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On the cover: An integrated head assembly for tandem narrow groove submerged arc welding. (Photo courtesy of AMET, Inc., Rexberg, Idaho.)
AWS Foundation Promotes the Welding Profession

Since it was established in 1989, the AWS Foundation has awarded more than $5.3 million to some 3900 students. Its programs include:

• National Scholarship program. Each national scholarship was established with a minimum funding endowment of $50,000.
• District Scholarship program. Each of the 22 AWS Districts awards $7500 in scholarships annually for a total of $165,000. These awards typically range from $200 to $2500.
• There are 17 Section and 6 District Named Scholarships funded at the local level with a minimum endowment of $10,000 each.
• In addition, there are several Graduate Research Fellowships each endowed for $500,000, and this year, AWS funded a new scholarship endowment to support welding educators.

In recent years, the Foundation has also developed programs to enhance the image of welding and help recruit welders to the workforce. These efforts include:

• Enhanced Image of Welding. The AWS Foundation has worked with media to ensure coverage is accurate and portrays today’s welding industry.
• Using National Spokespersons. Well-known personalities represent the welding industry. For example, a DVD titled Hot Bikes, Fast Cars, Cool Careers features Jay Leno and three young cable television personalities.
• Careers in Welding Mobile Exhibit. A newly launched semi tractor/trailer offers virtual welding experience and promotes careers in welding.
• Student Recruitment Collateral. Through collaboration with the National Center for Welding Education & Training (Weld-Ed) and other industry partners, the Foundation develops and distributes resources that connect students, school counselors, parents, and teachers with welding career opportunities.
• Careers Web Site. www.careersinwelding.com includes career exploration articles, industry and professional profiles, a welding school locator database, scholarship information, résumé building, social networking, and more.
• Job Search Web Site. A job board, www.jobsinwelding.com provides job seekers with access to more than 90% of the welding jobs posted on the Internet. Employers can post job openings and conduct a résumé search to find qualified candidates.
• Professional Development Events for Educators/Counselors/School Administrators. Through collaboration with Weld-Ed, the AWS Foundation offers events to educate middle and high school administrators about careers in the welding industry.

National Forums with Government, Industry, and Educators. Through collaboration with Weld-Ed and industry partners, the Foundation has organized and participated in national events focused on dialogue, awareness, innovation, and action. Such an event took place September 9 in Chicago. At the State of the Welding Industry Workforce Roundtable, 18 panelists and more than 50 participants discussed challenges in recruiting, training, and retaining students and workers in the welding field. The panelists came from all walks of our industry and included high-level executives. Solutions to these challenges were developed in small group discussions and included: 1) The need to develop employer-sponsored education (access to facilities, instructors, equipment, internships); 2) Improving the image of the industry and being clear on what is required to be employed (drug testing, security clearances, certifications, work ethic); 3) Leveraging experienced talent in new strategies to train the next-generation workforce; 4) Upskilling the incumbent workforce in new technologies; and 5) Developing training programs that fit employer needs and constraints.

I am excited about our Foundation’s efforts to convey information about careers in our industry. Qualified welders are needed to provide the resources to tackle the improvements in infrastructure and energy our country needs. The AWS Foundation is taking a lead in communicating how our rewarding profession can provide valuable careers. We welcome your support through a donation or inclusion of the Foundation in your estate planning.

Gerald Uttrachi
Chair, AWS Foundation
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AWS Forms Book Partnership and Launches E-Newsletter

SAE Intl., Warrendale, Pa., and the American Welding Society (AWS), Miami, Fla., agreed to a partnership that will enable SAE to sell print and electronic versions of selected AWS books in their entirety and as individual chapters.


In addition, AWS members and industry professionals can stay on top of important welding news with This Week in Welding, the Society’s recently launched e-newsletter. To sign up, visit www.aws.org/news. Published by Multibriefs, a publisher of e-mail publications, it’s delivered on Tuesday afternoons. The newsletter contains coverage of today’s most relevant issues gathered from sources like the Associated Press, New York Times, Financial Times, and other industry publications.

Nearly $23 Million Granted for Technology Center in Illinois

Illinois Governor Pat Quinn recently joined Illinois Valley Community College President Jerry Corcoran to announce $22.8 million in Illinois Jobs Now! capital funding.

A Community Technology Center will be constructed, and buildings will be renovated at the school’s Oglesby campus. It’s also set to create about 210 construction jobs.

The 80,000-sq-ft center will include classroom, lab, office, and support spaces. The two-story building has been designed to achieve LEED Silver Certification as well. Work is expected to begin this fall with completion scheduled for December 2013.

The college’s projects total $30.4 million, with the state paying $22.8 million and the school coming up with $7.6 million. Other work covered by the funding includes enhancing the welding and automotive shops, plus creating a 2500-sq-ft maintenance building.

Free Miller Weld Setting Calculator Offered

Miller Electric Mfg. Co., Appleton, Wis., recently developed a Miller Weld Setting Calculator available via the iPhone App Store or MillerWelds.com/weldsettings. The calculator allows welders to conveniently access shielded metal arc, gas tungsten arc, and gas metal arc equipment settings and other helpful tips.

Upon entering weld parameters, e.g., the type of material and material thickness being welded, the calculator will provide suggested settings including wire size and wire feed speed, shielding gas, and voltage and amperage ranges. All suggested settings are approximate. Welds should be tested to comply to user specifications.

Eight Cities, States to Receive Funding for Rail Relocations

U.S. Secretary of Transportation Ray LaHood recently announced eight cities and states will share $19.4 million to replace, relocate, and improve segments of railroad track. The U.S. Department of Transportation’s Federal Railroad Administration received 51 applications for the Rail Line Relocation and Improvement grants.

“The strong desire to improve infrastructure and foster economic development throughout America is evident in the overwhelming demand by our nation’s cities and states,” said LaHood.

These rail line relocation dollars will fund projects in the following locations: Port of San Francisco, Calif.; Sprague, Conn.; Maryland Department of Transportation; Tavares, Fla.; Minnesota Department of Transportation; Arkansas State Highway and Transportation Department; Springfield, Mo.; and Alaska Railroad.
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Lincoln Electric Inaugurates One of the Largest Urban Wind Towers in North America

The Lincoln Electric Co. recently dedicated a new wind tower installed at its world headquarters and manufacturing campus in Euclid, Ohio.

The company has long been an important supplier to the wind tower manufacturing industry, and this tower shows how this new technology can be efficiently incorporated in an urban community and how wind power can be a viable source of energy. The tower will generate 10% of the electricity used for Lincoln Electric’s main plant, yielding approximately $500,000 in annual savings.

This project was made possible by extensive collaboration with the public sector, including the Cleveland Foundation, the city of Cleveland, and Cuyahoga County, among other entities.

“This is a great testimonial of how private business and government resources can come together in a very cooperative way to create something very special for the community and the company,” said John Stropki, president, CEO, and chairman of Lincoln Electric.

“The tower represents important cost savings, as well as our commitment to integrating renewable energy sources, among other ongoing green initiatives, into our manufacturing processes,” said George Blankenship, the company’s senior vice president.

The four tubular steel sections of the tower were built and welded by Katana Summit in Columbus, Neb., then shipped by truck to Euclid. The 2.5-MW turbine was manufactured in Germany by Kenersys GmbH, and the blades, formed from a glass fiber-reinforced polymer, were manufactured in Poland by LM Wind Power Blades.

“This turbine will provide Lincoln with energy savings, and it will reduce our whole community’s reliance on fossil fuels,” said Bill Cervenik, mayor of the city of Euclid.

Here’s an in-depth look at the Lincoln Electric wind tower:

- 2.5-MW Kenersys® K100 turbine can produce enough energy to power 686 homes
- Composed of four tower sections that are welded steel construction
- 2951-lb of submerged arc wire and 5875-lb of flux used in tower section fabrication
- Measures 443 ft tall from the tower base to the tip of the blade
- The nacelle, which houses the turbine and electronics, is the size of a single-car garage and weighs more than 198,000 lb
- A total of 624 bolts secure the tower components, with 240 bolts measuring 1½ in. in diameter and 384 measuring 1½ in.
- Roughly 2800 cubic yards of earth were excavated to 14 ft below grade for base construction
  - Overall weight of the tower, including the nacelle and the hub, is more than 800,000 lb
  - Wind operating speed is 6.5 to 56 mph.

The cumulative installed capacity of wind power in the United States was more than 42,000 MW as of the second quarter of 2011 (making it second in the world behind China), and wind power accounted for 2.3% of the electricity generated in the United States in 2010, according to the American Wind Energy Association. — Carlos Guzman, editor, Welding Journal en Español
The roundtable's goal to develop recommendations as well as drive action will expand and improve programs to produce tomorrow’s welding industry workforce. Pictured above (from left) are panelists Jennifer McNelly; Glenn Campbell; Jeff Allman; Lloyd Robinson; Jimmy Morgan; Kurt Hofman; Mike Pelegrino; Michael Castner; Kelly Zelesnik; Chris Heitzman; Lin Chapé; Dean Wilson; Ray Shook; Patricio Mendez; Sundaram Nagaranjan; and Elton Stuckly.

The “State of the Welding Industry Workforce” roundtable, held on September 9 by the National Center for Welding Education and Training (Weld-Ed) and the American Welding Society (AWS), addressed difficulties and solutions for a roadmap to recruiting and training of welding personnel. Nearly 70 people attended this event at the Crowne Plaza Chicago O'Hare Hotel, Rosemont, Ill.
The morning session featured facilitated executive dialogue with an 18-member panel. Dean Wilson, director of business development, welding with Kimberly-Clark Professional, global safety and AWS vice president, served as moderator.

Ray Shook, AWS executive director, presented the opening speech.

Various topics were reviewed, including challenges employers face in recruiting, training, and retaining welders and other welding professionals; challenges educators have in recruiting, educating, and retaining students in welding-related programs; the impact of new technologies, welding advancements, and globalization; plus creative solutions and partnerships to educate and hire the right people.

Monica Pfarr, AWS corporate director and Weld-Ed National Science Foundation grant principal investigator, cited the State of the Welding Industry Report: Executive Summary and that 238,000 welders are needed from now to the year 2019.

Common themes in this session focused on forming collaborations with companies, employers, colleges, and vocational/technical schools; changing impressions of the field and fixing perceptions; using new equipment to stay current with up-to-date technologies; making welding jobs look more attractive; and finding workers with good work ethics.

“Welding impacts every section of manufacturing,” said Jennifer McNelly, senior vice president, NAM Manufacturing Institute.

Several key points made by Dr. Elton Stuckly, president, Texas State Technical College, Waco, engaged the audience. “You’ve got to start early,” Stuckly said regarding attracting children to technical education. As a nation, there’s a need to get people interested in the field. “It’s a worthy career,” Stuckly concluded.

Dr. Patricio Mendez, Weldco/industry chair in welding and joining, University of Alberta, has the latest machines available at his college. “Excitement is what drives learning. For this new generation, it’s their language,” Mendez said.

Mike Pelegrino, welding instructor, UA Local 597, Chicago, thinks it’s a society issue and parents should be informed. “There’s money to be made,” Pelegrino said, with respectable pay ranges. He spreads the word by going to career days and high schools.

Additional panelists were Jeff Allman, Huntington-Ingalls Industries; George Blankenship, Lincoln Electric North America; Glenn Campbell, Bechtel Power; Michael Castner, ESAB; Lin Chapé, Vermeer Corp.; Chris Heitzman, Caterpillar, Inc.; Kurt Hofman, RoMan Engineering Services; Jimmy Morgan, Westinghouse Electric Co.; Sundaram Nagarajan, Illinois Tool Works, Inc.; Lloyd Robinson, AWISCO Intl.; and Kelly Zelesnik, Lorain County Community College.

The roundtable’s afternoon session concentrated on the development of solutions/pilot projects. Panelists and audience members, placed into eight groups, discussed the following issues: employer-sponsored education; common core competencies with career pathways grounded in basic academics for success; parents/counselors/teachers: improving the image of the industry and being clear on what students need to find jobs; students: improving the image of the industry and being clear on what is required to be employed; identifying new pipelines to address workforce shortages; leveraging experienced talent in new strategies to train the next-generation workforce; updating the skills of the incumbent workforce for new technologies; and developing training programs that fit employer needs and constraints.

Highlights were presented for current best practices, critical attributes, key stakeholders, resources, and scalability/implementation barriers. The goal of these recommendations for industry, education, and government is to generate a series of projects that focus on key challenges to recruiting, educating, and retaining a skilled welding industry workforce. AWS will issue a final report. It’s expected printed copies will be available from the AWS Foundation by mid-November. — Kristin Campbell, associate editor, Welding Journal
ESAB CEO Andrew Masterman and South Carolina Governor Nikki Haley cut a ribbon to open the company’s automation center.

ESAB Welding and Cutting Products recently launched a new automation process center at its Florence, S.C., facility. The 5000-sq-ft showroom includes a demonstration area, training room, and meeting facilities focused on welding automation products.

South Carolina Governor Nikki Haley, State Senators Hugh Leatherman and Yancey McGill, and local dignitaries were on hand to celebrate. The demo lab features tractors, column and boom equipment, the company’s new Telbo telescopic beam system, side beam welding machines, welding gantries, robotic welding systems, and a hybrid laser arc welding system.

The center also features more than one dozen welding equipment systems. It includes simple tractor welding packages valued at approximately $20,000 to hybrid laser systems valued at more than $2 million. In total, the automation process center houses more than $3 million worth of demonstration equipment.

ESAB invested more than $500,000 to renovate the center located in the Florence manufacturing facility. The center is staffed by 12 employees in sales, engineering, and customer support.

Miller Electric Partners with Fox Valley Technical College to Unveil Center

Fox Valley Technical College held a ribbon cutting of a different sort, using a Miller Electric plasma cutting tool to cut a steel ribbon at the opening for its advanced manufacturing technology center.

Miller Electric Mfg. Co., Appleton, Wis., joined Fox Valley Technical College to launch its 26,000-sq-ft advanced manufacturing technology center in Oshkosh, Wis.

The facility features up-to-date welding, cutting, and fume extraction systems.

For info go to www.aws.org/ad-index
traction equipment, as well as fabrication and testing resources from Miller Electric. The college built the center with the goal of expanding its welding curriculum to train a new skilled welding workforce for the region’s manufacturing and fabrication industries, including shipbuilding, truck fabrication, and numerous foundries and manufacturers.

“This facility came about based on the needs of the community. The metals manufacturing sector in the region was expressing that they simply did not have enough skilled welders and fabricators. We started working with a number of partners to find a way to quadruple our welding lab space, as well as our fabrication and robotics weld space,” said Dr. Susan May, president, Fox Valley Technical College.

“This partnership started with a unique problem we had 25 years ago,” said Mike Weller, president, Miller Electric Mfg. Co. and ITW Welding North America. “Our technology was changing, and we needed new skill sets in the organization. We needed help with electrical and mechanical testing capabilities. The college put a full-time instructor in our facilities, and we graduated 65 employees on that program.”

**Space Capsule Comes Alive with First Weld**

Construction recently began on the first new NASA spacecraft built to take humans to orbit since space shuttle Endeavour left the factory in 1991.

Engineers at NASA’s Michoud Assembly Facility in New Orleans started welding together the first space-bound Orion Multi-Purpose Crew Vehicle. These welds, completed using a new friction stir welding process developed especially for Orion construction, creates a seamless and leak-proof joint.

After welding is finished at Michoud, the Orion spacecraft orbital test article will be shipped to NASA’s Kennedy Space Center in Florida, where the heat shield will be installed. At Kennedy, it will undergo final assembly and checkout operations for flight.

**Industry Notes**

- Exova, Spijkenisse, The Netherlands, introduced a new immersion ultrasonic testing technique that has become part of the AUT validation procedure for girth weld inspection.
- H&H Sales Co., Inc., Huntsertown, Ind., a manufacturer and distributor of custom service and delivery truck bodies, plus steel fabrications, is celebrating its 60th anniversary this year.
- A contractor in the nuclear field has awarded Solar Atmospheres, Western, Pa., a multimillion dollar purchase order for the vacuum thermal processing of nickel-based nuclear steam generator tubing.
- Hobart Brothers, Troy, Ohio, launched a redesigned Web site at www.hobartbrothers.com. It features improved navigation options and product search features; more detailed product information; ability to locate the nearest distributor; and the option to subscribe for notification of product safety updates.
- At Mahany Welding Supply Co., Inc., Gates, N.Y., ground has been broken on a 5000-sq-ft training facility for welding, glasswork, blacksmithing, and jewelry making. The venture, Rochester Arc and Flame Center, is set to open in January.
- Applied Tooling Technologies, Waukesha, Wis., formerly Waukesha Industrial Supply, changed its name to better reflect changes within the company and metalworking industry.
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Tata Steel Makes Major Investment in Welding Equipment for UK Plant

In a move designed to improve productivity and customer service at its Hartlepool, UK, site, Tata Steel recently announced plans to invest $9.35 million in enhanced welding and materials handling equipment.

The investment will improve the welding capabilities at two of the company’s Hartlepool mills, the 42-in. submerged arc welding (SAW) mill and the 20-in. high-frequency induction (HFI) mill, as well as improving handling equipment at both mills.

The 42-in. SAW mill produces thick wall, small-diameter line pipes used primarily in deepwater environments by the oil and gas industry. The company is adding a fifth welding line that will increase the mill’s internal welding output by 25%. The new equipment will incorporate digital technology to enhance accuracy and control of the welding process.

The 20-in. HFI mill produces a range of tubular products for the structural, mechanical, process plant, and energy markets. It will receive a new 1.8-MW solid-state induction welding machine to enhance weld integrity and increase manufacturing output.

The mills will also receive new cranes, handling equipment, and storage. According to the company, the investment forms a critical component of its five-year plan to increase the productivity and cost effectiveness of the Hartlepool plants. Preparatory work has already begun and the installation and commissioning of the new equipment is scheduled for the first half of 2012.

RMT Robotics Names Mobile Robot Sales Agent in India

RMT Robotics®, Grimsby, Ont., Canada, recently entered into an agreement with Larsen & Toubro’s LTM business unit that gives exclusive rights for the promotion and sale of the company’s ADAM™ autonomous mobile robot products. The robots are designed to perform tasks independently, navigating around fixed and moving objects.

The robots transport work-in-process materials and finished goods in lean manufacturing and assembly applications. It is designed to perform tasks independently, navigating around fixed and moving objects.

LTM, Chennai, India, designs, manufactures, and implements a wide range of rubber processing machinery, auxiliary equipment for plastics processing, and custom-engineered products.

“LTM recognizes the need for automated materials handling solutions in the growing Indian manufacturing sector,” said S. Arul, the company’s head of marketing, customer service, and testing.

Serimax Wins Welding Contract for Angolan Offshore Project

Serimax EMEA/CIS, a member of the Serimax Group headquartered in Villepinte, France, was recently awarded the welding contract for Total’s CLOV SURF project offshore of Angola.

The project will be carried out next year onboard its partner Subsea 7’s new flagship vessel, Borealis, and involves fabrication of approximately 5500 welds on 10- and 12-in. pipes at water depths of 1000 to 1400 m (~3281 to 4593 ft). A large part of the project will be welded in a J-mig setup and includes corrosion and fatigue-sensitive sections.

Eriez Announces Expansion Plans

Eriez® recently announced it will expand its operations in the United States, Canada, China, and India. The company manufactures and markets technology for separation, vibratory, and inspection applications through 12 international facilities located in six continents.

The company has purchased a 114,000-sq-ft building approximately 15 miles from its world headquarters in Erie, Pa. The new building will house a service center and handle manufacturing of the company’s largest and best selling equipment.

The Eriez Minerals Flotation Group, headquartered in Vancouver, BC, Canada, will move from its current location to a larger building nearby, which will allow the company to build its largest proprietary equipment in-house rather than utilizing subcontractors.

Eriez-China will add another manufacturing plant in Tianjin to supplement its current Qinhuangdao plant, and Eriez-India will move to a new 25,600-sq-ft plant. Besides the factory space, the new facility in Chennai, India, includes an 8700-sq-ft laboratory that will be capable of testing wet and dry samples.

Donaldson Opens Test Labs in Three Countries

The new lab at Donaldson’s Greater China R&D Center in Wuxi, China, has facilities for conducting a variety of performance tests.

Donaldson Co., Inc., recently opened three new testing labs in China, India, and the United States to support its customers around the world. Donaldson, headquartered in Minneapolis, Minn., manufactures filtration systems and parts.

The company added a new lab to its Greater China R&D Center in Wuxi, China, to support its engine products business. Donaldson expanded its regional headquarters and manufacturing facility in Gurgaon, state of Haryana, India, to include a new air intake testing lab. Donaldson Torit®, a division of the company’s Industrial Filtration Solutions business, opened a new test lab in Bloomington, Minn., to evaluate combustible and noncombustible materials in new and existing filtration products.
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Q: In the September 2010 Stainless Q&A column, you proposed that the suggestion in AWS D1.6/D1.6M:2007, Clause 5.3.4, that stainless steels should “be welded with as little restraint as possible” was an unnecessary restriction for nominally austenitic stainless steels and their weld metals that normally solidify as primary ferrite, such as 304L, 308L, 316L, and the like. The reason is that these steels and their weld metals are virtually immune to hydrogen-induced cracking and are highly resistant to solidification cracking. I understand that, but these steels and weld metals are susceptible to stress corrosion cracking (SCC). If a weldment of 304L or 316L is going into service where SCC is of concern, would it not be prudent to return to the D1.6 suggestion to minimize restraint in order to lessen SCC likelihood?

A: AWS D1.6/D1.6M:2007, Structural Welding Code — Stainless Steel, is written for applications where corrosion is not a primary concern. But let’s look beyond D1.6 and consider whether weld restraint is important when SCC is a possibility.

Stress corrosion cracking is a form of localized corrosion that can be very damaging to austenitic stainless steels. Three factors seem necessary for it to occur: an aggressive corrosion medium, relatively high tensile stress at the exposed surface, and a susceptible alloy. As it happens, austenitic stainless steels with neither austenite nor carbide content (around 7 to 15% Ni) seem to be most susceptible to SCC. This includes steels like 304L, 316L, 317L, and their matching weld metals including 308L. The aggressive corrosion media usually is an aqueous solution containing chloride ions, although any of the halogen element ions can produce SCC. Given these facts, once the base metal is chosen, what we can influence in a given chloride-containing solution is the tensile stress. So it might seem that minimizing weld restraint should be beneficial.

The local stress state at the exposed surface includes both applied stresses and residual stresses from welding, fitup, forming, etc. In many (probably the vast majority) of the cases of SCC, it is the weld residual stresses that are the main contributors to the cracking. These residual stresses arise when the weld metal and heat-affected zone (HAZ) cool and contract. The surrounding base metal resists this contraction because it is much cooler than the weld metal and HAZ. In the simple case of a single-pass weld in a butt joint between two initially flat plates, the weld and HAZ contraction are responsible for the well-known tendency for the unrestrained weldment to assume something akin to the flatness of a potato chip when cooled. To achieve this potato chip shape, tremendous residual stresses are necessary. You can also get an appreciation of the severity of these residual stresses by trying to use an abrasive saw to cut a weldment in two from one edge perpendicular to the weld. As you cut away base metal on only one side of the weld, you allow the tensile stresses along the weld length to try to close the kerf. In my experience, the cut does not reach the weld because the residual stresses pinch the base metal into the blade and actually cause the saw to seize.

As long ago as 1944, Spraragen and Cordovi (Ref. 1) reviewed literature concerning residual stresses in weldments. Their literature review indicated tensile residual stresses approaching the yield strength in many unrestrained arc welds, especially at the surface along the weld centerline. Much more recently, simulation and experimental data reported by Dong et al. (Ref. 2) likewise showed residual stress levels approaching the yield strength in austenitic stainless steel pipe weldments.

Restraint may change the distribution of the residual stresses. Removal of the restraint after welding may actually allow some relaxation of residual stresses. But the core fact is that residual stresses approaching the yield strength are likely to be found in any weldment of significant size in the as-welded condition. So, in the as-welded condition, any austenitic stainless steel weldment in the common grades like 304L, 316L, and 317L is likely to be susceptible to SCC in an aqueous chloride environment. Minimizing restraint is unlikely to have any beneficial effect in this regard.

There are treatments that can be done to reduce residual stresses and thereby lessen susceptibility to SCC. Postweld heat treatment can provide some stress relief. However, stress relaxation is slower in austenitic stainless steel than it is in carbon steel because the austenitic stainless steel is stronger at elevated temperatures. Also, there is some risk of sensitizing the steel and/or forming sigma phase where ferrite was. The risk of sensitization is minimal when low-carbon grades of stainless steel base metal and weld metal make up the weldment. But sigma phase can be more of a problem. Both chromium carbides (which can cause sensitization) and sigma phase form in the temperature range of about 1000°F to 1650°F (540°C to 900°C). This is also the temperature range in which thermal stress relief is most commonly done.

Peening of the weld can be used to induce compressive stresses at the exposed surface. This can be very effective in mitigating SCC, but it is difficult to verify that the tensile stresses have indeed been reduced or reversed. Peening is a bit of an art, and some fabrication codes do not allow it for stainless steels. D1.6/D1.6M:2007 allows it with approval of the engineer, but is more restrictive on root and cover passes than on the interior passes of a multipass weld. And it is the root and cover passes that are exposed and, therefore, are at risk for SCC.

Another possibility for residual stress relaxation is mechanical stress relief. This is mostly done to pipe. The pipe can be internally pressurized to near yield stress, which causes plastic deformation in the areas where there are already tensile residual stresses. Then, when the internal pressure is removed, the entire weldment relaxes to a much lower stress level. But, in general, mechanical stress relief is difficult to apply and it is difficult to be certain that the desired effect has been achieved.

In conclusion, if SCC is a concern, I think austenitic stainless steel base metals like 304L or 316L are being misapplied. Rather than attempting somewhat uncertain methods of reducing susceptibility to SCC in a common austenitic stainless steel weldment such as 304L or 316L, I would suggest selecting a SCC-resistant base metal such as a duplex stainless steel, with more-or-less matching duplex stainless steel filler metal.

References


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Q: My company is in the process of quoting several new assemblies that require resistance spot welding. I am concerned that the specified widths of the flanges are too small for the required electrodes. Are there sources for flange width design recommendations that I can reference so as to determine whether or not the proposed concept is capable of supporting the required resistance spot weld?

A: We discussed this same question in the RWMA Q&A that ran in the September 2011 Welding Journal. In that column, I mentioned that the subject of a required minimum flange width is a source of continual debate within the resistance welding community. To illustrate this point, several design recommendation sources were cited (Refs. 1, 2) to show that no one really agrees on what the proper flange width should be. With that as background, this column will illustrate some of the variables that tooling and product designers should be aware of as they determine how much flange width is necessary to support a proper resistance spot weld (RSW).

Fig. 1 — Representation of a generic electrode cap/weld flange interface and possible location dimensional variables.

To better understand the relationship between the welding flange and where the actual weld ends up, it is necessary to identify and understand the different variables, or elements, that contribute to the required minimum flange width. To varying degrees, all are present and have an effect every time a weld is made. How-
ever, as is common in most analyses of a complex and dynamic situation, the hard part is not identifying the elements that contribute to process variability, but rather the effect, or contribution, that each individual element has on the total variability. The representation in Fig. 1 details a generic electrode cap/welding flange interface and the identified elements that can affect the required minimum width. These elements are further discussed below.

A note of clarification: The assumption we are making here is that we are dealing with a single side of a weld flange, as shown in Fig. 1. If we assume we add an identical mating flange (mirror image) the analysis still holds true, unless one flange shifts along the mating surface of the other. Some designers say this shifting means the parts are no longer “line to line.” Also, we are not accounting for the effects of either the wall angle or bend radius. However, both are important considerations with regard to the selection of the electrode adapter and cap geometry.

**Maximum Electrode Face Diameter (MFD):** It is a given that the electrodes associated with RSW will wear over time. This phenomenon, also known as mushrooming, results in an increase in the electrode contact face diameter. The exact amount of wear per weld is difficult to predict as many factors can affect the rate of degradation. Nevertheless, this wear must be accounted for by determining the maximum acceptable face diameter the process can tolerate. Also, the degree that electrode face growth has on the location of the weld will vary with the process and the electrode maintenance philosophy. For example, the effect of electrode maintenance on altering the amount of wear can be tied directly to the periodicity of electrode redressing/changing. Also, the amount of variability associated with MFD, as a percentage of total variability, tends to increase as the ratio of body diameter to contact face diameter decreases.

**Assembly Positional Tolerance (APT):** The definition for APT is the variation of the assembly from its desired location with respect to an established reference point. This critical element applies whether the assembly is located by means of manual positioning, hard automation (i.e., a dump or a slide), a robot, or any combination thereof, and is needed to account for the inherent variations associated with positioning any part to be welded.

**Electrode Positional Tolerance (EPT):** The definition for EPT is similar to APT and is the variation of the electrode position from its desired location, with respect to an established reference point. This variation may also be the result of manual positioning, hard automation, or a...
robot. To further understand this source of variability, two different aspects must be considered: the physical condition of the tooling that is locating the electrode (i.e., the robot itself) and the process utilized to actually position the electrode (i.e., the robot program). As in all mechanical systems, EPT will be at its lowest value when the tooling is in its most mechanically robust condition. Please note that we must be careful not to assume new tooling is at its most robust condition and therefore contributing its lowest value for EPT. Why? This assumption would discount any potential improvements the hard-working folks on the plant floor make as they continuously strive to improve the assembly and welding process.

It almost goes without saying that the process utilized to position the electrode caps has an effect on the EPT. We only need to visualize how unrepeatable we are pounding in a nail, let alone how we would be attempting to position a manual welding gun. It should be noted that some modern assembly lines employ separate robots to independently position both the assembly to be welded and the welding gun simultaneously, with the resultant potential to significantly increase overall variation as both EPT and APT come into play.

**Expulsion Dam (ED):** The act of creating a proper resistance spot weld is, by its very nature, a quick and violent physical transformation. To help constrain this process, a certain amount of unaffected base material must be present to surround the newly forming weld nugget. This required base material is called the expulsion dam (ED). The minimum required amount of material needed to act as an effective ED can vary by material, stock-up (total, ratio, 2T, 3T, etc.), and electrode cap configuration. Figure 2 illustrates a generic stock-up/electrode cap combination and serves to illustrate how weld nugget growth can relate to the contact area of the electrode faying surface. From a design perspective, values for ED of ap-
proximately $1.5 \times \text{Governing Metal Thickness (GMT)}$ should be sufficient.

