company’s national sales leadership team as vice president — technology and services markets. Manley joined the company in 2001 as a sales manager and became president in 2007. Simonetta, with the company since 2004, most recently served as vice president for the eastern Pennsylvania area of Airgas East.

RathGibson Appoints VP and CFO

RathGibson, Lincolnshire, Ill., a manufacturer of welded and seamless stainless steel, nickel, and titanium tubing, has appointed Edward Carpenter to lead its North Branch, N.J., facility as vice president — operations; and Will Wolf as chief financial officer. Carpenter previously held key positions at Pro Logic, Ltd., Hysan Corp., Ryerson Tull/Washington Specialty Metals, Barjan, LLC, and Sangamon Industries. Wolf held leadership roles at Sara Lee and Champion Jogbra, including CFO, vice president of operations and finance, and vice president of strategic planning and international sales.

Jet Edge Opens New Office in Shanghai

Jet Edge, Inc., St. Michael, Minn., has named Haihong (Samuel) Song area manager for its new sales office in Shanghai, China. Song, who has extensive engineering and 3D waterjet experience, speaks fluent Chinese, English, and German.
Laboratory Testing
Appoints Supervisor

Laboratory Testing, Inc., Hatfield, Pa., a provider of corrosion analysis, material characterization, and positive material identification services, has promoted Marion Crooks to chemistry supervisor. With the company for nine years, Crooks formerly served as a chemistry technician performing corrosion, SEM, and EDS analyses.

CenterLine Fills Key Post

CenterLine (Windsor) Ltd., Windsor, Canada, has appointed Greg Crain corporate account manager responsible for Chrysler Group LLC. For the past four years, Crain has been with the company's Special Machinery division.

COMEQ Taps Product Manager

COMEQ, Inc., White Marsh, Md., has appointed Eric Lenhart North American product manager for the Parmigiani line of angle and plate bending rolls and American 3-roll and 4-roll plate-bending rolls. Before joining the company, Lenhart served as national sales and product manager for Euromac, LLC, a supplier of punching machines.

Executives Announced for Generation mPower

Generation mPower LLC, Charlotte, N.C., a joint company formed by The Babcock & Wilcox Co. (B&W) and Bechtel to design and build the next generation of nuclear power plants based on B&W mPower™ reactor technology, has filled its executive leadership posts. Christofor Mowry has been appointed chairman, Ali Azad president and CEO, and Ted Feigenbaum COO. Mowry is president of B&W Nuclear Energy, Inc. Azad previously served as senior vice president — international and chief business development officer for Aquilex Corp. Feigenbaum most recently was with Bechtel as project director at the Hanford Waste Treatment Plant.

Palmer Wahl Names Mexico Representative

Palmer Wahl Instrumentation Group, Asheville, N.C., has appointed Victor Garza to manage its new sales office in Monterrey, Mexico. Garza, formerly with Fairchild Semiconductors, has experience with distributors and end-users in the Central and South American markets.

Weld Tooling Names Manufacturing Director

Weld Tooling Corp., Canonsburg, Pa., manufacturer of Bug-O Systems/Cypress Welding Equipment, has named Larry Johnson director of manufacturing. Johnson brings more than 30 years of manufacturing management experience to the company.

SMDI Names Manager

The Steel Market Development Institute (SMDI) has appointed Jennifer L. Greenfelder manager, communications — automotive market. Before joining the institute, Greenfelder was a senior account executive at Bianchi Public Relations, Inc., in Troy, Mich.

ThyssenKrupp Announces Board Changes

ThyssenKrupp AG has recommended Guido Kerkhoff be appointed a member of its executive board as successor to Alan Hippe, who left the board March 31. Kerkhoff was a member of the board of management of Deutsche Telekom AG.

2011 Robotics Awards Presented

The Engelberger Robotics Award, the industry's highest honor, has been presented to Ake Lindqvist and Henrik Christensen. Lindqvist, who recently retired as vice president of ABB Robotics after 37 years in the industry, received the award for leadership. Christensen earned the award for education. He currently is KUKA chair of robotics and a professor of computing with Georgia Institute of Technology in Atlanta. He also serves as director of the Center for Robotics and Intelligent Machines. The awards, presented by the Robotic Industries Assn. (RIA), include a commemorative medallion and a $5000 honorarium.

Airgas Presents Leadership Award

Airgas, Inc., Radnor, Pa., has presented its tenth annual Scott Melman Award to David F. Harrigan, Airgas logistics vice president. The award honors Airgas employees who exhibit the qualities remembered in Scott M. Melman: professionalism, perseverance, enthusiasm, energy, a sense of honor, and the courage to speak up and make a difference. Harrigan, with the company since 1996, is credited for developing the company's hard goods supply chain into a network of six regional distribution centers using a small staff and limited budget.

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Welding the Enchanted Highway

A former school principal has spent more than 20 years welding gigantic, whimsical sculptures in hopes of bringing visitors to his rural North Dakota town

BY MARY RUTH JOHNSEN

Could welded art save a town? For more than 20 years, Gary Greff has been working to make yes the answer to that question.

Fearing that his tiny home town of Regent, N.Dak., would eventually die out if it continued to rely solely on agriculture, he began building huge, fanciful welded metal sculptures in hopes they would bring visitors and businesses to the town.

The “Enchanted Highway,” as it has come to be known, runs for 32 miles from exit 72 off Interstate 94 in the southwest corner of North Dakota into Regent, population 211 in the 2000 census. Seven sculptures are spaced along the highway; final plans call for 11 along the highway, but the final four are on hold in order to build one in town. The sculptures represent area wildlife, history, and culture.

Prior to building the Enchanted Highway, Greff admits he had “no welding experience, no art experience, and no money (to fund such a large-scale project).” His career was in education. He taught and then became a principal at schools in South Dakota and Montana. In 1989, he returned to Regent to visit his parents and came up with the idea of building the sculptures.

“I wanted to bring attention to Regent,” he said. “To keep our small town alive. I knew a big factory would never come here, but we had this long farm/market road.”

Inspiration came from a metal sculpture a local farmer created of a man holding a hay bale. Greff noticed people would stop and take photos of the piece. “I thought of using wood, but wood deteriorates quickly,” he recalled. “Then I thought of used tires, but knowing how kids are, I felt they would make bonfires out of the tires.

Seven old tanks were used to construct the two deer depicted in Deer Crossing.
This sculpture was created to honor the bird, which is in abundance in the area. Together, the five pheasants weigh nearly 30,000 lb.

“The ranchers and farmers around here, they’re good at welding,” Greff said. “I thought, ‘Let’s use what they’re good at.’” At first he considered making regular-sized sculptures, but then decided only figures on a grand scale would draw the attention to the community he desired.

“I gave up a $60,000 job to go to nothing,” Greff said. “I retired at age 40 when I started the project. People thought I was crazy.”

The Enchanted Highway Sculptures

Of course, he never imagined the project would take so long. “I thought we’d be done in little or no time,” he recalled. Everyone in town and in the surrounding area rallied around the project in the beginning, and the first two sculptures were raised fairly quickly. *Tin Family* was erected in 1991, and was built from used farm materials with the help of farmers and friends from the community. The man is 45 ft tall, the woman 43 ft tall, and their “son” is 23 ft tall. Greff made the woman’s hair from barbed wire and used augers for her earrings. *Theodore Roosevelt Rides Again* took its position along the highway in 1993. It serves as a tribute to the role Roosevelt played in North Dakota history and features Teddy in silhouette astride his horse, along with a stage coach. The sculpture stands 51 ft tall and weighs 9000 pounds.

*Regent* is known for its pheasant hunting, since the birds are in abundance in the area, so *Pheasants on the Prairie* was erected in 1996. It includes a 70-ft-long, 40-ft-tall rooster; a 35-ft-tall, 60-ft-long hen; and three 15-ft-tall, 20-ft-long chicks — Fig. 1. They were made from wire mesh originally used for screening gravel.

Grasshoppers Delight (Fig. 2) made its appearance in 1999. The largest grasshopper is 60 ft long and 40 ft tall. This sculpture serves as a reminder of the difficulties farming present. Greff is especially proud of *Geese in Flight*, which has been listed in the Guinness Book of World Records as the largest scrap metal sculpture in the world. The sculpture — erected in 2001 — is 110 ft tall, 154 ft long, and weighs 78.8 tons — Fig. 3. The sunburst was made of more than 300 lengths of pipe, and the sculpture contains nearly five miles of welds.

*Deer Crossing* came soon after in 2002 (see lead photo). It features a 75-ft-tall buck jumping over a fence and a 50-ft-tall doe. To create them, Greff utilized a technique called shadowing in which pieces of metal were removed from the sculpture to accentuate the look of muscles and other parts of the deer. It was built from seven rusty oil well tanks.

The most recent sculpture is *Fisherman’s Dream*, which was erected in 2006. It contains a giant bass, northern pike, walleye, bluegill, salmon, catfish, and a 70-ft-long trout, as well as pieces that represent lake vegetation.

Greff is always looking for help, especially volunteers with welding experience, because over time, Greff admits, community interest has waned. However, he’s grateful to the farmers and ranchers who initially taught him to weld and who helped with the first few sculptures. “The ones who originally helped got older, and the younger ones don’t have as much interest,” he said. As the townspeople

The wire was heated, then bent to form the bodies.

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faded away, Greff hired the services of students from the local high school. When the school closed five years ago — the town consolidated its schools with another nearby community — it was a blow to the town and the Enchanted Highway project. One summer, three members of the National Guard helped him with the center segment of Geese in Flight. Today, a small core of volunteers remain, but Greff handles the majority of the work from designing, welding, and painting new pieces to weed eating and mowing the grass around the pieces already in place.

There is no charge to view the sculptures; funding for the Enchanted Highway comes primarily from private donations, although Greff has obtained a few arts-related grants. He has set up a 501(c)3 not-for-profit organization, which runs the Enchanted Highway Gift Shop during the summer months and has purchased the town’s former school building and is turning it into the Enchanted Highway Motel. The proceeds from the gift shop also help pay for construction of the art. Most of the sculptures cost about $50,000 to produce and erect; however, Geese in Flight cost three times that. “I can usually raise about $10,000 a year, so it takes four to five years for each sculpture.”

Materials

Initially, Greff and his teachers/helpers used the shielded metal arc welding process, but in year three he switched to gas metal arc welding because it was more economical and easier to learn and use. Greff admits his technical knowledge about welding is limited and that he works not under the best welding conditions. Almost all welding is done in a pasture, often during North Dakota’s severe winter conditions because in the summer he’s repainting the already erected sculptures, mowing the fields around them, and working on the signage that leads visitors down the highway. Greff said he brushes off the snow, turns his back to the wind, and keeps on welding. He has a small Quonset hut where he goes to get warm and to do some small jobs (Fig. 4), but the size of the workpieces necessitates most of it being done outside. Nearly all Greff’s metal is recycled. “I buy old oil well tanks,” he explained. “I cut the ends off, cut down the center, and then drive over it with a tractor to flatten it. “I think I’ve used one 4 x 8 sheet of new metal (over the years),” he recalled. “The rest has all been old metal.” That will change with the next sculpture. The board of directors for the Enchanted Highway has decided the next project should be a sculpture in Regent itself. Greff hopes to build the world’s largest, to-scale sculpture of a motorcycle. The subject was chosen in hopes of drawing some of the people who attend the huge Sturgis, S.Dak., motorcycle rally held each year during the first week of August. Sturgis is about 200 miles south of Regent. Greff expects the motorcycle will cost about $120,000 because he’ll be purchasing new metal and paying for precision cutting services.

Is the Enchanted Highway a Success?

Although losing the school was a blow, Regent is holding its own. The population today remains about the same as when Greff began the Tin Family in 1989. Each summer visitors drive the 32 miles of the Enchanted Highway into the town. “They don’t make it their home, but it brings in dollars,” he remarked. Greff realizes not everyone understands his dedication to the project over so many years. “I ask myself why I keep doing it,” he said. “The answer is if I back away now, it’s done. No one else will take it over. I’ve never quit on anything I’ve started in my life, so I won’t now.” He said he doesn’t regret the decision to give up his career in education because “I came home and spent time with my folks before they passed away.”

Today, work on the motel is underway, and Greff hopes someday to open a dinner theatre and a café. He envisions a school for metal arts in the town and Main Street bedecked with metal sculptures. Greff’s dreams for his tiny hometown are as big as his sculptures.

Dear Readers:

The Welding Journal encourages an exchange of ideas through letters to the editor. Please send your letters to the Welding Journal Dept., 550 NW LeJeune Rd., Miami, FL 33126. You can also reach us by FAX at (305) 443-7404 or by sending an e-mail to Kristin Campbell at kcampbell@aws.org.
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Backfires and Flashbacks in Oxyfuel Gas Welding and Cutting
When Does Three Equal Two?

BY AUGUST F. MANZ

Backfires and flashbacks can cause problems with the operation of oxyfuel gas welding and cutting torches, as well as cause fires and injuries. This article discusses these terms and why, after a hundred years, the terminologies have changed.

The Way It Was

More than a hundred years ago, circa 1903, in France, Fouche and Picard invented one of the first practical oxyfuel gas torches. Even then it was found to be necessary to take care of backfiring.

The following is excerpted from Oxy-Acetylene Welding (Ref. 1), published in 1920. “In early torches with comparatively large acetylene openings, it was necessary to provide a chamber in the torch filled with asbestos and provided with wire gauze partitions to prevent this back firing.” (emphasis added).

Before the American Welding Society (AWS) published the current A3.0:2010,
Standard Welding Terms and Definitions (Ref. 2) superseding the 2001 edition (Ref. 3), AWS defined backfire as:

“backfire. The momentary recession of the flame into the welding tip, cutting tip, or flame spraying gun. Followed by immediate reappearance or complete extinction of the flame, accompanied by a loud report.”

When the backfire flame did not go out, but traveled upstream into the torch body, it was called a flashback. The definition in Ref. 3 is:

“flashback. A recession of the flame into or back of the mixing chamber of the oxyfuel gas torch or flame spraying gun.”

For almost a hundred years, these two terms, flashback and backfire, were understood and used by the operators and manufacturers of oxyfuel gas equipment. For example, an article published by Linde Air Products Co. in 1935 (Ref. 4) states, “These terms are used quite often...given here are the official definitions set forth by Underwriters Laboratories...A flashback is when the flame goes back into the mixing chamber accompanied by the well-known hissing or squealing sound.”

The Way It Is

The early asbestos and wire gauze safety devices are now made from different materials and called flashback arresters. In Refs. 2 and 3, it is defined as:

“flashback arrester. A device to limit damage from a flashback by preventing the propagation of the flame front beyond the location of the arrester.”

These flashback arresters are usually placed at the torch where the hoses are attached, or where the hoses connect to the cylinders.

Now, instead of just two terms, backfire and flashback, a third term, sustained backfire, has been introduced in the new standard (Ref. 2). The definition is:

“sustained backfire. The recession of the flame into the torch body with continued burning characterized by an initial popping sound followed by a squealing or hissing sound, potentially burning through the torch body. See also backfire and flashback.”

Sustained backfire describes the condition where the backfire flame burns back to inside the torch body and stops there. In the past, this was called a flashback. With this change, the term flashback now describes the condition where the flame front continues to burn and passes beyond the torch, into the hoses and upstream devices, toward the cylinder and the regulators — Fig. 1.

Reference 2 states:

“flashback. The recession of the flame through the torch and into the hose, regulator, and/or cylinder, potentially causing an explosion. See also backfire and sustained backfire.”

As a consequence, the original definition of backfire has been slightly modified in Ref. 2 to read:

“backfire. The momentary recession of the flame into the torch, potentially causing a flashback or sustained backfire. It is usually signaled by a popping sound, after which the flame may either extinguish or reignite at the end of the tip. See also flashback and sustained backfire.”

When Three Equals Two

Now we have three terms, backfire, sustained backfire, and flashback, to describe what for a hundred years was covered by just two terms, backfire and flashback. Become familiar with the three terminologies. These three terms are beginning to appear in manufacturers’ instructions, publications, and standards of AWS and other organizations. Now you know why three equals two.

References

Williston State College Reinvests in Welding Technology

After a hiatus of 20 years, a North Dakota college is building new facilities to train students for careers in welding technology

BY HOWARD M. WOODWARD

The rapidly growing need for welders in North Dakota has prompted Williston State College (WSC) to invest in welding technology in a big way after 20 years of not offering this program. The project includes a new building, nearing completion (lead photo), to be fitted with the latest welding machines and lab equipment. Most important, the curriculum has been prepared by Bruce “Buck” Dannar, a well-qualified and experienced educator in welding technology who will also serve as the dynamic force presenting the course.

Dannar is an AWS Certified Welding Inspector, AWS Certified Welding Instructor, Certified Welding Trainer, and Certified Core Curriculum Trainer through the National Center for Construction Education and Research, a Level 1 ultrasound technician, and a trainer for OSHA’s 10- and 30-hour safety courses, and a merit badge counselor for the Boy Scouts of America. Moreover, Dannar has worked in industry and taught welding for eight years at Pine Ridge Job Corps in Chadron, Neb., and two years at Montana State University in Billings.

Dannar said, “The first year of the two-year welding program will be developed to teach students the basics of welding with shielded metal arc welding. The second semester will feature flux core and hard wire using wire feed. The second year of the program will be geared toward learning to weld pipe and gas tungsten arc welding.

“Then,” he said, “after the students have completed the welding program, beside earning an associate’s degree of applied science degree in welding technology from WSC they will be able to receive certifications from the American Welding Society, ASME (American Society of Mechanical Engineers), or even the API (American Petroleum Institute) codes.”

Dannar said he has high hopes for the program and sees it growing quickly. “I think there’s going to be a real big interest

HOWARD M. WOODWARD (woodward@aws.org) is associate editor of the Welding Journal.
Dannar said, “The goal of the program I am establishing is to take a student through to a DI.L, Structural Welding Code — Steel, certification in the first year, and in the second year to a ASME 6G certification with GTAW and SMAW. Along the way I can toss in some blueprint reading some fabrication and whatever else I can squeeze in that will help prepare them for a career in welding.

“One of my capstone projects for the pipe layout class is to separate my students into four groups and assign each group a portion of a spool drawing, then have the groups fabricate their part and grade them on how the four pieces fit together when they’re done, as well as the quality of welds and teamwork. The groups hopefully won’t realize that the four pieces are supposed to fit together but I won’t bank on that since the students are pretty smart. I got this team-working idea from working with Bob Blackwell at Montana State University Billings.”

While the permanent lab is under construction, Dannar noted, “I have been teaching welding out of the high schools this year.” When the new lab is ready, “it will have all kinds of new equipment. However, I plan on mixing in some old equipment for my students to work with — there is just no telling what a person will find for equipment at any given job site.”

### About Williston State College

Roxane Molinari, director of college relations, said, “The college has a student body of about 950 students with facilities to house 200 students on campus. The majority of the students are from North Dakota but currently it has students from 26 other states and eight countries. In addition to adding the state-of-the-art career and technology center, the college will soon open a science lab for the study of physics, engineering, and chemistry and biology and anatomy, plus a new student lounge and a new student residence planned to open in the fall of this year.” Molinari noted, “There’s a lot of personal attention available with a student-to-faculty ratio of eleven to one.”

Robb Floco, director of career and technology education, stated, “In collecting feedback from area businesses, community members, and high schools in the northwest region of North Dakota, many areas of interest were identified in the trade fields. Williston State College is poised to develop and bring forward a degree pathway in the following programs: welding, residential carpentry, automotive, diesel, and information technology. In addition, courses will also be brought forward in the areas of health careers and systems integration (digital electronics).”

The Dual Credit/Early Entry program offers a great opportunity for high school students in grades 10–12 and home-educated to earn college credit while still in high school. This program allows students to get a head start on their college educations. A handbook detailing the program can be downloaded from the WSC Web site.

### Tuition and Fees

Currently, the tuition and fees per on-campus credit is $133.44. This rate applies to all students, out-of-state, Canadian, and North Dakota students, alike. Tuition and fees for the 2010–2011 academic year based on a 16-credit semester is $3456.

### Financial Aid Opportunities

Admittedly, the cost of college can be daunting, but financial aid makes it manageable for most students. The college currently offers financial assistance to an overwhelming majority of its students. More than 86% of those enrolled and nearly every degree-seeking student re-
receives at least some form of financial aid. Numerous scholarship awards are provided by the Williston State College Foundation that is supported by area businesses and individuals. The Foundation awards up to $500,000 in scholarship money annually. Seven out of ten applicants receive a scholarship. Visit the Web site to download the Financial Aid and Scholarships brochure.

Other sources of assistance include grants, loans, work opportunities, fee waivers, and a combination of solutions.

Academic Options

The college offers several interesting academic options. A new student can be job-ready in two years in more than 25 career and technical programs in high-demand programs. Or choose an associate’s degree in arts or sciences that can be used toward a university degree in more than 70 areas of study. Bachelor’s and master’s degree programs can also be earned on the WSC campus with collaborative agreements with other colleges. In addition to welding, its Trades Technology department offers programs in automotive, carpentry, diesel, and petroleum production.

Where It Is

Williston, N.Dak., is located in western part of the state. It’s noted for its walleye fishing lakes, and fine deer and game-bird hunting areas. The region has a strong economy led by a history rich in agriculture and a booming oil industry. The average Williston resident earns $49,567 a year. Many opportunities exist in the community for students looking for part-time employment, activities, events, and attractions. Notably, the state is ranked among the top ten safest, most livable, and healthiest in the nation.

The Virtual Classrooms

The college offers a variety of programs taught entirely online. It uses the Moodle learning management system to deliver courses. It is the virtual classroom where students attend class, interact with the instructor, submit assignments, and take exams. Visit the Web for complete information, then apply online.

Come Visit the Campus

First, review the wealth of information published on the WSC Web site, then call the college to arrange a visit that will meet your specific needs in addition to touring the campus. You can arrange to meet with an adviser, an instructor in your area of interest, discuss financial aid and scholarship options, etc. To arrange for a tour, contact Leah Hess, campus visit coordinator, leah.hess@wsc.nodak.edu; (888) 863-9455, ext. 4220.

Raymond A. Nadolny, WSC president, said, “With 1.8% unemployment, WSC lives in an economic bubble. As an example, every one of our diesel students works in the field. It is about time we start meeting the high demand for welders in our region. Williston State College has many opportunities for you to grow, not only academically, but in every other area as well.”

Recently, Nadolny announced, “The decision was made to pursue a bachelor’s degree, such as a bachelor’s of applied science.” He added, “Even though we have good partnership opportunities for students to take distance education and earn a bachelor’s degree, it’s not the same as having that on-campus experience and having the support of being in an on-campus baccalaureate experience.” In closing, he said, “Come discover the college, and please, take a moment to stop by my office to say hello!”

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WELDING JOURNAL 113
Carbon steels are readily cut with the oxyfuel gas cutting processes. Low-carbon steels are cut without difficulty using standard procedures. Table 1 shows typical data for cutting low-carbon steel using commonly available fuel gases. The gas flow rates and cutting speeds are to be considered as guides for determining more precise settings for a particular job. When a new material is to be cut, a few trial cuts should be made to obtain the most efficient operating conditions. The table presents data on thicknesses up to 12 in., the maximum thickness normally encountered when shape cutting in production shops.

Alloying elements have two possible effects on the oxyfuel gas cutting of steel. They may make the steel more difficult to cut, or they may give rise to hardened or heat-checked cut surfaces, or both. The effects of alloying elements are summarized in Table 2.

### Table 1 — Data for the Manual and Mechanized Cutting of Clean Low-Carbon Steel without Preheat (in inch-pound units)

<table>
<thead>
<tr>
<th>Thickness of Steel, in.</th>
<th>Diameter of Cutting Orifice, in.</th>
<th>Cutting Speed, in./min</th>
<th>Oxygen, %</th>
<th>Acetylene, %</th>
<th>Gas Flow, ft³/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>½</td>
<td>0.020-0.040</td>
<td>16-32</td>
<td>15-45</td>
<td>3-9</td>
<td>2-10</td>
</tr>
<tr>
<td>½</td>
<td>0.030-0.060</td>
<td>16-26</td>
<td>30-55</td>
<td>3-9</td>
<td>4-10</td>
</tr>
<tr>
<td>¾</td>
<td>0.030-0.060</td>
<td>15-24</td>
<td>40-70</td>
<td>6-12</td>
<td>4-10</td>
</tr>
<tr>
<td>⅞</td>
<td>0.040-0.060</td>
<td>12-23</td>
<td>55-85</td>
<td>6-12</td>
<td>6-10</td>
</tr>
<tr>
<td>⅞</td>
<td>0.045-0.060</td>
<td>12-21</td>
<td>100-150</td>
<td>7-14</td>
<td>8-15</td>
</tr>
<tr>
<td>1</td>
<td>0.060-0.080</td>
<td>6-14</td>
<td>110-175</td>
<td>8-16</td>
<td>8-15</td>
</tr>
<tr>
<td>2</td>
<td>0.060-0.080</td>
<td>6-13</td>
<td>130-190</td>
<td>8-16</td>
<td>8-20</td>
</tr>
<tr>
<td>3</td>
<td>0.065-0.085</td>
<td>4-11</td>
<td>190-300</td>
<td>9-20</td>
<td>8-20</td>
</tr>
<tr>
<td>4</td>
<td>0.080-0.090</td>
<td>4-10</td>
<td>240-360</td>
<td>9-20</td>
<td>10-20</td>
</tr>
<tr>
<td>5</td>
<td>0.080-0.095</td>
<td>4-8</td>
<td>270-360</td>
<td>10-25</td>
<td>10-20</td>
</tr>
<tr>
<td>6</td>
<td>0.095-0.105</td>
<td>3-7</td>
<td>260-500</td>
<td>10-25</td>
<td>20-40</td>
</tr>
<tr>
<td>8</td>
<td>0.095-0.110</td>
<td>3-5</td>
<td>460-620</td>
<td>15-30</td>
<td>30-40</td>
</tr>
<tr>
<td>10</td>
<td>0.095-0.110</td>
<td>2-4</td>
<td>590-700</td>
<td>15-35</td>
<td>30-60</td>
</tr>
<tr>
<td>12</td>
<td>0.110-0.130</td>
<td>2-4</td>
<td>720-850</td>
<td>20-40</td>
<td>30-60</td>
</tr>
</tbody>
</table>