**Cut Flange Tolerance (CFT):** This element of variability is perhaps the easiest for anyone associated with manufacturing to grasp, most likely due to the fact that “short metal” is the initial default answer for almost any edge welding condition, whether the flange is actually dimensionally within specification or not. That being said, even if the plant welding engineer is fortunate enough to have parts designed with sufficient flange width, vigilance is still needed. The steady accumulation of hits will take their toll on the stamping dies, and despite the best efforts of the maintenance staff, subtle changes in dimensions will occur due to wear. This wear can manifest itself in many ways, with a common issue being flange bend radii “wash out,” or an increase in radii diameter. If it is assumed the overall dimension of the stamped part blank hasn’t changed, an increase in the bend radius has the effect of reducing the width of the flange’s weldable flat area, with the resultant complications associated therein. If, because of the apparent length increase, the blank is trimmed to compensate, there will be a too-short flange condition when the die is repaired and returns the bend radius to design intent.

All of these elements are present every time a weld is made. But, as stated previously, the effect that each has on the total variability of weld location on a given flange is difficult to quantify. Some engineering groups argue that it is statistically unusual for all of the tolerances to stack up in a purely additive manner, so they, therefore, do not advocate the use of a worst-case, linear-condition sum of the tolerances. Instead, the square-root of all squared and summed tolerances is used for determining the required minimum flange width. This is called an RMS tolerance and is used as a more realistic approach to make tolerance calculations more reasonable.

While the previous items focused on welding, there can be other considerations that directly affect the required minimum flange that may have nothing to do with welding at all. Examples include the addition of sealers and adhesives into the weld joint. These essential items require sufficient surface contact area in the joint to be fully effective and sometimes mandate the selection of a welding flange that is wider than would be the case without their presence. Also, the higher-strength materials used more common in today’s designs may drive the need for a wider flange as they present a challenge to the stamping facilities that are asked to form them. These are but two quick examples that come to mind, and I am sure there are others.

These points, taken as a whole, attempt to illustrate a few of the many considerations that must be taken into account when designing just the welding flange of a part to be spot welded. However, the maturity of the RSW process has resulted in product designs, and designers, that have a great deal of intrinsic inertia associated with them, resulting in many very weldable joints. This maturity can be both a blessing and a curse, as it is possible for those tied to the product design and review process to become complacent. The addition of newer materials to the system that do not conform with the “norm” and/or product designers’ attempts to reduce flange widths too much because they were never taught why they were that wide to begin with, are but two examples of why the design standards were created and need to be adhered to, lest a less-then-robust process be given to the manufacturing facility. In other words, just because you have a voice-activated dialing system in your car does not mean you shouldn’t memorize your home phone number. After all, you might find yourself in a situation where you must dial it manually.◆

**Acknowledgment**

I would like to thank Tom Morrissett, a past AWS D8 chair, for his invaluable perspective on minimum flange width requirements.

**References**


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Automatic Evaluation of Digital Radiographic Images

Image processing techniques make digital radiography less expensive, especially for batch inspections

BY S. DAS, D. MUKHERJEE, AND B. K. SHAH

The current trend in radiographic inspection is toward digital image-based evaluation of radiographs. The digital version of the image offers a substantial advantage over conventional film radiography in terms of dynamic range, linearity, and reusability of the image recording medium. Radiographic image inspection is more economical if it is fully automated. Work is now being carried out in automatic image evaluation, particularly for batch inspection where a large number of similar objects are examined. Image processing plays a unique role in automatic image evaluation as it modifies the image and makes evaluation easier. This article discusses various image processing techniques and their roles in automatic evaluation.

In one situation, an automatic radiographic inspection system was employed in which the whole inspection process was completed with a dedicated computer radiography system without any interference from the operator. The process starts with the acquisition of X-ray images, followed by automatic image processing, and concludes with automatic evaluation of the image. The automatic image evaluation is highly consistent and improves productivity. The complete flow sheet of automatic image evaluation is as follows:

1. Generation of digital radiograph using Digital Detector Array (DDA)
2. Contrast optimization of acquired image using look-up table (LUT)
3. Noise suppression using image integration or low pass filtering
4. Modification of image using high and low pass filtering
5. Threshold setting for segmentation
6. Feature measurement and classification of flaws

Therefore, image processing plays a vital role in automated inspection and comes into play immediately after formation of the digital radiograph. The automated system places high demands on the control software as there is little human supervision of the process.

Noise Reduction

The quantum nature of X-ray emissions from the target makes the radiographic image noisy, which is sometimes noticeable in the image. The quantum of noise is a function of X-ray intensity and read-out time of the detector. Therefore, the signal-to-noise ratio needs to be improved at this stage, otherwise it will induce errors in the subsequent processing operation. The signal-to-noise ratio in the digital radiographic image is defined as the ratio of mean gray value to its standard deviation in a region of interest. One way to improve the signal-to-noise ratio is to average a number of single X-ray images identical in nature, i.e., digital frame integration. This is achieved by calculating the arithmetic mean of the signals collected over a certain period of time or certain number of video images. The improvement in signal-to-noise ratio achieved in image integration is proportional to the square root of the number of images integrated, as shown in Fig. 1. A prerequisite of automated image evaluation is to obtain noise-free images; image integration has solved noise-related problems in many cases.

Look-Up Table

The digital radiograph, to be displayed on the monitor, is first loaded into the primary memory (RAM) of the image processing system. Sometimes the image needs to be displayed differently from the original image to emphasize structural
features. This is accomplished with the help of a look-up table (LUT). Contemporary image processing units offer both an input and an output LUT. The input LUT is a bridge between the camera and the computer’s central processing unit (CPU); the output LUT connects the CPU with the monitor. With the help of the LUT, the brightness and contrast of the original image can be changed as desired. It can even be used to convert the original image into a binary image. This step is important in the segmentation process, where images of defects are isolated from the background. The threshold value for binary coding is selected in such a way that it segments only the image of the flaw from the rest. In Fig. 2, the LUT increases the brightness of the original images and the intensity saturates at an input gray value of 155, where all values greater than 155 in the input LUT are marked as 255 in the output image.

Noise Suppression

Noise is an irrelevant part of the signal and is supposed to be sorted out before evaluation. There are different types of noises, and they are broadly classified into two categories. The first is additive noise, which can be removed from the signal through simple modeling. The other is multiplicative in nature, and requires special and complex algorithms for removal. Before applying a particular algorithm to remove noise, the type of noise first needs to be identified. Afterward, a particular filtering technique can be applied on the raw image.

Most noises are high-frequency components as their intensity changes sharply across the noise. Therefore, in many cases, a simple low-pass filter will be appropriate for removing most noises. The low-pass filter is characterized by putting only positive values in the filter mask. The size of the filter mask determines the strength of the effects. For most of the filtering operation, a small 3 × 3 filter mask removes all noises in a single operation. An increase in filter size increases the computation times considerably as it puts an additional burden on the image processing.
unit. A noisy radiograph of a simple butt-joint weld is shown in Fig. 3. Note that the presence of white spots can be confused with weld spatter. A simple, low-pass, $3 \times 3$ filter was used to remove such noises from the radiograph.

The kernel used for the convolution operation is as follows:

\begin{center}
\begin{tabular}{ccc}
1 & 1 & 1 \\
1 & 2 & 1 \\
1 & 1 & 1 \\
\end{tabular}
\end{center}

Figure 4 shows the filtered radiograph after convolution. Most of the noise was eliminated during the process.

**Edge Enhancement Operation**

Unlike a photographic image, a radiographic image is low in contrast and lacks sharpness. Therefore, it is necessary to enhance the edge details of the objects in radiographs. If any flaw appears in the radiographs, its adverse impact on structural integrity need to be assessed; therefore, flaws need to be dimensioned. The exact dimensioning of flaws in the image is sometimes difficult for certain types of flaws. Under such circumstances, image processing can be a valuable tool to enhance the edge boundary of flaws. Edges of flaws in radiographs are high-frequency components and, therefore, convolving the digital radiograph with a high-pass filter sharpens the edges of a flaw from the background. Once the flaw’s boundary is enhanced, different features of the flaw are measured and the flaw can be classified. Figure 5 shows the radiographic image of a weld with excess root reinforcement.

The image was filtered with a high-pass filter to obtain three-dimensional impression (“pseudo 3-D”) of the specimen. The kernel used for the filtering operation is as follows. As it gives a three-dimensional appearance of the job, it is sometimes called a pseudo-plast filter. The final image with a clear boundary between the weld and the heat-affected zone is shown in Fig. 6.

\begin{center}
\begin{tabular}{ccc}
0 & 1 & 1 \\
-1 & 0 & 1 \\
-1 & -1 & 0 \\
\end{tabular}
\end{center}

**Conclusion**

Automatic image evaluation is a newer concept for batch-type inspections and is being used in the automobile industry. This type of evaluation must ensure that flaws that lead to a rejection are detected by the system. The false reject rate, i.e., number of parts falsely classified as reject, has to be negligibly low. To ensure reliability of inspection, image processing techniques are used at different levels to ensure a high confidence level and minimum false reject rate.

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Advanced Technologies for Tandem SAW Narrow Groove Applications

Automation technology takes on the challenges of the tandem narrow groove submerged arc welding process

BY DON SCHWEMMER, BOB BEATTIE, AND PATRICK WAHLEN

The use of narrow, deep joints reduces the number of passes as well as the time and materials it takes to build pressure vessels such as the one shown above.

As the section thickness of vessels for the nuclear and petroleum industry increase, the desire for reduced weld time and material consumption has driven the joints on these vessels to become narrower and deeper. Narrow joints significantly reduce the number of passes, time, and materials needed to complete each weld. Whenever the needed material and specification allow, the submerged arc welding (SAW) process — ideally, the tandem process using two torches — is preferred due to its ability to provide higher deposition rates and to produce high-quality, reliable weldments.

To achieve the desired weld properties, these joints are typically produced by depositing one or more root passes and then making two passes per layer until the joint is filled — Fig. 1. The two passes per layer method minimizes undercut, trapped or mechanically locked slag, and concave weld profiles. This method requires the ability to swing the weld wire nozzles from side to side as each pass is made. The process may also require changing the mode of the power supplies from DC to AC as the weld transitions from the root passes to the fill passes to achieve the greater deposition associated with AC SAW. In some cases, the use of AC-only welding may be necessary due to arc blow in a deep narrow joint.

Consider looking down 12 in. inside the 1.5-in.-wide weld joint of a thick-section reactor vessel, 16 ft in diameter, 40 ft long, weighing more than 500 tons, that’s sitting on turning rolls, and is preheated to greater than 250°C, while trying to control the vertical and horizontal position of two SAW torches to maintain exactly 0.110 in. off the moving side wall for more than 24 h. Don’t forget that you also need to smoothly switch to the other sidewall every 360 deg. These are only a few of the important requirements of this process.

Tandem narrow groove SAW is among the most challenging welding processes to perform and automate. Consistent performance is a balance between wire position from the sidewall and the deposition rate. For a given deposition rate, if the wire is too close to the side, undercutting and underfilling will likely occur; if too far, the bead becomes more concave and incomplete fusion and flux entrapment can occur. Successful automation of this process requires critically accurate control of the wire position with respect to the joint sidewall as well as the power delivered to each weld wire. However, the latest technologies are now being applied to make this demanding process more automated, manageable, and successful.

There are four areas in which significant advances have been applied to this application: 1) Rigid and precise servo-controlled weld heads; 2) scanning spot laser tracking systems; 3) accurate digitally controlled power supplies; and 4) totally integrated digital control and process monitoring systems.

Narrow Groove Weld Heads

Successful narrow groove welding must begin with the head — Fig. 2. A narrow groove head needs to be relatively long and thin to reach into these joints, and it must also be designed to be rigid and to maintain dimensional stability at high temperatures for long periods of time. Designs and materials are optimized for the long, thin profiles while providing consistent performance.
as massive a frame as possible for rigidity, current transfer, and heat dissipation. The latest heads are a composite of materials to provide structural integrity, thermal stability, and electrical conductivity, as well as isolation and contamination protection from potential contact with the sidewall of the part in these “tight” joints.

The deep, narrow profile of these joints, especially beyond 6 in., prohibits actually tilting of the whole head from side to side as the joint fills, so the head must have articulating nozzles that allow the weld tips to be angled into each sidewall. After each pass, the nozzles must swing to the other side to provide the appropriate entry angle. This also has to be coordinated with the head cross-seam slide as the entire head will need to move slightly to maintain the same sidewall offset with this entry angle as the joint widens and is filled.

Although torch angle articulation has been historically performed pneumatically or with relatively simple mechanical devices, new generations of heads are utilizing precision servomotor- and encoder-based systems to be able to move under programmable control. This provides several significant advantages including the ability to vary the entry angle as the weld progresses, to have different angles for each torch nozzle (lead or trail torch), and the ability to control the speed or smoothness of the transition from one sidewall to the next after completion of each pass. Servo-encoder-based control of the torch angle as well as the cross-seam and height position slides allows for the coordination of all of these positioning devices to better ensure the desired position of the weld wire.

The overall narrow groove torch heads now, appropriately, become massive rigid structures with heavy-duty precision slide assemblies, redundant wire straighteners, integrated video cameras, laser sensors, and flux delivery/recovery systems — Fig. 3. This is all to ensure the accuracy and repeatability of this process.

**Scanning Spot Laser Tracking Systems**

As important as accurately placing the wires is, having the ability to precisely know where to place them is equally crucial. Thus, being able to determine the joint profile in real time is vital.

Mechanical tracking with probes has been a common and reliable method of tracking joints to accommodate for movement of the part, or variations in the part or weld geometries. However, mechanical tracking systems must contact the part and can only give position information where the probe is in contact. Also, unless there is a probe on both sidewalls, transitioning from one side to the other can be difficult and usually requires the process to stop and be reset for the opposite sidewall. When there are two probes for the sidewalls and one for the base of the joint, the amount of equipment inside the joint becomes significant and cumbersome.

Laser tracking would be an ideal solution as it is noncontact (located away from the joint) and could provide a complete profile of the joint. However, as joints became deeper and narrower, the reliability of conventional laser tracking systems to “see” these joints became more and more of a problem. Fortunately, an unconventional approach to laser tracking provides a viable solution.

There are two main approaches to laser-based weld joint tracking: one uses a laser stripe and the other a laser spot. The simpler, more common approach to laser tracking is to project a laser stripe onto the part and then image the complete stripe with an area detector (camera). However, there are potential image quality problems with this approach for narrow groove joints. Since the entire laser stripe is always on and the entire image is always illuminated, shiny surfaces, typical of narrow groove joints, create secondary reflections, which may return more light to the sensing camera than the primary surface of interest. This results in difficulty analyzing the image to determine the actual weld profile. Due to the steep and long sidewalls of these joints, significant secondary reflections can be present, thus reducing the reliability of the system to accurately track and characterize the joint.
A laser spot scanner uses a laser spot instead of a laser stripe. The spot scanner makes only a single point measurement at any one time and thereby requires a scanning mechanism (Galvo Scanner) to sweep the spot (and linear detector) across the weld joint. This principle is illustrated conceptually in Fig. 4.

The reflection of light from one side of the joint to the other and then reflecting back to the imager associated with the laser stripe method is not a problem with the scanning spot sensor. Since the detector is only looking on a line perpendicular to the scan, it literally does not see the reflection. Scanning spot laser sensors also perform well in situations where there is a requirement for a small width of field but a very large depth of field, such as welding deep, narrow grooves. Since a profile of the weld joint is obtained, other advanced software solutions can be applied to calculate the volume of the joint and adaptively control the process to compensate for variances in the groove and sidewalls to achieve more even fill. Finally, because it is measuring at a single point, it is easy to implement an effective automatic gain control on a laser spot scanner so that the sensor compensates dynamically and automatically for variations in surface conditions.

Meta Vision Systems has optimized such a scanner specifically for this application. The joint profile information from its DLS 300 scanning system can be combined with the weld head and torch angle position to accurately determine and display the position of the wire tip with respect to the sidewall and bottom of the joint. Figure 4 also shows a scan of the weld profile from a weld in progress. The marker on the display indicates the position where the wire intersects the bottom of the joint. This scanner also provides important information for controlling the head cross-seam and height slides to maintain the constant sidewall position. The scanning spot laser sensor is, therefore, a powerful tool and a key component in the successful automation of the process.

**Advanced Digital Power Supplies**

All the efforts to accurately characterize the joint in real time and precisely place the wires are for naught if consistent and reliable power cannot be delivered to the wire contact tips. This process can demand more than 700 A per supply for more than 24 hours. It requires both accurate DC and AC output and the ability to switch between modes. The most advanced power sources have enhanced digital control circuitry and software that compensates for variances in power input, temperature, and demand to ensure a consistent, stable output.

In addition to enhanced performance characteristics, the ability for direct digital control has also markedly expanded the automation possibilities of difficult welding processes. This direct control allows these supplies to become an integral part of the complete system and all of their capabilities to be accessed and controlled from a single controller. With the ability to enable/disable the supplies, change modes between DC and AC, vary current, voltage, and AC phasing, all based on part or torch position, automated continuous root-to-cap multipass welds are achievable.

The Lincoln Electric Co. has developed its Power Wave® digitally controlled power supplies specifically for these demanding applications — Fig. 5. The Power Wave® AC/DC 1000® SD is a high power, high-speed inverter design that delivers Waveform Control Technology® for submerged arc welding. The power supplies provide constant current or constant voltage operation and allow variable frequency and amplitude for AC output. The software-driven AC, DC-positive, or DC-negative output allows the user to control
the deposition and penetration. The result is a more consistent, smoother arc at a wider range of parameters, increased weld speeds, consistently higher-quality welds, and improved efficiencies in a single- or multi-arc environment.

The sophistication of the software-based inverter design allows a significant ability to be integrated into an adaptively controlled dynamic system required for the challenging narrow groove environment. Previous-generation SAW power sources had a limited range of functionality, which greatly limited the capability of the welding process to execute a high-quality, high-productivity weld. Newer, more advanced power sources and seamless integration into the overall narrow groove system architecture have dramatically enhanced the operating envelope and flexibility of the welding process.

It is important to note that the efficiency of these inverter-based power supplies yields significant savings in operating costs over traditional transformer/rectifier designs. In a typical industrial operating environment fabricating pressure vessels, each machine can potentially save up to $15,000 per year in operating costs due to its unique design and use of energy-efficient, high-speed inverters.

**Integrated Control and Process Monitoring Systems**

A complex automated system, with servo-controlled weld heads, turning rolls, manipulator boom, two wire feeders, two articulating weld torches, scanning spot laser systems, two advanced power supplies, flux delivery/recovery — each with its independent control devices — can overwhelm even the most experienced engineers and operators. Setting up and monitoring all of the controls for these devices is a procedural challenge and has potential for many costly errors. Process repeatability, minimized operator setup, ease of programming, and reliable process verification are all associated with the quality and design of the control system.

Traditional control approaches for automated systems are to link the controllers together so that the start or change of any given component is activated, or linked, together with the start or change of another component. For example, the process may start with the operator pushing the start button on the turning rolls, which would immediately activate the flux-delivery control, and then activate the controls for the power supplies, beginning the weld. A change in the part diameter or material would most likely require all settings and/or dials of several or all controllers to be changed. Also, since the
communication is typically one way, the “system” would not necessarily be aware that any given function did not occur or was incorrectly set.

Consider how individuals in a workgroup have their own computer processors to focus on their individual tasks. If the computers are networked, then the individuals working on the same project can share all of the relevant information and respond, if necessary, to all other users. The most advanced approaches to complex automated control are based around this same technology as dedicated processors are assigned to control and monitor each process task, and share the information over a network so that other, appropriate components of the system can respond or react. These multiprocessor, networked-based systems have many advantages, especially for complex systems that require many tasks to be programmed, controlled, and monitored. One of the most significant is that all of the parameters for the process can be programmed, stored, transferred, and displayed through a single main controller on the network. This comprehensive control of all process parameters through a single controller provides enhanced accuracy and significantly reduces setup and operational errors as all process parameters are programmed and stored for each weld or part type. This method is shown in Fig. 6.

The AMET XM control system uses such a network to control and monitor each task through digital signal processor powered modules that are dedicated to each task. The ability to share information and have other components of the system respond allows for greater automation than otherwise achieved.

The system can do the following:

- Obtain the laser sensor information and combine it with the servo position information of the head position, torch angle, and preset contact tip-to-work distance to control the head position, maintaining the required sidewall offset and torch height.
- Vary any of the process parameters

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Fig. 5 — Power supplies integrated into the weld system.

Fig. 6 — A — Multiprocessor networked-based control method for a narrow groove application and how each device can be selected and programmed from a single controller; B — a typical monitor view.
Constantly monitor each process and provide process data as well as alerts for out-of-tolerance conditions to the operator at the main controller.

- Provide ethernet connectivity so that the system performance can be monitored from a central station as well as transferring programs and data.
- Provide pre- and postweld automation programming to allow for programmed timing of flux delivery start, prepositioning of the weld head to aid in setup, and other desired functions or moves before or after the weld.
- Easily integrate with other sensors such as temperature measurement because another module for the sensor can be added to the network and the information shared.

The overall effectiveness of these control capabilities also depends on how effectively information is obtained from and provided to system operators and engineers. Systems that can be programmed by selecting desired parameters and entering desired values without any specific programming language or code are more intuitive and valuable. Controllers for integrated systems can be specifically designed to include not only displays, but appropriately placed and integrated joy-sticks, knobs, and buttons with tactile feedback allowing the operator to focus on the process instead of several controllers. Figure 7 shows the operator display and controller for a narrow groove system.

**Summary**

Although the welding community has historically struggled with new technologies, the advances in electronics, processing capability, laser systems, high current control, and network communications have recently provided reliable solutions for several of industry’s most difficult processes. Tandem submerged arc narrow groove welding is now one of them (Fig. 8) as significant improvements in process efficiency and quality can now be achieved with the appropriate automation.

**Acknowledgments**

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Monitoring the Performance of Your Radiography System

An automated, easy-to-use tool simplifies monitoring of digital radiographic imaging systems

BY STEVEN A. MANGO

As the transition to digital imaging technologies continues to gain momentum in the NDE industry, users are concerned with monitoring the performance and stability of their imaging systems. Industry standards (ASTM, CEN) have defined test “phantoms” and methods, but many users are finding these cumbersome to use and/or too expensive. As a result, several military and government defense contractors have developed lower cost alternatives, but these still require tedious and sometimes subjective analyses.

This article describes a unique phantom and an automated method for the quality assurance (QA) of digital imaging systems, providing a simple and quick way to quantitatively measure the key characteristics of storage phosphor-based computed radiography (CR) imaging systems and direct-digital, flat-panel, detector-based direct radiography (DR) imaging systems.

The procedure to acquire images is quick and simple to conduct, which helps to reduce system downtime. The analysis is fully automated, providing precise and sensitive quantitative measures, eliminating all subjectivity and third-party measurement-device dependence. The interface provides a go/no-go status of key performance parameters such as spatial resolution, noise, detective efficiency, exposure response, dark image signal level, geometric accuracy, etc., enabling the inspector to have complete confidence in the imaging system.

Current Process Control Methods

Since the adoption and acceptance of digital radiography in nondestructive examination, users have invested a great deal of time, money, and other resources to learn the technology and make it a success. Hence, there is much interest in protecting these investments and ensuring these digital imaging systems are performing at optimum levels, and that they are delivering what their manufacturers claim. In many cases, such monitoring is required by prime contractors or spelled out in purchaser-supplier agreements.

There are a number of test targets, or phantoms, currently available for such performance monitoring. International standards now specify a comprehensive set of user tests, and phantoms have been designed and are now commercially available for long-term performance and system stability monitoring. These phantoms, while meeting the intent of the standards, are frustrating current and potential users in a number of ways. First, they can be somewhat time-consuming to analyze, taking time away from revenue-producing inspections. Further, the variety of targets often requires either subjective analyses or tedious manual methods. And finally, the cost of these phantoms can be overwhelming for many small- and medium-sized inspection organizations.

As a result, resourceful users are developing alternatives that are simple to create and more cost effective. While these alternatives seem like logical solutions, they can further complicate the situation with more and confusing choices, and they still do not address the need for simplicity and reliability.

A New Approach

Now there is another way. A patented method provides for a simple phantom created by a combination of stamped and laser-cut apertures in a metal absorber — Fig. 1. In addition to providing sharp edges, some of the apertures contain absorbers to provide various degrees of exposure attenuation. The digital image of this phantom is analyzed by a unique software application that precisely locates the apertures and edges, and performs a variety of calculations to characterize system performance. The following descriptions show how the system is used to monitor a CR system, although it can be used with either/both computed radiography and direct digital radiography imaging systems.

How does the system work? When a digital image of the phantom is produced at a given pixel pitch, the apertures are imaged at known and precise locations rel-

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The software can precisely locate the position of each aperture.

The precise locations of the reference markers (apertures) are used to compute a variety of geometric parameters; in this example, pixel aspect ratios.

Modulation transfer function (MTF), a measure of sharpness, is derived from the edges of the large apertures near the center of the phantom. The derivative of the edge produces a line spread function, and the Fourier transform of the line
spread function results in the MTF — Fig. 4. Modulation transfer function is a measure of image modulation as a function of spatial frequency; therefore, the software performs the calculation at all frequencies from zero to the Nyquist frequency. For monitoring purposes, however, a single point at 50% of the Nyquist frequency is chosen, although the entire MTF curve is available for display to those so inclined. While such calculations are not for the timid, the software can accomplish this with speed and accuracy.

The large apertures near the center of the phantom are fitted with absorbers of known properties, producing varying pixel values. With a standardized X-ray exposure technique of 80 kV and 10 mR dose, and standardized scanner calibration, these absorber properties produce “expected values” from which exposure latitude and linearity can be determined. The pixel values in a 2.0 x 2.0 cm (0.8 x 0.8 in.) square are also analyzed for a calculation of image noise level.

A Quality Tool

In addition to the analyses described above, we can put the software to work on a standardized flat-field uniformity image to characterize a variety of critical uniformity parameters. The maximum variation in response to a uniform exposure is an overall measure of field uniformity. The difference in response between adjacent lines in the slow scan direction is a measure of transport “chatter.” A line position noise function is derived from the position of the start of any of the fast scan lines. Similarly, periodic fluctuations in the slow scan direction indicate banding associated with the drive mechanism, and any other fluctuations between adjacent lines or rows of pixels are logged as general streaks.

What makes the tool unique among modern process monitoring tools is its automated nature. A user interface allows the operator to analyze an exposed imaging plate and get an immediate reading on the health of the system with status lights for each of the system tests. The calculations are compared against a table of expected results and tolerances and will present a green light if the system is “good to go,” an amber light when results are approaching their limits, or a red light when service or recalibration is indicated — Fig. 5.

There is no subjectivity on the operator’s part, so there is no need to be concerned with numbers, tolerances, or decisions. User-friendly documentation guides the operator to an appropriate course of action in the case of an amber or red light, eliminating guesswork and minimizing downtime. The system logs the latest 50 test results, and the operator may review any of these test logs and/or individual test results.

It is important to note that this tool is not intended for digital imaging system qualification, per se. Nor is it intended to be used across different imaging platforms for comparison purposes, as it is designed to accommodate a particular system’s imaging and operating modes. The real performance capabilities of an imaging system, and its relative performance against competing systems, should be determined well ahead of its acquisition, through practical demonstrations with real imaging and inspection applications. It is after the acquisition, during routine use, handling, maintenance, and transportation over a period of months and years when the capability for long-term stability and performance monitoring becomes important.

Summary

Today’s NDE professionals are fortunate to have a variety of tools and resources available to help them navigate through the maze of digital technology. However, the choice of tools can sometimes be overwhelming and frustrating, adding unnecessary stress to the task at hand. This automated, user-friendly tool for the monitoring of digital radiographic imaging systems simplifies CR and DR system monitoring. This helps to make the NDE inspector’s job easier and the operation more cost effective.
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The AWS Foundation is pleased to announce additional scholarships for the 2011-2012 school year

National Scholarship Program

Congratulations to Derek Jacobson, recipient of the Hypertherm International Hy-Tech Leadership Scholarship

“I am very honored and thankful to be awarded the Hypertherm International Hy-Tech Leadership Scholarship for the 2011-2012 school year. With the help of the American Welding Society and the Hypertherm Scholarship, my goals and dreams are becoming a reality. I am honored to represent them both while continue my leadership and education at Utah State University. I would also like to give a sincere thanks to my family, friends, and professors that have supported me throughout my education.”

Utah State University
Masters of Business Administration

Section Named Scholarship Program

Section Named Scholarship Program

Scholarships sponsored by AWS Sections to support students

Congratulations to Jacob Quisenberry, recipient of the Amos and Marilyn Winsand – Detroit Section Named Scholarship

“I am very thankful to be selected as the recipient of the 2011-2012 Amos and Marilyn Winsand – Detroit Section Named Scholarship. The Winsand family and the AWS have made it possible for me to continue my welding education so that I can pursue my dream of working as an engineer. I would like to thank the Winsand family for their contribution to my education.”

Ferris State University
Welding Engineering Technology

Congratulations to Narciso Gutierrez, recipient of the George Kampfhafer – Houston Section Named Scholarship

“I just wanted to say thank you for awarding me this scholarship, so that I was able to return to school at the age of 34 and get a trade at the Ocean Corporation in Houston, TX. I’ve never been happier in my life. The AWS has definitely been a blessing in my life. For all the support and encouragement.”

The Ocean Corporation
Welding/NDE Inspection

Congratulations to Hugo Aquino, recipient of the Ronald S. Theiss – Houston Section Named Scholarship I

Lone Star College – Cyfair – Welding

Congratulations to Trevor Tedrick, recipient of the Ronald S. Theiss – Houston Section Named Scholarship II

“I am truly honored to be the recipient of the 2011-2012 Ronald Theiss-Houston Section Named Scholarship. I would like to thank the American Welding Society, especially the Houston Section, for helping individuals like myself who need assistance to fulfill their dreams and goals. I attend Brazosport College and by getting an associates degree in Welding and Quality Assurance Technology, I will be able to have a career and a good future. I am sincerely grateful.”

Brazosport College
Welding and Quality Assurance Technology

Section Named Scholarship Program

Congratulations to Justin Gordy, recipient of the Ron VanArsdale – Houston Section Named Scholarship

“Thank you to all the hard working volunteers of the Houston Section and our District 18 Director for their support of students like me!”