### Table 2 — Effect of Alloying Elements on the Resistance of Steel to Oxyfuel Gas Cutting

<table>
<thead>
<tr>
<th>Element</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon</td>
<td>Steels up to 0.25% carbon can be cut without difficulty. Steels with a higher carbon content should be preheated to prevent hardening and cracking. Graphite and cementite (Fe₃C) are detrimental, but cast irons containing up to 4% carbon can be cut using special techniques.</td>
</tr>
<tr>
<td>Manganese</td>
<td>Steels containing approximately 14% manganese and 1.5% carbon are difficult to cut and should be preheated for best results.</td>
</tr>
<tr>
<td>Silicon</td>
<td>Silicon, in the amounts usually present, has no effect. Transformer irons containing as much as 4% silicon are cut. Silicon steel containing large amounts of carbon and manganese must be carefully preheated and post-annealed to avoid air hardening and possible surface fissures.</td>
</tr>
<tr>
<td>Chromium</td>
<td>Steels with up to 5% chromium are cut without much difficulty when the surface is clean. Higher chromium steels, such as 10% chromium steels, require special techniques, and the cuts are rough when the usual oxyacetylene cutting process is used. In general, carburizing preheat flames are desirable when cutting this type of steel. In addition, the flux cutting and metal powder cutting processes enable cuts to be made in the common straight chromium irons and steels as well as in stainless steel.</td>
</tr>
<tr>
<td>Nickel</td>
<td>Steels containing up to 3% nickel may be cut using the conventional oxyfuel gas cutting processes; cuts are satisfactory in steels up to about 7% nickel content.</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>This element affects cutting about the same as chromium. Aircraft-quality chrome-molybdenum steel presents no difficulty. High molybdenum-tungsten steels, however, may be cut only with special techniques.</td>
</tr>
<tr>
<td>Tungsten</td>
<td>The usual alloys with up to 14% tungsten may be readily cut, but cutting is difficult with a higher percentage of tungsten. The limit is approximately 20% tungsten.</td>
</tr>
<tr>
<td>Copper</td>
<td>Copper has no effect in amounts up to about 2%.</td>
</tr>
<tr>
<td>Aluminum</td>
<td>The effect of aluminum is not appreciable unless present in large amounts (on the order of 10%).</td>
</tr>
<tr>
<td>Phosphorus</td>
<td>This element has no effect in the amounts usually tolerated in steel.</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Small amounts such as are present in steels have no effect. With higher percentages of sulfur, the rate of cutting is reduced and sulfur dioxide fumes are noticeable.</td>
</tr>
<tr>
<td>Vanadium</td>
<td>In the amounts usually found in steels, this alloy may improve rather than interfere with cutting.</td>
</tr>
</tbody>
</table>

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Founded in 1919 to advance the science, technology and application of welding and allied processes including joining, brazing, soldering, cutting and thermal spraying.
Friends and Colleagues:

The American Welding Society established the honor of Counselor to recognize individual members for a career of distinguished organizational leadership that has enhanced the image and impact of the welding industry. Election as a Counselor shall be based on an individual’s career of outstanding accomplishment.

To be eligible for appointment, an individual shall have demonstrated his or her leadership in the welding industry by one or more of the following:

- Leadership of or within an organization that has made a substantial contribution to the welding industry. The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities.

- Leadership of or within an organization that has made a substantial contribution to training and vocational education in the welding industry. The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employee in industry activities.

For specifica on the nomination requirements, please contact Wendy Sue Reeve at AWS headquarters in Miami, or simply follow the instructions on the Counselor nomination form in this issue of the Welding Journal. The deadline for submission is July 1, 2011. The committee looks forward to receiving these nominations for 2012 consideration.

Sincerely,

Alfred F. Fleury
Chair, Counselor Selection Committee
CLASS OF 2012
COUNSELOR NOMINATION FORM

DATE
NAME OF CANDIDATE

AWS MEMBER NO. YEARS OF AWS MEMBERSHIP

HOME ADDRESS
CITY STATE ZIP CODE PHONE

PRESENT COMPANY/INSTITUTION AFFILIATION

TITLE/POSITION

BUSINESS ADDRESS
CITY STATE ZIP CODE PHONE

ACADEMIC BACKGROUND, AS APPLICABLE:

INSTITUTION

MAJOR & MINOR

DEGREES OR CERTIFICATES/YEAR

LICENSED PROFESSIONAL ENGINEER: YES NO STATE

SIGNIFICANT WORK EXPERIENCE:

COMPANY/CITY/STATE
POSITION YEARS

COMPANY/CITY/STATE
POSITION YEARS

SUMMARIZE MAJOR CONTRIBUTIONS IN THESE POSITIONS:


IT IS MANDATORY THAT A CITATION (50 TO 100 WORDS, USE SEPARATE SHEET) INDICATING WHY THE NOMINEE SHOULD BE SELECTED AS AN AWS COUNSELOR ACCOMPANY THE NOMINATION PACKET. IF NOMINEE IS SELECTED, THIS STATEMENT MAY BE INCORPORATED WITHIN THE CITATION CERTIFICATE.

**MOST IMPORTANT**

The Counselor Selection Committee criteria are strongly based on and extracted from the categories identified below. All information and support material provided by the candidate's Counselor Proposer, Nominating Members and peers are considered.

SUBMITTED BY:
PROPOSER
AWS Member No.
The proposer will serve as the contact if the Selection Committee requires further information. The proposer is encouraged to include a detailed biography of the candidate and letters of recommendation from individuals describing the specific accomplishments of the candidate. Signatures on this nominating form, or supporting letters from each nominator, are required from four AWS members in addition to the proposer. Signatures may be acquired by photocopying the original and transmitting to each nominating member. Once the signatures are secured, the total package should be submitted.

NOMINATING MEMBER: Print Name
AWS Member No.

NOMINATING MEMBER: Print Name
AWS Member No.

NOMINATING MEMBER: Print Name
AWS Member No.

NOMINATING MEMBER: Print Name
AWS Member No.

NOMINATING MEMBER: Print Name
AWS Member No.

SUBMISSION DEADLINE JULY 1, 2011
Nomination of AWS Counselor

I. HISTORY AND BACKGROUND

In 1999, the American Welding Society established the honor of Counselor to recognize individual members for a career of distinguished organizational leadership that has enhanced the image and impact of the welding industry. Election as a Counselor shall be based on an individual’s career of outstanding accomplishment.

To be eligible for appointment, an individual shall have demonstrated his or her leadership in the welding industry by one or more of the following:

- Leadership of or within an organization that has made a substantial contribution to the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, SkillsUSA, NEMA, NSRP SP7 or other similar groups.)
- Leadership of or within an organization that has made substantial contribution to training and vocational education in the welding industry. (The individual’s organization shall have shown an ongoing commitment to the industry, as evidenced by support of participation of its employees in industry activities such as AWS, IIW, WRC, SkillsUSA, NEMA, NSRP SP7 or other similar groups.)

II. RULES

A. Candidates for Counselor shall have at least 10 years of membership in AWS.
B. Each candidate for Counselor shall be nominated by at least five members of the Society.
C. Nominations shall be submitted on the official form available from AWS headquarters.
D. Nominations must be submitted to AWS headquarters no later than July 1 of the year prior to that in which the award is to be presented.
E. Nominations shall remain valid for three years.
F. All information on nominees will be held in strict confidence.
G. Candidates who have been elected as Fellows of AWS shall not be eligible for election as Counselors. Candidates may not be nominated for both of these awards at the same time.

III. NUMBER OF COUNSELORS TO BE SELECTED

Maximum of 10 Counselors selected each year.

Return completed Counselor nomination package to:

Wendy S. Reeve
American Welding Society
Senior Manager
Award Programs and Administrative Support
550 N.W. LeJeune Road
Miami, FL 33126

Telephone: 800-443-9353, extension 293

SUBMISSION DEADLINE: July 1, 2011
NEW PRODUCTS
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manufacturing process to increase the gas pressure. The product can hold both pure gases and gas mixtures. It's also approved for safe transport by the DOT. Specifications are as follows: part number, 66L and 66ES; pressure, 1200 lb/in.²; gas type, reactive/nonreactive; dimensions, 9.8 x 2.9 in.; water capacity, 0.79 L; weight, 1.7 lb; valve inlet, 5/8-18 UNF (C10); regulator, demand flow, 70 Series, 70-SS Series; and contents, 2.33 ft³.

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— continued on page 124
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A doctoral degree in Welding Engineering, Materials Science and Engineering, Mechanical Engineering, or related fields is required. Postdoctoral research experience in materials joining is preferred and a strong publication record is expected. Successful candidates should be proficient and have demonstrated skills in one (or more) of the following areas: computational materials modeling, process modeling, structural design, structural integrity, fitness-for-service, welding process technology, or welding metallurgy.

The evaluation of applications will begin immediately. It is anticipated that this position will be filled by October 1, 2011. A complete curriculum vitae and separate teaching and research statements can be sent by e-mail to msearch@matsceng.ohio-state.edu or sent by mail to:

Prof. John C. Lippold, Dept. of Materials Science and Engineering
The Ohio State University, 1248 Arthur E. Adams Drive, Columbus, OH 43221

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- **August**
  - Safety on the Job
  - Tips for Controlling Shop Costs
  - Bonus: The American Welder
- **September**
  - Brazing and Soldering Today
  - Cutting and Weld Finishing Operations
- **October**
  - 2011 FABTECH 2011 Show Preview
  - Bonus Distribution: FABTECH 2011 Show
- **November**
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The Welding Journal staff encourages an exchange of ideas with you, our readers. If you’d like to ask a question, share an idea or voice an opinion, you can call, write, e-mail or fax. Staff e-mail addresses are listed below, along with a guide to help you interact with the right person.

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Gas Metal Arc Weld Pool Surface Imaging: Modeling and Processing

A reflection-based observation system successfully reduced arc light interference

BY X. MA AND Y. ZHANG

ABSTRACT

Observing and measuring the weld pool geometry in the gas metal arc welding (GMAW) process is the key to understanding and control of a complex welding process. The harsh environment and highly dynamic characteristic of a weld pool surface made the observation extremely challenging. In this paper, a reflection-based GMA weld pool surface observation system is proposed to monitor the three-dimensional weld pool geometry. A low-power five-line laser pattern is projected onto the weld pool and the reflected pattern, which is the result of an intercepted reflected laser beam on an imaging plane, is captured and analyzed. To image the reflected laser pattern, the elements in the imaging system including laser and weld pool surface are analyzed and modeled. The effects of their parameters such as laser density, projection angle, weld pool surface geometry, and weld pool surface fluctuation on the imaging of the laser pattern are examined and analyzed. The effectiveness of the proposed method and parameter ranges are verified through simulation and experiments. As a result, acceptable images of laser pattern reflected from the weld pool surface in pulsed GMAW were acquired. An image processing algorithm has been developed to successfully extract the reflected laser pattern for subsequent weld pool surface reconstruction.

Introduction

Observation of the weld pool provides an effective path to understand and control the welding process. Observation data also attribute to the validation of numerical models, which helps researchers to analyze and evaluate the welding process.

Extensive research has been conducted to provide in situ monitoring of the weld pool. The arc sensor was one of the first few sensors that was adopted for weld pool observation. X-ray (Ref. 1), infrared, and vision-based sensors were also developed and implemented. The weld pool surface is the most direct source of information for human welders to obtain feedback. Skilled welders estimate the welding process by visually observing the weld pool and adjust welding parameters accordingly.

In recent years, machine vision has been more and more widely adopted to monitor the welding process. Early efforts focused on extracting a two-dimensional weld pool boundary by directly viewing the scene under the welding gun. Richardson (Ref. 2) developed a coaxial arc weld pool viewing system for the gas tungsten arc welding (GTAW) process. Kovacevic et al. (Ref. 3) used a high-power auxiliary illumination laser to suppress arc radiation. In recent years, weld pool observation evolved from two-dimensional (2-D) boundary extraction to three-dimensional (3-D) surface geometry measurement. Stereo vision (Ref. 4) and shape from shading (SNF) algorithms (Ref. 5) are proposed to reconstruct 3-D weld pool geometry from directly captured weld pool images.

However, one of the most challenging tasks that direct-viewing vision-based monitoring techniques must overcome is the interference of arc radiation, which degrades the quality of captured images. The radiation from the arc body is much stronger than that radiated/reflected from the weld pool surface and workpiece. A scene, including weld pool and welding arc, contains a lot more variations than can be captured by a high-speed camera. The majority of the dynamics on the captured image is assigned to the bright arc body, which is not the area of interest. The dynamics of the weld pool area are significantly reduced and cause an inevitable loss of information.

The most common techniques that were adopted to reduce arc influence included blocking the arc body using a mechanical method (Ref. 1), using optical filters to observe the weld pool surface at a specific wavelength, and using an auxiliary light source, such as laser (Ref. 3), to suppress arc influence. However, according to current reports, the dynamics of the captured weld pool surface are still not satisfying.

Arc light reflected from the weld pool surface is another issue direct-viewing methods have difficulty in overcoming. In the case of weld pool fluctuation, bright spots, which are a result of arc light reflection, are observed in certain local areas on the weld pool. The reflection is significantly brighter than the average weld pool intensity on the captured image, which degrades the dynamic range of the captured weld pool area. When the weld pool surface is reconstructed using stereo vision or SNF method, surface geometry is calculated from captured texture on the weld pool images. The existence of arc light reflection inevitably degrades the weld pool texture and reduces reconstruction accuracy.

Reflection-based weld pool monitoring methods, which take advantage of the specular nature of the weld pool surface, successfully reduced arc light interference. Pioneering work was conducted at the Uni-

KEYWORDS

Gas Metal Arc Imaging Sensor Weld Pool

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versity of Kentucky by Kovacevic and Zhang (Ref. 6). The 3-D geometry of the weld pool is extracted by directly viewing the reflection of an illumination laser pattern from the weld pool surface. However, a high-power auxiliary laser is required to generate the laser pattern and suppress the arc light.