Lone Star College
Football

Congratulations to Joe Stavinvaha, recipient of the Paul O’Leary Memorial – Idaho/Montana Section Named Scholarship

“As the recipient of the 2011-2012 Paul O’Leary Memorial – Idaho/Montana Section Named Scholarship, I want to extend my sincerest thanks to those who have contributed to this prestigious award. Due to such graciously donations, I am able to pursue my Master’s degree in General Engineering with the Welding Engineering Option at Montana Tech of The University of Montana. I would also like to thank the individuals responsible for selecting me as this year’s award recipient.”

Montana Tech of the University of Montana
Masters in General Engineering
Welding Engineering Option

Congratulations to Kelvin Dewalt, recipient of the Lehigh Valley Professor Robert D. Stout Named Scholarship

“I am thankful and honored to be the recipient once again of the professor Robert D. Stout Scholarship. This scholarship is very valuable to me as I continue my welding education and strive to achieve my goals. I am very appreciative of the Lehigh Valley Section of AWS and their support of the future of the welding profession.”

Pennsylvania College of Technology
Welding Technology

Congratulations to Kelly Michelle Wilson, recipient of the Ronald C. and Joyce Pierce – Mobile Section Named Scholarship

“I am honored to receive the Ronald C. and Joyce Pierce-Mobile Section Named Scholarship and would like to thank the members of the AWS Foundation and the Pierce family for their outstanding generosity. The AWS Foundation has been a huge support throughout my collegiate years, and they have motivated me to seek out new opportunities in my field. I look forward to an exciting career upon finishing my degree.”

University of Alabama
Materials and Metallurgical Engineering
Section Named Scholarship Program

Congratulations to William Tyler Miller, recipient of the Ronald C. and Joyce Pierce – Mobile Section Named Scholarship

"I am very grateful and honored to be selected recipient of the Ronald C. and Joyce Pierce Scholarship award. The financial assistance and support from the AWS Foundation gives students like me the opportunities to pursue my dreams of a career in engineering and other welding-related fields. Thank you for making this experience possible!"
University of Central Florida
Mechanical Engineering

Congratulations to Brittany Lynne Mandell, recipient of the Ronald C. and Joyce Pierce – Mobile Section Named Scholarship

"I am very thankful and honored to be the recipient of the Ronald and Joyce Pierce – Mobile Section Named Scholarship. I want to thank the American Welding Society Foundation for this scholarship to help me continue my education. It is a privilege to have been chosen for this scholarship which inspires me to succeed in school and to reach my goals. Thank you again AWS for your generosity."
Louisiana State University
Mechanical Engineering

Congratulations to Derrick Anrecht, recipient of the Shelton Ritter – New Orleans Section Named Scholarship

"In order to achieve a goal, you must be willing to fail along the way."
Southeastern Louisiana University
Engineering Technology

Congratulations to Jessica Jelinski, recipient of the Northwest Section Named Scholarship

"My welding education has given me a successful career in welding. I have given that up for the opportunity to go back to school to become a welding instructor so that I can help others have the same chance at a successful career in welding. I am grateful that the AWS Northwest Section has found my educational pursuits worthy of a scholarship award. It is difficult to follow your dreams, but it becomes easier when you realize how many people believe in you."
University of Wisconsin – Stout
Technology Education

Congratulations to Brady Laffinere, recipient of the Dietrich and Betty Ruth Scholarship

"It is an honor to be this year’s recipient of the Dietrich and Betty Ruth Scholarship. I would like to thank the American Welding Society and all of the people involved with the scholarship programs. The AWS foundation will help me further my education, to becoming a welding engineer. Thanks again for all the support given to me, and other welding students across the country."
Ferris State University
Welding Engineering Technology

Section Named Scholarship Program

Tri-Tool, Inc. – Sacramento Section Named Scholarship

This award is sponsored by Tri-Tool and the Sacramento Section, and was awarded to students in District 22 as part of their District Scholarships

Louis DeFreitas – Santa Clara Valley Section Named Scholarship

This award is sponsored the Santa Clara Valley Section in recognition of Lou DeFreitas, and was awarded to students in District 22 as part of their District Scholarships

District Named Scholarship Program

Scholarships sponsored by AWS Districts and local companies to support students in their communities.

Congratulations to Thomas Davenport, recipient of the District 3 Shirley Bollinger Scholarship

"I am honored to have been selected to receive the 2011-2012 District 3 Shirley Bollinger Scholarship. College costs can be formidable. As a student planning to earn a Bachelor’s degree, and considering my Master’s degree, in Material Joining Engineering, I really appreciate the support of AWS and the Bollinger Scholarship."
Framingham University
Materials Joining Engineering

Congratulations to Dan Hamoud, recipient of the Ed Cable BUG-O District 7 Named Scholarship

"Thank you so much for the 2011-2012 Ed Cable Bug-O District 7 Scholarship. It will help me to pursue an Associates Degree in Certified Welding Inspection."
Yuba Welding School
Certified Welding Inspector

Congratulations to Franklin Loehlein, recipient of the AWS-Detroit Section, District 11 Fred Elliott Scholarship for Arc Welding

"Gratitude to the members of AWS. In support of their time and commitment to the welding industry now, furthermore the future. To have received the Fred Elliott Scholarship is a privilege; it will help me ascertain additional knowledge to continue my career in the industry. The continued support of AWS has and will allow me to reach my goals—thank you."
Ferris State University
Welding Engineering Technology

Congratulations to Sarah M. Ross, recipient of the AWS-Detroit Section, District 11 Dietrich Ruth Scholarship for Resistance Welding

"Thanks to the AWS-Detroit Section District 11 Dietrich Ruth Scholarship for Resistance Welding, I am able to continue pursuing my education in Welding Technology. I am very honored to receive this award. I appreciate foundations, like these, that recognize the need for scholarships and commend hard working students. I am eager to learn more and become part of the future technology, involved with welding. Thank you very much!"
Ferris State University
Welding Engineering Technology

For specific information on the Scholarship Programs, please visit our website at www.aws.org/foundation.
CONFERENCES

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. For additional information, contact Monica Pfarr at mpfarr@aws.org.

Welding Technology to the Rescue
November 14

A number of major research efforts and technological wizardries are beginning to pay off in big ways throughout industry. The effects are numerous, including major improvements in productivity, reduced costs, and quality. Solutions to lingering problems are also being discovered. The trend in new developments is bound to introduce more science into the overall welding scene.

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. The different types of cracking, their causes, and their solutions will be discussed. Learn how to identify the types of cracks, and what to do about them.

What’s New in Power Sources?
November 16

Learn about the advanced features and capabilities available on the latest welding power supplies, including multiprocess operation. Transformer-rectifiers and inverters are on a roll. Experts will be on hand to explain many of these innovations.

Thermal Spray Technology: High-Performance Surfaces
November 16

The International Thermal Spray Association (ITSA) and the American Welding Society have organized this one-day educational coatings conference to introduce and highlight various advantages of the thermal spray process. This program will benefit both potential users and those actively involved with thermal spray coatings as it will focus on actual applications and new developments in thermal spray technology. In addition, on Tuesday, Nov. 15, ITSA will sponsor a free half-day tutorial on thermal spray fundamentals titled Thermal Spray Basics: Putting Coatings to Work.

2012 Conferences

International Electron Beam Welding Conference
March 26–30
Aachen, Germany

The International Electron Beam Welding Conference (IEBW) will bring together scientists, engineers, and technical personnel from around the globe involved in the research, development, and application of electron beam welding processes.

The American Welding Society, the German Welding Society (DVS), and the International Institute of Welding (IIW) are organizing this second IEBW. After the successful first IEBW in Chicago, Ill., in November 2009, it was decided to stage the conference every two years, alternating between the USA, Germany, and, in the future, Asia. The event will receive further support from the Japan Welding Society.

This event is truly one that anyone involved in the electron beam welding community should plan to attend.

For information, visit dvs-ev.de/iebw2012.

5th International Brazing & Soldering Conference
April 22–25
Las Vegas, Nevada

When you attend IBSC 2012, you’ll join hundreds of other professionals, scientists, and engineers from around the globe involved in the research, development, and application of brazing and soldering. The three-day conference will provide one of the most comprehensive technical programs available to the brazing and soldering community, as well as valuable networking opportunities, preconference educational programs, and exhibits where attendees can find out more about the latest trends, products, processes, and techniques available in the brazing and soldering industry. ♦

For more information, please contact the AWS Conferences and Seminars Business Unit at (800) 443-9353, ext. 264, or e-mail zo-liva@aws.org. You can also visit the Conference Department Web site at www.aws.org/conferences for upcoming conferences and registration information.
AWS understands the need for certified individuals within the robotic arc welding industry. In response to this need, a program based on the AWS QC19 and D1.6.4 specifications, has been developed.

Depending on the level of experience, individuals who pass a written exam and performance test can be certified as either Robotic Arc Welding Technicians or Operators.

For more information regarding this program, including how to become an AWS Approved Testing Center, visit our website today at www.aws.org/certification/CRAW or call (800) 443-9353 ext. 211 [email flopez@aws.org].

To schedule training and testing to become certified in robotic arc welding, contact one of these AWS Approved Testing Centers.

Colorado // Wolf Robotics // 4600 Innovation Drive // Fort Collins, CO 80525 // (970) 225-7736 // FABTECH Booth #6322

Iowa // Genesis-Systems Group // 8900 Harrison Street // Davenport, IA 52806 // (563) 445-5688 // FABTECH Booth #5933

Michigan // ABB, Inc. // 1250 Brown Road // Auburn Hills, MI 48326 // (248) 391-8421 // FABTECH Booth #5758

Ohio // The Lincoln Electric Co. // 22221 St. Clair Ave. // Cleveland, OH 44117 // (216) 383-8542 // FABTECH Booth #6122

Ohio // OTC Daihen, Inc. // 1400 Blauser Drive // Tipp City, OH 45371 // (937) 867-0800 // FABTECH Booth #6358

Wisconsin // Milwaukee Area Technical College // 1200 South 71st Street // West Allis, WI 53214 // (414) 297-6996 // On request

ABB, Inc. FABTECH Booth #5758
Genesis–Systems Group FABTECH Booth #5933
OTC Daihen, Inc. FABTECH Booth #6358
The Lincoln Electric Co. FABTECH Booth #6122
Wolf Robotics FABTECH Booth #6322

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<tr>
<th>Date</th>
<th>ABB, Inc.</th>
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<th>OTC Daihen, Inc.</th>
<th>The Lincoln Electric Co.</th>
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<td>10/22/2012</td>
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COMING EVENTS

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


China Aerospace & Aviation Technology Show (CAATS). Nov. 1–5. SNIEC, Shanghai, China; www.caats.aero/.


♦ FABTECH. Nov. 14–17. McCormick Place, Chicago, 111. 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.


Has the lack of a CWI become an obstacle to your success?

The Hobart Institute of Welding Technology has many years of proven experience and success in training and preparing AWS Certified Welding Inspector/Certified Welding Educator students. Our students take the exam on the last day of their 2-week course, right in their classroom.

Visual Inspection
Nov. 21-22 • Jan. 4-5

Arc Welding Inspection & Quality Control
Nov. 28-Dec. 2 • Feb. 20-24 • May 7-11 • Jun. 11-15

Prep for AWS Welding Inspector/Educator Exam
Dec. 5-16 • Jan. 23-Feb. 3 • Feb. 27-Mar. 9 • Apr. 9-20

These and other comprehensive Technical Training courses are offered throughout the year—

Call Today! 1-800-332-9448

or visit us at www.welding.org for more information.

400 Trade Square East, Troy, OH 45373 St. of Ohio Reg. No. 70-12-0064HT

For info go to www.aws.org/ad-index


Educational Opportunities


CWI/CWE Preparation with Exam. AWS Certified Welding Inspector and AWS Certified Welding Educator, two-week-long classes beginning Dec. 5. Hobart Institute of Welding Technology, Troy, Ohio; www.welding.org; hiwt@welding.org; (800) 332-9448.


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

ASM Int’l Courses. Numerous classes on welding, corrosion, failure analysis, metallurgy, 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.

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For info go to www.aws.org/ad-index

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@realeducation.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.


EPRI NDE Training Seminars. Training in visual and ultrasonic examination and ASME Section XI. Sherryl Stogner (704) 547-6174; sstogner@epri.com.

Environmental Online Webinars. Free, online, real-time seminars conducted by industry experts. For topics and schedule, visit www.augustmack.com.


Hellier NDT Courses. Hellier, 277 W. Main St., Ste. 2, Niantic, CT 06357; (860) 739-8950; FAX (860) 739-6732.


INTEG Courses. Courses in NDE disciplines to meet certifications to Canadian General Standards Board or Canadian Nuclear Safety Commission. The Canadian Welding Bureau; (800) 844-6790; www.cwbgroup.org.


Laser Safety Training Courses. Courses based on ANSI Z136.1, Safe Use of Lasers, Orlando, Fla., or customer’s site. Laser Institute of America; (800) 345-3737; www.laserinstitute.org.
The most complete event on weld cracking
Learn different types... Understand the causes... Discover solutions.

At AWS’s eighth conference on weld cracking, the different types of cracking, their respective causes, and their solutions will be thoroughly examined. No incident causes so much alarm as a weld crack. This program will identify and analyze the types of cracks — and more importantly — what to do about them.

For the latest conference information visit our website at www.aws.org/conferences or call 800-443-9353, ext. 264

Register at www.aws.org/fabtechevents
Registration code: W29

Hosted by: American Welding Society®

Earn PDH’s toward your AWS recertification or renewal when you attend the conference!
### Certified Welding Inspector (CWI)

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<thead>
<tr>
<th>LOCATION</th>
<th>SEMINAR DATES</th>
<th>EXAM DATE</th>
<th>LOCATION</th>
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<th>EXAM DATE</th>
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<td>Nov. 12</td>
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<td>New Orleans, LA</td>
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### Advanced Visual Inspection Workshop

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### Important: This schedule is subject to change without notice. Please verify your event dates with the Certification Dept. and confirm your course status before making your travel plans. For information on AWS seminars and certification programs, visit www.aws.org/certification, or call (800/305) 443-9353, ext. 273, for Certification; or ext. 455 for Seminars. Apply early to avoid paying the Fast Track fee.
IT’S ALL HERE. Discover the most innovative technologies, resources and ideas. Engage with industry experts. Find solutions to improve productivity and keep your business competitive.

Get the most out of your time at FABTECH, with career-enhancing programs from AWS!

Special events at

November 14-17, 2011
McCormick Place • Chicago
www.aws.org/fabtechevents
AWS Conferences at FABTECH

AWS conferences and the RWMA Resistance Welding School present innovations and insight you can use in your career and enterprise, while affording the opportunity to network and exchange information with your peers. All conferences include lunch, breaks, and Q&A time.

Welding Technology to the Rescue
Mon., Nov. 14 • 8:30-3:00 • Reg. Code W28
$345 members/$480 nonmembers

A number of major research efforts and technological wizardries are paying off in big ways throughout industry. The effects are numerous. Some are in huge improvements in productivity. Others are in quality. There are brand-new solutions to lingering problems. This trend in new developments is bound to introduce more science into the overall welding scene.

Advancements in CO₂ Shielded Gas Metal Arc Welding
Bill Guest, OTC-Dalhen Inc.

Computed Radiography
R.W. Kruzic, Chicago Bridge & Iron Co.

Quality Assurance in Field Heat Treatment
Gary Lewis, Superheat FGH

DeltaSpot — Resistance Spot Welding with Process Tape
Stefan Mayr, Fronius USA LLC

Reciprocating Wire Feed Systems for Plate Products
Randy Dull, Edison Welding Institute

20 kW Hybrid Laser Arc Welder
Duncan Pratt, GE Global Research

Automated Back Gouging of Thick Plate Weld Joints for DDG 1000 Construction
Bruce Horn and Timothy Freihoff, Concurrent Technologies Corp.

A New Hybrid Laser Arc Welding Center Opens Up
Doug Zoller, American Tank & Fabricating Co.

8th AWS Conference on Weld Crack
Tues., Nov. 15 • 8:30-4:00 • Reg. Code W29
$345 members/$480 nonmembers

At AWS’s eighth conference on weld cracking, the different types of cracking, their respective causes, and their solutions will be thoroughly examined. No incident causes so much alarm as a weld crack. The different types of cracking, their causes, and their solutions will be discussed. This program will identify and analyze the types of cracks — and more importantly — what to do about them.

Understanding Weld Cracking in Steels
Joseph C. Bundy, Hobart Brothers Co.

Crack Avoidance in Creep Strength-Enhanced Ferritic Steels
William F. Newell, Jr., Euroweld Ltd.

Hot Cracking in Austenitic Stainless Steels
Damian J. Kotecki, Damian Kotecki Welding Consultants

Hot Cracking in Austenitic Stainless Steels
Damian J. Kotecki, Damian Kotecki Welding Consultants

How to Prevent Cracking When Welding Aluminum Alloys
Tony Anderson, ITW Global Welding Technology Center

Hydrogen Induced Cracking in Welding High Performance Steels
Yoni Adonyi, LeTourneau University

Investigation of Weld Metal Cracking in a Hydrotreater Vessel
Robert W. Warke, LeTourneau University

Preventing Cracking in Nickel-Base Alloys
Donald J. Tillack, Tillack Metallurgical Consulting, Inc.

Phased Array Ultrasons for Detecting and Sizing Cracks in Welds
Michael Moles, Olympus NDT

Pressure Vessel Crack Prevention in Weld Repairs and Alterations
James T. Worman, The National Board of Boiler and Pressure Vessel Inspectors

National Welding Education Conference
Tues., Nov. 15 • 9:00-4:30 • Reg. Code W27
$149 members/$149 nonmembers

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 post-secondary schools, welding education trends, curriculum, materials science education and applications, distance learning updates, new technology applications, and presentations from welding educators who will share their best practices.

What’s New in Power Sources
Wed., Nov. 16 • 8:30-4:00 • Reg. Code W30
$345 members/$480 nonmembers

The latest welding machines are equipped with greatly improved capabilities, including multi-process operation. Meet the experts and understand the relative benefits of emerging power source technologies, for example, transformer-rectifiers and inverters. The experts will be on hand to compare these innovations.

Modern Power Source Technology That Drives Process Improvement
Todd McEllis, Miller Electric Mfg. Co.

AC Pulse GMAW for Aluminum, Mild and Stainless Steels
Phil Mosquera, OTC-Dalhen Inc.

Advances in Production Monitoring
Bruce Chantry, The Lincoln Electric Co.

Advanced GMA Welding
Wesley Doneth, Fronius USA LLC

High Performance GMAW - New Machines, New Techniques Will Provide a Boost in Performance
Paul Blomquist, Applied Thermal Sciences, Inc.

WeldScore - Embedded Weld Data Quality Monitoring

Gold Track VI
Robert Tollett, Liburdi Automation Inc.

Controlled Short Circuit GMAW Process Competes Favorably with SMAW, GTAW
Jim Cuhel, Miller Electric Mfg. Co. and Ron Halpenny, Graham Group
RWMA Resistance Welding School  
**Wed., Nov. 16 (7:45-5:30) — Thurs., Nov. 17 (8:00-3:45)**  
• Reg. Code W32  
$475 members/$695 nonmembers  
This intensive two-day course covers the basics of resistance welding. The school is designed to give operators, production supervisors, engineers, and others the opportunity to study, better understand, and further their knowledge in the theory, applications, and equipment used in the resistance welding process.

Electrodes and Tooling  
*Bill Brafford, Tuffaloy Products, Inc.*

Welding Controls  
*Don Sorenson, ENTRON Controls, LLC*

Electrical Power Systems  
*Mark Siehling, RoMan Manufacturing, Inc.*

Welding Processes and Machines  
*Tim Foley, Automation International, Inc.*

Troubleshooting and Maintenance  
*Bruce Kelly, Kelly Welding Solutions*

Initial Machine Setup  

**Thermal Spray Technology: High-Performance Surfaces**  
**Wed., Nov. 16 • 9:00-5:00 • Reg. Code W31**  
$345 members/$480 nonmembers  
The third joint conference of AWS and the International Thermal Spray Association (ITSA) will introduce the thermal spray process and its uses to new potential users with morning and afternoon sessions focusing on actual applications and new developments in thermal spray technology.

Conference chairs: David Wright and Dan Hayden.

Thermal Spray - Around the World in 80 Ways  
*Jean Mozolic, The Mozolic Consulting Group*

Advancing Cold Spray Applications to Industry Markets  
*David W. Wright, Accuwright Industries, Inc.*

“Should We Offer Thermal Spray Coated Fabricated Products?” What a Steel Fabricator Should Know About Thermal Spray Applied Anodic Coatings  
*James Weber, James K. Weber Consulting*

What is Thermal Spray?  
*Larry F. Grimenstein, Nation Coating Systems, Inc.*

Quality Control of Thermal Spray Coatings  
*Joseph P. Stricker, St. Louis Metallizing Company*

High Density Twin Wire Arc Spray Coatings  
*Frank Rogers, Thermion, Inc.*

Corrosion Protection Technology Without Size Limitations  
*Fred van Rodijnen, Sulzer Metco Europe GmbH*

Effect of HVOF Process Conditions on Chrome Replacement Coatings  
*Satish Dixit, Plasma Technology, Inc.*

Thermal Sprayed Zinc and Aluminum Coatings for Atmospheric Corrosion Protection  
*Dan Hayden, Hayden Corp.*

Much Ado About Nothing: Why the Concern About Porosity  
*Dale Moody, Plasma Powders and Systems*

Using Robotic Offline Programming for Improved Thermal Spray  
*Kevin Nelson, Blue Technik LLC*

Measurement and Sensing Requirements for Improved Plasma Spray Process Capabilities  
*Dennis Radgowski, Cyber Materials LLC*
**AWS Professional Program**

Pick and choose between concurrent sessions on the latest in welding research and commercial developments. Pay by the day or register for the entire four-day program.

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<th>Day</th>
<th>Event</th>
<th>Time</th>
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<tr>
<td>Mon., Nov. 14</td>
<td><strong>SESSION 1: International Trends in Welding Research</strong>&lt;br&gt;<strong>Chair:</strong> Stephen Liu, Colorado School of Mines&lt;br&gt;State of the Welding Related Industries and Trends of Welding Research &amp; Development in Singapore by Ang Chee Peng, President of the Singapore Welding Society</td>
<td>8:00</td>
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<td><strong>NSF-CIMISEA Program Introduction</strong> by Suresh Babu, The Ohio State University, Stephen Liu, Colorado School of Mines, John DuPont, Lehigh University, and Sindou Kou, University of Wisconsin</td>
<td>9:00</td>
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<td><strong>SESSION 2: NSF I / UCRC Sponsored</strong>&lt;br&gt;<strong>Chair:</strong> Stephen Liu, Colorado School of Mines&lt;br&gt;Separating the Good Welds from the Bad Welds by John P. H. Steele, Colorado School of Mines</td>
<td>2:00</td>
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<td>Development of a High-Chromium Nickel-base Filler Metal with Improved Weldability for Nuclear Power Plant Construction and Repair Applications by Adam T. Hope, Eric Fusner and John C. Lippold, The Ohio State University, and Steve L. McCracken</td>
<td>2:30</td>
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<td>Weldability of A356+0.5Cu and its Nanocomposites by Dake Wang, Hongseok Choi, Xiaochun Li and Sindou Kou, University of Wisconsin</td>
<td>3:00</td>
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<td>Welding of Stainless Steel-Effect of Sulfur on Weld Pool Phenomena by Sindou Kou, University of Wisconsin, C. Limmameevitchi, King Mongkut’s University of Technology-Thonburi, and P.S. Wei</td>
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<td>Newly Developed Low Transformation Temperature (LTT) Welding by Tanq Alghamdi and Stephen Liu, Colorado School of Mines</td>
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<td>Weld Solidification Behavior of Ni-based Superalloys for Use in Advanced Supercritical Coal-fired Power Plants by David Tung and John C. Lippold, The Ohio State University</td>
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<td><strong>SESSION 3: Solid-State Processing</strong>&lt;br&gt;<strong>Chair:</strong> Yoni Adonyi, LeTourneau University&lt;br&gt;Friction Stir Welding of ISO 3183 X80M Steel by Antonio J. Ramirez, Tahiana F. C. Hemenegildo and Tiago F. A. Santos, Brazilian Synchrotron Light Laboratory, and Conrado R. M. Afonso and Ricardo R. Marinho, CENPES-Petrobras</td>
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<td>Adaptation of Al-to-Steel FRW-I to Thick Sections by Wendell L. Johnson and Jerry E. Gould, Edison Welding Institute</td>
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<td>Solid-State Welding of High Performance Steels by Nathan Dix, Josh Hammond and Yoni Adonyi, LeTourneau University</td>
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<td>Friction Stir Welding of Lean Duplex Stainless Steel by Tiago F. A. Santos, Marina Magnani and Antonio J. Ramirez, Brazilian Synchrotron Light Laboratory</td>
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<td>Susceptibility of Carbon Steel Welds to Hydrogen Embrittlement by Wei Zhang, Zhili Feng, John Wang and Larry Anovitz, Oak Ridge National Laboratory</td>
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<td>Mechanical and Microstructural Evaluation of Friction Stir Processed Diffusion Bonded Magnesium and Magnesium Metal Matrix Composites by Scott Gordon and Stephen Liu, Colorado School of Mines</td>
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<td>Tues., Nov. 15</td>
<td><strong>SESSION 4: Shipbuilding</strong>&lt;br&gt;<strong>Chair:</strong> Maria Posada, Naval Surface Warfare Center-Carderock Division&lt;br&gt;Fracture Toughness of Welded NUCu-140 by Brett Leister, John DuPont and Jeffrey Farren, Lehigh University</td>
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<td>Microsampling of Friction Stir Welded Ti Alloys by Sal Nimer and Marc Zupan, University of Maryland – Baltimore County; and Jennifer Wolk, Naval Surface Warfare Center-Carderock Division</td>
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<td>Automated Welding Technology for VCS Submarines by Nancy C. Porter and Steve Massey, Edison Welding Institute, and Ned Kaminski, General Dynamics Electric Boat</td>
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<td>Ultrasonic Impact Treatment of Aluminum 5456 Plate and Welds by Kim N. Tran and Caroline Scheck, Naval Surface Warfare Center Carderock Division; Lourdes Salamanca-Riba, University of Maryland – College Park; and Marc Zupan, University of Maryland – Baltimore County</td>
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<td>Understanding the Effect of Tool Design in Friction Stir Welding of HSLA-65 Steels by David Lammlein and Maria Posada, Naval Surface Warfare Center – Carderock Division</td>
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<td>Fusion Welding Repair of 500x Series Aluminum Friction Stir Welds by Maria Posada, Naval Surface Warfare Center – Carderock Division</td>
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<td>Underwater Friction Stir Welding of HY80 Steel by Terry R. McNelley, Sarath K. Menon, Garth W. Young and William C. Stewart, Naval Postgraduate School; and Murray W. Mahoney, Consultant</td>
<td>10:30</td>
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<td>Nondestructive Testing False Positives on Friction Stir Weld Applications by Bruce H. Halversen, Marinette Marine Corporation</td>
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<td><strong>SESSION 5: Arc Welding Processes</strong>&lt;br&gt;<strong>Chair:</strong> Daniel Hartman, Manufacturing Behavioral Science&lt;br&gt;Double Electrode GMAW with One Welding Power Supply by Jinsong Chen, Adaptive Intelligent Systems; and Yi Lu and YuMing Zhang, University of Kentucky</td>
<td>8:00</td>
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<td>Submerged Arc Welding of High Strength Steel by Cold Wire Feed by Biswajyoti Basu, Naval Materials Research Laboratory; R. Rahul and E. Jeevarasan, National Institute of Technology; and S. Jerome and Arun Kumar Shah, Panipat Institute of Engineering Technology</td>
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<td>Welding Arc Interruptions in Tandem Pulsed GMAW by Ruham Pablo Reis, Federal University of Rio Grande</td>
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<td>Study of Silicate Islands in GMAW by Richard Derrien, Stephen Liu, and Erik Lord, Colorado School of Mines</td>
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<td>Full Penetration Welding Using Laser Enhanced GMAW by Yi Huang and YuMing Zhang,University of Kentucky</td>
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<td>Submerged Arc Welding Line Pipe with Three Electrodes by Stephen Kenny, University of Alberta</td>
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<td>Residual Stress Analysis in Machining of Duplex Welds by Carolina Payares-Aspino and Patricio Muñoz-Escalona, Universidad Simón Bolívar, and Anamels Sanchez, Fundación Instituto de Ingenieria</td>
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<td>Selection of Welding Consumables for Metal Arc Welding Under OI (MAW-UO) by Hamad H. Almostaneer, Stephen Liu, and David L. Olson, Colorado School of Mines</td>
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<td>Droplet Heat Content in Nickel Sheathed WC-Cored GMAW Wires by Kevin Scott and Patricio Mendez, University of Alberta</td>
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<td><strong>SESSION 6: NSF I / UCRC Sponsored</strong>&lt;br&gt;<strong>Chair:</strong> John DuPont, Lehigh University&lt;br&gt;Corrosion Behavior of Nickel Based Alloy Coatings by Andrew W. Stockdale and John DuPont, Lehigh University</td>
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<td>Thermal Stir Welding of Steel by Feng Pan and Sindou Kou, University of Wisconsin; and R.J. Ding, Marshall Space Flight Center</td>
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<td>Preventing Dissimilar Metal Weld Failures by Gregory J. Brentnup, John DuPont, Brett M. Leister, Brett S. Snowden, and Joachim L. Grenestedt, Lehigh University</td>
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<td>Hot Bending of Armor Alloys by Nicholas A. Kullman and Boian T. Alexandrov, The Ohio State University</td>
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<td>Stress Rupture Evaluation of Steel Welding Consumables by Chai Xiao and Sindou Kou, University of Wisconsin</td>
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<td>Laser Impact Welding by Huimin Wang, The Ohio State University</td>
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<td><strong>SESSION 7: Weld Modeling</strong>&lt;br&gt;<strong>Chair:</strong> Zhili Feng, Oak Ridge National Laboratory&lt;br&gt;Surface and Interface Phenomena in Thermoelectric Element Welding by Ithamar Glumac, Ben Sokolove, and Yoni Adonyi, LeTourneau University</td>
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<td>A Computational Modeling Tool for Welding Repair of Irradiated Materials by Zhili Feng, Oak Ridge National Laboratory; and Eric Willis and Ken Wolfe, Electric Power Research Institute</td>
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SESSION 8: Laser Materials Processing
Chair: Tom Lienert, Los Alamos National Laboratory
Characterization of a Materials Processing Laser by T.J. Lienert, J.O. Sutton, M.S. Pilch and P. Burgardt, Los Alamos National Laboratory. .............................................. 8:00
Issues with Laser Welding Through a Fused Silica Window by T.J. Lienert, J.O. Sutton, M.S. Pilch, R.T. Forsyth and P.A. Papin, Los Alamos National Laboratory. .............................................. 8:30
Reducing Alloying Element Vaporization from Stainless Steel Weld Pools Produced by Pulsed Laser Welding by T. DebRoy, Penn State University; and T.J. Lienert, Los Alamos National Laboratory. .............................................. 9:00
Properties Variation in Stainless Steel Laser Welds by Charles V. Robino, Brad L. Boyce and Corbett C. Battalle, Sandia National Laboratories. .............................................. 9:30
Modeling of Laser Spot Micro-Welding of Silicon by Ashwin Raghavan, Penn State University. .............................................. 10:00
Scaling Thermocapillary Weld Pool Shape by Peng S. Wei, C.L Lin and H.J. Liu, National Sun Yat-Sen University; and T. DebRoy, Penn State University. .............................................. 10:30
Comparing Laser and Resistance Interconnection Welds by Gerald A. Knorovsky, Danny O. MacCallum and Louis A. Malizia Jr, Sandia National Laboratories. .............................................. 11:00
SESSION 9: Filler Metals, Overlays and Repair
Chair: Patricio Mendez, University of Alberta
Welding Fume Study for Certain SMAW Electrodes Used in the Mining Industry by Kin-Ling Sham and Stephen Liu, Colorado School of Mines. .............................................. 8:00
Analysis of Molten Surface End Face of Al-Mg Filler Metal Alloy and Process-Integrated Quality Assurance in Pulse GMAW by Rajasekaran Shanmugam and Umarani Rajasekaran, El-Shaddai Welding and Cutting Consultants. .............................................. 8:30
New Self-Shielded Flux Cored Electrode by Wesley Wang and Stanley Ferree, ESAB. .............................................. 9:00
Reduction of Cr(VI) in Stainless Steel Welding Fume by Tetsuhiro Ikeda, Hiroshi Sugahara and Hirohisa Watanabe, Kobe Steel, Ltd / Kobelec Welding of America. .............................................. 9:30
Depositing Ni-WC Wear Resistant Coatings with Hot-Wire Assisted GTAW by Stuart Guest, Adrian Gerich and Patricio Mendez, Canadian Center for Welding and Joining, University of Alberta. .............................................. 10:00
Wear Performance of Welded Hardbanding Materials by Dan Danks, Abbe Doering and Joe Scott, Wear & Friction Resources. .............................................. 10:30
Structure and Properties of FBW Rail Repairs by David Workman and Jerry E. Gould, Edison Welding Institute. .............................................. 11:00
Combating Corrosion by Weld Overlay - A Unique Experience by J. V. D. Murty, Qatargas Operating Company Limited. .............................................. 11:30
SESSION 10: Sensing and Control
Chair: YuMing Zhang, University of Kentucky
Computation of GMAW Pool Surface from Laser Reflection by Xiaoji Ma and YuMing Zhang, University of Kentucky. .............................................. 2:00
Near-Infrared Vision System for Arc-Welding Monitoring by Carolina Pimenta Mota, Marcus Vinicius Ribeiro Machado, and Lourel Oliveira Vilainho, Federal University of Uberlandia; and Roberto Mendes Finzi Neto, Federal University of Goias. .............................................. 2:30
Analytical Computation of GTAW Weld Pool Surface by Zhenzhou Wang, University of Kentucky. .............................................. 3:00
Temperature Measurement of Low-Carbon Steel TIG Welding Heat Affected Zone Using Fiber Bragg Grating by Yulong Li, Harbin Institute of Technology, and Zhichao Jiang, Yang Feng, and Hua Zhang, Nanchang University. .............................................. 3:30
Machine-Human Cooperative Control of Welding Process by Waijie Zhang and YuMing Zhang, University of Kentucky. .............................................. 4:00
Wireless Embedded System for Signal Monitoring by Carolina Pimenta Mota, Marcus Vinicius Ribeiro Machado, and Lourel Oliveira Vilainho, Federal University of Uberlandia; and Roberto Mendes Finzi Neto, Federal University of Goias. .............................................. 4:30
Adaptive Filler Algorithm in Varying Weld Groove by Yong-Baek Kim, Jeom-Goo Kim, Pyeong-Soon Moon and Ji-On Kim, Hyundai Heavy Industries. .............................................. 5:00
SESSION 11: Joining Metallurgy
Chair: Suresh Babu, The Ohio State University
Ultrasonic Soldering for Dissimilar Material Joining by Edward D. Herderick, Edison Welding Institute. .............................................. 2:00
Au-Al Intermetallic Formation in a Resistance Weld by Donald F. Susan, Gerald A. Knorovsky and Paul T. Vianco, Sandia National Laboratories. .............................................. 2:30
Constitution Diagram for Dissimilar Metal Welds by Elijah K. Gould, BP America; and John C. Lippold and Boian T. Alexandrov, The Ohio State University. .............................................. 3:00
Weld Behavior of Ultra-High-Strength Egin Steel by Daniel H. Bechetti Jr. and John N. DuPont, Lehigh University. .............................................. 3:30
Advanced Brazing Technologies for Nuclear Fuel Cladding by Edward D. Herderick, Kirk Cooper and Nate Ames, Edison Welding Institute. .............................................. 4:00
Microstructure of Alloy 625 Weld Overlay by Clinton Carvalho Silva, Conrado R. M. Afonso, Hélio Cordeiro de Miranda and Jesualdo Pereira Fantas, Federal University of Ceará; and Antonio J. Ramirez, Brazilian Synchrotron Light Laboratory. .............................................. 4:30
SESSION 12: Materials Weldability
Chair: Boian Alexandrov, The Ohio State University
Application of Cold Cracking Tests for Determining the Preheating Temperature in High Strength Steels by Monica Zalazar, Universidad Nacional del Comahue; and Eduardo Asta, ESAB Argentina. .............................................. 8:00
Hydrogen Assisted Cracking in Dissimilar Metal Welds by Boian T. Alexandrov, Jeffrey M. Rodelas and John C. Lippold, The Ohio State University; and Shu Shi, Shell International Exploration and Production. .............................................. 8:30
Impermeable Low Hydrogen Covered Electrodes by Alexandre Queiroz Bracarense, Claudio Turani, Ezzequil Caires Pereira Pessoa, and Ivanizla Felizardo, Federal University of Minas Gerais. .............................................. 9:00
Characterization of Grade 91 Steels to Tempering by Daniel Saltmann, Boian T. Alexandrov and John C. Lippold, The Ohio State University. .............................................. 9:30
Development of Welding Technology for Bicycle Frame by Mok-Young Lee and Woong-Seong Chang, RIST; and Norman Zhou, University of Waterloo. .............................................. 10:00
Effect of Oxide/Ferrite Phase on the Toughness of SDSS by Kim Dae Joo, Bae Sang Deock and Choi Jun Tae, Hyundai Heavy Industries. .............................................. 10:30
SESSION 13: Industrial Technology
Chair: Nancy Porter, Edison Welding Institute
Automated Narrow Gap GTAW by Barbara K. Henon, Arc Machines; and Jonathan T. Salkin, Arc Applications. .............................................. 8:00
Green Stud Welding Technologies Save Energy and Labor by Chris Hsu, Nelson Stud Welding. .............................................. 8:30
Increase Joint Success with an Internal Groove by Larry Zirker, Marve Parker and Kyle Kofford, Idaho National Laboratory. .............................................. 9:00
Product and Process Comparisons of Welding Fumes by Stanley E. Ferree, ESAB. .............................................. 9:30
Mechanization of Short Welds in Heavy Fabrications by Steve Massey and Nancy Porter, Edison Welding Institute. .............................................. 10:00
Wrapped Textile Cord Process for Welding Wire Finish by Kai Boockmann, Michaela Boockmann and Gerhard Boockmann, Boockmann GmbH. .............................................. 10:30
AWS Exam and Preparation Events