Song (Ref. 7) extended this approach by projecting a low-power dot-matrix laser pattern onto the GTA weld pool surface and observing the intercepted reflected laser on an imaging plane. In that application, the weld pool surface is stable with little fluctuation, and the weld pool surface is flat with minor deformation, which can be considered as a special case for the welding process.

Little work was conducted in precisely measuring the 3-D weld pool surface geometry of the gas metal arc welding (GMAW) process. Most current research is based on the direct viewing method, such as shape from shading or stereo vision. In our previous work (Ref. 8), a reflection-based GMA weld pool monitoring system was proposed. Weld pool surface monitoring was partially achieved by projecting a single-line laser pattern onto the GMA weld pool surface. Experimental results showed that the reflection of the single-line laser pattern could be observed, and was of convex shape.

In this paper, the revised weld pool surface measuring system for the pulsed gas metal arc welding process (GMAW-P) is demonstrated. It is capable of providing surface geometry information for the entire area of interest, i.e., the 3-D geometry of the weld pool surface. System modeling and simulation was carried out to demonstrate the principle of the potential to implement this method to reconstruct 3-D geometry of the weld pool in GMAW-P. The corresponding relationship between captured reflection pattern and original projected pattern is demonstrated. System parameters that affect observation quality are analyzed. An image processing algorithm is developed to extract and separate the reflected laser line from the captured image.

**Observation System**

The proposed system is shown in Fig. 1. The welding gun is fixed perpendicular to the workpiece. A 375-mW laser with 670 nm center wavelength is fixed at the backside of the welding torch. A five-line laser pattern, which is referred to as projected laser, is projected to cover the entire weld pool area. During welding progress, after the weld pool is established, specular reflection of the projected laser occurs on the weld pool surface. The reflected laser was intercepted by an imaging plane fixed vertically at the opposite side of the welding gun. The welding gun, laser pattern generator, and imaging plane are carefully aligned. The pattern shown on the imaging plane is referred to as the reflected pattern, and is captured by a high-speed camera. Raw images and enhanced images are shown in Fig. 2.

The laser pattern generator used in this study is a Coherent Powerline 670 continuous wave diode laser. The energy of projected laser is evenly distributed along each line, which ensures that the projected pattern consists of lines with uniform intensity with sharp ends. Therefore, the reflected pattern shown on the imaging plane will have relatively even intensity.

The high-speed camera is fitted with a 20-nm band-pass filter centered at the same center wavelength of the laser to enhance image contrast. Most of the arc radiation interference, which distributes on the entire wavelength spectrum, is eliminated.

The proposed reflection-based GMAW-P weld pool observation system successfully bypassed arc interference. Although the arc influence still exists, by observing the reflected laser from an imaging plane, the bright arc body is no longer part of the captured scene. Arc radiation simply functions as a close range light source that illuminates the imaging plane, resulting in a background gray level intensity. The imaging plane only contains evenly distributed arc radiation and reflected laser. Since specular reflection preserves the low-divergence character of laser, the energy of reflected laser is still concentrated. During image integration interval, as long as the energy density of reflected laser exceeds arc radiation on the intercepted area, which ensures that the reflected pattern stands out of the background, the reflected pattern can be separated. The dynamic range of the image is also fully employed because the reflected laser and the background are light are of the same magnitude.

**Reflection Image Simulation**

System modeling provides a systematic tool to study the relationship between the reflected pattern and system parameters. It also helps to select optimal system parameters. It is divided into three parts: modeling of weld pool surface, modeling of projected laser, and modeling of reflection and interception.

Simulation result demonstrated that for different weld pool geometry, the resultant reflected pattern is of different shape, which suggests that the reflected pattern reveals the 3-D geometry of the weld pool surface. Meanwhile, when the weld pool surface is smooth, the height of each projected line is sequentially placed. Dynamic analysis based on simulation results demonstrates that the quality of captured images is also affected by weld pool fluctuation and camera parameters.

**Modeling of Weld Pool Surface**

Most current weld pool models are based on numerical analysis. The objective of such models is to evaluate how welding parameters affect weld quality, which mainly focused on the internal fluid flow and temperature distribution in the weld pool rather than the 3-D weld pool surface geometry. These models are complicated and the calculation is time consuming.

The only concern of this research is how top-side geometry of the weld pool affects laser reflection, and the consequent reflected pattern. It is not efficient to adopt existing numerical models to simulate the weld pool surface. Therefore, a simplified model based on weld pool surface geometrical appearance is selected and implemented. Although the model is not accurate, it provides fundamental understanding of the principle of the proposed observation method.
Directly captured weld pool surface using the GMAW-P process is shown in Fig. 3. It can be observed from the captured image and solidified welding bead that the weld bead can be divided into two parts, weld pool surface and weld bead body. The weld pool surface can be estimated using part of an ellipsoid and the weld bead can be simulated using part of a cylinder. The geometry of the solidified weld specimen using designed welding parameters is measured to provide parameters for system modeling, including weld pool length, weld pool width, and weld bead height, as is shown in Fig. 4.

The weld bead is modeled using part of the cylinder. Cylinder axis is parallel to the x axis. The cylinder passes the highest point of the weld bead and the weld bead boundary on the workpiece. The function of the cylinder can be expressed as

$$F^y_z (x, y, z) = y^2 + (z - z_0)^2 - R^2 = 0; \quad x <-1, z > 0$$

(1)

The weld pool surface is simulated using part of an ellipsoid. The semi-major axis of the ellipsoid is the same as the axis of the weld bead cylinder, and the other two axes are parallel to y-axis and z-axis, respectively. Since the weld pool is continuous at all points, the weld pool model is designed to be continuous at the boundary between the partial ellipsoid and the cylinder. Ellipsoid function can be expressed as

$$F^i_z (x, y, z) = \frac{(x + l)^2}{a^2} + \frac{y^2}{b^2} + \frac{(z - z_0)^2}{c^2} - 1 = 0; \quad x > -1, z > 0$$

(2)

Therefore, the reflection surface, denoted as $S$, which is the actual surface where reflection occurs, can be expressed as the equation below. $F_3$ denotes the top side workpiece surface.

$$F_3 (x, y, z) = \begin{cases} y^2 + (z - z_0)^2 - R^2 = 0 & x < -1, z > 0 \\ \frac{(x + l)^2}{a^2} + \frac{y^2}{b^2} + \frac{(z - z_0)^2}{c^2} - 1 = 0 & x > -1, z > 0 \\ z = 0 & \text{for other points} \end{cases}$$

(3)

Modeling of Projected Laser

Laser pattern generator projects a five-line parallel pattern onto the weld pool surface. It uses a refraction mechanism to split one single-line pattern to a five-line pattern. Each line is parallel with each other and every laser ray can be traced back to a single point, which is denoted as laser origin $P_0$.

The equation of projected laser in the universal coordinate system is determined by two fixed internal parameters, laser fan

---

**Fig. 2** — Original and enhanced images captured in bead-on-plate experiment. A, B, C — Sequential images captured in the experiment; D, E, F — Corresponding images after image enhancement.

**Fig. 3** — Directly captured weld pool geometry during welding process.

---
angle $\theta_f$, interbeam angle $\theta_i$, and one adjustable external parameter, laser projection angle $\beta$, for each line, as is illustrated in Fig. 5A–C, respectively.

The five-line laser pattern is projected onto the workpiece plane with each line parallel to the y-axis. Laser origin is denoted as $P_0 = (x_0, y_0, z_0)$, the projection angle for the $i$th line is denoted as $\beta_i$, every ray on the $i$th projected laser beam can be expressed using the following equation:

\[
\begin{align*}
\tilde{r}_i &= r_i + \tilde{v}_i t, \quad t > 0 \\
\tilde{v}_i &= \begin{bmatrix} \cos \theta_i \cos \beta, \sin \theta_i \cos \beta, \sin \beta \end{bmatrix} \\
&= \begin{bmatrix} 2j - n \theta_i \end{bmatrix}, \quad j = 1, 2, \ldots n
\end{align*}
\]

The interception point of projected laser ray $\tilde{r}_i$, with weld pool surface $S$, denoted as $PW_{ij}$, is the projected laser point on $S$, and is where reflection occurs.

**Modeling of Reflected Ray and Captured Reflected Pattern**

Surface $S$ is composed of the weld pool surface and partial workpiece surface. Only the weld pool surface can specularly reflect the projected laser while diffuse reflection occurs on the workpiece surface. Consequently, only $PW_{ij}$ that is on the weld pool surface will have a reflection ray, denoted as $r'_{ij}$.

The surface normal at point $PW_{ij} = (x_{ij}, y_{ij}, z_{ij})$ on surface $S = F(x, y, z)$, denoted as $\hat{n}_{ij}$ and corresponding outgoing ray, $\tilde{r}'_{ij}$, can be expressed using the following equation:

\[
\hat{n}_{ij} = \begin{bmatrix} \frac{\partial F(x, y, z)}{\partial x} \ \frac{\partial F(x, y, z)}{\partial y} \ \frac{\partial F(x, y, z)}{\partial z} \end{bmatrix} \begin{bmatrix} x_{ij} \\
y_{ij} \\
z_{ij} \end{bmatrix}
\]

(6)

The reflection of the projected laser follows the law of reflection, which states that the angle of incident ray reflection from a boundary, conventionally measured from the normal to the interface, is equal to the angle of reflection measured from the same interface. And the incident ray, the outgoing ray, and the surface normal at the interface all lie in the same plane. The outgoing ray, $\tilde{r}'_{ij}$, can be expressed as

\[
\tilde{r}'_{ij} = PW_{ij} + t\left(\tilde{v}_{ij} + 2\hat{n}_{ij} \times \left(-\tilde{v}_{ij}\hat{n}_{ij}\right)\right)
\]

(7)

The reflected pattern captured is the interception of reflected rays by the imaging plane, which is placed parallel to the YOZ plane as is shown in Fig. 1. The distance between imaging plane and z-axis is referred to as imaging distance $d$. Since the corresponding reflected pattern from $PW_{ij}$, denoted as $PR_{ij} = (x_{ij}, y_{ij}, z_{ij})$, has a fixed x-coordinate $x_{ij} = d$ and is on outgoing ray $\tilde{r}'_{ij}$, it can be expressed as

\[
PR_{ij} = (x_{ij}, y_{ij}, z_{ij}) = r'_{ij} |_{x_{ij}=d}
\]

(8)

**Static Simulation**

Static simulation evaluates the reflected pattern when the weld pool surface is stable without any fluctuation. The objective is to verify that each line in the reflected pattern is of certain order so that mapping between reflected line and projected line can be established. Second objective is to evaluate the sensitivity of proposed method, i.e., does the weld pool surface affect the reflected pattern. The third objective is to optimize system parameters.

If weld pool fluctuation is not considered, the appearance of the reflected laser is determined by the following aspect: weld pool geometry, laser projection angle, laser origin, laser fan angle, and laser interbeam angle. The last two parameters are determined by the optical characteristic of the pattern generator and cannot be adjusted.

Figure 6 demonstrates the reflected pattern generated using different weld pool geometry. The weld pool width is set.
Fig. 6 — Simulation results: A — Test 1 weld pool surface; B — Test 1 reflected pattern; C — Test 2 weld pool surface; D — Test 2 reflected pattern; E — Test 3 weld pool surface; F — Test 3 reflected pattern; G — Test 4 weld pool surface; H — Test 4 reflected pattern; I — Test 5 weld pool surface; J — Test 6 reflected pattern.
at 7.55 mm and the weld pool length is set as 12.75 mm in all three trials, which is measured from the solidified welding specimen. The only difference in three trials is that the weld pool surface height is decreasing, i.e. the weld pool is less convex. It is set at 2.77 mm in Test 1, which is the actual measured value, and decreases to 1.77 mm in Test 2, and 0.77 mm in Test 3. Simple statistics of the reflected line parameters, including the highest point of line, the horizontal span of each line, are demonstrated in Table 1.

Laser parameters are \( P_0 = (-135,0,180) \); laser projection angle, 55 deg; laser fan angle, 2 deg; and interbeam angle, 0.35 deg. The distance between the imaging plane and the welding gun was set at 70 mm.

Simulation results demonstrate that in all three tests, the lowest reflected line (Line 1 in Table 1) is the result of the foremost projected laser line toward the imaging plane, and the highest reflected line (Line 5 in Table 1) is the result of the laser line projected at the tail of the weld pool. Other lines are sequentially associated, which is the lower lines corresponding to the front lines, and the higher lines corresponding to the lines that are projected toward the tail of the weld pool. This result suggests that when the weld pool surface is smooth, for instance during the base current period of the GMAW-P process when the weld pool surface reaches an equilibrium status, the relationship between projected laser and reflected pattern is sequential.

It can also be observed that the reflected patterns from different weld pool geometries are distinct from each other. When the weld pool surface is relatively convex, the difference in weld pool surface geometry changes are relatively larger than that of the flatter weld pool shape. The corresponding reflected pattern spreads on the entire imaging plane. When the weld pool surface is relatively flat, which is the case when the weld pool is constrained in the I-shaped groove of a butt joint, the alternation to normal surface has minor changes. In this case, as is shown in Fig. 6F, the resultant reflected pattern is close to each other.

Tests 4 and 5 were conducted using the same weld pool surface geometry as Test 1, but with a different laser projection angle. In Test 1, the laser projection angle is set at 55 deg. It changes to 40 deg in Test 4 and 60 deg in Test 5, respectively. In order to compare with the Test 3 results, the laser origin is adjusted accordingly to ensure that in each test, the distance between each projected laser on the workpiece is kept constant. Simulation results demonstrate that the shape of the covering area of the reflected pattern increases when the laser projection angle increases.