**D1.5 Bridge Code Clinic**
Mon., Nov. 14 • 8:00-12:00 • Reg. Code W20
$175 members/$310 nonmembers
Prepare for the Bridge Code exam option for CWI certification or endorsement.

**D15.1 Railroad Code Clinic**
Mon., Nov. 14 • 1:00-5:00 • Reg. Code W21
$175 members/$310 nonmembers
Prepare for the Railroad Code exam option for CWI certification or endorsement.

**D1.1 Road Map**
Tues., Nov. 15 • 8:00-5:00 • Reg. Code W23
$345 members/$480 nonmembers
Prepare for the D1.1 exam option for CWI certification or endorsement.

**ASME Section IX Code Clinic**
Tues., Nov. 15 • 8:00-5:00 • Reg. Code W24
$345 members/$480 nonmembers
Prepare for the ASME Section IX, B31.1 & B31.3 exam option for CWI certification or endorsement.

**Advanced Visual Inspection Workshop**
Tues., Nov. 15 • Wed., Nov. 16 • 8:00-5:00 • Reg. Code W26
$550 members/$685 nonmembers
Prepare for Part B of the CWI or recertification exam.

**Certification Examination**
Thurs., Nov. 17 • 7:00-6:00
Take your exam to certify as a CWI, CWE, CWS, CWSR, SCWI, CWEng, or test for endorsements. Advance application through AWS is required to take exams. Call 1-800-443-9353 ext. 273, or go to http://www.aws.org/certification for details on certification and registration requirements.

**Other Seminars**

**Metallurgy Applied to Everyday Welding**
Mon., Nov. 14 • 8:00-5:00 • Reg. Code W22
$345 members/$480 nonmembers
Improve your understanding of the science behind good welding.

**The Why and How of Welding Procedure Specifications**
Wed., Nov. 16 • 8:00-5:00 • Reg. Code W25
$345 members/$480 nonmembers
A valuable seminar on qualifying and following procedures.

**Free AWS Events at FABTECH**

**Professional Welders Open Competition**
Mon., Nov. 14 — Wed., Nov. 16
Watch contestants compete for hard cash and the title of best welder in America. Awards presented Thurs., Nov. 17 at 11 a.m. For more info, call (800) 443-9353 ext. 237.

**Free Seminar Sample Sessions**
Attend a special one-hour portion of an AWS exam seminar.
Mon., Nov. 14
Certified Welding Sales Rep (Reg. Code W41) 1:00-2:00
Certified Welding Inspector (Reg. Code W42) 2:00-3:00
Tues., Nov. 15
Certified Welding Supervisor (Reg. Code W43) 8:00-9:00
Certified Radiographic Interpreter (Reg. Code W44) 9:00-10:00

Register for the show and events at www.aws.org/fabtechevents

IIW and 2012 Annual Assembly Session
Mon., Nov. 14 • 11:30 – 1:00
Everything you wanted to know about the American Council of the International Institute of Welding (IIW) and the 2012 IIW Annual Assembly in Denver. Light lunch and refreshments will be provided.

**Weld-Ed's Professional Development Offerings for Welding Educators Session**
Mon., Nov. 14 • 8:00 – 9:00 • Reg. Code W46
Presented by the National Center for Welding Education and Training (Weld-Ed), this free session is designed to inform attendees of available professional development for welding instructors. Duncan Estep, center director of Weld-Ed, will be the speaker.

**Thermal Spray Basics: Putting Coatings to Work**
Tues., Nov. 15 • 1:00 – 5:00 • Reg. Code W45
Presented by the International Thermal Spray Association (ITSA), this free intro to the benefits of thermal spraying will cover processes, equipment, applications, and industry usage.

**Prayer Breakfast: Helping the Poor**
Wed., Nov. 16 • 7:00 – 8:30 • Reg. Code W47 • $10
Come join an open prayer breakfast, with speaker Ken Isaacs, vice president of projects at Samaritan’s Purse. Learn how to help the poor with the skills you have. Ken Isaacs has over 25 years’ experience working in the relief and development community in dozens of countries.

**Education Annual Program**
Valuable free programs for educators and trainers are held every day of the show. Registration Code W40.

**Topics in Welding Education**
Mon., Nov. 14
Using Practical Welding Metallurgy Object Lessons ........................................8:00-9:00
Common Errors in Applying AWS A2.4 Welding Symbols ..................................9:00-10:00

**Career Counselor & Welding Educator Workshop**
Mon., Nov. 14 • 10:00 – 5:00
Representatives from AWS, the welding industry and trade unions will make short presentations on career paths, scholarships and job outlook. A walking tour of exhibits on the show floor will highlight high-tech topics in welding related to the most rewarding career opportunities.

**Lectures in Welding Education**
Tues., Nov. 15
Plummer Memorial Award Lecture .................................................................10:30-12:00
Adams Memorial Membership Award Lecture ...............................................1:30-2:30
Howard E. Adkins Memorial Instructor Membership Award Lecture ... 2:30-3:30
Panel Discussion with Award Recipients .........................................................3:30-5:00

**Educators' Program**
Wed., Nov. 16
Writing Engaging Lesson Plans Workshop ...................................................9:00-11:00
Complying with National and State Standards ..............................................11:00-12:00
E-learning on a Budget: Introducing Interactive Tools in the Classroom ..........1:00-2:00
Recruiting Students into Welding Programs ...............................................2:00-3:00
Techniques for Developing Accurate and Fair Welding Assessments .............3:00-4:00
Developing a Welding Curriculum ..............................................................4:00-5:00
Thurs., Nov. 17
Project and Community Based Curriculum Design .....................................9:00-10:00
Structuring the Welding Shop Experience .................................................10:00-11:00
Implementing the SENSE Program .........................................................11:00-12:00

**Free Seminar Sample Sessions**

Mon., Nov. 14
Certified Welding Sales Rep (Reg. Code W41) 1:00-2:00
Certified Welding Inspector (Reg. Code W42) 2:00-3:00
Tues., Nov. 15
Certified Welding Supervisor (Reg. Code W43) 8:00-9:00
Certified Radiographic Interpreter (Reg. Code W44) 9:00-10:00

**Valuable free programs for educators and trainers are held every day of the show. Registration Code W40.**
Extraordinary Welding Award Presented to Sculptor of 9-11 Fireman Statue

BY KRISTIN CAMPBELL AND HOWARD WOODWARD

A sculpture of a fireman, created to memorialize the 343 firemen who died at the World Trade Center (WTC) ten years ago, earned the 2011 AWS Extraordinary Welding Award. Its creator, Felix Gonzalez (photo at left), a retired firefighter, worked 17 months to create the 8.5-ft-tall, 2.5-ton tribute. He received the award from Victor Y. Matthews (photo on page 59), an AWS past president and a volunteer firefighter, as part of the statue's formal unveiling during the City of Pembroke Pines, Fla., 9/11 World Trade Center remembrance program.

The fireman sculpture and other artworks were dedicated as part of the city's permanent September 11, 2001, Memorial displayed in an elegant 500-sq-ft gazebo near the city hall.

The sculpture abounds in minute details. The helmet shield reads “F.D.N.Y. 343,” denoting the number of firefighters who died on 9/11. It faithfully replicates the traditional firefighter jacket, pants, and boots. The left hand holds a large pike pole, used to explore for hidden fire, and the right hand holds a pike axe. The air tank gauge on his back displays 8:46 AM to represent the time of the first WTC strike, and there is a flashlight and a pouch for storing a gas mask. The fireman’s oversized fists symbolize strength.

The AWS Extraordinary Welding Award is presented in recognition of welding excellence in construction, fabrication, and manufacturing, and designates those welded structures with an importance in, or influence on, history.

Upon receiving the award, Gonzalez said, “I’m incredibly and deeply honored to have my firefighter in that company. I’ll treasure it.” Gonzalez explained his sculpture was built using techniques he learned making artworks from wood. The firefighter statue was made from tailored cut sections of %-in. steel joined using gas metal arc welding and flux cored wire.

Included in the gazebo exhibit are several other welded sculptures by Gonzalez: North Tower and South Tower, two works he made using many tall beams representing the WTC's two buildings; and Fallen Angel, a 13-ft-tall steel image of a girl with flowing hair and her right hand extended to symbolize quiet determination, freedom, and a child’s innocence. He said he wanted these statues to retell the story of the nearly 3000 people who died that day. “The sculptures have to speak to your heart. It brings you to the moment,” he said. He has plans to create additional works to add to his 9/11 collection.

The gazebo’s centerpiece is a 9.5-ton, 4-ft-tall white carrara marble stone sculpture by Benoit Menasche. Each of its four sides depicts an emotion provoked by the attack: shock, grief, acceptance, and rebuilding. On its top is a steel girder salvaged from one of the towers.

About 1000 people attended the event. Participating were Pembroke Pines Mayor Frank Ortis, Vice Mayor Iris Siple, Commissioners Carl Shechter, Jack McCluskey, and Angelo Castillo, Florida State Senator Nan Rich, Marcus Christian from the U.S. Attorney's office, Broward County Commissioner Lois Wexler, AWS Executive Director Ray Shook, AWS Public Relations Manager Cindy Weihl, Welding Journal Associate Editors Kristin Campbell and Howard Woodward, and many school children. 
Interpretation
AWS D1.3
Structural Welding Code — Sheet Steel

Subject: Welder Qualification for SMAW Electrodes
Code Provision: Clause 4.7.1.3
AWS Log: D1.3-98-105

Inquiry: Is a welder qualified using E7018 SMAW electrodes, F4, qualified to run E6022 SMAW Electrodes, F1?
Response: No, see table listing in clause 4.7.1.3.

New Standards Projects
Development work has begun on the following revised standards. Affected individuals are invited to contribute to the development of these standards. Contact the staff engineer listed with the document.

A5.9/A5.9M:20XX, Specification for Bare Stainless Steel Welding Electrodes and Rods. This specification prescribes the requirements for classification of solid and composite stainless steel electrodes (both as wire and strip) for gas metal arc welding, submerged arc welding, and other fusion welding processes. It also includes wire and rods for use in gas tungsten arc welding. Classification is based on chemical composition of the filler metal. Additional requirements are included for manufacture, sizes, lengths, and packaging. Stakeholders: Welding Industry. Rakesh Gupta, ext. 301.

G2.3M/G2.3:20XX, Guide for the Joining of Solid Solution Austenitic Stainless Steels. This guide presents a description of solid solution austenitic stainless steels and the processes and procedures that can be used to join these materials. It discusses the welding processes and welding parameters, qualifications, inspection, and repair methods, cleaning, and safety considerations. Practical information is presented in the form of figures, tables, and graphs that should prove useful in determining capabilities and limitations in the joining of austenitic stainless steels. Stakeholders: Fabricators who work with austenitic stainless steels. Alex Diaz, ext. 304.

Standards for Public Review


AWS 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. Draft copies may be ordered from R. O’Neill, roneill@aws.org; (305) 443-9355, ext. 451.

Revised Standards Approved by ANSI


ISO Draft Standards for Public Review

ISO/DIS 14346, Welding — Static design procedure for hollow section joints
ISO/DIS 16338, Welding for aerospace applications — Resistance spot and seam welding

In the United States, if you wish to participate in the development of International Standards for welding, contact Andrew Davis, adavis@aws.org; (800/305) 443-9355, ext. 466. Copies of draft international standards are available for review and comment from your national standards body, which in the United States is ANSI, 25 W. 43rd St., 4th Fl., New York, NY 10036; (212) 642-4900. Send comments regarding ISO documents to your national standards body.

Addenda Standard Approved by ANSI


Technical Committee Meetings

All AWS technical committee meetings are open to the public. Persons wishing to attend a meeting should call the staff secretary of the committee. Call (800/305) 443-9355 and the extention shown.

Nov. 2, SH1 Subcommittee on Fumes and Gases. Columbus, Ohio. Steve Hedrick, ext. 305.

The following meetings will be held at FABTECH in Chicago, Ill.


Nov. 14, C7 Committee on High Energy Beam Welding and Cutting. Brian McGrath, ext. 311.

Nov. 14, C7B Subcommittee on Energy Beam Welding and Cutting. Brian McGrath, ext. 311.


Nov. 14, D18 Committee on Welding and Sanitary Applications. Steve Hedrick, ext. 305.

Nov. 15, C5 Committee on Arc Welding and Cutting. Rakesh Gupta, ext. 301.

Nov. 15, C6 Committee on Friction Welding. Brian McGrath, ext. 311.

Nov. 15, D9 Committee on the Welding, Brazing, and Soldering of Sheet Metal. Alex Diaz, ext. 304.
Nickel-Based Alloys, and participate in the—

geometric product specification and recommended practices for local heating system for oxyfuel nozzles; C4.6, Alex Diaz, ext. 304. adiaz@aws.org; contact B. of welds in piping and tubing. cutting classification of thermal cuts—

uniform designation to update C4.5, meting and teleconferences. contact steve borrero, ext. 334.

welding. steve borrero, ext. 334. examination of welds. Brian McGrath, ext. 311. bmcgrath@aws.org;

gupta@aws.org, ext. 301.

and automatic welding. Brian McGrath, ext. 311.

D17K Subcommittee on Fusion Welding. Alex Diaz, ext. 304.

Nov. 16, G2D Subcommittee on Reaction Alloys. Call Alex Diaz, ext. 304.

Nov. 17, C1 Committee on Resistance Welding. Efram Abrams, ext. 307.

Past AWS President Victor Matthews (right) worked July 16–31 building an earthquake-resistant church building in El Girrion, Guatemala. Pleaseed he has not lost his touch for welding, he noted the walls are made of cinder blocks with concrete pillars reinforced with rebar. The steel trusses were fabricated from 14-gauge, three-sided channel welded together into box beams for strength.

Sculptor felix Gonzalez (left) and AWS past-President Vic Matthews hold the AWS Extraordinary Welding Award, which recognized Gonzalez’s 9/11 firefighter statue. See lead story on page 57.

Welding Award Presented

Nov. 15, D14 Committee on Machinery and Equipment. Matt Rubin, ext. 215.


Nov. 15, D15C Subcommittee on Track Welding. Steve Borrero, ext. 334.

Nov. 15, D17D Subcommittee on Resistance Welding. Alex Diaz, ext. 304.

Nov. 15, D17J Subcommittee on Friction Stir Welding. Alex Diaz, ext. 304.

Nov. 16, A5K Subcommittee on Titanium and Zirconium Filler Metals. Alex Diaz, ext. 304.

Nov. 16, B1 Committee on Methods of Inspection. Brian McGrath, ext. 311.

Nov. 16, B1B Subcommittee on Visual Examination of Welds. Brian McGrath, ext. 311.

Nov. 16, D15 Committee on Railroad Welding. Steve Borrero, ext. 334.


Nov. 16, D16 Committee on Robotic and Automatic Welding. Brian McGrath, ext. 311.

Nov. 16, D17K Subcommittee on Fusion Welding. Alex Diaz, ext. 304.

Nov. 16, G2D Subcommittee on Reaction Alloys. Call Alex Diaz, ext. 304.

Nov. 17, C1 Committee on Resistance Welding. Efram Abrams, ext. 307.

Opportunities to Contribute to AWS Welding Standards and Codes

Volunteer to serve on an AWS technical committee to help develop the standards that serve industry’s ever-changing needs. Currently, more than 1800 volunteers participate 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 important work. E-mail the committee secretary listed, or call (800/305) 443-9353 at the extension shown.

Local Heat Treating of Pipe Work

The D10P Subcommittee for Local Heat Treating of Pipe to revise D10.10, Recommended Practices for Local Heating of Welds in Piping and Tubing. Contact B. McGrath, bmcgrath@aws.org; ext. 311.

Joining Wrought Nickel Alloys

The G2C Subcommittee on Nickel Alloys seeks volunteers to review G2.1M/G2.2.1, Guide for the Joining of Wrought Nickel-Based Alloys, and participate in the meetings and teleconferences. Contact Alex Diaz, adiaz@aws.org; ext. 304.

Oxyfuel Gas

C4 Committee on Oxyfuel Gas Welding to update C4.5, Uniform Designation System for Oxyfuel Nozzles; C4.6, Thermal Cutting — Classification of Thermal Cuts — Geometric Product Specification and Quality Tolerances; and to prepare C4.7,
Addenda: D1.9, *Structural Welding Code — Titanium*

The following addenda has been made and incorporated into the current edition of this document.

**AWS Standard:** D1.9/D1.9M:2007, *Structural Welding Code — Titanium*

**Addenda No.:** ADD1

**Subject:** Radiographic Crack Allowance in Table 5.2

Page 81: Add a row above “Fine Scattered Porosity” to Table 5.2 for crack discontinuity types as follows:

<table>
<thead>
<tr>
<th>Discontinuity Types</th>
<th>Base Material Thickness Range, in [mm]</th>
<th>Radiograph Category, in [mm]</th>
<th>Acceptance Level (Reference ASTM E 390 Radiographs)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cracks</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fine Scattered Porosity</td>
<td>≥1/8 [3] and ≤1/2 [12]</td>
<td>Up to 3/8 [10], incl.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;1/2 [12] and ≤1-1/2 [38]</td>
<td>Up to 3/4 [19], incl.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;1-1/2 [38] and ≤3 [76]</td>
<td>Up to 2 [50], incl.</td>
<td>2</td>
</tr>
<tr>
<td>Coarse Scattered Porosity</td>
<td>≥1/8 [3] and ≤1/2 [12]</td>
<td>Up to 3/8 [10], incl.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;1/2 [12] and ≤1-1/2 [12]</td>
<td>Up to 3/4 [19], incl.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;1-1/2 [38] and ≤3 [76]</td>
<td>Up to 2 [50], incl.</td>
<td>2</td>
</tr>
<tr>
<td>Linear Porosity or Rounded Indications</td>
<td>≥1/8 [3] and ≤1/2 [12]</td>
<td>Up to 3/8 [10], incl.</td>
<td>1</td>
</tr>
<tr>
<td>Indications</td>
<td>&gt;1/2 [12] and ≤1-1/2 [38]</td>
<td>Up to 3/4 [19], incl.</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>&gt;1-1/2 [38] and ≤3 [76]</td>
<td>Up to 2 [50], incl.</td>
<td>2</td>
</tr>
<tr>
<td>Nonmetallic Inclusions</td>
<td>≥1/8 [3] and ≤1/2 [12]</td>
<td>Up to 3/8 [10], incl.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>&gt;1/2 [12] and ≤1-1/2 [38]</td>
<td>Up to 3/4 [19], incl.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>&gt;1-1/2 [38] and ≤3 [76]</td>
<td>Up to 2 [50], incl.</td>
<td>3</td>
</tr>
<tr>
<td>Tungsten Inclusions</td>
<td>≥1/8 [3] and ≤1/2 [12]</td>
<td>Up to 3/8 [10], incl.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>&gt;1/2 [12] and ≤1-1/2 [38]</td>
<td>Up to 3/4 [19], incl.</td>
<td>2</td>
</tr>
<tr>
<td>Incomplete Joint Penetration CJP only</td>
<td>≥1/8 [3] and ≤1/2 [12]</td>
<td>Up to 3/8 [10], incl.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>&gt;1/2 [12] and ≤1-1/2 [38]</td>
<td>Up to 3/4 [19], incl.</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>&gt;1-1/2 [38] and ≤3 [76]</td>
<td>Up to 2 [50], incl.</td>
<td>3</td>
</tr>
<tr>
<td>Incomplete Joint Penetration—Partial joint penetration welds only</td>
<td>All</td>
<td>N/A</td>
<td>1/32 [0.8] width full weld length 1/16 [1.5] width 4T in 8T weld length</td>
</tr>
<tr>
<td>Incomplete Fusion—Partial joint penetration welds only</td>
<td>All</td>
<td>N/A</td>
<td>1/32 [0.8] width full weld length 1/16 [1.5] width 4T 8T weld length</td>
</tr>
</tbody>
</table>

**Notes:**

1. Porosity or inclusions allowed by this table shall be cause for rejection when closer than twice their maximum dimension to an edge or extremity of a weldment in a highly stressed or critical area, as determined by design engineering personnel.
2. Linear is described as having a length greater than three times the width. Rounded is defined by the converse.

BY WALTER J. SPERKO

The following is a summary of the significant changes that appear in the 2011 Addenda to the 2010 edition of ASME Section IX. All changes, including editorial corrections that are not usually mentioned in these articles, are readily identified in the “Summary of Changes” that begins on page xxviii of the Addenda. Readers are advised that the opinions expressed in this article are those of the author and not the official opinion of the Boiler and Pressure Vessel Standards Committee IX. These changes become mandatory January 1, 2012.

Administrative Changes

The 2011 addenda are the last addenda that will be issued for the ASME Boiler and Pressure Vessel Code. There will not be 2012 addenda, and as of 2013, the Code will be published biennially, without addenda, during intervening years. That means that we will no longer spend time in front of our computer screens inserting addenda. Alleluia!

Errata and corrections will be posted at www.asme.org/kb/standards/publications/parc-resources so that Code users can readily see the revisions and corrections. We should also expect to see more use of Code Cases to provide interim rules between editions so that new technology can be implemented in a timely manner without waiting for the next publication cycle; these will be posted at the same site. ASME has advised that the price of Code books will be adjusted to be “revenue neutral.”

Another administrative change is to allow materials that are not permitted for Code construction to be assigned P-numbers. See the discussion under materials.

Welding Procedure (QW-200) Changes

QW-161 on preparing bend test specimens has been revised to require that additional specimens be removed when the width of the weld and the heat-affected zone (HAZ) are so wide that both sides of the weld and HAZ cannot be included in each specimen.

For materials that use the standard bend radius of ½ in. and side bend specimens that are ⅛ in. thick, this occurs when the width of the weld and HAZ exceed about 4.7 in. Allowing ¼ in. for the HAZ on both sides, a cover pass that is more than ⅛ in. wide would require that multiple bend test specimens be prepared and tested — assuming that the weld is exactly centered on the specimen after testing. When multiple specimens are necessary, all the specimens needed to include the weld and HAZ are a set and represent one required bend test.

Diffusion welding, which was previously approved by Code Case for Section III and VIII heat exchangers, was added to Section IX for any application. In a typical heat exchanger application, sheets of stainless steel or similar corrosion-resistant alloy are etched or machined to form channels in the sheet, then the sheets are stacked so that the channels on each layer are laid out perpendicular to the previous layer. Typically, hundreds of sheets are stacked with heavy plates on the top and bottom, placed into an atmosphere-controlled furnace and held at elevated temperature for a specified time.

During that time, atoms from each plate surface diffuse into the neighboring plate surfaces to form a single-piece block. After cooling to room temperature, covers are welded to each of the four surfaces with the channels to allow gas or other fluid to flow through the channels resulting in a very efficient and compact plate-type heat exchanger.