The optimal system parameter satisfies the following conditions: Firstly, since the imaging plane is of finite dimension, the resultant reflected pattern when the weld pool is in an equilibrium state cannot exceed the predetermined imaging plane area. Secondly, the reflection angle should be determined such that the distance between each reflected line is as large as possible for easy segmentation. Thirdly, when the weld pool surface fluctuates in a small range, the resultant intercepted pattern on the weld pool surface should still be able to be identified.

**Dynamic Analysis**

The weld pool geometry is not the only parameter that determines the shape of the reflected pattern on the captured image. Weld pool fluctuation due to droplet impingement and arc pressure alternation severely complicated the observation. Since it is not possible to eliminate weld pool fluctuation, several other parameters must be carefully determined to
compensate for the difficulty.

Most vision-based weld pool observation methods do not address the effect camera parameters have on the quality of measurement result. However, camera setting is one of the most important parameters that determines observation results.

As a surface-normal sensitive measurement method, the rapid alternation of weld pool geometry results in a rapid change of the intercepted pattern on the imaging plane. In the ideal case, the camera frame rate is high enough so that the change of surface geometry during the integration period of one frame can be ignored. Meanwhile, laser energy density is sufficient so that on each captured image, the reflected laser pattern is distinct from that of the background arc light. In this case, when the weld pool surface geometry changes, a continuously transformed series of reflected patterns can be observed on consecutive frames, which reflect the geometry change between each integration instance. However, using one digital high-speed camera imposes certain limitations. The primary factors that affect observation results are laser energy density, camera exposure interval, lens aperture, and instant of capture.

The progress of obtaining one image can be described as follows: The scene on the imaging plane is projected onto the camera sensor plane through the lens and optical filters. During exposure interval, the camera sensor integrates the light signal that is collected on the sensor plane and the corresponding integration result is saved as captured image. If an 8-bit representation is used, such as the device we adopted in the experiment, each pixel is represented using one value from a set of integers that have only 256 different values. When the weld pool is stable during the integration interval, the appearance of the reflected pattern only has a minor change but keeps the general shape. The corresponding result is an image with a distinct reflected pattern as is shown in Fig. 2. However, when the weld pool geometry changes from $S_1$ to $S_2$, according to our previous analysis, the shape of the reflected pattern will change from $PR_1$ to $PR_2$. When $S_1$ and $S_2$ are different, the corresponding motion blur due to change of scene degrades the quality of the image. Another corresponding problem caused by motion blur is that during the integration period, since the laser energy spreads on the area between patterns $PR_1$ and $PR_2$, the average laser energy on the area that reflected pattern and scanned through may not exceed the background arc light energy on the corresponding area. The contrast of the laser and background arc light is reduced. In the most severe case, the pattern is not recognizable.

![Fig. 9 — Images captured in the bead-on-plate experiment. A — Original image; B — enhanced image.](image)

The simplest solution seems to decrease the exposure period so that the change of the reflected pattern on each image is reduced. However, with the decrease in the integration period, the total amount of light that falls onto the sensor is reduced proportionally. The low-illumination condition dramatically decreases the signal-to-noise ratio in the capture image. The integrated laser energy also reduces with the decrease in exposure period. Consequently, the difference in laser energy and background arc light is also reduced. In this case, increasing laser energy, or increasing lens aperture, which will collect more light on the camera sensor, will compensate for the cost of reducing the integration period.

Based on the experiment experience, in order to obtain a clear captured reflected pattern, the following principles should be followed:

- A lens with a large aperture should be selected. A large aperture increases the total light collected on the imaging sensor, which results in a relatively bright image compared to that captured using a lens with a small aperture. Secondly, the minimum exposure interval should be determined to ensure that it is capable of capturing the change of reflected pattern that reveals surface fluctuation at required frequency. Laser energy is therefore selected based on the determined exposure interval to ensure that even if the reflected pattern has a slight alternation during the exposure interval, it will still stand out of the background.

**Experiment Results**

The proposed observation system was implemented to view the laser reflection from a pulsed gas metal arc welding (GMAW-P) pool surface. In the conventional GMAW process, droplets transfer from the wire onto the workpiece during the entire progress. The uncontrollable periodic droplet impingement induces severe weld pool fluctuation. A highly dynamic pool surface significantly increases observation difficulty. However, this technical difficulty can be solved by adopting a more powerful laser and camera.
In the GMAW-P process, metal transfer only occurs during the peak current period. After the welding current switches to base current, due to reduced arc pressure and absence of droplet impingement, the external disturbance that is applied onto the weld pool is dramatically reduced. After a short period, which is typically less than 20 ms according to our observation, the weld pool surface becomes a smooth surface with relative less fluctuation. The reflected pattern captured after this period till the end of the base current period is of a regular shape and the features of reflected pattern can be extracted using image processing algorithms.

In order to demonstrate the effectiveness of the proposed method, two experiments of different weld pool geometries were conducted using the same GMAW-P parameters. The welding condition is shown in Table 2, and pulse parameters are shown in Table 3.

Images captured using a bead-on-plate experiment setup are shown in Fig. 7. This process is of partial penetration with high reinforcement. In all the images, reflected lines can be clearly identified. (The dark region in the upper-middle position that causes discontinuities in the upper three reflected lines is due to the blockage of the laser reflection by the wire and droplet.) The appearance of the reflected lines matches the simulation result shown in Fig. 6B.

An experiment using a flat butt joint with backside support was demonstrated in Fig. 8. The groove width was 1 mm. In the test, the weld pool surface is constrained in the joint, and is of relative smooth shape. The relative flat appearance of the reflected pattern coincides with the simulation result as is shown in Fig. 6F. The relative concave shape in certain images demonstrated that at that moment, the weld pool geometry was still of concave shape.

### Image Processing of the Captured Reflected Pattern

The objective of the proposed weld pool observation system is to measure the 3-D weld pool geometry from the captured reflected pattern. Simulation demonstrated that reflected pattern changes when the weld pool surface geometry changes, which suggests the potential that weld pool geometry can be reconstructed from the reflected pattern. The first step is to use a segmentation method to extract the line pattern.

A typical raw image captured at base current period is shown in Fig. 9A. An enhanced image using contrast stretching is shown in Fig. 9B in order to better demonstrate the property of the raw image. It can be observed that the captured raw images contain significant noise and uneven background intensity. Due to weld pool surface fluctuation, certain lines in the reflected pattern may intercept or overlap with each other. One reflected line also might appear as several discontinuous segments rather than a single continuous line. The contrast between laser pattern and background arc light might be low in certain areas, for instance at the upper right part in Fig. 9, and certain lines might be much wider than others.

A robust feature extraction algorithm

<table>
<thead>
<tr>
<th>Table 2 — Welding Condition</th>
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<tr>
<td><strong>Base Metal</strong></td>
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<tr>
<td><strong>Wire diameter</strong></td>
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<tr>
<td><strong>Shielding gas</strong></td>
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<tr>
<td><strong>Gas flow</strong></td>
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<tr>
<td><strong>Welding speed</strong></td>
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<tr>
<td><strong>Wire feeding speed</strong></td>
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<tr>
<td><strong>Contact-tube-to-workpiece distance</strong></td>
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<th>Table 3 — Pulse Parameters</th>
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<tr>
<td><strong>Average welding current</strong></td>
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<tr>
<td><strong>Peak current</strong></td>
</tr>
<tr>
<td><strong>Base current</strong></td>
</tr>
<tr>
<td><strong>Pulse frequency</strong></td>
</tr>
<tr>
<td><strong>Peak current duration</strong></td>
</tr>
<tr>
<td><strong>Base current duration</strong></td>
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is proposed to extract and link the reflected lines. The objective is first to segment the laser pattern from the background arc light, and then to separate and link each line from segmented results. The ideal output is specific coordinates for each segmented laser line. The flow chart of the image processing algorithm is shown in Fig. 10.

**Noise Reduction and Background Removal**

The captured images were generated using low exposure time, large aperture, and under insufficient illumination, which inevitably introduced noises that degraded the image. A frequency domain Gaussian low-pass filter as described in Equation 9 was applied to smooth the obtained image and remove noise.

$$H(u, v) = e^{-D^2(u,v)/D^2}$$ \tag{9}

The background arc light is unevenly distributed. As can be observed, it is of greater value at the lower center of the imaging plane, which is closer to the arc, than at other parts of the image. A morphological top-hat transformation (Ref. 9) is proposed to remove background and increase contrast between the reflected laser pattern and background. It is achieved by first applying a low-pass filter to the image, then subtracting it from the original image by one 7x7 structuring element, resulting in a clear segmentation with little noise.

**Reflected Image Segmentation — Adaptive Thresholding**

Segmentation subdivides the obtained image into its constituent regions of reflected pattern and background arc light, and extracts one of the regions. It is typically achieved by global thresholding, which cannot give a satisfying result when applied to the top-hat transformation result. Due to the uneven illumination and uneven brightness of the reflected pattern on a certain part of the processed image, even after top-hat transformation, the remaining background intensity still exceeds the darkest reflected pattern on the other area.

In this application, the decision whether to segment a pixel as a reflected pattern or background is only determined by its neighboring pixels. Therefore, adaptive thresholding was adopted, which first divided the original image into square blocks, then assigned different thresholds to each block. To reduce segmentation error, blocks were divided in such a way that for each pair of neighboring blocks, 50% of their area overlapped with each other.

The adaptive thresholding algorithm can be described as follows: for every pixel $(x,y)$ in the original image, its gray value is denoted as $f(x,y)$. Background pixels are denoted as $B$ and reflected pattern pixels denoted as $PW$. The average gray level in the $i$th block, which contains pixel $(x,y)$, is denoted as $\mu_i$, and the threshold is described as $T_i = \mu_i + \Delta T$. Then, we will have

$$\begin{align*}
(x,y) &\in B_i, \quad f(x,y) < T_i \\
(x,y) &\in PW_i, \quad f(x,y) \geq T_i
\end{align*}$$ \tag{10}

One pixel was treated as a reflected pattern only when it was determined to be part of the reflected pattern in more than three different blocks. The corresponding segmentation result is shown in Fig. 12, which gives a clear segmentation with little noise.

**Line Linking**

As can be observed in Fig. 12, in the segmentation results, the reflected lines are not necessarily distinct continuous lines as is the simulation results shown in Fig. 6. In certain areas, the reflected lines intercept or even overlap with each other. Gaps between line segments, which is due to electrode blockage of the reflected laser or insufficient contrast between the reflected pattern and the background, also exist.

The basic principle for the line-linking algorithm is that each line can be modeled as a continuous arc. If we define a point $O(x_0,y_0)$ at the captured image, the arc equation $f(x,y) = 0$ can be expressed in a polar coordinate system, which has $O$ as pole and $y^+$ as polar axis, as $g(r, \theta) = 0$. If we travel along each line, both $\theta$ and $r$ are continuous.

Both simulation and experimental results demonstrated that the arc is of a convex shape, therefore, if the pole is selected at the center bottom of the captured image, every segment on the same line can be clustered by utilizing the continuous characteristic of $\theta$ and $r$.

The line-linking algorithm is divided into seven steps. The flow chart is shown...
in Fig. 13. Each segment is first represented using its morphological skeleton to reduce redundant information and reduce calculation load, as is shown in Fig. 14A. Branch points in the skeleton, at the interception points of different lines, are located and removed, as is shown in Fig. 14 B. Each skeleton branch is labeled and then transformed into a polar coordinate, as is shown in Fig. 14C.

Line linking in the polar system starts from segments, which have relatively larger elements, located at the center of the image, and having a larger r value. It follows the angle and distance continuity characteristic of the line, which means the search for the next candidate is along the θ axis. The difference in r between two neighboring segments must not exceed a certain threshold. When all the segments that are larger than a certain threshold have been clustered, the segmentation clustering result is evaluated and each line is sorted based on its average r. From the simulation result, it can be assumed that the fifth line has the largest r and the first line has the smallest r.

Segmentation results in both the polar coordinate system and the original image are shown in Fig. 15. The segmented and linked reflected lines created a foundation for future reconstruction of the weld pool surface.

Conclusion

The proposed system, which projects a five-line pattern onto the weld pool surface and observes its reflection on an imaging plane, provides an effective method to monitor specular GMAW-P pool surface.

System modeling and simulation have been used to help find appropriate ranges of the parameters in the imaging system elements to successfully image the laser pattern reflected from the weld pool surface in GMAW-P.

System modeling and simulation also demonstrated that the observed imaging plane pattern reflects 3-D geometry of GMAW-P weld pool surface. As a surface-normal sensitive measuring method, the reflected pattern is sensitive to weld pool surface fluctuation, which in severe cases will significantly degrade observation results, which is defined as whether clear line reflection is present on the captured image.

Dynamic analysis demonstrated that the quality of captured images is also determined by laser energy density and camera parameters. The effect of weld pool fluctuation can be compensated by increasing laser energy, increasing camera lens aperture, to reduce the image integration interval.

Corresponding analysis demonstrated that when the weld pool is relatively smooth, which is similar to the weld pool shape at the base current period in GMAW-P, the intercepted laser lines can be sequentially matched with projected lines.

Each individual reflected line can be automatically separated from the captured image using the proposed image processing algorithm.

The system modeling, which projects a five-line pattern onto the weld pool surface and observes its reflection on an imaging plane, provides an effective method to monitor specular GMAW-P pool surface.