Diffusion welding qualification consists of welding a minimum 25 sheets without channels plus a top and bottom plate to form a solid block 8 in. square. Three tension tests are performed in the sheet area perpendicular to the sheet interface and three more are performed parallel to the sheet interface. Finally, three cross sections are prepared and examined metallographically. This test qualifies all sizes and number of layers of sheet and may be used for any application, not just heat exchangers.

There were major changes in the variables for procedures and qualification for laser beam welding (LBW). The previous rules, written in the 1980s, were conservative since the industry had little experience with LBW. The revisions reduce the number of qualifications that are typically required and tighten up some aspects. For example,

• The joint design to be used is limited to that qualified.
• The base metal thickness qualified now has only a maximum qualified thickness instead of a minimum and a maximum.
• Filler metal is no longer limited to the specific chemical composition qualified as long as it is the same P-number and A-number.
• A tolerance of ±10% has been added to oscillation width, frequency, and dwell time and to beam pulsing frequency and duration.
• A tolerance of 10 deg has been added to the angle of the beam relative to the workpiece surface.
• The type of equipment is no longer an essential variable, but additional variables have been added to address the type of laser (YAG, CO2, etc.), beam optics, and gas.

QW-409.1, which was revised extensively last year to incorporate waveform-controlled heat input measurement, was corrected for both instantaneous energy formulas. In the 2010 edition, the divisor “weld bead length” units were shown as “[in./min]” in one formula and “[in. (min)]” in the other. Both should have read [in. (mm)]. This correction was by errata, which means that it is retroactive.

In related changes, QW-409.26 and QW-409.29 were revised editorially to coordinate better with the methods for determining heat input based on QW-409.1 formulas. These variables only apply to corrosion-resistant overlay and temper bead welding.

The bend test fixture dimensions in QW-466.1 have been revised; but only the metric units are changed. Previously, the metric dimensions were converted from U.S. Customary Units resulting in a 10-mm-thick test specimen wrapping around a 38.1-mm-diameter mandrel. The revision changes the dimension to the correct mandrel diameter of 40 mm based on the specimen thickness of 2t. Similar corrections were made for all other materials shown in the table.

Welder Qualification (QW-300) Changes

QW-300.3 on “mass qualification” of welders was revised to specifically allow the use of AWS Standard Welding Procedures where they are permitted by QW-500. Minor changes were made in QW-500 to recognize that ultrasonic examination (“volumetric”) could be used to test the demonstration test coupon in addition to radiography and bend test.

Base Metals and Filler Metals

The paragraph addressing the column in the P-number table regarding ISO 15608 and what it is about was finally

WALTER J. SPERKO (sperko@asme.org), P.E., is president of Sperko Engineering and chairman of ASME Boiler and Pressure Vessel Standards Committee IX.
— ASME continued from previous page

Printed in the current edition; it had been accidentally omitted since the ISO 15608 column was added in 2009.

A number of new materials was added to the P-number tables (see page xxix for a list) and various corrections were made by errata.

**Filler Metals ERNiCu-7; ERNiCrFe-13, and ERNiCrMo-22 Assigned F-number 43**

Updated versions SFA-5.01, Filler Metal Procurement Guidelines, and SFA-5.22, Stainless Steel Flux Cored and Metal Cored Electrodes and Filler Metal, were added to Section II, Part C. There is a change in the philosophy regarding the location of metal cored wires in the filler metal specification that has come from the ISO world that is evident in SFA-5.22; it now covers metal cored electrodes, which were previously covered in SFA-5.9. While this change in location of filler metals does not change the qualification ranges (i.e., solid and metal cored wires are still interchangeable), WPSs that permit the use of both solid wire and metal cored wire have to be revised to show both the solid wire and the cored wire specifications. That is, if your current WPS for gas tungsten arc welding (GTAW) using SFA-5.9 ER308L filler metal allows the use of both solid and metal cored filler metals, it will have to be revised to add provisions to use SFA-5.22 and EC308L designations if the WPS will continue to permit metal cored filler metal. This change will also occur for the carbon- and low-alloy steel wires as the ISO versions of those filler metal specifications are adopted.

The biggest change in these addenda was the addition of Appendix J, Guideline for Requesting P-Number Assignments for Base Metals Not Listed in QW/QB-422. Previously, it was required that a material had to be approved for use in either the ASME Boiler and Pressure Vessel Code or in the B31 Code for Pressure Piping for it to be assigned a P-number. The new appendix states that the committee will consider assignment of all materials listed in ASME Section II, Parts A and B, and it will consider materials manufactured to other recognized national or international standards. It provides the following list of information to be provided:

- The product application or the intended use
- The material specification, grade, class, and type as applicable
- The mechanical properties and chemical composition requirements
- Welding or brazing data such as compatible materials already assigned a P-number; published welding or brazing data; typical BPSs or WPSs, and PQRs
- Properties of welded or brazed joints if less than the minimum specified in the applicable materials specification.

The information required for a material to be assigned a P-number is not as extensive as that required for materials to be considered for Code construction. It is recommended that anyone requesting a P-number assignment review ASME Section II Part D, Mandatory Appendix 5, posted at [http://files.asme.org/ASMEorg/Codes/Publications/BPVC/10680.pdf](http://files.asme.org/ASMEorg/Codes/Publications/BPVC/10680.pdf) for more details about the information that is required in order for materials to be adopted by the Code. The new appendix emphasizes that the assignment of a P-number to a material does not mean that the material is permitted to be used for Code Construction; however, having a P-number assigned to a non-Code material will simplify the qualification process for welding on materials that are outside the jurisdictional boundary of the Code, such as supports, heat-transfer attachments and even pressure parts when such parts are part of non-code items (e.g., stop valves on a turbine) and are made using non-ASME materials. The appendix also provides details for submittal of the request to the committee.

If base materials that have not been approved for Code construction can now be assigned P-numbers, how about filler metals? Section II Part C, page xxviii, has guidelines for getting materials listed in Section II, Part C, and once they are in Section II, Part C, they can be assigned F-numbers. The requirements are different from those for base metals, however. Filler metals have to be manufactured to recognized national or international standards to be adopted, and the organization that publishes the standard has to agree to allow ASME to publish its standard in Section II, Part C. Other than that, the information required to be submitted is somewhat more detailed than that listed above, plus any licensing issues must also be disclosed.

Note that filler metals do not have to have an F-number or be listed in Section II, Part C, in order to be used for Code construction, including construction of pressure-retaining parts. Such filler metals simply need to be qualified by being used in a procedure qualification test coupon, and the resulting WPS must limit the material to the manufacturer’s trade name or other unique designation that identifies that filler metal.

**Brazing (QB) Changes**

No significant changes were made in the brazing rules.

**Inquiries**

The question of what should one write down on the POR for the heat input on a multipass weld when the pass heat inputs are different has become a common question that deserves some discussion. QW-409.1 clearly specifies that the heat input recorded on the POR is the maximum heat input that the WPS may permit.

The existing interpretations are not a lot of help. Interpretation IX-04-14 says that the heat input calculated has to be based on the volts, amps, and travel speed in the same unit of weld length, so the volts, amps, and travel speed for each pass or each electrode is used to calculate the heat input for that pass or electrode. Interpretation IX-81-19 says that the average heat input of all the passes does not have to be calculated and become the heat input qualified, but it also says that you do not have to record the heat input for each pass on the POR. It is, however, appropriate to record the heat input for each pass in your records. I use a spreadsheet that is posted on my Web site to do that so I can review it to establish the heat input that I will enter into my POR.

Let’s look at some ways to calculate the heat input you could put down on the POR. ASME Section IX does not tell you what value to pick (min, max, average, or other) for the qualified heat input, but you should keep in mind that whatever value you enter on the POR is the maximum heat input that the welder is permitted to use, and the WPS has to reflect that fact.

If you take the lowest heat input that you recorded on your spreadsheet, that does not approach the heat input that was used on the test coupon — obviously, unreasonably conservative. If you take the average or mean heat input of all the passes, roughly half of those values will be above the average heat input and half of them below. That means that the heat input that the welder could use would be less than half of the heat input used on the test coupon — again unreasonably conservative — and the welder may have a hard time welding with such low heat input. Finally, if you scan the spreadsheet and find the pass that exhibited the maximum heat input, that pass may be significantly higher than the heat input for any other passes. This heat input would not reflect the heat input generally used on the test coupon. On the other hand, if the highest heat input value was in a cluster of similar heat inputs, that might be a reasonable value to enter on the POR for the maximum heat input qualified.

I use a spreadsheet (Table 1) to record the volts, amps, travel speed, deposit length per unit length of electrode (for SMAW only), bead size, etc., and to calculate the heat input. I also calculate the
average heat input and the standard deviation of the heat input for each process used to weld the coupon. I then look at the heat input numbers for each pass for each process, and if they are pretty uniform (standard deviation is small — Fig. 1A), I find the highest one and put that down on my PQR as the maximum. If there is a wide range (big standard deviation), I put down the third- or fourth-highest heat input value as my “qualified maximum” heat input. This throws out any extreme outliers that are not representative of the test coupon maximum heat input.

An even more sophisticated approach is to compute the average heat input and the standard deviation for all passes using spreadsheet software. If you take the average heat input plus 1.23 standard deviations above the average and call that your maximum heat input qualified, 90% of the heat input values in your spreadsheet will be below that value, neatly throwing out significant outliers, and provides a reasonable upper limit value for your PQR — Fig. 1B. Using the mean plus 1.65 standard deviations would make that 95%.

The bottom line is that what you enter on your PQR is your call based on your numbers, but keep in mind that what you put down on the PQR is going to be the maximum heat input permitted in the WPS and the value you choose should recognize the consequences of that fact.

**Coming Attractions**

As mentioned in my previous summary, a whole new section on joining plastic is being prepared. While the current effort is to write rules for joining HDPE using the hot plate method, the formatting is such that other methods can be added at later dates. Since the addition of plastic will bring a third section into Section IX, there is a plan to put all the common administrative rules into their own sections, so the 2013 edition should be less redundant, less cluttered, and easier to use.

Where the A-number table of weld metal chemical composition presently has three dots (ellipses) for some elements, there will single values added indicating a maximum amount of that element in the weld metal. The new values are based on the limits on these elements that are found in the SFA specifications.

Readers are advised that ASME Code Committee meetings are open to the public; the schedule is available on the writer’s Web site and at www.asme.org.

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**Honorary Meritorious Awards**

*The deadline for nominating 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.

- **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.

- **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 to 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.
New AWS Supporters

**Sustaining Members**
Bkt Fraser Thermal Technology Sdn Bhd
Unit 10-08, 10th Fl., Block A, Damansara Intan No 1 Jalan Se20/27, Petaling Jaya, Selangor 47400, Malaysia
Representative: Graham McClelland
Bkt Fraser Thermal Technology is a designer and manufacturer of heat transfer and process equipment mainly for the oil and gas industries.

**General Tool Co.**
101 Landy Ln.
Cincinnati, OH 45215
Representative: Arin R. Hargett
www.gentool.com
General Tool Co. is a full-service contract manufacturer offering precision machining, fabrication, and assembly integration. It works to AWS, NAVSEA, and MIL-STD standards, and is NADCAP certified in nondestructive evaluation and welding.

**Supporting Companies**
Bawco Fabricators
PO Box 60165
Houston, TX 77205

Certified Tank
2500 Richards Ln.
Springfield, IL 62702

**Affiliate Companies**
1st Source Welding
37334 Porter Ln.
Hempstead, TX 77445

Burbank Water & Power
164 W. Magnolia Blvd.
Burbank, CA 91502

J. R. Smith Welding Service, Inc.
1217 Beechwood Dr.
Long Pond, PA 18334

Kansas City Structural Steel, Inc.
3801 Raytown Rd.
Kansas City, MO 64129

Rosenbauer Minnesota
5181 260th St.
Wyne, MN 55092

Superior Stainless, Inc.
PO Box 2271
Windsor, CA 95492

Voyage Marine Services
10660 NW 21 St.
Sunrise, FL 33322

**Educational Institutions**
C.S.I. Industrial School
Nazareth, Ind. Estate Rd.
Manjeri, Kerala 676121, India

Global Training
11/4, Jeyammar Rd., Teynampet, Chennai
Tamil Nadu 600018, India

Grant County Career and Tech Center
715 Warsaw Rd.
Dry Ridge, KY 41035

Hutchinson Community College
613 E. 14th Ave.
Hutchinson, KS 67502

Industrial Quality Management
Plot No-8 C-23 Gorai-1 Borivli W.
Borivli Mumbai, Maharashtra 400092
India

Over view of AWS Member Benefits

**Individual Member**
Subscription to the *Welding Journal* plus members-only discounts on FedEx shipping, Liberty Mutual auto and home insurance, health insurance plans, auto rentals, T-Mobile services, credit cards, and major discounts on certifications, education, technical publications, and AWS products.

**Sustaining Company Member**
Includes ten Individual memberships, an engraved Sustaining Company Member plaque, listing on the AWS Web site with hyperlink to your company’s Web site, and your choice of the AWS Standards Library with complimentary updates (a $10,000 value), or discounts on *Welding Journal* advertising, or ten additional Individual memberships.

**Supporting Company Member**
Includes five Individual memberships, the engraved Supporting Company Member plaque, a listing on the AWS Web site, major members-only discounts.

**Educational Institution Member**
Includes three Individual memberships, engraved plaque, institution name listed on the AWS Web site with option to add a hyperlink to your Web site.

**Affiliate Company Member**
Includes one Individual membership, Affiliate Company Member certificate, your company name listed on AWS Web site, three *Everyday Pocket Handbooks*, storefront window decal.

**Welding Distributor Member**
Includes five Individual memberships, free listing on Distributor Locator Map (interactive map on AWS Web site that allows end-users to find your locations quickly), Distributor Company Member plaque, and options for adding a hyperlink to your Web site.

Visit www.aws.org/membership or call (800/305) 443-9353, ext. 480, for complete information about AWS memberships.

**AWS Member Counts**
October 1, 2011

<table>
<thead>
<tr>
<th>Grades</th>
<th>Count</th>
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<tr>
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<td>Supporting</td>
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<tr>
<td><strong>Total Members</strong></td>
<td><strong>68,429</strong></td>
</tr>
</tbody>
</table>
District 1
Thomas Ferri, director
(508) 527-1884
thomas_ferri@thermadyne.com

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

NEW JERSEY
SEPTEMBER 20
Activity: The Section conducted a CWI preparation course at Snuffy’s Steak House in Scotch Plains, N.J. Paul Lennox of DCM Erectors, World Trade Center Project, served as the moderator for the class.

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

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

District 5
Carl Matricardi, director
(770) 979-6344
cmatricardi@aol.com

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

District 7
Don Howard, director
(814) 269-2895
howard@ctc.com

COLUMBUS
SEPTEMBER 7
Speaker: Tom Crouch, senior curator
Affiliation: National Air and Space Museum
Topic: Why Wilbur and Orville?
Activity: The Section members joined members of the local chapters of SWE, ASME, ASM International, AIAA, and NACE for this program. The event, attracting about 60 attendees, was held at Arlington Banquets in Columbus, Ohio.

PITTSBURGH
SEPTEMBER 20
Activity: The Section members met at the Caterpillar Manufacturing facility in Houston, Pa., to study its operations. Highlights were its robotic torch beveling and welding systems. The tour guides included Derek Hall, Ethan Aitken, and John Menhart, a Caterpillar welding engineer and Section executive committee member.
Shown during the Pittsburgh Section’s Caterpillar facility tour are (from left) Derek Hall, Section Chair Brad King, John Menhart, and Ethan Aitken.

Shown at the Mobile Section scholarship award program are (from left) Seth Johnson, Tony Simmons, Matthew Kennedy, Scholarship Chair Jerry Betts, and Brian Goodale.

George Fairbanks (left), District 9 director, is shown with Eleanor Ezell and Johnnie Dedeaux at the Mobile Section event.

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

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

MOBILE
SEPTEMBER 8
Speaker: Jackie Morris, owner, president
Affiliation: Morris Marine Consulting, LLC
Topic: CWI/CWS program and prep courses
Activity: George Fairbanks, District 9 director, presented Eleanor Ezell and Johnnie Dedeaux the District Director Certificate Award for their services. Scholarship Chair Jerry Betts awarded scholarships to Seth Johnson, Tony Simmons, Matthew Kennedy, Brian Goodale, Daniel Withers II, Sean Dooley, Kelly Wilson, and Tyler Miller.

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

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

DETROIT
SEPTEMBER 8
Speaker 1: John Mendoza, AWS president
Affiliation: Lone Star Welding
Topic: AWS activities
Speaker 2: Matthew Rogers, welding engineer
Affiliation: Tank Automotive Research, Development, and Engineering Center
Topic: Welding armored steels
Activity: The Section hosted its annual students’ night program at the Ukrainian Cultural Center in Warren, Mich. The Section awarded 31 scholarships totaling $34,500. The recipients will be attending welding-related programs at Lansing C. C., St. Claire County C. C., Michigan Tech University, or Ferris State University. This was the tenth anniversary of the Amos and Marilyn Winsand Scholarship, funded by the AWS Foundation. This $22,000 award was given to Jacob Quisenberry, who is studying at Ferris State University.
Northwest Ohio
May 24
Speaker: Theresa Pollick, public information officer
Affiliation: Ohio Dept. of Transportation
Topic: Update on area highway projects and future plans
Activity: The Section held its annual old timers’ and awards-presentation program in Toledo, Ohio. Chair Richard West presented Silver Membership Certificate Awards to Sam J. Conte, Terry A. Lowe, and Donald W. Griffin for 25 years of service to the Society. Pennie Wetzel accepted the Silver Membership Award on behalf of her late husband, James Wetzel. Christy Trivette and Sean Bayes each received a $600 scholarship.

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

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

Chicago
August 31
Activity: The Section held a meeting of its board of directors at Jullianni’s Restaurant in Palos Heights, Ill.

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

District 14 Conference
Lexington
June 12
Activity: The Section hosted the District 14 conference in Lexington, Ky. Past Lexington Section Chair Alan Mattox presented $900 District scholarships to Mary Paulhamus and Andrew Standiford.
The Kansas City Section members are shown during their tour in September.

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

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

KANSAS CITY
September 8
Activity: Thirty-three Section members met at Kansas City Structural Steel for a tour of the facility. Tab White presented a history of the company then led the tour, assisted by Mr. Olah. Richard Blaisdell was presented his Gold Member Certificate for 50 years of service to the Society.

Calendar of Upcoming Events
E-mail Grant Von Lunen
gvlonun@kckcc.edu
Nov. 10: Kyle Dunning, speaker
Jan. 12: SPX plant tour, Howard Rinne
Feb. 9: Apprentice training/tour
March 8: Webco Mfg. tour, Tom Breen
April 12: Richard Fort, speaker

Richard Blaisdell (left) receives his Gold Member Certificate from Joey Bleam at the Kansas City Section program.

Siepert was the District 16 representative at the course, held at AWS headquarters.

KANSAS
September 8
Speaker: David McDonnell
Affiliation: OSHA
Topic: Safety issues related to the welding industry, or “How to Get OSHA’s Attention during an Inspection”
Activity: Vice Chair Greg Siepert told the group about the AWS Instructor Institute.
Shown at the Lincoln College of Technology Student Chapter program are from left (top row) Advisor Samuel Elizondo, Chair Orlando Valenzuela, Cochair Eddie Sanchez, Secretary Kyle Shifflet, and Treasurer James Brown, (bottom row) Advisor Phil Harris, Advisor Donnie Williams, Juan Hernandez, Andrew Aguirre, and Membership Chair Corey McCollum.

District 17
J. Jones, director
(940) 368-3130
jjones@thermadyne.com

CENTRAL ARKANSAS

AUGUST 9
Speaker: Jimmy Brewer
Affiliation: United Assn. of Plumbers and Pipe Fitters Local #155
Topic: The SkillsUSA welding committee
Activity: Outgoing Chair Jimmy Brewer presented Matt Fair the District Director Certificate Award. Incoming Chair Dennis Pickering presented Jimmy Brewer the Dalton E. Hamilton CWI of the Year Award.

Lincoln College of Technology Student Chapter
SEPTEMBER 23
Activity: The Student Chapter held its election of officers for the fall-spring term at the college campus in Grand Prairie, Tex. Participating were Advisors Donnie Williams, Samuel Elizondo, and Juan Hernandez, Chair Orlando Valenzuela, Cochair Eddie Sanchez, Secretary Kyle Shifflet, Treasurer James Brown, Membership Chair Corey McCollum, Phil Harris, and Andrew Aguirre.

NORTH TEXAS
SEPTEMBER 20
Speaker: Jack Rector, Fort Worth area director
Affiliation: OSHA
Topic: OSHA and You
Activity: The program was held at Humperdinck’s in Arlington, Tex.

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

Incoming Central Arkansas Section Chair Dennis Pickering (left) is shown with Jimmy Brewer, outgoing Section chair.

Speaker Jack Rector (left) is shown with Bill Hall, North Texas Section chair.

Matt Fair (left) receives the District Director Award from Jimmy Brewer, outgoing Central Arkansas Section chair.
The Colorado Section members are shown during their tour of Ironworkers JATC Local #24 in September.

Arizona Section members are shown during one of the welder training sessions.

Sacramento Section members and guests are shown at the September program.

The Olympic Section golfers pose for a group shot during their competition in September.

Speaker Robert Sanders (left) is shown with Ken Johnson, Puget Sound Section vice chair.
Shown at the Sacramento Section program are (from left) Jason Rafter, David Kilburn, Mark Reese, Melvin Johnson, Ken Morris, District 22 Director Dale Flood, Jerry Wendland, Bill Wenzel, AWS President John Mendoza, Troy Hall, Will Childress, and Nathan Flatt.

Shown at the San Francisco Section program are (from left) Chair Elizabeth Moore, Secretary Liisa Pine, Nora and John Mendoza, AWS president, and Dale Flood, District 22 director.

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

OLYMPIC
September 11
Activity: The Section hosted its annual golf outing for about 50 contenders.

PUGET SOUND
September 1
Speaker: Robert Sanders
Affiliation: Avesta Welding LLC
Topic: Pre- and postweld cleaning of stainless steel
Activity: Forty-one members attended this program, held at Rock Salt Steak House in Seattle, Wash. Dan Sheets of Airgas is working with Chair Steve Pollard and Robert White, publicity chair, to bring a robotics workshop to Everett Community College.

District 20
William A. Komlos, director
(801) 560-2353
bkoz@arctechllc.com
Veteran CWI David Norris (left) is shown with AWS President John Mendoza (center) and Dale Flood, District 22 director, at the San Francisco Section event.

Presenter Jerry Siko (left) is shown with Rob Jozwiak, Arizona Section chair, during one of the virtual reality welding programs.

ARIZONA

AUGUST 17
Activity: Thirty Section member visited Mesa Community College in Mesa, Ariz., to learn about its welding program, meet the educators, and tour the facilities.

SEPTEMBER 8
Speaker: Brent Boling, owner
Affiliation: Arc-Tech Welding, Inc.
Topic: This is AWS
Activity: This Arizona Section program was held at the Hampton Inn in Prescott Valley, Ariz. Attending were educators, manufacturer’s representatives, and high school students. Contributing to the raffle prizes were Miller Electric, Praxair, and Weld Consulting and Engineering Solutions.

SEPTEMBER
Presenters: Jerry Siko, John Weber
Affiliation: The Lincoln Electric Co.
Topic: The VRTEX™ 360 virtual reality arc welding training system
Activity: Arizona Section Chair Rob Jozwiak and the Section members participated in four presentations of this event offering an introduction to welder training using virtual reality. These programs were presented at Mesa Community College in Mesa, Pima and Tucson Community Colleges in Tucson, and East Valley Institute of Technology in Phoenix, Ariz.

COLORADO

SEPTEMBER 8
Activity: Twenty-two Section members met at Ironworkers JATC Local #24 in Denver, Colo., for a tour of the facilities. Jimmie Shasteen, a CWI and union welding instructor, conducted the program.

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

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

SACRAMENTO

SEPTEMBER 13
Speaker: John Mendoza, AWS president
Affiliation: Lone Star Welding
Topic: History of the AWS CWI program
Activity: The Section, in partnership with the Fresno, Santa Clara, and Sierra Nevada Sections, presented Mendoza with a check for $22,000 to add to the District 22 Scholarship Endowment. Ken Morris was named incoming chair and Troy Hall the new secretary. The event was held at American River College in Sacramento, Calif.

Calendar of Upcoming Events
Contact Ken Morris
E-mail kmorris@gnbvalves.com
Nov. 16: Meeting with San Francisco Section
Dec. 9: Officers’ dinner
Jan. 18: UC at Davis, Bill Wenzel
Feb. 15: Gayle Mfg., Hometown Buffet
March 21: Yuba City College, Ken Morris

SAN FRANCISCO

SEPTEMBER 12
Speaker: John Mendoza, AWS president
Affiliation: Lone Star Welding
Topic: History of the AWS CWI program
Activities: Eighty-nine members and guests attended this awards banquet meeting held at Spenger’s Restaurant in Berkeley, Calif. District 22 Director Dale Flood presented Scott Miner the Section Educator Award, and District Director Awards to Sharon Jones and Jerry Azaro. Doug Williams received the Section Meritorious and Section Dalton E. Hamilton Memorial CWI of the Year Awards. Mendoza recognized veteran CWI David Norris in his talk with a scan of his 1977 CWI certificate.

International Section

L.A./INLAND EMPIRE
SEPTEMBER 9 AND 14
Speaker: John Mendoza, AWS president
Affiliation: Lone Star Welding
Topic: AWS certifications
Activity: The program was held at Mill Creek Restaurant in Corona, Calif.

SAUDI ARABIA

Calendar
The 14th Middle East Corrosion Conference & Exhibition is scheduled for Feb. 12-15, 2012, at Gulf International Convention Center Gulf Hotel, Kingdom of Bahrain. Contact Dr. Moufaq Jafar, chairman, technical committee, moufaq.jafar@aramco.com; or visit www.mecconline.org.
 Listed below are the members participating in the 2011–2012 AWS Member-Get-A-Member Campaign. Standings are as of September 19. For campaign rules and a prize list, see page 65 of this Welding Journal. For complete campaign rules, visit www.aws.org/mgm. Call the AWS Membership Department at (800) 443-9353, ext. 480, with any questions about your member proposer status.

Winners’ Circle
Listed are the sponsors of 20 or more Individual Members per year, since June 1, 1999. The superscript denotes the number of years the member has earned Winners’ Circle status.

- E. Ezell, Mobile
- J. Compton, San Fernando Valley
- J. Merzthal, Peru
- G. Taylor, Pascagoula
- L. Taylor, Pascagoula
- B. Chin, Auburn
- S. Esders, Detroit
- M. Haggard, Inland Empire
- M. Karagoulis, Detroit
- S. McGill, NE Tennessee
- B. Mikesa, Houston
- W. Shreve, Fox Valley
- T. Weaver, Johnstown/Altoona
- G. Woomer, Johnstown/Altoona
- R. Wray, Nebraska

President’s Club
Sponsored 3–8 new members
- E. Ezell, Mobile — 7
- G. Bish, Atlanta — 3
- B. Goerg — 3
- G. Mulee, South Carolina — 3

President’s Honor Roll
Sponsored 2 new members
- O. Burrion, South Florida
- G. Fehrman, Philadelphia
- G. Jacobson, Cumberland Valley
- J. Mueller, Ozark

District 20 Names Student Chapter Member Awardee

Michael Ramstetter, Wyoming Section, was selected to receive the AWS Student Chapter Member Award by District 20 Section representatives during their annual District conference.

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 advisors, Section officers, and District directors to recognize outstanding Student Members, as well as to enhance the image of welding within their communities.

The criteria and nomination form can be downloaded from www.aws.org/sections/awards/student_chapter.pdf or call the Membership Dept. at (800) 443-9353, ext. 260, to request the information be mailed to you.

AWS Life Members Get Free FABTECH Professional Program

AWS Life Members get free admission to the upcoming FABTECH expo plus complimentary registration for the entire Professional Program — a $325 value.

FABTECH is scheduled for Nov. 14–17 at McCormick Place in Chicago, Ill.

The free registration entitles Life Members to attend any of the technical sessions presented during the four-day period.

Life Members are urged to take advantage of this valuable benefit. The registration form may be ordered from the Membership Dept.; call toll-free (800) 443-9353, ext. 260.

To obtain your free registration, mark “AWS Life Member: Free Registration” at the top of your Registration Form. Then FAX both sides of the form to (305) 443-7559, Attn: Ruben Lara, accounting director; or mail the form to Ruben Lara, AWS, 550 NW LeJeune Rd., Miami, FL 33126.

Nominate Your Candidate for the M.I.T. Prof. Masubuchi Award

November 2, 2011, is the deadline for submitting nominations for the 2012 Prof. Koichi Masubuchi Award. 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. Sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology (M.I.T.), this award includes a $5000 honorarium.
Welding Electrode Catalog Expanded

The company has released its expanded 100-page catalog describing its complete lines of flux cored and metal cored welding electrode products. Detailed information is presented for more than 170 products including low-alloy, stainless steel, nickel alloy, and hardfacing electrodes. Presented are complete descriptions, classifications, shielding gases, welding positions, characteristics, typical mechanical properties, typical deposit compositions, and applications. Included is information on tubular welding electrodes with electrode comparability charts, welding parameters, agency approvals, and electrode packaging options. The enhanced table of contents simplifies finding the desired products.

Select-Arc, Inc.
www.select-arc.com
(800) 341-5215

OSHA Training Guide Updated

Just released, the OSHA Training Guide, 13th edition, is described as an essential tool for complying with OSHA training regulations and for reducing workplace injuries. It offers an in-depth treatment of 16 critical training areas that are likely to be the source of an OSHA in-
spection and where training is essential to prevent work-related incidents. The guide is supplied in a looseleaf-binder format to facilitate adding and removing pages as needed for the annual updates. Included are coursework, handouts, and tests with answer sheets. This edition provides new information on forklift safety training, bloodborne pathogens training, personal safety equipment, power tool safety, back safety, and numerous other topics. The price, $339.95, includes the complete training guide plus one annual update; providing two years of compliance information. Visit the Web site for complete information and to purchase.

Blue Gavel Press
www.bluegavel.com
(800) 417-2669

Study Forecasts Strong Welding Equipment Growth

Released last July, Welding Equipment and Supplies: The Global Market states the global market for welding products will reach $16.3 billion this year, is projected to exceed $17 billion in 2012, and further increase to $21.9 billion by 2017. The report states the market sector for consumables, gas, and protective equipment accounts for the highest market share that is expected to reach $10.9 billion by 2012, and increase to $14.4 billion by 2017. Welding equipment is valued at $4.5 billion this year and is expected to reach $5.5 billion by 2017. The 376-page report is available in electronic format (PDF) for $4850. For more information and to order, visit the Web site shown then type “welding equipment” in the search window.

Companies and Markets
www.companiesandmarkets.com
+44 (0) 203 086 8600

The Aluminum Association
www.aluminum.org/SustainabilityReport
(703) 358-2960

Just released, Aluminum: The Element of Sustainability, documents sustainability improvements in the North American aluminum industry over the past 20 years. Among the findings are significant reductions in the energy demands and greenhouse gas emissions, while citing 70% of all the aluminum ever manufactured, dating back 125 years, is still in use today. Recycling aluminum uses only 5% of the energy and generates only 5% of the emissions associated with primary aluminum production. Discussed are the impacts of innovative products like Audi auto space frames, beverage cans, and Apple® uni-body laptops. Other topics include aluminum product fabrication, forgings, cast, sheet, rods, bars, strips, plus a wealth of interesting data about the workings of this industry. The full-color, well-illustrated, 71-page report can be downloaded free at the Web site shown.

The Aluminum Association
www.aluminum.org/SustainabilityReport
(703) 358-2960

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For info go to www.aws.org/ad-index
**Concise Int’l. Appoints President**

Concise Int’l., Inc., with facilities in Illinois, Arizona, and Mexico, has appointed J. D. Johnson CEO and president of the diversified precision metal fabricator. Previously, Johnson served as president of Norgren Americas.

**TigerStop Announces VP**

TigerStop LLC®, Vancouver, Wash., a provider of stop-gauge and linear positioning systems, has named Jack Ragan vice president of sales and service. Ragan has 20 years of experience in manufacturing.

**Aluminum Assoc. Names President and Directors**

The Aluminum Association, Arlington, Va., has named Heidi Biggs Brock president, succeeding Steve Larkin who has served in the post since 1998 and plans to retire at the end of the year. Brock most recently served as vice president of federal and international affairs for the Weyerhaeuser Co. and currently serves as a member of the executive committees and boards of the National Institute of Building Sciences and the United States-Japan Leadership Program. Thomas A. Brackman, president of Nichols Aluminum, was elected chairman of the board, replacing Steven J. Demetriou. Jean-Marc Germain, president of Novelis North America was named vice chairman. Incoming directors representing producer members included William Aronson, Patrick Lawlor, Wesley Oberholzer, Jerry Sweeney, Patrick Franc, Dietrich M. Gross, Kurt F. Leopold, Robert J. Longenecker, and Layle “Kip” Smith. Incoming directors representing associate members include Patrick Taylor, Michael O. Falk, and Andrew R. Fellon.

**Sales Engineer Named at Intelligrated**

Intelligrated®, Cincinnati, Ohio, a provider of automated material-handling solutions, has appointed Michael Snyder sales engineer for its U.S. Eastern sales region, based in Somerset, N.J. Snyder has 18 years of experience in the field serving as a systems installation technician, sales representative, and a manager of new product development and systems analysis.

**Sales Manager Named at Titanium Brazing**

Titanium Brazing, Inc., Hilliard, Ohio, has appointed Leonid A. Shapiro manager of sales-operations. Shapiro, an economist, works in materials science engineering performing data analysis, valuation, and risk calculation procedures. His first project is marketing and distribution of silver-free brazing filler metals.

**Airgas Names Safety Officer**

Airgas, Inc., Radnor, Pa., has appointed Jim McCarthy vice president — safety and compliance. With the company since 1988, McCarthy most recently has served as director of gas supply chain since 2008.

**Northeast C. C. Hires CWI**

Northeast Community College, Norfolk, Neb., has appointed John J. Knapp, an AWS Certified Welding Inspector (CWI), as a new welding instructor. For 21 years, Knapp was the welding industrial coordinator and welding technology instructor at Tulsa Technology Center, Tulsa, Okla., and served as a CWI for an AWS-accredited welding test facility.

**Sheet Metal Director Named to ACCSH**

The Advisory Committee on Construction Safety and Health (ACCSH), Alexandria, Va., has named Gary Batykefer one of eight new members appointed by U.S. Secretary of Labor Hilda L. Solis. Batykefer is administrative director for the Sheet Metal Occupational Health Institute Trust. He will join the other 14 members of the committee who represent the interests of labor, management, government, and the public to promote occupational safety and health.

**Miller Weldmaster Names Field Service Engineer**

Miller Weldmaster, Navarre, Ohio, a manufacturer of hot air, hot wedge, and impulse welding equipment for the industrial fabric and thermoplastic industries, has named Jim Yarger a field service engineer. With the company for five years, Yarger previously performed assembly and testing operations on the shop floor.

**Nederman Hires Welding Segment Manager**

Nederman LLC, a supplier of welding fume source-capture equipment, has hired Joe Salyer as its welding segment manager. Salyer brings more than 12 years of experience selling welding equipment and supplies to the position.

**Cee Kay Supply Fills Two Key Posts**

Cee Kay Supply, St. Louis, Mo., a supplier of industrial gases, welding and cutting equipment, and supplies, has appointed Brad Dunn micro-bulk sales specialist and Andrew Swyers as marketing coordinator. Dunn recently earned his MBA from Denver University. Swyers is a recent graduate from the University of Missouri with a degree in journalism.

**Jergens Names Tooling Manager**

Jergens, Inc., Cleveland, Ohio, a supplier of work-holding solutions, lifting, and specialty fasteners, has appointed Patrick Rienks general manager, Tooling Components division. Previously, Rienks was vice president and general manager for Crane Pumps and Systems, Industrial, Commercial, and Plumbing Groups.
Corporate Memberships for Companies Large or Small

Find the AWS Corporate Membership that best fits your organization.

1. **Sustaining Company**
   Join an elite group of 500+ leading companies in the materials joining industry. Sustaining Company Membership is AWS’ most prestigious level of membership, and is perfect for companies looking for the Best Value of all AWS Memberships. Upon becoming a Sustaining Company member, you’ll receive your choice of one of three exclusive money-saving benefits:
   1. AWS Standards Library ($10,000+ Value),
   2. Discount Promotional Package - save 5% on Welding Journal advertising,
   3. 10 additional AWS Memberships ($920 value).

2. **Supporting Company**
   The ideal fit for mid-size companies that want to give their employees the power of AWS, but need more than one Individual Membership. AWS Supporting Company Members have access to practical knowledge on how to improve productivity, solve production problems and improve their competitive position.

3. **Affiliate Company**
   Independent Welders and Welding Shops worldwide can take advantage of an AWS Affiliate Company Membership. Designed exclusively for independent welding and fabricating shops, this membership was developed to meet specific needs: to keep you better informed, aware and responsive to the tides and trends of the welding industry; to improve productivity, solve production problems, and improve your competitive position. AWS Affiliate Company Members are provided with benefits to help them compete in the marketplace.

4. **Welding Distributor**
   Welding Distributors worldwide can take advantage of this Membership designed to help increase their end-user base and improve their competitive position in the marketplace. AWS’ web of communication tools will put distributors in touch with key industry manufacturers, including AWS’ nearly 1,000 Sustaining and Supporting Company Members, most of which are leading producers of welding and equipment supplies. Any welding distributor, small or large, would greatly benefit from this membership.

5. **Educational Institution**
   Designed exclusively for educational institutions that strive to maintain the professionalism of their teaching staff, and strive to be a leader in the education community. AWS Educational Institution Members are committed to the future of the industry, and set a great example for their educators, staff and students. AWS Educational Institution Members are provided with benefits to help their educators, staff and students.

To Learn More About AWS Corporate Memberships, please call 800-443-9353, ext. 480, or visit www.aws.org/membership
The American Welding Society and The International Thermal Spray Association are presenting a thermal spray and coatings conference to be held in conjunction with the 2011 FABTECH show. The program is intended to highlight the Thermal Spray Process and its uses with morning and afternoon sessions focusing on actual applications and new developments in thermal spray technology. This program will benefit both potential users and those actively involved with thermal spray coatings as it will focus on actual applications and new developments in thermal spray technology.

In addition, a free half-day seminar on Thermal Spray Basics: Putting Coatings to Work will be held on Tuesday, Nov. 15.

For the latest conference information, visit our website at www.aws.org/conferences or call 800-443-9353, ext. 264.

Wednesday, Nov. 16, 2011, 9:00 am to 5:00 pm
McCormick Place, Chicago
(at the FABTECH Show)

AWS Members: $345
Nonmembers: $480

Register at www.aws.org/fabtechevents
Reg. code: W31
PROFESSIONAL PROGRAM ABSTRACT SUBMITTAL
ANNUAL FABTECH SHOW
Las Vegas, Nevada - November 12-14, 2012
Submission Deadline: March 9, 2012
(Complete a separate submittal for each paper to be presented.)

<table>
<thead>
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Answer the following about this paper:

Original submittal? Yes ☐ No ☐  Progress report? Yes ☐ No ☐  Review paper? Yes ☐ No ☐  Tutorial? Yes ☐ No ☐

What are the welding/Joining processes used?
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Explain the technical approach, experimental methods and the reasons why this approach was taken.

### Results/Discussion (300 words max.)

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### Conclusions (100 words max.)

Summarize the conclusions and how they could be put to use – how and by whom.

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**NOTE:** Abstract must not exceed one page and must not exceed the recommended word limit given above

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**ANNUAL FABTECH SHOW**
Las Vegas, Nevada – November 12-14, 2012

**Submission Deadline:** April 13, 2012  
*(Complete a separate submittal for each poster.)*

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- Practical application is important and should be demonstrated.

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How to Avoid Lower-Back Injuries

A physician describes how to size up lifting situations to dramatically reduce workers’ chances of getting hurt on the job

BY W. TOM FOGARTY, M.D.

Each year, Americans spend more than $50 billion treating lower-back pain. It is the most common cause of job-related disability and a leading contributor to missed work, according to the National Institute of Neurological Disorders and Strokes.

As we age, our bodies are more prone to develop lower-back problems, starting as early as our 30s. Additionally, our routine daily activities and habits can cause or aggravate back problems.

The factors affecting back injuries include traumatic accidents, poor posture, impaired physical condition, use of improper body mechanics when lifting bulky objects, and stretching or forcing the body into unusual positions.

It is imperative for workers to frequently review and practice safe-lifting techniques to avoid the pain and suffering of lower-back injuries, the missed time at work, and costly claims for the employer.

Use Your Brain before Your Brawn

Think carefully before moving or lifting a heavy or bulky object. Plan how you will lift the object. Map out your hand placement and lifting leverage. Test the object’s weight. Be sure the object is not too heavy for you to handle by yourself. If it’s difficult to hold the object while standing, it might be impossible to safely carry the object — Fig. 1. Get someone to help you to avoid injury. It’s good advice to confirm you have a clear walking path before carrying any object. When in doubt, ask for help. If the object’s shape or weight is questionable, it is better to be overcautious to be safe rather than risk an injury.

Lift using your legs. Use the stronger leg muscles by bending the knees rather
than straining the back muscles. Support your back by maintaining core strength using the abdominal muscles while lifting, and maintain the natural lumbar spinal curve in your lower back by keeping your back straight while performing the upward lifting motion.

Keep objects close to the body to avoid putting extra strain on your back muscles — Fig. 2.

**Hold the object steady.** Once in motion with an item, avoid twisting your body, bending, or making any rapid or jerky movements.

**Maintain good balance.** Keep your feet approximately shoulder-width apart to maintain better balance throughout the lifting and moving process.

It is important to breathe normally while lifting. Avoid holding your breath.

**Staying in Shape**

In addition to practicing the above safe-lifting tips, workers can improve their overall strength and wellness with certain lifestyle changes. Regular exercise is the best way to strengthen your muscles to minimize the risk of back injuries. Working out with a partner or a spouse can make exercise a more enjoyable lifestyle change. Routine physical activity will not only stave off back injuries, but remaining active is also key to recovering from simple strains, aches, and pains. Begin all exercise activities with stretching and warming up to avoid straining your muscles. It’s a good idea to stretch and warm up before all physical activities, including lifting bulky objects.

**Stay active.** Change your positions frequently when it is necessary to sit or stand for long periods.

When a heavy object must be moved, take the time to carefully think about the task to determine whether there is a better, safer way of doing it with less risk, and when to seek assistance.

**Don't Get Hurt, but If You Do**

Finally, if you do suffer lower-back pain, avoid bed rest. For a faster recovery, it is better to keep moving and try to maintain normal activity.
Cheese on the ‘Moo’ve

High school students in North Carolina recently used their welding and cutting skills to transform steel into ‘udderly’ good works of art for a local factory

BY KRISTIN CAMPBELL

When the advanced welding class at Ashe County High School, West Jefferson, N.C., started a fabrication project for Ashe County Cheese, they had no idea what a cow-sational craze it would become.

Their mission: to create three large, in-proportion cow heads from steel and attach them to three 5000-gal milk tanks.

It was part of a renovation plan, led by Steve Willingham’s artistic vision, for North Carolina’s oldest cheese plant.

The finished black and white sculptures have drawn attention to the small town with a population of 1299.

“I think the fact that this is something very visible to the public in a positive way is the most rewarding part for me and the students,” said Rusty Rogers, the school’s welding instructor. “Every time we go through town and see people standing beside them, having their pictures taken, reminds us that we have made something that will be enjoyed by many people for many years.”

‘Herding’ the Students to Cow Construction

Rogers helped his advanced welding students assemble the first steel cow head. After that, he let them do the work and provided guidance where needed.

In the school’s shop, the students welded together two 4 × 8 ft pieces of 16-gauge carbon steel sheet metal and laid them flat. Then, they clamped a plywood template made by Willingham to the sheets and used a hand-held plasma cutting device to cut the head shapes. These formed the sides to connect the two profiles and were tack welded in place. Rounded pieces were shaped by hand rolling, then tack welded to the profiles.

The finished black and white cows, surrounded by red petunias and sunflowers, make a welcome addition to Ashe County Cheese. Visitors enjoy taking pictures of this landmark.

KRISTIN CAMPBELL
(kcampbell@aws.org) is associate editor of the Welding Journal.
Ears were added as well. Once all the pieces were together and reinforced with inside bracing using gas metal arc welding (GMAW), they finished by using gas tungsten arc welding (GTAW) to complete welds around all seams.

Each steel cow head, from its neck to its nose, measured 8 ft and weighed 250 to 300 lb — Fig. 1.

It took about 15 h to make each figure with the students spending an average of 2 h per school day on the task.

The following junior and senior advanced welding students participated in the project: Josh Weinberg, Levi Shepherd, Thomas Miles, Josh Johnson, Jonathan Greer, Robert Blevins, Johnny Sloan, David Mendoza, Collin Weaver, Michael Baldwin, Robert Heavner, and Ben Miller.

“They have the benefit of leaving their mark on the town they live in that they can be proud of,” Rogers said.

Also, the project coincided with the end of the school year, so students got an inside look of working under a tight timeframe. They finished the job on their last full day of classes, amid final exams.

“The real challenge was the deadline, just ensuring that all hands were engaged in helping in some way just to ensure we got it finished,” Rogers added. This included giving each student a responsibility for cutting, tacking, welding, cleaning, and priming.

### Installation Process Featured Online

The steel cow heads were transported from the school to the cheese plant on a flatbed trailer.

For on-site installation, Rogers brought a portable GMAW machine and oxyfuel cutting tool. Lifting the heads in place required manpower and a forklift.

It took nearly an entire school day to get the heads mounted on the tanks and another half day during Memorial Day weekend to finish welding them in place — Figs. 2, 3. Cutting these heads to fit the tank contour was done on-site, too.

Additionally, a creative video tribute to this project, complete with dynamic music and various keywords flashed across the screen, is highlighted on YouTube. Just look for Three Cow Town.mov by the user saggywagontrail. The welding and on-site work by Rogers, his students, and Willingham are chronicled for viewers to enjoy.

### Grazing in the Grass

The festive cows, painted by Willingham in black and white to resemble a Holstein cow, are roughly 23 ft long. They are surrounded by a wooden fence; rock flower bed wall featuring red petunias and sunflowers; a sign that reads “See Cheese Made”; plus two barrels of hay with a small seating area off to its side — see lead photo.

“They did a great job and worked hard,” said Josh Williams, co-owner of Ashe County Cheese, about the efforts Rogers and his advanced welding students dedicated toward the project.

Recently, the project won an Award of Merit in the promotion category as part of the 2011 North Carolina Small Town Main Street Award. The Town of West Jefferson planner, Matthew Levi, submitted the nomination. This honor will be presented at the organization’s annual awards reception and program in Clayton on January 26, 2012.

### What's Next

In the future, Rogers is open to just about any project that will support the local community, as long as it’s possible to make. He has several students every year who go on to weld in the community or receive postsecondary training for various careers, including pipe welding.

Rogers also mentioned Willingham was pleased with the project and expressed a desire to work with the school again in doing more town beautification projects.

Milking this cooperative relationship might produce more artistic efforts for Ashe County. And who knows? Maybe these advanced welding students will help create another sensation that will be a big hit.
Meeting the New EPA Air-Pollution Standards

Metal fabricators have only until Nov. 22 to file their Notification of Compliance Status reports with the Environmental Protection Agency

BY TRAVIS HAYNAM AND ED RAVERT

In July 2011, the U.S. Environmental Protection Agency (EPA) began enforcement on a subset of the National Emission Standards for Hazardous Air Pollutants, commonly referred to as MFHAP (Metal Fabrication Hazardous Air Pollutants).

The new regulation seeks to control emissions generated by metalworking processes including welding and abrasive blasting.

Other government and safety organizations, including the Occupational Safety and Health Administration (OSHA) and the National Institute for Occupational Safety and Health (NIOSH) have existing standards and permissible exposure limits (PELs) in place to control some of these hazardous contaminants, such as hexavalent chromium, to protect workers’ health.

Focus Is on Reducing Outdoor Air Pollution

What makes this latest MFHAP regulation different is the focus lies not on the safety of the workers but on controlling the indoor pollutants before they can become outdoor emissions.

What this means for facility managers is that exhausting air or using natural ventilation as a means of controlling indoor air pollution may no longer be an acceptable practice. While the implications of these new regulations will be far reaching, it presents an opportunity for fabrication shops to review their indoor air-pollution control strategy and adopt a more productive, healthier, and more energy-efficient course for the future.

Are You Affected, Are You in Compliance?

Important considerations to help understand how this new MFHAP regulation could impact your company and ensure its compliance are:

1. Determine whether your company is subject to the new regulation.

   The standard applies to what the EPA defines as area source producers engaged primarily in the metalworking industry. Applicable North American Industry Classification System/Standard Industrial Classification codes are available within the standard, but if metalworking is a core function of your business, it is likely the standard applies to your company.

   The next step is to determine whether the airborne contaminants are considered hazardous. The EPA defines hazardous as consisting of greater than 0.1% of cadmium, chromium, lead, or nickel, or greater than 1.0% of manganese. There are a few notable exemptions such as the U.S. Armed Forces, NASA, and the National Nuclear Security Administration.

2. Register and document your compliance with the EPA.
Companies that have MFHAP emissions are required to submit an Initial Notification Letter to both state and regional EPA offices. If your company is operating an existing affected process, the company must submit a Notification of Compliance Status no later than Nov. 22, 2011.

Manufacturers are also required to submit Annual Certification and Compliance Reports no later than Jan. 31 each year and maintain detailed records for five years of applicability determinations, testing results, control device specifications, etc.

**Checklist for a Viable Air-Pollution Control System**

3. Achieve compliance with the proper air-pollution control systems.

Compliance varies with each metalworking process, but all require fabricators to minimize dust within in surrounding areas. The welding process requirements go further by requiring no visible emissions observed exiting the facility. Achieving this level of air quality will require a well-designed and engineered air-pollution control system. Air-pollution control systems can vary greatly, but it is important to keep the following in mind when selecting the solution that is best for your company:

- Make sure the system matches your fabrication process and will allow you to continue to operate efficiently. Include the operators in the discussion as it will be important to get their buy-in and ensure their understanding of the necessity to routinely and properly utilize the system.

- Capturing the fume or dust at the source will yield the best results and require the least amount of energy — Fig. 1. When source capture is not practical, other solutions such as ambient collection, including push-pull recirculation systems, can be effective — Fig. 2.

- Select the correct filter technology to provide the efficiency required to capture — not just relocate — the collected dust or fume. Cartridge filters with a nanofiber layer are widely accepted as an optimal solution given their high initial efficiency, superior dust release during cleaning cycles, extended filter life, and affordable replacement filter cost.

- Take into account other standards when developing your solution, such as OSHA exposure limits or National Fire Protection Association standards dealing with combustible or explosive dusts. A well-designed system can achieve compliance across all of the applicable standards. For welding, ongoing monitoring of the emissions is required. It should be assessed first by EPA Method 22, which is a series of visual observations of indoor opacity over fixed time intervals. The frequency and duration of future testing systematically adjusts depending on the observed results. For heavy emitters, EPA Method 9, which requires special training and regular certification to conduct, may be necessary.

**Complying Can Net Cost Savings and Other Benefits**

4. Seize the opportunity to reduce your operational costs.

The latest EPA standard provides an opportunity to become a more environmentally friendly and sustainable fabricator while reducing the overall cost of operation at the same time. Better indoor air quality is linked to higher worker productivity, lower absenteeism, reduced health care costs, and improved product quality. Fabricators who currently exhaust conditioned air can achieve significant savings through filtering and recirculating the air within their factory. In fact, many energy companies are offering incentives for doing this very thing in an effort to aid industry in reducing energy consumption. All of these factors provide sufficient reasons and justification for improved indoor air quality. The EPA regulation is just a nudge to get the process started.

With a filing deadline of Nov. 22, 2011, for the Notification of Compliance Status report, there is no time to waste. Begin your evaluation now by determining whether you are a qualified supplier. Then, contact experienced air-pollution control specialists to determine the appropriate emission-collection solutions for your specific applications. They will evaluate your needs and recommend the solutions to ensure compliance with the applicable standards. A well-designed air-pollution control system is the best way to ensure your facility achieves EPA compliance, attains performance expectations, and realizes potential operational cost savings.

The complete texts of the MFHAP regulation as well as EPA Visitable Emissions Field Manual, EPA Methods 9 and 22, and associated information, can be downloaded online. Just Google “MFHAP regulation” or “EPA Methods 9 and 22” for the various sites.
Types of Welds

Following are descriptions and illustrations for six types of welds.

**Upset welding (UW)** is a resistance welding process producing a weld over the entire area of faying surfaces or progressively along a butt joint — Fig. 1A.

**Flash welding (FW)** is a resistance welding process producing a weld at the faying surfaces of butting members by the rapid upsetting of the workpieces after a controlled period of flashing action. An example of a flash weld is shown in Fig. 1B.

**Surfacing weld** is a weld applied to a surface, as opposed to making a joint, to obtain desired properties or dimensions — Fig. 1C.

**Slot welds** are welds made in an elongated hole in one member of a joint fusing that member to another member. The hole may be open at one end. A fillet-welded slot is not to be construed as conforming to this definition. See Fig. 1D.

A **plug weld** is a weld made in a circular hole in one member of a joint fusing that member to another member. A fillet-welded hole is not to be construed as conforming to this definition. See Fig. 1E.

**Fillet welds** are welds of approximately triangular cross section joining two surfaces approximately at right angles to each other in a lap joint, T-joint, or corner joint — Fig. 1F.

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*Fig. 1 — Various weld types.*
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Laser-Enhanced Metal Transfer – Part II: Analysis and Influence Factors

Laser intensity and arc voltage were examined for their effects on metal transfer

BY Y. HUANG AND Y. M. ZHANG

ABSTRACT

Experiments were previously done to demonstrate that applying a relatively low-power laser to the liquid droplet could produce free flight transfers with welding currents below the transition one. In this paper, the effects of the laser intensity and arc voltage on metal transfer process in laser-enhanced GMAW were discussed and analyzed. The enhancement of the laser was shown to increase as the laser intensity increased. The larger laser intensity tended to help reduce the size of the droplet detached. The arc voltage affected the metal transfer process through changing the current and changing the gap and possible time interval of the droplet development. A larger arc voltage helped reduce the size of the droplet detached through an increased electromagnetic force. It also tended to provide a longer time to grow the droplet. In both cases, the chance for short-circuiting or repelled drop globular was reduced.

Introduction

In the first part of this investigation (Ref. 1), it was shown that the laser affected the metal transfer process as an additional detaching force that tended to change a short-circuiting transfer to drop globular transfer (even drop spray), reduce the diameter of the droplet detached in drop globular transfer, or reduce the diameter of the droplet such that the metal transfer changes from drop globular to drop spray.

Metal transfer, which is referred to as the periodical metal melting and droplet forming, growing, detaching, and traveling process, is a key issue in gas metal arc welding (GMAW). As previously mentioned (Ref. 1), the American Welding Society classifies the metal transfer into three major types/modes: short circuiting, globular, and spray (Ref. 2). Metal transfer modes are affected by several operational factors, such as welding current, composition of shielding gas, wire extension, the ambient pressure, active elements in the electrode, polarity, and welding material (Refs. 3–6). Of all of these, welding current is the most important factor to determine the metal transfer mode. When a continuous waveform current is used and the current is small, the droplet may not be detached until it contacts the weld pool. This transfer mode is referred to as short-circuiting transfer. If the welding current increases or the arc length increases, the droplet will gradually grow until the gravitational force balances the surface tension, and then the droplet will detach. This transfer mode is globular transfer. When the current further increases, the electromagnetic force may become a sufficiently large enough detaching force to detach the droplets whose diameter is similar (drop spray) to or much smaller (streaming spray) than that of the electrode wire. The metal transfer modes were widely studied in the literature (Refs. 6–8). Metal transfer control was also a focus in the research community (Refs. 9–12). The International Institute of Welding (IIW) further classifies globular transfer into drop globular and spelled globular (Refs. 8, 13). The IIW classification for metal transfer is shown in Table 1.

In Part I, welding current was preliminarily discussed as a major factor affecting the metal transfer. Laser recoil pressure force was found to be responsible for achieving free-flight transfer modes with welding currents below the transition current. However, there are other major factors that affect the metal transfer in laser-enhanced GMAW. This part of the paper is thus devoted to understanding how the laser intensity and arc voltage affect the metal transfer in laser-enhanced GMAW.

Effects of Laser Intensity

The major parameter of the laser in the laser-enhanced GMAW is the recoil pressure that is determined by the laser intensity and the cross section of the droplet that intercepts the laser. To study the effect of the laser intensity, three levels of laser power were used: 645, 754, and 862 watts (W). The laser beam used in this study is 1 x 14 mm. The corresponding intensity is thus 46, 54, and 62 W/mm². Because the laser is applied along the wire axis direction, if the diameter of the droplet is smaller than 1 mm, the interception area aforementioned increases quadratically with the droplet diameter; however, for the majority of the experiments studied in this investigation, the droplet detached has a diameter greater than 1 mm, and the interception area increases linearly with the diameter of the droplet.

Figures 1 and 2 show the metal transfer at different laser intensity levels for 300 in./min, 30 V, 0–62 W/mm². (Figure 1 is the Fig. 6 in Part I, and is represented here to make analysis clear.) When the laser intensity was zero (Fig. 1A), the metal transfer was short circuiting. (For shorting-circuiting transfer, the diameter of the droplet such as that given in Fig. 3 is measured right before...
Table 1 — Classification of Metal Transfer in GMAW (Refs. 8, 14)

<table>
<thead>
<tr>
<th>Metal Transfer Mode</th>
<th>Sketch</th>
<th>Examples</th>
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<tbody>
<tr>
<td>Free Flight Transfer</td>
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<tr>
<td>Globular drop</td>
<td>Low-current GMAW</td>
<td></td>
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<tr>
<td>Repelled</td>
<td>CO₂ shielded GMAW</td>
<td></td>
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<td>Spray projected</td>
<td>Intermediate-current GMAW</td>
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<tr>
<td>Streaming</td>
<td>Medium-current GMAW</td>
<td></td>
</tr>
<tr>
<td>Rotating</td>
<td>High-current GMAW</td>
<td></td>
</tr>
<tr>
<td>Explosive</td>
<td>SMA (covered electrode)</td>
<td></td>
</tr>
<tr>
<td>Bridging Transfer</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Short circuiting</td>
<td>Short-circuiting GMAW</td>
<td></td>
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<tr>
<td>Bridging without</td>
<td>Welding with filler metal</td>
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</table>

Fig. 1 — Typical metal transfer in comparative experiments with and without laser under 300 in./min, 30 V, 0–62 W/mm² and 300 in./min, 30 V, 62 W/mm².

the droplet touches the weld pool.) When it increased to 46 W/mm², the transfer was a mix of short circuiting and drop globular at approximately 50–50%, but the droplet was typically detached right before the droplet touched the weld pool. Hence, in Fig. 3, its droplet diameter is the same as that without the laser. (One should note that the diameter of the droplet detached under a short-circuiting condition differs from that under a drop globular transfer. Hence, the same droplet diameter observed in Fig. 3 for without a laser, reasonably equals a laser intensity of 46 W/mm².) When the laser intensity increased to 54 W/mm², the metal transfer became drop globular (Fig. 2); when the laser intensity further increased to 62 W/mm², the diameter of the detached droplet further reduced — Fig. 1B. As can be seen in Fig. 4B in Part 1, the current approximately remained unchanged. The increase in the laser intensity thus did not increase the electromagnetic force. Figure 3 clearly shows the tendency that the droplet diameter reduces as the laser intensity increases. The increased laser intensity decreased the need for a larger diameter for a larger interception area and large mass.

Metal transfer images in additional experiments at the different laser intensity levels for 250/350/400 in./min, 30 V, 0–62 W/mm² are shown in Figs. 4–6. To form a complete set of data to examine the effect of laser intensity at the 30 V setting, those previously presented images for laser intensity at zero (without laser) and 62 W/mm² in Part 1 are presented again. The complete set of data is illustrated in Fig. 7 to show tendency how the laser intensity affects the droplet diameter. However, there are details that deserve attention and are discussed below.

Let’s first examine the experiment series associated with 250 in./min (250 in./min, 30 V, 0–62 W/mm²), as shown in Fig. 4. It is seen that the transfer with 46 W/mm² (Fig. 4B) is a mix of short circuiting and drop globular but the droplet diameter is almost the same as the one without a laser (Fig. 4A), as can be seen from Fig. 7. In these two cases, the laser recoil pressure (if any) is not large enough to compensate for the lack of gravitational force for a complete free flight transfer and a relatively large gravitational force is still needed to detach the droplet. In this mixed mode, short circuiting transfer dominated, but the drop globular transfer also occurred.