Acknowledgments

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References

Correlation of Microstructures and Process Variables in FSW HSLA-65 Steel

Of the FSW process heat indexes investigated, heat input provided the best correlation with post-friction stir weld microstructures

BY L. Y. WEI AND T. W. NELSON

ABSTRACT

The present study focuses on developing a relationship between process variables and postweld microstructure in friction stir welded HSLA-65 steel. Fully consolidated welds were produced in HSLA-65 steel using a PCBN convex-scrolled-shoulder-step-spiral (CS4) tool over a wide range of parameters. Microstructures in the nugget center (NC) are governed by lath bainite and with some polygonal/allotriomorphic grain boundary ferrite, which are highly dependent on heat input. Friction stir welded dependent variables are related with FSW independent variables by non-linear relationship. Heat input is identified as the best parameter index. With increasing heat input, the volume of bainite decreases and the ferrite grain and lath sizes increase. A linear relationship was established between heat input and semi-quantitative postweld microstructures.

Introduction

Friction stir welding (FSW) is a solid-state technology that has attracted considerable interest since it was invented at TWI in 1991. Friction stir welding utilizes a nonconsumable tool that is inserted into the abutting edges of the base metal. The rotating tool generates heat by friction and plastic deformation between itself and a nonferrous material, such as liquid metal, to form a weld. The intense plastic deformation produces uniform refined microstructures providing superior combinations of strength and toughness (Ref. 16). In conventional arc welding of HSLA steel, the heat-affected zone (HAZ) is susceptible to hydrogen-assisted cracking (HAC). Moreover, significant loss of strength and toughness in the HAZ can seriously compromise the mechanical properties of the weld (Ref. 16).

Friction stir welding has offered distinct advantages relative to the arc welding of HSLA-type steels. Previous research demonstrated the feasibility of FSW HSLA 65 (Ref. 17), and X80 and L80 steels (Ref. 18), all of which exhibited satisfactory mechanical properties. Softening of the HAZ in HSLA 65 (Ref. 21) and X80 (Ref. 18) weldments were reported. Post- FSW microstructural analyses of HSLA 65 (Refs. 19–21), X80, and L80 (Ref. 18) were limited. In addition, the effect of FSW parameters on postweld microstructure and properties in HSLA steels has not been thoroughly investigated.

The influence of FSW parameters on the microstructure and mechanical properties has been studied by a number of investigators in Al and Mg alloys. Querin (Ref. 22) and Rodrigues (Ref. 23) found higher rotation speed resulted in finer microstructures in FSW Al2219-T87 and AA6016-T4. Afrin (Ref. 24) and Cao (Ref. 25) reported larger grain size and decreasing tensile properties at lower welding speed in FSW AZ31B magnesium alloy. Cui (Ref. 26) concluded the welding speed strongly affected the total size of the stir zone of A356 cast alloy. Pichak (Ref. 27) showed the welding speed had an insignificant effect on grain size of FSW Ti-6Al-4V alloy.

Most research to date has tried to establish correlations between FSW independent variables (travel speed, rotation speed) with postweld properties. Research is limited on the investigation of the correlations between FSW dependent variables, e.g., power and heat input, and postweld characteristics. In traditional arc welding, it is common practice to correlate welding process parameters and mi-

KEYWORDS

Friction Stir Welding
HSLA-65 Steel
Nugget Center
Heat Indexes
Ferrite Grain Size
Bainite Lath Size

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crostructures with weld heat input. Correlations between HAZ grain size and width with process parameters have been well established in traditional fusion welding (Refs. 28, 29).

In FSW, Nelson et al (Ref. 30) reported that peak temperatures in the HAZ and microhardness increased with increasing heat input in FSW HSLA 65. However, the extent to which the dependent variables influenced the microstructural evolution of FSW HSLA 65 weld is yet unknown. No correlation between dependent variables and microstructures has been established.

The objective of this study was to establish correlations between FSW process variables, both dependent and independent, and postweld microstructures in HSLA 65 steel.

Table 1: Measured Chemical Composition of HSLA-65 Steel (Ref. 16)

<table>
<thead>
<tr>
<th>Element</th>
<th>wt-%</th>
<th>Element</th>
<th>wt-%</th>
</tr>
</thead>
<tbody>
<tr>
<td>C</td>
<td>0.081</td>
<td>Cr</td>
<td>0.15</td>
</tr>
<tr>
<td>Mn</td>
<td>1.43</td>
<td>Cu</td>
<td>0.26</td>
</tr>
<tr>
<td>Si</td>
<td>0.2</td>
<td>N</td>
<td>0.009</td>
</tr>
<tr>
<td>S</td>
<td>0.003</td>
<td>V</td>
<td>0.055</td>
</tr>
<tr>
<td>P</td>
<td>0.022</td>
<td>Ti</td>
<td>0.013</td>
</tr>
<tr>
<td>Ni</td>
<td>0.35</td>
<td>Nb</td>
<td>0.021</td>
</tr>
<tr>
<td>Mo</td>
<td>0.063</td>
<td>Al</td>
<td>0.018</td>
</tr>
<tr>
<td>Fe</td>
<td>Balance</td>
<td>Boron</td>
<td>&lt;0.0005</td>
</tr>
</tbody>
</table>

Table 2: Average Heat Input Value for Each Process Parameter of HSLA-65 FSW (the bold parameters are selected to establish the correlations with post-weld microstructures)

<table>
<thead>
<tr>
<th>Rotation Speed (rev/min)</th>
<th>Welding Speed (mm/min)</th>
<th>Axial Force (kg)</th>
<th>Spindle Torque (N.m)</th>
<th>Power (kW)</th>
<th>Heat Input (kJ/mm)</th>
<th>Advance per Revolution (mm/rev)</th>
<th>Pseudo Heat Index (rev/mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>51</td>
<td>3410</td>
<td>90</td>
<td>2.8</td>
<td>3.33</td>
<td>0.17</td>
<td>1772</td>
</tr>
<tr>
<td>300</td>
<td>127</td>
<td>4297</td>
<td>119</td>
<td>3.8</td>
<td>1.77</td>
<td>0.42</td>
<td>709</td>
</tr>
<tr>
<td>300</td>
<td>203</td>
<td>4725</td>
<td>141</td>
<td>4.4</td>
<td>1.31</td>
<td>0.68</td>
<td>443</td>
</tr>
<tr>
<td>450</td>
<td>51</td>
<td>3144</td>
<td>71</td>
<td>3.3</td>
<td>3.93</td>
<td>0.11</td>
<td>3986</td>
</tr>
<tr>
<td>450</td>
<td>127</td>
<td>3769</td>
<td>85</td>
<td>4.1</td>
<td>1.91</td>
<td>0.28</td>
<td>1594</td>
</tr>
<tr>
<td>450</td>
<td>203</td>
<td>3740</td>
<td>98</td>
<td>4.6</td>
<td>1.37</td>
<td>0.45</td>
<td>997</td>
</tr>
<tr>
<td>600</td>
<td>51</td>
<td>3051</td>
<td>58</td>
<td>3.6</td>
<td>4.27</td>
<td>0.08</td>
<td>7087</td>
</tr>
<tr>
<td>600</td>
<td>127</td>
<td>4970</td>
<td>76</td>
<td>4.8</td>
<td>2.25</td>
<td>0.21</td>
<td>2835</td>
</tr>
<tr>
<td>600</td>
<td>203</td>
<td>3956</td>
<td>85</td>
<td>5.4</td>
<td>1.58</td>
<td>0.34</td>
<td>1772</td>
</tr>
</tbody>
</table>

Experiments

The chemical composition of the HSLA 65 (ASTM A945) used in this study is provided in Table 1. The base metal microstructure consists of refined upper bainite islands randomly embedded in the polygonal fine-grained ferrite matrix, with the average grain size about 8 μm as shown in Fig. 1.

Test plates were prepared from 9.5-mm-thick rolled plate with dimensions of 762 mm in length and 203.2 mm in width. The long axis of the test plate was parallel to the rolling direction. Each plate was lightly ground on both sides to remove oxide and surface scale prior to welding. Before welding, the plates were degreased with methanol. All welds were performed under Argon, at a flow rate of 1.1 m³/h, was used as shielding gas to protect the weld area from surface oxidation.

A convex-scrolled-shoulder-step-spiral (CS4) tool was used for all the welds. The shoulder and pin section of the tool are manufactured from solid PCBN (polycrystalline cubic boron nitride). The geometry of the CS4 tool is shown in Fig. 2. A 0.5-deg head tilt was applied during plunge and rolling direction. Argon, at a flow rate of 1.1 m³/h, was used as shielding gas to protect the tool and the weld area from surface oxidation.

Equations 1 and 2 were used to calculate the power and heat input, respectively.

\[ P = \frac{2\pi \Omega T}{60} \]  

\[ HI = \frac{P}{v} \]  

where \( P \) is power (kW); \( \Omega \) is rotation speed (rev/min); \( T \) is recorded spindle torque (N.m); \( v \) is travel speed (mm/rev); \( HI \) is heat index (kW.mm/rev); \( Q \) is torque by FSW machine (N.m); \( HI \) is heat input in FSW HSLA 65. However, the extent to which the dependent variables influenced the microstructural evolution of FSW HSLA 65 weld is yet unknown. No correlation between dependent variables and microstructures has been established.

Fig. 1 — Grain structures of the base metal.

Fig. 2 — Geometry of CS4 tool used in the welding.
In order to establish correlations between postweld microstructures and FSW process variables, four different welding parameters (highlighted in bold text in Table 2) were chosen. The selected welding parameters covered the extreme and intermediate levels of power and heat input, based on the data in Table 2.

Transverse samples were removed from the welds for optical metallography analysis. Each sample was ground and polished successfully through 1-μm diamond paste. Samples were etched with 2% Nital and analyzed optically at magnifications up to 1000× using an Olympus GX51 microscope.

Results and Discussions

Relations between Independent and Dependent Variables in FSW

In order to correlate postweld microstructures with process variables, it is necessary to understand the relationship between FSW independent and dependent variables. In traditional arc welding, those relations have been well-established. Power and heat input are controlled directly by the independent variables, i.e., welding current, voltage, and travel speed (Ref. 28). Power and heat input have a linear relationship with these independent variables, e.g., increasing with increasing welding voltage and current, and decreasing welding speed.

Friction stir welding is substantially different from arc welding. The independent variables in FSW include rotation speed, welding speed, axial force, tool geometry, and tool material. These variables can be directly controlled by the operator. Dependent process variables are heat input, power, and spindle torque. Unlike arc welding, power and heat input in FSW cannot be controlled directly by independent variables. Power is dependent on rotation speed and spindle torque. Spindle torque is not a controlled variable, but rather a response variable (Ref. 31). To complicate matters, spindle torque is a function of rotation speed, welding speed, tool geometry, tool material, and tool depth/axial force. Thus, it is difficult to develop simple relationships between independent and dependent variables in FSW.

Early FSW machines did not have the ability to monitor or record spindle torque. As a result, earlier researchers attempted to establish simple empirical relationships between input variables and machine outputs. Pseudo heat index (PHI) (Refs. 32–34) and advance per revolution (APR) (Ref. 31) were developed as parameter indexes to correlate with peak temperature and postmechanical properties. The PHI and APR are defined in Equations 3 and 4, respectively.

\[
PHI = \frac{\Omega^2}{\nu} \quad (3)
\]

\[
APR = \frac{\nu}{\Omega} \quad (4)
\]

Where \(\Omega\) is rotation speed (rev/min), \(\nu\) is welding speed (mm/min).

These indexes do not take into account the effect of spindle torque or capture the specific energy of the process. Given that postweld microstructures are strongly dependent on heat input in traditional arc welding (Refs. 28, 29), it would seem necessary to capture the effect of the specific energy in FSW. Therefore, it is likely that power and heat input will exhibit better correlation with postweld microstructures. The comparison of these parameter indexes in the following section provides additional evidence to identify the process index that correlates best with postweld microstructures.

Comparison of FSW Parameter Indexes

In order to illustrate the characteristics of PHI, APR, power, and HI (heat input), comparisons of these parameter indexes are discussed below. Using the data in Table 2, PHI, APR, power, and HI are plotted vs. FSW rotation speed and welding speed. These three-dimensional plots are shown in Fig. 3.

Fig. 3 — A — PHI; B — APR; C — power; D — heat input vs. FSW process parameters.
The PHI exhibits a second-order linear relationship with rotation speed and a reciprocal relationship with welding speed as shown in Fig. 3A. The APR exhibits the linear relationship with welding speed and a reciprocal relationship with rotation speed as shown in Fig. 3B. These characteristics imply that APR is less complicated parameter index, since it has a lower order relationship than PHI.

Both PHI and APR are not unique in that multiple combinations of these indexes may have the same heat input. For example, in Fig. 3A, 600 rev/min-203 mm/min, and 300 rev/min-51 mm/min, have the same PHI values, but these two parameters have different power and heat inputs. The APR has similar redundancies. For example, 600 rev/min-203 mm/min has the same APR value as 300 rev/min-102 mm/min, but these have different heat inputs. Redundancies prevent accurate correlations between parameters and postweld microstructural features.

Power and heat input display nonlinear relationships with rotation speed and welding speed, as shown in Fig. 3C, D. This is similar to that reported by Pew (Ref. 35) in FSW Al Alloys 7075, 5083, and 2024. The nonlinear relationships exist because power and heat input are the function of spindle torque, and spindle torque, as discussed earlier, is a response variable.

The nonlinearity suggests that single or even two parameter investigations are inadequate to develop correlation between FSW process parameters and postweld microstructure and properties. In this study, four parameters were chosen to investigate correlations between postweld microstructural characteristics and process parameters in FSW HSLA-65. The parameters used for this aspect of the investigation are highlighted in bold in Table 2.