In this series of experiments, an interesting phenomenon can be observed from Fig. 4A and B that the laser-enhanced short-circuiting transfer (Fig. 4B) still produced spatter but at a much reduced amount from conventional GMAW (Fig. 4A). Careful observation shows that the short-circuiting time was reduced approximately 20% by the laser at the intensity of
Typical metal transfer in comparative experiments with and without laser under 300 in./min, 30 V, 46 W/mm² and 300 in./min, 30 V, 54 W/mm².

46 W/mm². This may possibly be the cause that reduced the spatter.

Examine the experiment series associated with 350 in./min (350 in./min, 30 V, 0-62 W/mm²), as shown in Fig. 5. With a laser intensity of 46 W/mm² (Fig. 5B), the drop globular dominated and short-circuiting transfer seldom occurred. For 54 W/mm² (Fig. 5C), the transfer is a stable drop globular process, but the droplet diameter is larger than that with 62 W/mm² (Fig. 5D).

For the experiment series associated with 400 in./min (400 in./min, 30 V, 0-62 W/mm²), as shown in Fig. 6, the metal transfer mode is different from the two aforementioned. As shown in Fig. 6B–D, the metal transfer mode is the drop spray transfer. Increasing the laser intensity will decrease the diameter of the droplet, though this change is not obvious.

As summarized in Fig. 7, for all the wire feed speeds, the diameter of droplet in each laser-enhanced GMAW experiment is smaller than its respective counterpart in conventional GMAW experiment. If the diameter for an increased laser intensity is the same with or very close to one for a lower laser intensity (or without laser), they both must be either short-circuiting or very close to short-circuiting (i.e., the droplet is detached right before it touches the weld pool). Of course, all these phenomena can be well explained based on force analysis as has been done in the Part 1.

Effects of Arc Length

The voltage setting on the metal transfer affects the metal transfer through its effect on the arc length, i.e., increasing/decreasing the voltage increases/decreases the arc length. The change in the arc length affects the metal transfer through 1) an increased arc length that reduces the wire extension such that the welding current increases when using a constant voltage power supply as in this study, and 2) an increased arc length provides a longer gap to allow a longer time for a new droplet to develop after a droplet detachment. (This gap, the distance from the bottom of the new droplet to the weld pool surface right after a droplet is detached, is referred to as the development gap hereafter in this study.) In laser-enhanced GMAW, an increased laser intensity does not increase the welding current, as shown in Fig. 4 in Part 1. (Instead, it reduces the current slightly.) However, when the voltage increased by 6 V, the welding current increased by 10 to 15 A (Fig. 4 in Part 1). Because the electromagnetic force as a de-
Fig. 5 — Typical metal transfer in comparative experiments with and without laser under 350 in./min, 30 V, 0 W/mm$^2$; 350 in./min, 30 V, 46 W/mm$^2$; and 350 in./min, 30 V, 54 W/mm$^2$.

Fig. 6 — Typical metal transfer in comparative experiments with and without laser under 400 in./min, 30 V, 0 W/mm$^2$; 400 in./min, 30 V, 46 W/mm$^2$; and 400 in./min, 30 V, 54 W/mm$^2$.

Fig. 7 — Droplet diameter with 30 V under different wire feed speed and laser power levels. The droplet diameter is the mean of the diameter of the droplet that is detached or touches the weld pool.

Fig. 8 — Typical metal transfer in comparative experiments with a laser under 350 in./min, 26 V, 62 W/mm$^2$; 350 in./min, 28 V, 62 W/mm$^2$; and 350 in./min, 32 V, 62 W/mm$^2$.

The detaching force increases faster than a quadratic speed as the current increases, the increase in the detaching force would be significant. Let’s take the experiment series with 350 in./min wire feed speed (Figs. 5 and 8) as an example to illustrate how the voltage setting affects the metal transfer. When the voltage was 26 V, as shown in Fig. 8A, even if the laser power was 62 W/mm$^2$, the metal transfer was still short circuiting. This is because the development gap was short such that there was not
enough time to grow the droplet. As a result, its small gravitational force together with the detaching electromagnetic force and laser recoil pressure force was not still sufficient to balance out the surface tension before the droplet touched the weld pool. When the voltage increased to 28 V (Fig. 8B), the development gap increased for the droplet to grow longer. In addition, the electromagnetic force increased. However, those increases were still not sufficient, and the metal transfer was still short circuiting. When the voltage increased to 30 V (Fig. 5D), the metal transfer changed to drop globular. When it further increased to 32 V, the droplet diameter is further reduced to a level comparable with that of the wire (Fig. 8C) due to the increased current/electromagnetic detaching force.

Figure 9 plots how the droplet size changed with the voltage setting for the experiment series analyzed above. The observed droplet size increase from 26 to 28 V was due to the increased development gap that provided a longer time for the droplet to grow. The increased electromagnetic force should have tended to help detach the droplet. However, since the droplet was not detached (still short-circuiting transfer), the electromagnetic force played no role in determining the droplet size. Hence, it was the increased development gap that contributed to increasing the droplet size before short-circuiting. The droplet size decreases when increasing from 28 to 30 V and from 30 to 32 V were due to the respective increase in the current/electromagnetic force. The increased development gap played no role in this decrease. The laser may only help reduce the droplet size further or help the transfer to change from short circuiting to drop globular or drop spray.

Similar analysis can be done to understand how the voltage affects the metal transfer process for other wire feed speeds such as for 400 in./min — Fig. 10. Despite the change in the current that directly affects the electromagnetic force, the voltage setting still affects the metal transfer through its associated current change and development gap change.

In summary, a higher voltage setting increases the current and development gap. The increased development gap may help change the metal transfer from short circuiting to drop globular or even drop spray, but it plays neither role in affecting the size of the droplet detached under free-flight transfers nor a role in changing the transfer from drop globular to drop spray. The increased current affects the metal transfer by increasing the electromagnetic detaching force.

Conclusions

- Laser intensity and arc voltage are major factors affecting the metal transfer in laser-enhanced GMAW.
- The enhancement of the laser increases as the laser intensity increases and the droplet size could be effectively controlled by changing the laser intensity in an appropriate range.
- An increased arc voltage increases the current and can affect the metal transfer through an increased electromagnetic force.
- An increased arc voltage also increases the arc gap and possible time interval for the droplet to develop to reduce the chances for short-circuiting transfer or repelled drop globular transfer.
- Droplets can be detached at a given/desired diameter in a reasonable range by applying an appropriate laser intensity under a given current (arc variable) in a reasonable range, and the needed laser intensity is determined by the desired droplet diameter and the welding current used (arc variable).

Acknowledgment

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Microstructure and Properties of Laser Brazed Magnesium to Coated Steel

BY A. M. NASIRI, L. LI, S. H. KIM, Y. ZHOU, D. C. WECKMAN, AND T. C. NGUYEN

ABSTRACT

A diode laser brazing procedure has been developed for joining AZ31B-H24 Mg alloy sheet to aluminum-coated, cold-rolled carbon steel sheet in the single flare bevel lap joint configuration using a Mg-Al based welding wire. In this process, the Mg-Al based filler metal and a shallow surface layer of the Mg alloy sheet were melted simultaneously by a diode laser beam, while no melting of the steel sheet occurred. The results of this study suggest that feasibility of this process depends strongly on the pre-existing Al-12Si coating layer on the steel sheet that promotes wetting of the Mg-Al filler alloy as well as formation of a layer of Fe(Al, Si), intermetallic compound along the braze/steel interface. From the middle part of the braze/steel interface to the root of the joint, the Al-Si layer melted and mixed into the braze alloy and the intermetallic layer grew up to 8 μm thick. From the middle part of the braze/steel interface to the top of the joint, both the Al-Si and the intermetallic layer were dissolved. These two simultaneous phenomena led to an intermetallic layer with nonuniform thickness ranging from 0 to 8 μm along the braze/steel interface. The average fracture load of the joint was 767 N, representing a 72% joint efficiency relative to the steel sheet. Failure occurred when cracks propagated along the intermetallic layer starting at the root of the bevel joint and moved into the braze metal at the upper part of the joint.

Introduction

In recent years, interest has grown in the joining of dissimilar metal combinations. In the automotive and aerospace industries (Refs. 1, 2), the development of dissimilar metal joints is a natural advancement of the concept of tailor-welded blanks (TWBs). Besides allowing further improvements and optimization of material utilization and mechanical properties in parts, dissimilar metal joints can offer additional benefits related to functionality requirements (Ref. 3). To date, researchers have focused on joining of dissimilar metals such as aluminum to steel and aluminum to titanium, using solid-state (Refs. 4, 5), reactive wetting (Refs. 6–8), and laser welding (Refs. 9, 10) joining processes.

The use of high strength-to-weight ratio magnesium alloys in automotive structures is attractive because it can help to lower the overall weight of the vehicle, thereby facilitating improvement in fuel efficiency and reduction of harmful greenhouse gas emissions (Ref. 11). The increased application of Mg alloys in automotive structures will be further facilitated by research and development of methods for joining steel to Mg alloys. To date, only limited studies have been conducted in the joining of magnesium alloys to steel. Friction stir welding (FSW) (Ref. 12) and laser-arc hybrid welding (Refs. 13–16) techniques to join magnesium alloys to steel have been examined.

Solid-state joining processes, such as FSW, can be used to make dissimilar metal joints between Mg and steel (Refs. 12, 17). However, the designs of FSW joints are restricted. Also, FSW is difficult to use as a joining process in industry, especially for high-melting-point materials like steel, because heavy-duty clamping systems are required to hold the parts together and also there are difficulties with thickness variation and nonlinear welds. Joint strengths up to 70% of the Mg base material strength have been obtained when using the FSW process to join Mg alloys to steel (Ref. 12).

Fusion welding processes are normally not suitable for joining of Mg and steel due to the large difference in melting temperatures between Mg and steel, i.e., 649°C and 1538°C, respectively. In addition, the boiling point of magnesium is only 1091°C. As a result, molten steel will vaporize magnesium that is in contact with it. At ambient pressure, molten magnesium and molten steel do not mix nor react with each other (Ref. 18). Catastrophic vaporization of the magnesium is inevitable when using recently developed fusion welding processes such as laser-gas tungsten arc hybrid welding. In addition, protection of the steel-Mg alloy interface from oxidation in a lap joint design is difficult (Refs. 13–16).

The benefits of using laser brazing and laser welding-brazing technologies for joining dissimilar materials are becoming increasingly recognized due to the combined attributes of furnace brazing and laser welding (Ref. 19). With a more localized energy input and more precise
control of the laser beam energy, high joining speeds and accompanying high cooling rates can be realized with minimal heating of the parts. Also, laser brazing and laser welding-brazing can prevent or minimize excessive formation of detrimental intermetallic phases. The formation of intermetallic layers can be limited to a size below 10 μm, which leads to desirable mechanical properties (Refs. 3, 19, 20). Miao et al. (Refs. 21, 22) developed the technology for laser penetration brazing (LPB) of a magnesium alloy to steel using a high-power CO2 laser without welding wire. In this process, the laser beam was radiated on the magnesium alloy side of a butt joint to get full fusion of the magnesium alloy (Ref. 21). However, melting of the steel side was inevitable, and cracking and porosity occurred at the interface due to evaporation of magnesium and lack of solubility and reaction between the magnesium alloy and the steel (Ref. 21). A direct relationship was found between weld cracking and excessive melting of the steel (Ref. 21).

A lower-intensity laser beam, such as provided by a diode laser, can be used with welding wire to control the heat flow in a laser brazing process, thus avoiding melting of the steel. In such a process, the welding wire and surface of the Mg alloy base material are melted simultaneously by a high-power diode laser, while the steel remains unmelted. In the present study, a procedure has been developed for laser brazing of AZ31B-H24 magnesium alloy to aluminum-coated steel sheet. The brazing process was designed to avoid the vaporization of magnesium. The aim of this work was to investigate the microstructure and mechanical properties of the brazed joints between the Mg alloy and Al-12Si coated steel sheet using a welding wire.

**Experimental Procedures**

In the present study, 2-mm-thick commercial grade twin-roll strip cast AZ31B-H24 Mg alloy sheet and 1-mm-thick aluminum-coated steel sheet were used. The Al-12 wt-% Si coating layer on the steel sheet was 20 ± 2 μm thick. The AZ31B Mg sheet contained Mn for improved corrosion resistance (Ref. 23). The compositions of these materials are given in Tables 1 and 2. An optical microscopic image of the steel/Al-12Si coating layer interface before the brazing process is shown in Fig. 1. In Fig. 1B, a 3.5-μm-thick Fe-Al-Si intermetallic compound (IMC) layer is clearly shown at the interface. This IMC layer was confirmed by X-ray diffraction to be the $\text{Fe(Al,Si)}_3$ phase.

A 2.4-mm-diameter TiBraze Mg 600 welding wire with solidus and liquidus temperatures of 445° and 600°C, respectively, was chosen for this study. The composition of the filler metal is shown in Table 1. This brazing alloy is compatible with the AZ31B magnesium base metal alloy. The commercial flux used in the experiments was Superior No. 21 manufactured by Superior Flux and Mfg. Co.

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**Fig. 1** — Transverse section of original steel sheet showing: A — The Al-12Si coating layer; B — the preexisting Fe-Al-Si IMC layer at the steel/coating layer interface.

**Fig. 2** — A — Schematic of the laser brazing system used for joining the AZ31 Mg and aluminum-coated steel sheets in the single flare bevel lap joint configuration; B — schematic of the 5-mm-wide tensile shear test specimens.

**Table 1 — Measured Chemical Compositions of the AZ31-H24 Mg Alloy Sheet and TiBraze Mg 600 Filler Metal (wt-%)**

<table>
<thead>
<tr>
<th></th>
<th>Al</th>
<th>Zn</th>
<th>Mn</th>
<th>Si</th>
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</thead>
<tbody>
<tr>
<td>AZ31B-H24</td>
<td>3.02</td>
<td>0.80</td>
<td>0.30</td>
<td>0.01</td>
</tr>
<tr>
<td>TiBraze Mg 600</td>
<td>9</td>
<td>2</td>
<td>0.2</td>
<td>—</td>
</tr>
<tr>
<td>Mg</td>
<td>Bal.</td>
<td></td>
<td></td>
<td></td>
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</tbody>
</table>

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powder flux was composed of LiCl (35–40 wt-%), KCl (30–35 wt-%), NaF (10–25 wt-%), NaCl (8–13 wt-%), and ZnCl₂ (6–10 wt-%) (Ref. 24).

The AZ31 Mg and steel sheets were cut and mounted in epoxy resin. The workpiece at the fusion zone with some wire was cut into pieces and preset on the workpiece at the fusion zone with some flux before heating and brazing by the laser beam.

A diagram of the laser brazing apparatus used is shown in Fig. 2A. The edge of the steel sheet was bent and clamped against the magnesium sheet to make a single flare bevel lap joint. The wire was cut into pieces and preset on the workpiece at the fusion zone with some flux before heating and brazing by the laser beam.

In order to limit oxidation, helium shielding gas was provided in front of the molten pool with a flow rate of 30 L/min from a 6-mm-diameter soft copper feeding tube. The process parameters were 1.8 to 2.4 kW laser power, 5 to 10 mm/s travel speed, and –0.2 to 0.4 mm beam position offset relative to the steel.

After laser brazing, typical transverse cross-sections of the brazed specimens were cut and mounted in epoxy resin. The samples were then mechanically polished using 300, 600, 800, and 1000 grades of SiC grinding papers followed by polishing using a 1-μm diamond suspension. The polished specimens were etched to reveal the microstructure of the braze metal and AZ31B base material. The etchant was comprised of 20 mL acetic acid, 3-g picric acid, 50 mL ethanol, and 20 mL water (Ref. 26). Macro- and microstructures of the joints were observed using an optical metallographic microscope. The microstructure and composition of different zones at the joint cross section were determined using a JEOL JSM-6460 scanning electron microscope (SEM) and energy-dispersive X-ray spectrometer (EDS). Phase characterization of the steel fusion zone and the steel/AZ12Si coating layer interfaces after laser brazing was determined using X-ray diffraction (XRD) phase analysis with a Cu Kα source.

Vickers microhardness profiles across the brazed joints were measured using a 50-g loading force and 10-s holding time. As shown in Fig. 2B, the brazed 5-mm-wide, rectangular-shaped specimens were cut and subjected to tensile shear tests with a crosshead speed of 1 mm/min. Shims were used at each end of the specimens to ensure shear loads in the lap joint while minimizing induced couples or bending of the specimens. Average tensile shear strength was calculated from tensile specimens to estimate the static mechanical resistance of the joints.

Results and Discussion

Table 2 — Measured Chemical Composition of the Aluminum-Coated Steel Sheet (wt-%)

<table>
<thead>
<tr>
<th>C</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Fe</th>
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<td>0.010</td>
<td>0.004</td>
<td>Bal.</td>
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</table>

Table 3 — EDS Analysis Results of IMC Layers at the Original Steel/Coating Layer Interface Shown in Fig. 7 (wt-%)

<table>
<thead>
<tr>
<th>IMC</th>
<th>Al</th>
<th>Si</th>
<th>Fe</th>
</tr>
</thead>
<tbody>
<tr>
<td>I (P1-P4)</td>
<td>56.6 ± 1.4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>II (P5-P8)</td>
<td>62.6 ± 2.6</td>
<td></td>
<td></td>
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</table>

Results of IMC Layers

Fig. 3 — Laser brazed AZ31B-to-steel sheets made using 8 mm/s travel speed and 2.2 kW laser beam power: A — Top bead; B — Transverse section of a brazed Al12Si coating steel; C — Transverse section of a brazed uncoated steel sheet.

Fig. 4C. The thickness of the PMZ layer was...
Photomicrographs of different microstructural regions in the laser brazed AZ31B steel joint.

not uniform around the fusion zone (20–100 μm) due to the temperature gradient resulting from the laser brazing process. Inspection by optical microscopy suggested that the small extent of the liquated region did not result in intergranular cracking upon cooling.

As shown in Fig. 4D, the solidification microstructure adjacent to the fusion boundary was initially planar, but changed to cellular, then columnar dendritic, and finally equiaxed dendritic morphologies with increasing distance from the fusion boundary. The black arrow on Fig. 4D is the same arrow on Fig. 4A and identifies the orientation of Fig. 4D in Fig. 4A. As indicated in Fig. 4D, the planar, cellular, and columnar grains were only found in a narrow zone adjacent to the fusion boundary while the equiaxed dendrites were dominant in the fusion zone. The microstructure in the center of the fusion zone was homogeneous and characterized by numerous equiaxed dendrites with fine precipitates dispersed in the interdendritic regions, as shown in Fig. 4E.

Figure 4F shows the microstructure of the fusion zone adjacent to the steel side, which was mainly equiaxed dendritic. Planar and cellular structures were not observed at this interface due to low-temperature gradient and cooling rate in this interface compared to the AZ31B/fusion zone interface. This is a result of laser beam offset to the steel side during the laser brazing process and also the high thermal conductivity of AZ31B magnesium alloy as compared to steel, specifically 96 and 30 (Wm⁻¹K⁻¹), respectively (Ref. 23).

A SEM image of the filler metal fusion zone microstructure is shown in Fig. 5. An intermetallic phase was present at the equiaxed dendrite boundaries. This intermetallic phase appeared as the dark phase in optical microscopic images and as the white phase in the SEM images of the fusion zone. This phase had an average composition of 73.3 ± 3.8 wt-% Mg, 24.5 ± 3.7 wt-% Al, and 2.2 ± 0.1 wt-% Zn, and was thus identified as the β-Mg17Al12 intermetallic phase with zinc as a substitutional element. This was confirmed by XRD results. The intermetallic phase was surrounded by supersaturated eutectic α-Mg solid solution that contained on average 92.7 ± 0.5 wt-% Mg, 6.6 ± 0.4 wt-% Al, and approximately 0.7 ± 0.2 wt-% Zn. The eutectic α-Mg and the primary α-Mg dendrites (95.2 ± 1.2 wt-% Mg, 4.3 ± 1 wt-% Al, and 0.5 ± 0.2 wt-% Zn) are outlined in the SEM micrograph of Fig. 5. Each interdendritic region consisted of a single β-Mg17Al12 particle surrounded by eutectic supersaturated α-Mg grown from primary α-Mg dendrites. This type of eutectic is called a divorced eutectic, since the two eutectic phases (α-Mg and β-Mg17Al12) are completely separated. This divorced eutectic morphology has previously been reported in microstructures of Mg cast alloys either with high content of zinc or high cooling rates during solidification (Refs. 27, 28). In this study, the high cooling rate of the laser brazing process and also 2 wt-% Zn content of filler metal promoted formation of divorced eutectic shown in Fig. 5.

Thermal Effect on IMC at Steel/Al-12Si Coating Interface

In order to see the thermal effect of the laser brazing process on the IMC layer on
the steel, the opposite steel surface that did not come into contact with the brazing filler metal was examined (see Fig. 6A). As shown in Fig. 6B–D, growth of the IMC layer at the interface of the steel/coating layer occurred due to high temperature experienced during the brazing process. At the upper part of the interface (Fig. 6B), the IMC layer showed two morphologies. The first morphology labeled as IMC I in Fig. 6 adjacent to the steel was a compact plate-like phase thicker than the original IMC layer. The second morphology labeled as IMC II in Fig. 6 shows long needle-like crystals, which grew from IMC I.

It was observed that upon moving from the location of Fig. 6B to the location of Fig. 6D, the needle-like crystals of IMC II gradually disappeared due to the lower temperature experienced during the process. Also, the average thickness of the IMC I layer changed significantly from 8 μm at the upper location to about 4 μm at the location of Fig. 6D compared to the original preexisting IMC layer between the coating layer and the steel, which had an average thickness of 3.5 μm.

Figure 7 shows an SEM image and XRD result of the IMC layer between the steel and Al-12Si coating near the top of the joint. EDS analysis was carried out for the IMC I layer at locations P1 to P4 in Fig. 7A, and for IMC II at locations P5 to P8. The EDS results are summarized in Table 3. According to the XRD profile of the interface in Fig. 7B and also composition of the IMCs in Table 3, the IMCs were determined to be mixtures of the 0-Fe(Al,Si)₃ and τ₅-Al₇Fe₅Si phases. From the Fe-Al-Si ternary alloy phase diagram and typical characteristics of Fe-Al-Si systems (Refs. 29–32), the IMC I layer was determined to consist of the 0-Fe(Al,Si)₃ phase, and the needle-like IMC II layer was τ₅-Al₇Fe₅Si. These layers dissolved 10.4 and 16.1 wt-% of Si in solid solution, respectively, and Si atoms substituted for Al atoms in the IMC phases.

The rationale for having 12 wt-% Si in the composition of the coating layer is explained as follows. According to previous work on hot dip aluminizing (Ref. 33), the solubility of Fe in an aluminum bath increases from 5.3 to 12 wt-% with the content of Si increasing from 0 to 10 wt-% at 800°C. With the Al-12Si coating layer on the steel in this study, more Fe atoms were able to dissolve into the coating layer to form a thicker Fe-Al IMC layer. According to recent studies (Refs. 31, 32), the solubility of Si in Al-Fe IMC phase is 0.8–6 wt-% as substitute atoms in the 0-FeAl₃ phase. When up to 10 wt-% of Si atoms participate in the intermetallic phase formation, more Si atoms can dissolve in the 0-FeAl₃ phase to form a supersaturated solid solution during rapid cooling (Ref. 32), but this does not change the brittleness of this compound. According to Peyre et al. (Ref. 8), the same values of hardness were obtained for pure Fe-Al IMC and Fe-Al IMC containing up to 8 at-% Si (1200 ± 100 HV20 mN).

| Table 5 — EDS Analysis Results at Different Locations on the Fracture Surface Shown in Figs. 13A and 14A (wt-%) |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                 | Top (B)         | Middle (C)      | Bottom (D)      | Top (F)          | Middle (G)      | Bottom (H)      |
| Mg, Ka          | 90.18           | 68.88           | 18.05           | 90.01           | 32.69           | —               |
| Al, Ka          | 9.82            | 21.00           | 59.96           | 9.99            | 29.57           | 20.98           |
| Fe, Ka          | —               | 10.12           | 21.98           | —               | 37.74           | 79.02           |

Fig. 6 — Thickness and morphology variation of IMC layer in different positions of the steel/coating layer interface indicated in the following: A — Upper; C — middle; D — bottom part of the joint.

Fig. 7 — Al-12Si coating layer-steel interface of a laser brazed AZ31B-steel joint: A — SEM image of IMC layer along interface demonstrates locations with EDS analysis; B — X-ray diffraction pattern of the interface.
The IMC at the Steel/Fusion Zone Interface

In the laser brazing process, most of the Al-Si coating was melted and diffused into the FZ leaving only an IMC layer of nonuniform thickness as seen at the steel/braze interface in Fig. 8. Based on EDS analysis results, this IMC layer was found to contain 54.7 ± 6.1 wt-% Al, 40.1 ± 7.7 wt-% Fe, and 5.2 ± 3.7 wt-% Mg. Based on these measurements and an
XRD profile of the steel-fusion zone interface shown in Fig. 9, the IMC was identified as predominantly 6-FeAl3 with some Mg diffused into the IMC layer during laser brazing.

As shown in Fig. 8, the thickness of the IMC layer at the FZ/steel interface varied along the interface. At the top, closest to the heat source of the laser, the IMC layer largely dissolved into the FZ leaving a very thin layer less than 2 μm (Fig. 8B, C). However, farther down and away from the heat of the laser beam, the IMC had grown to approximately 8 μm in thickness (see Fig. 8D). The change in the thickness of the intermetallic layers is controlled by two simultaneous phenomena: the diffusion-controlled growth of intermetallic layers and their dissolution by molten alloy (Refs. 34, 35).

Roulin et al. (Ref. 36) studied the furnace brazing of steel-Al alloy dissimilar joints with Al-12Si filler metal. It was reported that the first formed phase along the steel-Al interface at 600°C was a ternary Fe-Al-Si IMC with a parabolic growth rate indicating a diffusion-controlled mechanism. At this temperature, dissolution of the IMC was negligible (Ref. 35). In contrast, Viala et al. (Ref. 35) reported the formation of a Fe-Al-Si IMC at 780°C during hot dipping of steel in molten Al-7Si alloy. It was reported that this IMC remained very thin (2–3 μm) at 780°C due to its rapid dissolution (Ref. 35). It can be concluded that with increasing temperature, the dissolution rate of Fe-Al-Si IMC increases more rapidly than the growth rate (diffusion rate).

From this information, the following mechanism can be proposed for change in IMC thickness along the steel-fusion zone interface from top to bottom portion of the joint. According to the binary phase diagram of Al-Si, the melting temperature of the eutectic composition coating layer (Al-12 wt-% Si) is approximately 577°C. When compared to the brazing temperature of the filler metal used in this study (600°C–620°C), the Al-Si coating layer experienced temperatures higher than its melting point during the process. Consequently, the high temperature of the process led to the melting of the Al-Si coating and also promoted dissolution of the preexisting IMC layer between the Al-12Si coating and the steel. At the top side of the interface, the dissolution mechanism of preexisting IMC was more dominant than the diffusion growth mechanism due to the rapid temperature increase. However, with decreasing temperatures from the top toward the bottom of the interface, the IMC dissolution rate in the fusion zone decreased and its growth rate increased (decreasing temperature favors the diffusion-controlled growth mechanism more than the dissolution mechanism).

Representative concentration profiles of Al, Mg, and Fe across the interface between the fusion zone and steel are shown in Fig. 10. Fe and Al atoms diffused into the fusion zone as a result of high temperature experienced during the laser brazing process. As a result, a diffusion or transition layer formed in front of the IMC layer on the fusion zone side (Refs. 21, 22). According to element distributions of Fe, Al, and Mg (Fig. 10B), in the diffusion layer I with the thickness of almost 1.5 μm, from the FZ side to IMC side, Fe and Al contents increased gradually while the Mg content decreased rapidly. As shown in
Fig. 10A, diffusion layer I is part of the IMC, thus the formation of this diffusion layer led to growth of the IMC layer from 5 to 6.5 μm. The latter occurred at the bottom of the brazed joint. The main mechanism that controls the composition of this area is the time- and temperature-dependent diffusion process.

Another diffusion layer (diffusion layer II) is shown in Fig. 10A on the steel side of the IMC layer between the fusion zone and the steel. The thickness of this layer was ≈3 μm and thus was wider than the diffusion layer I. In this layer, solid-state diffusion is believed to control the overall thickness. During diffusion of an element, the composition gradient is the driving force that allows an element to diffuse to a place of lower concentration. As a result, for diffusion layer I, the elements Fe and Al diffused from the IMC layer to the FZ, but the diffusion direction for the Mg would be the opposite. In diffusion layer II, the IMC layer showed a higher concentration of Al and Mg as compared to steel. Consequently, the diffusion direction changed from the IMC layer to the steel side (for Al and Mg), but Fe atoms diffused into solid solution of the IMC layer (from the steel side). The same type of diffusion layer has been observed by Miao et al. (Refs. 21, 22) after laser penetration brazing of Mg alloy to steel dissimilar joints.

It is worth noting that melting of the Al-12Si coating layer during the laser brazing process not only promoted the growth of the IMC layer in the bottom portion of the interface, but also caused formation and growth of Al/Mg eutectic in the form of β-Mg17Al12 phase. Regional quantitative analysis of the chemical compositions by EDS (Table 4) from the middle part of the fusion zone and near the steel/FZ interface showed that the area near the interface contained 15.7 wt-% Al, which is more than the 11.4 wt-% Al in the middle part of the FZ. This difference is the result of the coarse β-Mg17Al12 phase near the interface as compared to the middle part of the FZ.

**Mechanical Properties**

A Vickers microhardness profile across a brazed joint was measured using 50 g load and 10 s holding time. The microhardness distribution profile is shown in Fig. 11. The average hardness of the AZ31B Mg alloy and steel were 62.4 ± 2.3 HVN and 116.3 ± 3.4 HVN, respectively. In the fusion zone, the average hardness increased to 85.7 ± 8.5 HVN due to the strengthening effect of the increased Al content and β-Mg17Al12 phase particles in the intergranular regions. The size of the microhardness indenter was too large to measure the hardness of the thin IMC layers formed at the interface. However, higher hardness values are expected for the IMC layer, since the reported average hardness of the 0-FeAl phase is 700–800 HVN (Ref. 37), which is much higher than the hardness of the base metals.

Four 50-mm-long × 5-mm-wide tensile specimens were cut out of each sample and tested at a tensile crosshead speed of 1 mm/min. A schematic of the tensile test specimen is shown in Fig. 2B. Due to the nonsymmetric configuration of the tensile test specimen, a combination of shear and tensile forces existed at the interface. Consequently, the joint strengths were reported as fracture load, since it is impossible to separate tensile and shear stresses.

The average tensile shear strength of the laser brazed AZ31B steel joints using Mg-Al filler metal was 767 ± 138 N; representing a 72 ± 13% joint efficiency with respect to the fracture load of the Al-12Si coated steel (1068 N) for the same size tensile specimen. The joint efficiency values were obtained by dividing the fracture load of each laser brazed specimen by the fracture load of the base metal (Al-12Si coated steel).

High standard deviation of the tensile shear strength in this study indicates that this laser brazing process for Al-12Si coated steel-AZ31B joints has inherent instability. This instability caused variation in the brazed depth (defined in Fig. 3B) at different locations along the weld interface, which is associated with changing the actual load-carrying area of the joint resulting in different tensile shear strength along the weld interface. Further study is needed to improve the process stability for this dissimilar metal combination.

All tensile shear specimens fractured at the FZ-steel interface. The macro- and microstructure profiles of the joint after fracture are shown in Fig. 12. In each case, fracture initiated in the IMC layer at the bottom of the joint where the geometry of the joint created a high stress concentration area and the thickness of the brittle IMC layer was also at a maximum. Then the crack continued into the brazed FZ at the upper portion of the joint where the IMC layer was thinner. The thick layer of brittle intermetallic at the FZ/steel interface can significantly reduce the strength of the joint as any crack initiating in the layer can easily propagate through this continuous sheet of brittle material (Ref. 38). From these observations, the type and thickness of the IMC layer determined the joint strength. At the bottom of the joint, the thickness of the IMC layer was more than 8 μm, which significantly degraded the mechanical strength of the joints. At the upper portion of the joint, the crack deviated into the FZ and propagated along the grain boundaries of the brazed metal due to existence of β-Mg17Al12 phase in the grain boundaries. Therefore, the tensile shear properties and the thickness of the IMC layer appeared to dictate the overall strength of the joints.

Figures 13 and 14 show SEM images of typical fracture surfaces of the fusion zone and steel sides after tensile shear testing, respectively. The fracture morphologies indicate mixed characteristics of brittle and ductile fracture. At the upper portion of the joints (region 1 in Fig. 13A for the FZ side and region 1 in Fig. 14A for the steel side), where the crack propagated into the fusion zone, nonuniform ductile fracture was observed — Figs. 13B and 14B. Meanwhile, at the bottom portion of the fracture surface (regions 3 in Figs. 13A and 14A), where the crack formed in the IMC layer, evidence was seen of more brittle cleavage fracture as shown in Figs. 13D and 14D. In the middle of the fracture surface (regions 2 in Figs. 13A and 14A), an area was observed where the fracture surface contained both ductile and brittle fracture characteristics (see Figs. 13C and 14C). This area is called the transition zone from ductile to brittle fracture modes.

EDS analysis results of the fracture surfaces of both steel and FZ sides are shown in Table 5. At the top of the fracture surface (region B in Fig. 13A for the FZ side and region F in Fig. 14A for the steel side), the composition was similar to the FZ. This implied that the crack propagated into the FZ in the upper portion of the joint. In contrast, at the bottom area of the fracture surface (regions D in Fig. 13A and H in Fig. 14A), the compositions corresponded to the Fe-Al IMC layer indicating that the crack in this region propagated along the IMC layer adjacent to the steel.

**Conclusions**

Brazed joints between AZ31B-H24 Mg alloy and Al-12Si coated steel have been made by a laser brazing process using a Mg-Al based welding wire in a single flare bevel lap joint configuration. The major conclusions of this study can be summarized as follows:

1. A uniform brazed area with good wetting of base metals was obtained between the AZ31B and Al-Si coated steel sheets using optimized laser brazing parameters. The optimum parameters were 2.2-kW laser power, 8-mm/s travel speed, and 0.2-mm beam offset to the steel side using He shielding gas with a flow rate of 30 L/min.

2. A 0-Fe(Al,Si)$_3$ IMC layer was found in the interface between the steel and its Al-12Si coating layer before brazing. During brazing, the high temperature of the process caused this IMC in contact with the coating layer to grow in the form of compact plate-like 0-Fe(Al,Si)$_3$ on the


Material Properties for Welding Simulation — Measurement, Analysis, and Exemplary Data

It has been found that in the given application case from the automotive industry with laser beam welding flat plates, the most important boundary conditions for measurement are high heating and cooling rates.

ABSTRACT

Welding is a key technology in the area of industrial production due to its flexibility and efficiency. However, new materials and welding techniques necessitate permanent research activities in order to keep up with the demands. A detailed knowledge about the process itself and the heat effects of welding, e.g., temperatures, distortions, and stresses, is the basis for a target-oriented optimization instead of a trial-and-error approach. Numerical welding simulation is a powerful tool to meet these demands. Complementary to an experimental investigation, it enables the analysis of the specimen during the welding process, commonly known as computational welding mechanics (CWM). Whereas simulation is nowadays a common tool in different development processes, the modeling of welding still remains difficult because of the multiple physical effects taking place. One of the most important problems for the user is the lack of knowledge about the material properties as input data for the simulation. Furthermore, any scattering of the data causes uncertainties that can have major effects on the calculations. The objective of this paper is to give an overview about the experimental determination and analysis of the material properties needed as input data for a welding simulation. The measurement techniques and the occurring deviations of the results are discussed. Additionally, the collected data for three representative alloys (dual-phase steel, austenitic steel, precipitation-hardenable aluminum alloy) are analyzed. Finally, the temperature-dependent thermophysical and thermo-mechanical material properties for these three alloys are given in a ready-to-use format for a numerical welding simulation.

Introduction and Motivation

The flexibility and efficiency of modern welding techniques are main factors for their wide range of application in the industrial production process. Due to continuous development of materials, e.g., high-strength, fine-grain steels, as well as new welding techniques, e.g., laser-arc hybrid welding, ongoing research work is necessary to guarantee the quality of joined components.

Today, numerical simulation by means of a finite element analysis is a common tool in the development process of a large number of industrial products and helps to investigate the new material and welding technique combinations as stated above.

Nevertheless, the numerical analysis of the welding process and its effects on the specimen still remain difficult because of the multiple physical effects involved (Refs. 1, 2). The numerical welding simulation enables the detailed analysis of the heat effects of welding, i.e., the thermal and mechanical behavior of the specimen during welding. The understanding of these influences is the basis for an optimization of welded parts with respect to quality aspects like distortions and stresses (Ref. 3). Additionally, the influence of single parameters can be investigated without any coupling effects that normally occur during real welding experiments.

One of the most important challenges in welding simulation is the lack of temperature- and phase-dependent material properties that are needed as input data. For most modern alloys, these data are not available, neither from the supplier nor in literature. Consequently, an experimental determination of the values is often required in order to get high-quality simulation results. One remaining problem is the inevitable scattering of the experimental data, especially at relatively high temperatures. These uncertainties can have major effects on the subsequently calculated temperatures, distortions, and stresses (Refs. 4, 11).

In the following sections, the aspect of the experimental material property determination is investigated considering the special conditions during welding and its numerical simulation. This is done with respect to the special needs in the automotive industry because it resembles a key user for computational welding mechanics (CWM). Here, welding of thin metal sheets in car body production is a central task. One of the most important aspects is the high heating and cooling rates during the process. The investigated alloys — the high-strength, dual-phase steel DP-W 600 (1.0936), the austenitic steel H400 (1.4376), and the precipitation-hardenable aluminum alloy Ecodal 608 (EN AW-6181) — are common representatives in the automotive industry.

KEYWORDS

Thermophysical Material Properties
Thermomechanical Material Properties
Experimental Determination
Numerical Welding Simulation

Considered Alloys

The alloys considered in this paper are not only typical for automotive applications, but they are additionally chosen for a detailed sensitivity analysis of the material properties with respect to calculated welding temperature fields and distortions (Ref. 4). In this section, the criteria for the
selection of the actual alloys, their alloying contents, and their typical characteristics are discussed. The decision for the specific alloy was driven by two reasons. First, for a simulation and a sensitivity analysis, a comparison of different alloys and alloy groups is interesting. Second, all alloys in these groups should be in use in the automotive industry.

For the selected alloy groups (ferritic steel with phase transformation, austenitic steel without phase transformation, aluminum alloy), there are different possible ways of comparison. First of all, both steel alloys can be compared whereas the different metallurgical behaviors of the ferritic and austenitic steel, here for example the phase transformation, is of interest. Additionally, the two alloys cover, in a general view, both groups of low-alloyed and high-alloyed steels. Because of the small differences of the thermophysical properties, in contrast to the thermomechanical ones of specific alloys within their respective groups, they can also serve as rough data for future temperature field simulations of similar or future alloys with comparable alloying content. Furthermore, the comparison of the two materials not undergoing phase transformations, namely the austenitic steel and aluminum alloy, with the ferritic steel with phase transformation is interesting. Finally, the differences between the steels and aluminum alloy are of interest.

The investigated material for the group of low-alloyed steel with phase transformation is DP-W 600, a typical representative for high-strength steels in the automotive industry. For the high-alloyed austenitic steel, the decision fell upon Nirosta H400. This alloy was designed especially for automotive applications and can be used as a cost-effective alternative to the common steel 1.4301 (X5CrNi18 10). While keeping the mechanical properties at a comparable level, the production price is lower because of a reduced nickel content. A higher content of nitrogen as a partial surrogate for the nickel ensures a high work-hardening behavior. The selection of Ecodal 608 was driven by the fact that it is a standard material used for nonvisual inner parts where the criteria of lightweight characteristics and strength are important. In the following sections each of the three materials, their alloy contents, and the corresponding typical mechanical properties are given.

Table 1 — Chemical Composition of DP-W 600 According to Supplier Data Sheet (first row, [Ref. 12]) and Own Measurements (second row and below)

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<th>Element</th>
<th>Supplier Data</th>
<th>Own Measurements</th>
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<tr>
<td>Pb</td>
<td>0.01</td>
<td>0.004</td>
</tr>
<tr>
<td>Sn</td>
<td>0.004</td>
<td>0.01</td>
</tr>
<tr>
<td>As</td>
<td>0.004</td>
<td>0.002</td>
</tr>
<tr>
<td>Sb</td>
<td>0.01</td>
<td>0.002</td>
</tr>
<tr>
<td>Te</td>
<td>0.002</td>
<td></td>
</tr>
</tbody>
</table>

Carbon equivalent PCM: 0.117 mass-%
Carbon equivalent CET: 0.191 mass-%
The steel Nirosta H400 with the material number 1.4376 is a high-strength, corrosion-resistant stainless steel. It can be welded with nearly all established welding techniques and has, due to its metastable austenitic microstructure, a good ratio between strength and formability. However, during manufacturing processes, including cold forming, it needs higher forces and has a more significant springback behavior compared to standard Cr-Ni steels. The typical mechanical properties are listed in Table 3.

The chemical composition according to the manufacturer’s data and to our own spark emission spectroscopy measurements are stated in Table 4. The actual nickel content is 3.8% and is slightly above the allowed maximum value. This leads, according to the Schaeffler diagram in Fig. 2, to a smaller amount of the unwanted delta ferrite and hence has positive effects for the weldability.

The position for H400 is indicated in the diagram with the chrome and nickel equivalent according to Schuster (Ref. 14). The position of the alloy is not fully in the austenitic area but in the austenitic-ferritic mixed zone. Figure 3 shows a microsection of the base material where, beside the austenite, some carbides and small amounts of delta ferrite are visible.

Due to its positive characteristics like corrosion resistance, ultimate tensile strength, and, because of the work-hardening behavior, high-energy dissipation during crash, it is predestined for automotive applications. Typical parts are space frame structure parts or undercarriage assemblies.

**Aluminum Alloy Ecodal 608 (EN AW-6181)**

The Aluminum Alloy Ecodal 608 with material number EN AW-6181 (Ref. 17) is a copper-free AlMgSi alloy with very good cold forming behavior and strain hardening effects. It can be age hardened at room temperature and has a low-corrosion aptitude. Furthermore, it was specially designed for the recycling of different aluminum alloys to reduce energy and material consumption during manufacturing. The typical mechanical properties are given in Table 5 whereas Table 6 shows the chemical composition based on measured values. The calculated content, based on the measured values, of Mg2Si particles is approximately 0.38%. This value is included in the quasi binary Al-Mg2Si phase diagram in Fig. 4.

The applications of Ecodal 608 are mainly inner sections and reinforcements in automotive applications like sections of the front lid, hatchback, or doors. These parts normally have lower requirements for the surface quality than outer parts with direct visibility. Hence, a lightweight and cost-effective construction can be reached at the same time.

The main material properties of an alloy to be used for a numerical welding simulation cover the thermophysical and thermomechanical behavior of the material. The following section gives a detailed overview about what general aspect of the material data is required in order to perform a welding simulation.

### Required Material Properties and Temperature Range

As already stated, the numerical welding simulation requires a wide range of material properties as input data. Considering the temperature field calculation, the thermophysical properties

- density $\rho$
- specific heat capacity $c_p$
- thermal conductivity $\lambda$

Table 2 — Mechanical Properties of DPW 600, As-Delivered Condition at Room Temperature Values According to Supplier Data Sheet (Ref. 12)

<table>
<thead>
<tr>
<th>$R_{p0.2}$ in MPa</th>
<th>$R_m$ in MPa</th>
<th>$A_5$ in %</th>
<th>$A_{80}$ in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>330–450</td>
<td>580</td>
<td>24</td>
<td>20</td>
</tr>
</tbody>
</table>

Table 3 — Mechanical Properties of H400 (1.4376), As-Delivered Condition at Room Temperature Values According to Supplier Data Sheet (Ref. 13)

<table>
<thead>
<tr>
<th>$R_{p0.2}$ in MPa</th>
<th>$R_{p1.0}$ in MPa</th>
<th>$R_m$ in MPa</th>
<th>$A_5$ in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>400</td>
<td>420</td>
<td>600–900</td>
<td>$\geq 41$</td>
</tr>
</tbody>
</table>
are needed. Instead of the specific heat capacity and the density, the user can also use the enthalpy of the alloy. For the calculation of the distortions and stresses, the thermomechanical properties

- yield strength $R_{p0,2}$
- hardening behavior $H$
- Young's modulus $E$
- thermal expansion $\alpha_{th}$
- Poisson's ratio $\nu$

are a prerequisite. All these properties have to be temperature dependent from room temperature up to solidus temperature and above. The calculated temperatures can easily reach values of 2500°C and more, and the numerical approach presupposes available data for all the temperatures that occur. From the experimental point of view, the measurement at these temperatures is, in most cases, extremely difficult or even impossible, especially for the thermomechanical properties. A common practical compromise is the measurement of the properties from room temperature up to approximately 0.8 $T_{\text{Solidus}}$ of the alloy. In addition to this wide temperature range, alloys with phase transformation are needed phase dependent (e.g., ferrite, austenite, bainite, martensite) including the CCT diagram.

The correct measurement of the needed properties is a demanding task with respect to time, costs, and accuracy, especially with rising temperatures and for alloys with phase transformation like the DP-W 600. Some measurement techniques that are suitable for this task as well as the corresponding equipment are described in the following section. Further information about specific measurement devices that could be suitable can be found, for example, in Ref. 6.

![Fig. 5 — Comparison of experimentally determined specific heat capacity and literature values; reference data adopted from Radaj (Ref. 1) and Richter (Refs. 7, 8).](image)

![Fig. 6 — Comparison of exponent m for measured data and literature values. Left graph: steels; right graph: aluminum alloys. Adopted from Makhnenko (Ref. 9).](image)

**Measurement Techniques with Respect to Welding Conditions**

The measurement of the required material properties covers a thermophysical and thermomechanical part. During all experiments, one has to take care that the rising temperatures do not affect the surface of the material. In order to prevent scaling that can influence the accuracy of

<table>
<thead>
<tr>
<th>C</th>
<th>Si</th>
<th>Mn</th>
<th>P</th>
<th>S</th>
<th>Cr</th>
<th>Ni</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>≤0.12</td>
<td>≤1.50</td>
<td>≤0.15</td>
<td>≤0.06</td>
<td>≤0.010</td>
<td>≥0.015</td>
<td>≤1.0</td>
<td>≤0.005</td>
</tr>
<tr>
<td>0.03</td>
<td>0.469</td>
<td>7.129</td>
<td>0.027</td>
<td>0.003</td>
<td>17.5</td>
<td>3.795</td>
<td>0.25</td>
</tr>
<tr>
<td>Mo</td>
<td>Al</td>
<td>Ti</td>
<td>Nb</td>
<td>Zr</td>
<td>V</td>
<td>W</td>
<td>Co</td>
</tr>
<tr>
<td>0.298</td>
<td>0.001</td>
<td>0.012</td>
<td>0.013</td>
<td>0.013</td>
<td>0.06</td>
<td>0.015</td>
<td>0.093</td>
</tr>
<tr>
<td>B</td>
<td>Ca</td>
<td>Cu</td>
<td>Pb</td>
<td>Sn</td>
<td>As</td>
<td>Sb</td>
<td>Te</td>
</tr>
<tr>
<td>0.0</td>
<td>0.0007</td>
<td>0.195</td>
<td>0.011</td>
<td>0.006</td>
<td>0.007</td>
<td>0.001</td>
<td>0.004</td>
</tr>
<tr>
<td>Zn</td>
<td>Mg</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.012</td>
<td>0.003</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Carbon equivalent PCM: 1.376 mass-%
Carbon equivalent CET: 1.752 mass-%
optical detection methods, all measurements should be done under an inert atmosphere.

For the thermophysical data, one special aspect has to be taken into account. The material used in the automotive industry is often, like the DP-W 600, coated with zinc to prevent corrosion. These coatings have to be removed prior to the measurements because a clean and matte surface is needed for the correct measurement of the thermal diffusivity $\alpha(T)$ using a laser flash method. The density $\rho(T)$ and the specific heat capacity $c_p(T)$ can be determined using commercially available equipment and standard specimen preparation. After the experiments, a calculation of the thermal conductivity $\lambda(T)$ as input for the simulation is done using the gathered data in combination with Equation 1.

$$\lambda(T) = \alpha(T) \cdot \rho(T) \cdot c_p(T)$$ (1)

The measurement of the thermomechanical material properties has to be done with consideration of two important aspects that are characteristically for welding. Depending on the welding technique and specimen thickness, the heating and cooling rates can be very high. While the heating rate has a direct influence on the strain rates and therefore, the yield strength and hardening behavior of the material, the cooling rate is an important factor for the phase transformation effects of an alloy and the corresponding thermal expansion.

The tensile tests for the determination of the yield strength and hardening behavior have to be executed with both a quasistatic and at least one higher strain rate $\dot{\varepsilon}$. The latter can be approximated very roughly using the thermal expansion coefficient at room temperature $\alpha_{RT}$ as stated in the simplified Equation 2.

$$\dot{\varepsilon} = \alpha_{RT} \cdot \frac{\Delta T}{T}$$ (2)

For example, the temperature rate for laser beam welding with high power and velocity can easily reach $\dot{T} = 4000 \, \text{K/s}$. With an assumed averaged thermal expansion coefficient of $\alpha_{steel} = 1.3 \cdot 10^{-5}/\text{K}$ for steel and $\alpha_{al} = 2.5 \cdot 10^{-5}/\text{K}$ for aluminum alloys, the strain rates during laser beam welding can be estimated to values of $\dot{\varepsilon}_{steel} = 0.05/\text{s}$ and $\dot{\varepsilon}_{al} = 0.1/\text{s}$ in correspondence with literature values (Ref. 5). These values have to be adapted to the welding technique that has to be simulated. For other processes like gas metal arc welding (GMAW) or gas tungsten arc welding (GTAW), different heating rates are typical.

In the measurement setup of a tensile test at elevated temperatures, the testing machine should be run in distance control mode rather than force control mode for the following reason. At certain conditions with a special combination of temperature and strain rate, metallurgical effects can cause problems using the machine while running in force control mode. In such cases, the measured curves can show a step-like behavior because of the Portevin-LeChatelier effect where the atomic diffusion in the material has the same velocity as the movement of the dislocations. The movement of the dislocations is time and again locked, resulting in a fluctuation of the material flow and stiff-
ness of the specimen. This leads to problems in the force control of the testing machine, viewable in the tensile test plots, and can be overcome using the distance control mode. If needed in the simulation software, the hardening coefficient can be calculated subsequently using the measurement data (Ref. 18). Additionally, tensile tests of the fusion zone, e.g., by using microspecimen, can be very useful and are recommended because the values in the fusion and heat-affected zone (HAZ) can differ significantly from the base material values for some alloys.

The Young’s modulus of the alloys should not be derived from tensile test results. Especially with rising temperatures and higher strain rates, the gradient at the beginning of the data curves normally shows very high scattering. Instead, this value can be measured much more accurately with an ultrasonic device. Here, the specific vibration answer of a geometrically defined specimen that is stimulated with an ultrasonic wave of known properties is measured, and the difference can be recalculated to the Young’s modulus. Nevertheless, the extracted values should be cross checked with the tensile tests later on.

As stated above, the cooling rates have a direct influence on the phase transformation behavior and corresponding thermal expansion. This fact has to be accounted for the measurement of the thermal expansions, i.e., the dilatometric curves of the alloys. One typical information for the weldability of alloys is the cooling time between temperatures of 800°C and 500°C, the so-called t_{5/8} time. During high-power welding processes with a concentrated heat input such as laser beam welding, extremely low t_{5/8} times of less than a second are possible and have to be reached also in the experiments. As for the tensile tests, the welding technique has a significant influence on the cooling rates, too, and leads to different t_{5/8} times, e.g., for GMAW or GTAW processes.

The thermal expansion of a specimen undergoing high heating and cooling rates is normally measured with a specific dilatometric device, e.g., a Gleeble machine. Here, t_{5/8} times of about three seconds for a thin sheet metal specimen can be reached with passive cooling via the clamping devices. In contrast to that, the extremely low t_{5/8} times during laser beam welding of less than a second necessitate an active cooling that can be done using a direct gas spray on the specimen with an inert gas. As is shown in the following section, this causes problems for the optical measurement of the lateral contraction of the specimen and leads to deviations in the monitored dilatometric curves. The thermal expansion experiments have to be executed with a variation of the t_{5/8} time in order to monitor the phase transformation correctly and get the correct temperature intervals of the transformation. Caused by the very short heating and cooling of the specimen, the appearance of a small hysteresis between both cycles is normal and, in most cases, inevitable. The reference temperature that has been used for the experiments has to be given; for the material properties presented in Appendix A, it was 20°C.

The temperature-dependent measurement of the Poisson’s ratio is not necessary when doing a distortion calculation because the influence on the results is negligible. Our own investigations show that the room-temperature value from the literature is sufficient for a welding simulation (Refs. 4, 6). The correct measurement of the material properties is only the first step for the generation of a data set suitable for a numerical welding simulation. Equally important is the plausibility check of the raw data and the comparison with scatter bands of well-known alloys from literature or previous experiments as it is shown in the next section.

### Plausibility Check and Analysis of Data

After the experimental determination of the material properties, these collected data have to be analyzed to ensure the correctness of the measurements and check its appropriateness for a numerical welding simulation. This is important because the material property data have a strong and direct influence not only on the result quality but also on the convergence behavior of the numerical calculation and, as a result, on the overall computation time.

The cross check of the measurement data with scatter bands from literature values is shown exemplarily in Fig. 5 for the specific heat capacity of the three alloys. Both the austenitic steel H400 and dual-phase steel DP-W 600 are well within the scatter bands for high-alloy steel and mild steel, respectively. The data show only minor scattering; the progression of the graphs is smooth. The curve for Ecodal 608 shows some characteristics that have to be investigated. The general behavior is consistent with the data for pure aluminum and AlMgSiCu taken from Richter (Refs. 7, 8). Nevertheless, the deviations in certain temperature intervals are significant.

The local minimum in the temperature range between 200°C and 300°C is caused by an extensive precipitation of Mg2Si particles and the subsequent dissolution. Our own analyses show that this local minimum of the specific heat capacity has only small effects on the calculated temperature field, and the following macroscopic mechanical behavior, and can be neglected (Ref. 6). As stated above, such local effects in the material data curves can have a major effect on the convergence and computation time. Other examples for a similar nonlinear behavior are the specific heat capacity peak of the phase transformation or latent heat of fusion. If the peaks have to be considered in the material data set because their influence cannot be neglected, one possible solution is to stretch extremely steep or stepwise peaks over a slightly larger temperature interval. The effects on the result quality are negligible, but the convergence behavior is, in most cases, improved a lot. Finally, the temperature range in which the peak of the specific heat capacity is implemented should be given together with the temperature-dependent values.

As stated at the description of the measurement techniques, the strain rate effect during tensile tests can be significant due to the high strain rates during welding. The combined effect of the temperature and strain rate on the yield strength can be checked in accordance with Equation 3 proposed by Makhnenko (Ref. 9).

$$\sigma_y(T) = \frac{\sigma_y(T)}{\sigma_y(0)} \frac{e^{m_f T_j}}{e^{m_f T}}$$

(3)

Here, the parameters are the yield strength $\sigma_y(T)$ at the temperature $T$ and strain rate $\dot{e}$ as well as the yield strength $\sigma_y(0)$ at the quasi static strain rate $\dot{e}_0$. The temperature- and alloy-dependent exponent $m_f(T)$ is a measure for the dependence of the yield strength $\sigma_y(T)$ during a variation of the strain rates. A high value of the exponent $m_f(T)$ stands for a high dependency of the yield strength from the strain rate. In Fig. 6, one can see the extracted measurement data in comparison with literature values from Makhnenko (Ref. 9). In Fig. 6, on the left graph, it is visible that for the dual-phase steel DP-W 600, the strain rate influence becomes significant for temperatures above 500°C while the yield strength of the austenitic steel H400 is up to 700°C independent of the strain rate. Looking at the values for Ecodal 608, see the right graph of Fig. 6, one can see that the strain rate effect becomes visible for temperatures above 300°C. The information gathered using Equation 3 indicates that the tensile tests at elevated temperatures have to be executed with different strain rates for temperatures above 500°C for DP-W 600, 700°C for H400, and 300°C for Ecodal 608. Dependent on the desired simulation results (see Ref. 19 as well) and their quality, the user has to decide if it is needed to consider a strain rate dependent material behavior in the simulation model.

The experimental raw data for the
thermal expansion, i.e., the dilatometric curves, are shown exemplarily for DP-W 600 in Fig. 7A. The heating branch of the curves shows no noteworthy deviations for all four measurements. In contrast to that, in the cooling branch between 900° and 400°C, the curves for all cooling times except t85 = 3.1 s are deviated. The responsible effect is the active cooling of the specimen with inert gas causing flickering effects. While needed to reach the high cooling rates, it interferes with the optical measurement of the specimen as described in the preceding section.

For the usage in the numerical simulation, the cooling branch of the curves achieved with active cooling have to be corrected using the general characteristic of the t85 = 3.1 s curve with passive cooling — Fig. 7B. These corrected curves can now also be used to evaluate the required transformation temperatures Ar1 and Ar3 for the correct description of the CCT behavior. Using the standardized method in Ref. 10 leads to the derived values given in Fig. 7B.

The exemplary analysis of the measurement data gives an overview of the possible scattering of the material properties. A detailed plausibility check of the data is needed to derive a high-quality material property data set from the raw data of the measurements and is strongly recommended. The analysis methods help to identify possible systematic measurement errors. The temperature-dependent thermophysical and thermomechanical material properties for three different alloys are given as a result of the preceding measurements and plausibility checks. They can be found in the appendix and are represented in a ready-to-use format for a numerical welding simulation.

Summary and Conclusions

A numerical simulation of the welding-induced temperature field and corresponding distortions helps to investigate the heat effects of welding and, in the long run, to optimize the quality of welded parts. Due to the complexity of the welding process itself, the material property data for the simulation has to be temperature and phase dependent. The experimental determination of these data are, especially at the needed high-temperature values, very error prone. In the given exemplary application case from the automotive industry with laser beam welding of flat plates, the most important boundary conditions for the measurement are high heating and cooling rates.

The special characteristics of welding and its numerical calculation lead to the following aspects that have to be taken into account during the experiments. In general, all measurements have to be executed with an inert gas atmosphere to prevent scaling, and any coatings on the sheet metal have to be removed prior to the measurements.

The high heating rates cause high occurring strain rates that have an influence on the yield strength and hardening behavior of the material. Tensile tests at elevated temperatures have to be executed with a quasistatic and higher strain rate for certain temperatures dependent on the investigated alloy, here above 500°C for a dual-phase steel, above 700°C for an austenitic steel, and above 300°C for an aluminum alloy.

The high cooling rates, i.e., low t85 times, in the order of less than one second necessitate an active cooling of the specimen with an inert gas during the dilatometric curve measurement. This can lead to measurement problems that have to be taken into account during the interpretation of the data, especially for alloys undergoing phase transformation, in order to guarantee a correct replication of the CCT behavior and transformation temperatures.

References


Appendix A: Material Properties for Numerical Welding Simulation

The following figures show the thermophysical and thermomechanical material properties for the three alloys considered in this paper. The data is based on the experimental values and has been measured, checked, and validated as stated in the previous sections. The intended use of this data is the macroscopic temperature field and corresponding welding induced distortions and stresses, namely a welding structure simulation, where data for temperatures up to approximately 2000°C are sufficient. Before an application of the data, e.g., for a welding process simulation where the temperatures can be much higher, these values have to be adapted, cross checked, and validated again because otherwise, most simulation software extrapolates the last given gradient and assumes a linear behavior which is, especially when reaching the evaporation temperature, not the case anymore. A more detailed discussion of the presented material properties and their sensitivity, i.e., their influence on the simulation results, can be found in Ref. 4.
Fig. A1 — Temperature dependent thermophysical material properties of DP-W 600 (1.0936).

Fig. A2 — Temperature dependent thermomechanical material properties of DP-W 600 (1.0936).

Fig. A3 — Temperature dependent thermophysical material properties of H400 (1.4376).

Fig. A4 — Temperature dependent thermomechanical material properties of H400 (1.4376).

Fig. A5 — Temperature dependent thermophysical material properties of Ecodal 608 (EN AW-6181).

Fig. A6 — Temperature dependent thermomechanical material properties of Ecodal 608 (EN AW-6181).
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