Effects of Process Variables on Microstructures in Nugget Center (NC)

Microstructures in NC

In this section, some consideration is given to postweld microstructural changes in the friction stir weld nugget at different heat inputs. The nugget center defined in this study is located at the vertical centerline of the stir zone, which has equal distances between the top surface and bottom of HAZ in the weld.

Figure 4 compares the microstructural features within the NC at various heat inputs. The tool rotation speed (rev/min) and welding speed (mm/min) are noted in the upper right-hand corner of each micrograph. Heat inputs are noted in the bottom left-hand corners. The symbols in these images represent different transformation products: $\alpha$ represents polygonal ferrite; $\alpha_{gb}$ represents grain boundary allotriomorphic ferrite; B represents bainite; and $\alpha_{w}$ represents Widmanstätten ferrite. From these optical images, several microstructural characteristics can be observed.

There is no evidence of base metal (BM) microstructures shown in Fig. 4. The equiaxed grains in BM have completely transformed to lath bainite with some polygonal/grain boundary ferrite. This indicates the weld nugget reached a peak temperature in excess of the $A_3$, even at the lowest heat input 1.31 kJ/mm. It is well known that microstructural changes in the weld are primarily affected by heating rate, peak temperature, and subsequent cooling (Ref. 36). Cooling rate is associated with heat input, i.e., lower heat input produces faster cooling rate (Ref. 36). At the lowest heat input in Fig. 4.
4A, the microstructure is mainly lath bainite. The lath boundaries are relatively straight and parallel.

With increasing heat input, two kinds of microstructures are formed (shown in Fig. 4B, C): polygonal ferrite and upper bainite. Higher heat input produces a slower cooling rate, and equiaxed polygonal ferrite starts to nucleate at the ferrite/austenite boundaries and extend into untransformed austenite grain interiors (Ref. 37).

In Fig. 4D, the highest heat input at 4.3 kJ/mm, the primary microstructures are lath bainite along with dispersed particles at prior austenite grain boundaries coexisting with some polygonal and allotriomorphic grain boundary ferrite. Allotriomorphic ferrite forms at a triple junction of prior austenite grain boundaries (Ref. 37). Long needle-shaped Widmanstätten ferrite is also observed in Fig. 4D. Pao (Ref. 20) has reported similar structures in the stir zone of FSW HSLA-65.

In summary, additional polygonal/allotriomorphic grain boundary ferrite forms with increasing heat input. Although higher-temperature transformation products (polygonal and allotriomorphic grain boundary ferrite) are formed at higher heat input, lath bainite is still the dominant microstructure in the FSW NC. This is due to the relatively fast cooling rate in FSW compared to arc welding. Faster cooling rates are the result of 1) lower heat input, and 2) the large heat sinking effect produced by the backing anvil.

Prior austenite grains (PAGs) are also visible in these figures. However, most of the PAG boundaries are discontinuous. The limited alloy addition in these type alloys result in limited segregation to the PAG boundaries. As a result, etchants are unable to attack the prior austenite grain boundaries (GBs) enough to produce sufficient contract to clearly identify them. Discontinuous PAG boundaries are highlighted by white curved lines in Fig. 5. Prior austenite grains are identified by the existing boundaries with some estimation. In order to investigate correlations between microstructures in the NC and FSW process variables, quantitative grain/lath size measurements are needed. Since the prior austenite grain boundaries are absent for the most part, PAG measurements were not used in the present study for the correlations made. In addition, bainite lath size is difficult to quantify precisely by optical microscopy even at higher magnifications (up to 1000x) because some bainite lath structures are too fine to be distinguished under optical microscopy. Therefore, grain/lath size in the FSW NC were measured as accurately as possible by optical microscopy. Bainite lath size was measured using the line intercept approach. The data presented represent an average of at least eight measurements from each weld section. Although bainite lath sizes may only be semiquantitative at best, they are repeatable and adequate for establishing the desired correlations.

Figure 5 illustrates how the ferrite grain and bainite lath measurements are made to acquire semiquantitative data. Bainite lath is measured by drawing a trace line (in black) of known length perpendicular to the lath boundaries, counting the numbers (N) of the lath intersections along this trace line, then dividing the line length by the number of intersections. Polygonal ferrite grains are easy to identify as shown in this figure. The measurements of ferrite grains were taken on every ferrite grain found in the optical images by averaging the length of the long and short axes as shown in Fig. 5.

The average grain/lath sizes are shown in Table 3. The ferrite grain size ranges from about 10 to 25 μm as heat input increases from 1.31 to 4.27 kJ/mm. Over this same range, bainite lath size increases from 0.9 to 2.25 μm. The authors believe the bainite laths observed in these images consist of several thinner laths that are difficult to distinguish by optical microscopy. The lath sizes report may likely be larger than the actual value for reasons described previously.

---

**Table 3 — Variation of Grain Size in the NC with Changing Power and Heat Input**

<table>
<thead>
<tr>
<th>Rotation Speed (rev/min)</th>
<th>Welding Speed (mm/min)</th>
<th>Power (kW)</th>
<th>Heat Input (kJ/mm)</th>
<th>Bainite Lath (μm)</th>
<th>Ferrite Grain Size (μm)</th>
<th>Width of HAZ (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>300</td>
<td>203.2</td>
<td>4.4</td>
<td>1.31</td>
<td>0.9</td>
<td>10</td>
<td>0.14</td>
</tr>
<tr>
<td>600</td>
<td>203.2</td>
<td>5.4</td>
<td>1.58</td>
<td>1.25</td>
<td>12.5</td>
<td>0.26</td>
</tr>
<tr>
<td>300</td>
<td>50.8</td>
<td>2.8</td>
<td>3.33</td>
<td>1.5</td>
<td>13</td>
<td>0.35</td>
</tr>
<tr>
<td>600</td>
<td>50.8</td>
<td>3.6</td>
<td>4.27</td>
<td>2.25</td>
<td>25</td>
<td>0.50</td>
</tr>
</tbody>
</table>
Correlate Postweld Microstructures with Process Variables

In this section, correlations between FSW process variables and postweld microstructures are investigated. Using the data in Table 3, the bainite lath size is plotted against PHI, APR, P, and HI to identify which FSW process index exhibits the best correlation with postweld microstructures. The weld indexes were scaled to fit on the same plot as shown in Fig. 6.

The PHI is not a unique FSW heat index. Both the 600 rev/min and 203 mm/min, and the 300 rev/min and 51 mm/min (circled in Fig. 6) have the same PHI but a 17% difference in bainite lath size. Contrary to most heat indexes, APR exhibits a nonlinear inverse relationship with bainite lath size, e.g., bainite lath size increases with decreasing APR. Additionally, power exhibits essentially no relationship with bainite lath size. Bainite lath size correlates best with HI, exhibiting a nearly linear increase with increasing HI. Additionally, HI is a unique heat index, capturing all elements of the process that contribute to the specific energy. The HI will be used as the FSW heat index through the remainder of this paper.

Using the data in Table 3, bainite lath and ferrite grain sizes were plotted against heat input — Fig. 7. Ferrite grain size (Fig. 7A) and bainite lath size (Fig. 7B) increase linearly with increasing heat input. With an increase in heat input of 2.27 kJ/mm, ferrite grain size and lath sizes increased 150% and 150%, respectively.

The width of the HAZ in a friction stir weld provides additional evidence of heat input dependence. The width measurement was obtained from a Vickers hardness map of the weld as shown in Fig. 8. The weld contour map clearly displays the HAZ as indicated by the black arrow in the map. The range of 200 to 205 Hv was selected as the value of hardness at which the HAZ width was measured. The region adjacent to the weld is the HAZ, which turns a light blue color in the hardness map. The HAZ width was measured at ten different locations as shown by the white lines drawn in Fig. 8 to obtain the average measurement. Some protruding spots (as indicated with red arrows in Fig. 8) in the HAZ do not represent the actual HAZ, which is HAZ with some softening spots in the base metal or had hardness points. So measurements of the HAZ widths were not made at those protruding spots. In addition, the measurements were not taken at the bottom of the weld as the heat transfer was likely different at that location. The HAZ width as a function of HI is plotted and shown in Fig. 9. Similar to traditional arc welding (Refs. 28, 29), the width of the HAZ increases linearly with increasing heat input in FSW.

The linear relationship between bainite lath/ferrite grain sizes and heat input were established. Since the peak temperature and cooling rate are governed by the heat input in the FSW nugget center, higher heat input produces the following: 1) higher peak temperature above A3 in the NC, and 2) slower cooling rate. Peak temperature strongly affects prior austenite grain size, i.e., higher peak temperature produces coarser austenite grains. This in turn would produce coarser microstructures at the same cooling rate since larger PAG size provides fewer nucleation sites (Ref. 39). This combined with slower cooling rate prompt the formation of larger grain/lath structures with increasing heat input.

In the present study, linear correlations between heat input and postweld microstructures in the FSW nugget center (NC) are established. Although the fit is good, the accuracy would likely improve if quantitative microstructural data were obtained. These efforts are currently under investigation.

Conclusions

The following conclusions can be made from this investigation:

1. Of the FSW process heat indexes investigated, heat input provided the best correlation with post-friction stir weld microstructures. Heat input exhibits a linear
relationship with ferrite grain size and bainite lath size.

2. Other process indexes (APR, PHI, and power) exhibit nonlinear relationships with postweld microstructures. The APR and PHI are not unique: e.g., different weld parameters can have the same index value.

3. Ferrite grain size and bainite lath size both increased 150% with an increase in heat input of 2.27 kJ/mm.

References


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Effect of Friction Welding Parameters on Mechanical and Microstructural Properties of Dissimilar AISI 1010-ASTM B22 Joints

In this study, the characteristic of structures, tensile properties, hardness values, and microstructural changes of friction joints were investigated.

BY A. KURT, I. UYGUR, AND U. PAYLASAN

ABSTRACT

Rotary friction welding is one of the most economical and efficient production methods for joining similar and dissimilar materials. It is widely used with metals and thermoplastics in a wide variety of aviation, transport, and aerospace industrial component designs. Individually, mild steel to mild steel and copper to copper are normally easy to weld by fusion welding methods, but the joint of mild steel to copper can be extremely difficult due to the differences in the two materials' melting temperature, density, strength, and thermal conductivity. Thus, these kinds of problems can be eliminated by a solid-state friction welding technique. Hence, the current study attempts to understand the friction welding characteristics of mild steel-bronze dissimilar parts. This study looks into the influence of process parameters, which includes friction pressure, upsetting pressure, and upset time on the axial shortening, hardness, microstructure, and tensile properties of the welds. The optimum parameters for upset time, upset pressure, and friction pressure necessary for welding were obtained. Finally, the obtained mechanical properties results were commented on the light of optical microscopy.

Introduction

Welding of machinery components is compulsory in most engineering applications. Just a few decades ago, materials were classified as weldable and nonweldable, but innovations in technology allowed joining of most materials by fusion and solid-state welding techniques. Typical fusion welding techniques include gas welding (oxygen-acetylene), arc welding (shielded metal, gas tungsten, and submersed), and high-energy beam welding (electron and laser). Heat sources for these techniques are a gas flame, an electric arc, and a high beam, respectively. However, in the nature of these techniques, excessive heating can cause damage to the workpiece, including weakening and distortion. Some of the fusion techniques are applied for various materials (Refs. 1–3). Low carbon (mild) steel and copper alloys are widely applied prospects because of their economic value, plus good mechanical and physical properties. It is an easy process to weld these materials by themselves. Unfortunately, most engineering materials have to join with dissimilar counterparts. Thus, it is difficult to obtain good-quality weld joints using molten welding methods. Some defects and intermetallic phases can occur during the process because of the great differences between Fe and Cu in physical, mechanical, and chemical properties. Table 1 shows some physical and mechanical properties of AISI 1010 mild steel and ASTM B22 copper bronze (Ref. 4). These metals have good electrical and heat conductivity and have a good ability for casting and machining. In order to take advantage of the dissimilar metals involved, it is necessary to produce high-quality joints between them. Typical solid-state joining applications of diffusion welding for various content of the aluminum metal matrix composites (Refs. 5–7) and friction stir welding (Ref. 8) have been studied in detail. Welding copper alloys is usually difficult using a conventional fusion welding process because copper has high thermal diffusivity, which is about 10 to 100 times higher than in many steels and nickel alloys. The effects of diffusion welding parameters on the mechanical response of low carbon steel and commercially pure copper were studied in detail by Kurt et al. (Ref. 5). Welding time, applied load, welding temperature, and chemical composition of the steel are some of the key parameters to controlling the solid-state diffusion welding process.

Rotary friction welding is one of the solid-state techniques that is applied to the joining of similar and dissimilar counterparts. In this technique, machinery components are brought into contact. While one of them remains stationary, the other is rotated with the applied pressure. When the temperature of the interfaces has reached an optimum value for the extensive plastic deformation, the rotation is stopped, while the forging pressure remains unchanged or increased. The application of an axial force maintains intimate contact between the parts and causes plastic deformation of the material near the weld interface. If sufficient frictional heat has been produced during softening, larger wear particles begin to expel from the interfaces and axial shortening of the components begin as a result of the expelled upsetting. In general, heat is conducted away from the interfaces, and a plastic zone develops. The plasticized layer is formed on the interfaces and the local stress system with the assistance of the rotary movement extrudes material from the interface into the flash. It has been shown that weld integrity is strongly affected by the rate of flash expelled under

KEYWORDS

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Mild Steel-Bronze
Welding Parameters
Mechanical Properties

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Friction welding has a lot of advantages over other welding processes, such as no melting, high reproducibility, short production time, low energy input, limited heat-affected zone (HAZ), avoidance of porosity formation and grain growth, and the use of nonshielding gases during the welding process. Also, the technique is not only applied to round specimens but used for rectangular components. It is called linear friction welding and has recently been applied to steel (Ref. 10).

Although a large amount of previous studies (Refs. 7-11) in similar and dissimilar materials have been studied, mechanical properties of the mild steel to copper bronze joint by friction welding method have never been reported up-to-date. Thus, the aim of this study is to examine the mechanical properties and optimal welding conditions of friction welded joints of ASTM B22 Tin bronze and AISI 1010.

Materials and Methods

Chemical composition of the copper-based bronze and mild steel employed is given in Table 2. Cylindrical test specimens of 20 mm in diameter and 100 mm in length were prepared for friction welding. Before friction welding, the surfaces facing each other were machined using a lathe. Before welding, the surface of the workpieces were cleaned with a stainless steel brush and acetone to remove the oxide layer and stains. Joining of these two dissimilar alloys was performed on a continuous drive friction welding machine of 250 kN capacity at a constant rotation speed of 2500 rev/min, and constant friction time of 3 s. Friction and upset pressures can be observed on the screen, and the welding sequence stages are controlled by a solenoid valve. The welding parameters were as follows: friction pressures \( P_1 \): 10, 15, 20 MPa; upset pressures \( P_2 \): 22, 25, 30 MPa; and upset (forging) time \( t_2 \) of 1.5, 7, 8.5 s. Tensile test specimens were prepared according to ASTM E8M-00b. Ultimate tensile strength (UTS) and yield strength of the welded specimens were determined. Hardness values \( (VH_b) \) were determined by using a Zwick 3212 device. Measurements were taken in the welding center through base metals. For tensile strength and hardness test values, at least three specimens were carried out for each parameter. The axial shortening was estimated by measuring the length of the specimens before and after welding. The microstructure was investigated by optical microscopy. The steel specimens were polished and etched with a solution consisting of 70% HCl and 30% HNO\(_3\). The grains have equaxed shapes ranging from 30 to 150 \( \mu \text{m} \) in dimension. The bronze specimens were also polished and etched with a solution consisting of 40% NH\(_4\)OH, 60% H\(_2\)O. Typical microstructures of materials can be seen in Fig. 1A, B.

Results and Discussions

Effects of Welding Parameters on Axial Shortening

The effect of upset time and friction pressure on the axial shortening is presented in Fig. 2. Similarly, the effects of upset time and pressure on axial shortening are also shown in Fig. 3. It is clearly seen that axial shortening significantly increased with increasing friction, upset pressures, and times. To ensure good metallurgical integrity, it is necessary to break up and expel the contaminated surface layers. In rotary friction welding, this is achieved with greater pressure and upset times. Also, in light of these figures, the axial shortening exponentially increased by increasing these welding parameters. The fit of the results yields the following simple formula:

\[
A_s = 0.4 - 0.8 \rho^{0.22}
\]

where \( A_s \) is the axial shortening (mm) and

<table>
<thead>
<tr>
<th>Properties</th>
<th>Unit</th>
<th>AISI 1010</th>
<th>ASTM B22</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density</td>
<td>g/cc</td>
<td>7.87</td>
<td>8.72</td>
</tr>
<tr>
<td>Thermal Conductivity</td>
<td>W/m-K</td>
<td>51.9</td>
<td>74</td>
</tr>
<tr>
<td>CTE</td>
<td>\mu m/°C</td>
<td>12.2</td>
<td>20</td>
</tr>
<tr>
<td>Ultimate Tensile Strength</td>
<td>MPa</td>
<td>425</td>
<td>310</td>
</tr>
<tr>
<td>Yield Strength</td>
<td>MPa</td>
<td>180</td>
<td>150</td>
</tr>
<tr>
<td>Elongation</td>
<td>%</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>Elastic Modulus</td>
<td>GPa</td>
<td>200</td>
<td>105</td>
</tr>
<tr>
<td>Melting Temperature</td>
<td>°C</td>
<td>1535</td>
<td>1000</td>
</tr>
<tr>
<td>Hardness</td>
<td>Hv</td>
<td>100</td>
<td>83</td>
</tr>
</tbody>
</table>

Fig. 1 — Microstructure of A — AISI 1010 steel (x 500); B — ASTM B22 copper bronze (x 50).

Fig. 2 — The effect of upset time and friction pressure on the axial shortening with 22 MPa upset pressure.
The effect of upset time and pressure on the axial shortening with 10 MPa friction pressure.

Fig. 4 — Typical axial shortening against upset time graph with 15 MPa friction pressure and 22 MPa upset pressure.

Fig. 5 — The microhardness distribution of materials. A — The effect of friction pressure ($P_f = 22$ MPa, $t_f = 5$ s); B — the effect of upset pressure ($P_u = 10$ MPa, $t_u = 5$); C — the effect of upset time ($P_u = 10$ MPa, $P_f = 30$ MPa).

Fig. 6 — The effect of friction pressure on the tensile response of the 22 MPa upset pressure at 5 s upset time.

$t$ is the upset time (s). This formula can clearly explain the change of axial shortening with the upset time under the welding conditions in this study. However, this basic equation is primitive, and further experimental study should be done to incorporate the factors related to material physical and some mechanical properties. At the low friction and upset pressures, the friction heat is not enough to soften the interfacial materials; and the interface temperature is relatively low due to low heat input. As time increases, the friction and contact area also significantly increases the heat generation on the interfaces, and in return flash is formed. Hence, axial shortening increases remarkably with the interface temperature rise and softening of materials following the extruding process under the rotary motion. Therefore, upset friction pressures and times are key parameters in controlling the formation of a perfect joint.

Sathiya et al. (Ref. 11) found that in the case of stainless steel, a combination of high friction, upset pressure, friction time, and upset time produced more axial shortening (melt-off) that played an important role in the mechanical properties. They observed that increased axial shortening resulted in better mechanical properties of joints. In general, the mechanical properties of a weld are more closely related to the axial shortening rate, which can also be a factor indicative of joint quality.

Figure 4 shows the effect of the materials on axial shortening. The different thermal and physical properties of the materials to be welded in dissimilar metal welding (heat capacity, thermal conductivity, relationship between hardness and temperature) generally result in asymmetrical deformation. In this study, during the friction welding of steel to bronze, a flash forms mostly on the bronze side. While the axial shortening increased exponentially for the bronze materials, the steel showed a linear increase in axial shortening. Although both materials were axially shortened with increasing upset times, shortening of the bronze material was more pronounced compared with steel. It is well known that bronze melting temperature and yield strength are significantly low, and thermal conductivity and coefficient of thermal expansion are quite high, compared to steel. Thus, more bronze materials will be softened during the welding process due to the extensive plastic deformation, and relatively high temperature occurs on the joint surface. Hence, more bronze materials deformed plastically due to the decreased yield strength (effect of the high temperature) compared to the steel. The heat generation in the joint surface is significantly different from center to outer shell. This fact suggests that the extrusion rates of ma-

Table 2 — Chemical Compositions of Copper Bronze and Mild Steel

| Material | Sn | Zn | Pb | Ni | Fe | Cu | Elements wt-%
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>ASTM B22</td>
<td>30</td>
<td>1.14</td>
<td>0.5</td>
<td>0.16</td>
<td>0.04</td>
<td>remain</td>
<td></td>
</tr>
</tbody>
</table>
| Material | C | Mn | Ni | Cr | Si | Fe | remain
| AISI 1010 | 0.1 | 0.3 | 0.22 | 0.1 | 0.04 | remain |
materials in the middle and edges will have different microstructures in both specimens owing to the nonuniform temperature distribution. In friction welding, the temperature would be minimum at the center and maximum at the periphery because more intermixing takes place at the peripheral region of the weld. Thus, the maximum heat generation point occurred somewhere close to the periphery beneath the surface of dissimilar metals (Ref. 12). In addition, the flash was found to increase not only with the increase in friction welding parameters but also with the density of bronze. Similar results were also reported by Jayabharath et al. (Ref. 13). Furthermore, for a dissimilar weld in rheology and geometry, computer simulation demonstrates that the weaker material is thicker than the stronger part, which leads to different flash shapes and relative upset (Ref. 14).

Figure 5A shows the effect of friction pressures, B shows the effect of upset pressures, and C shows the effect of upset time on the hardness distribution in the direction perpendicular to the weld interface of the as-welded specimen. As can be seen from these figures, almost the same trend was observed in the microhardness profiles of all samples. The maximum hardness values of joints were obtained on the steel side next to the welding centerline. The hardness values generally increased with increasing friction pressure and upset pressures, but hardness values decreased with increasing upset time. Increasing hardness in the welding interface can be related to the microstructure formed in the weld interface as a result of the heat input and plastic deformation. As can be seen from Table 1, the hardness of bronze is 83–96 Hv, but the weld interface hardness is measured around 147 Hv. Similarly, the hardness value of mild steel is 100–118 Hv, but the welding interface is measured around 200 Hv. It can be said that microstructural evaluations around the interface, diffusion of elements on the sides, work hardening, dislocation density, grain refinement, and formation of precipitations may have caused this increase. Although work hardening is also effective on the hardening in the bronze side, hardening in steel is mostly a direct result of fine grains, rapid cooling from the welding temperature, and formation of precipitates. A similar hardness profile was also observed for dissimilar material couples (Refs. 11, 15, 16). It can be said that the hardness properties are influenced by an interactive effect of friction, upset pressures, and upset times, which are combinations of heat input and a degree of strain hardening.

Microstructure

Figure 7A–C shows the microstructural features of interfaces with increasing friction pressure. It is clearly seen that insufficient friction pressure on the joining surface resulted in an inadequate locking of the surfaces (Fig. 7A) where limited plastic deformation and microstructural changes occurred, and these facts caused poor tensile response of the joint. An increase in the friction pressure caused better joining surfaces (Fig. 7B, C) where recrystallization occurs on the bronze side, and grain refinement and strain hardening occurs on the steel side. The width of the recrystallized region is mainly affected by the friction pressure. An increase in the
friction pressure resulted in a wider fine grain region. A change in microstructure and axial shortening also notably occurred in the bronze side. The same phenomenon has been reported during friction welding of dissimilar welds, namely Fe-Ti, Cu-Ti, Fe-Cu, Fe-Ni (Ref. 12). The recrystallized region of Fig. 7C decreases compared to that of Fig. 7A, and fracture occurred in the faying surface. However, tensile fracture of the joint (Fig. 7C) did not occur in the faying surface but in the bronze side of the HAZ. This means that the decrease in recrystallized region was caused by high friction pressure that contributes to better tensile strength. Heat flow occurs preferentially in the material with the greatest thermal conductivity. Due to the different thermal conductivities between bronze and steel, the specific heat is so large, and hence, most of the frictional heat was generated in bronze. The difference in thermal conductivity explains the microstructural changes that occur preferentially in the bronze side. Similar microstructural observations for the Cu-Ti couples were also reported in Ref. 18. Most of the changes occurred preferentially in the copper, no evidence of microstructural variation was seen in the vicinity of the interface, neither grain growth nor grain boundary precipitation was observed. They attributed this behavior to the difference in thermal conductivity (Ref. 18). It can be said that for the perfect interfacial bond, sufficient upset time and friction pressures are necessary to reach the optimum temperature and severe plastic deformation to bring these materials within the attraction range. Sathiy et al. (Ref. 11) found that in the case of stainless steel, a combination of high friction, upset pressure, and high upset time produced high tensile strength and high impact values. A bond quality classification system was developed using a novel, noncontact, acoustic emission sensing technique. An increase in the friction and upset time resulted in higher tensile strength and high impact values. A bond quality classification system was developed using a novel, noncontact, acoustic emission sensing technique. An increase in the friction and upset time resulted in higher tensile strength and high impact values. A bond quality classification system was developed using a novel, noncontact, acoustic emission sensing technique. An increase in the friction and upset time resulted in higher tensile strength and high impact values.

Conclusions

To clarify the feasibility of friction welding to AISI1010-ASTM B22 copper bronze, the characteristic of structures, tensile properties, hardness values, and microstructural changes of friction joints were investigated with various welding parameters. The main conclusions are summarized as follows:

1. Friction welding can be used successfully to join mild steel to bronze. The processed joints exhibited better mechanical and metallurgical characteristics as compared to those made with fusion welding techniques.

2. The tensile strength of the obtained weld joints can reach a base metal strength of 70% if suitable welding parameters are determined. Fracture usually occurs either in the HAZ of soft material or in the joint surface.

3. The axial shortening exponentially increased by increasing the upset time. The best fit of data yields a formula: $A_s = 0.4 - 0.8 \, \rho^{0.22}$.

4. Upset time, friction time, and axial shortening play important roles in the metallurgical structure and mechanical response of the weld.

5. Extensive deformation is confined mostly to the bronze side due to their low flow stress and high thermal conductivity.

6. Higher hardness values are observed next to the interface, but they dramatically decreased with increasing distance and upset time.

7. An increase in the friction and upset pressure result in slightly higher hardness values.

8. Typical microstructural features were observed in the welding region. Recrystallized fine and elongated grains were evident adjacent to the joint surface.

9. For this study, the optimal joint performance was attained at a friction pressure of 20 MPa, upset pressure of 22 MPa, and upset time of 5 s.

Acknowledgments

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