WELDING Journal

July 2007

AWS

•Guide to Selecting FCAW Electrodes

•Consumable Certification Explained

•Safety and Health in the Workplace

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

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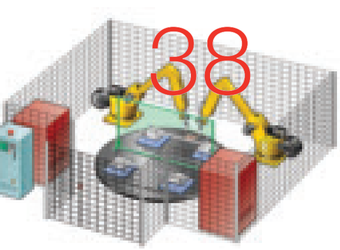

Features

Welding Research Supplement

Departments

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Illinois Tool Works Acquires Tregaskiss Welding Products

Illinois Tool Works Inc. (ITW), Glenview, Ill., has recently acquired Tregaskiss Welding Products, Windsor, Ont., Canada. Terms of the transaction were not disclosed.

Tregaskiss is a manufacturer of robotic and semiautomatic gas metal arc welding guns and peripherals. A privately held company, it employs 179 people and offers its products through welding supply distributors in Canada and the United States. It will also continue to operate independently. However, as part of ITW, Tregaskiss will have access to additional R&D, engineering, and technical resources.

Dynamic Materials Receives $8.3 Million Order for Explosion Welded Plates

The Explosive Metalworking business of Dynamic Materials Corp., Boulder, Colo., a provider of explosion-welded clad metal plates, has received an order valued at approximately $8.3 million from a U.S.-based customer.

The order is for explosion-welded plates that will be utilized in specialized equipment for the alternative energy sector. They will be produced by the company's Mt. Braddock, Pa., facility with shipment expected in the fourth quarter of this year.

Solidica to Execute Key Role in $1.1 Million Aircraft Damage Repair Project

Solidica, Inc., Ann Arbor, Mich., has recently been selected to provide its core Ultrasonic Consolidation technology to the task of field-based repair of titanium aerospace components for military and commercial applications. In this $1.15 million project, the company will be the technical lead within a cross-industry consortium formed through the National Center for Manufacturing Sciences.

Solidica was selected due to the capability of its ultrasonic welding technology to additively deposit titanium onto a variety of surfaces. Through this cold solid-state deposition process, an existing titanium component could potentially have its worn or fractured surfaces repaired without the need for a vacuum furnace.

General Dynamics NASSCO Lays Keel of Sixth T-AKE Ship

General Dynamics NASSCO, San Diego, Calif., a wholly owned subsidiary of General Dynamics, recently held a keel-laying ceremony for the sixth ship in the U.S. Navy's T-AKE program. The ship will be named *USNS Amelia Earhart*, the Navy announced, in honor of the first woman to fly solo, nonstop across the Atlantic and Pacific oceans.

Event honoree Darlene Costello welded her initials into the keel. Costello is the deputy director for naval warfare in the office of under secretary of defense for acquisition, technology and logistics.

In the fall of 2008, the *Amelia Earhart* is scheduled to be delivered to the Navy's Military Sealift Command. The ship will be 689 ft long and displace about 41,000 metric tons when fully loaded. Its primary mission will be to deliver food, ammunition, fuel, and other provisions to combat ships at sea.

Praxair Acquires Wilson Welding

Praxair Distribution, Inc., a subsidiary of Praxair, Inc., Danbury, Conn., has acquired Wilson Welding & Medical Gases, Warren, Mich. Financial terms of the transaction were not disclosed. The acquired company is an independent distributor of industrial, medical, specialty gases, and related equipment and supplies.

Wilson operates a cylinder filling plant and retail store in Warren, retail stores in Macomb and Pontiac, and a beverage CO_2 business in Flint, Mich. The business generated sales of $20 million last year and has 72 employees.

"We will be integrating the Wilson employees and operations with Praxair Distribution's 4200 employees in North America," said Praxair Distribution President Wayne Yakich.

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Welding: The Misunderstood Profession

AWS has taken to heart the challenge of rectifying the welder shortage anticipated for the United States in the coming years. Industry expects to lose 50,000 welders per year and is training only 25,000 per year. Expectations are that by 2010, industry will be short 200,000 welders. Many studies have been conducted, surveys taken, and strategies proposed. Plans to solve the problem are still in progress.

I believe there is much confusion and misunderstanding regarding welding as a profession. These misunderstandings involve our education system and several levels of society. Part of the problem is that because welding isn't always a separate job title, but is a major part of jobs with other titles, it is not well known.

With regard to our education system, guidance counselors will often be evaluated on how many students they send off to college. Therefore, they discourage the better student from attending any hands-on training such as trade school training. In addition, they often place students with behavioral issues in the hands-on classes. The proper response from industry should be to tell the local schools that it needs graduating students who excel in print reading, and who possess hands-on skills; math, reading, business skills; management skills; and people skills. It's true that welding does cover many disciplines — from the certified welder through many engineering-related degrees, both two-year and four-year, such as metallurgist, mechanical engineer, electrical engineer, welding engineer, chemical engineer, R&D scientist. The list goes on.

To illustrate what our school system can do to discourage good students who are interested in welding, I'd like to tell you about an acquaintance of mine, Clyde Shetler. He was a straight-A student. His high school guidance counselors thought he was "too smart" for welding, so he had to get his parents to write a note allowing him to enroll in the welding class. He eventually received the school's Welder of the Year Award. Clyde graduated in 1975 and worked in several fab shops before becoming a partner in CND Machine. Today he owns the shop, which has grown from 2 or 3 employees in 1987 to 62 employees in 2007. Clyde has helped many students enter a welding career path by sharing his experience and hosting many career days at the shop. During those career day visits, students can actually see first hand what welders and fabricators do and make (combining welding and machining) and the standards that are required.

The other misunderstanding about welding is more general in nature in that people only know what impacts them directly. If they do not weld or see it first hand, then welding does not exist in their mind. I once had a discussion about career values with a dear friend, Dr. Kerr, who is a pediatrician. Obviously, Dr. Kerr spent a lot time studying to become an MD. He is in a position to save lives, and is quite valuable to society. During our discussion, I asked him a hypothetical question. What if he was driving across a welded bridge and just as he reached the middle, an earthquake hit? How important is the skill of the construction or ironworkers who welded the bridge? My friend said that at that point in time, their skill level is of life-saving importance, and with his own safety at stake he hoped they were well paid. The point of the story is that people will take things for granted unless we in the profession make it a point to educate them.

I'm sure we all can tell a story about this type of misunderstanding. We should be willing to explain why we are proud to say "I am a welder." I got my career start by welding, and this profession has provided me and my family a solid life for 43 years. Welding is a building block for one's future; it is not a dead end street. Most welders go on to expand their careers through education and experience.

AWS wants to partner with many industries such as manufacturing, construction, and agriculture, as well as with the trades, educational institutions, individuals, and government entities. By working together, we can face the future with confidence that the infrastructure of society will be improved.

Victor Y. Matthews
AWS Vice President

Archie's Welding Services Makes Aluminum Megalodon Shark for Museum

Archie's Welding Services employees work in the company's parking lot in High Springs, Fla., on the 60-ft-long Megalodon sculpture they are assembling for an exhibition about the prehistoric shark at the Florida Museum of Natural History in Gainesville. The 6000-sq-ft exhibition is set to open June 16 and runs through January 6, 2008. (Florida Museum of Natural History photo by Eric Zamora.)

Over the past few months, four welders at Archie's Welding Services in High Springs, Fla., have been working to create a life-size model of a Megalodon shark. "It's been a project that we won't forget," said Archie Knowles, owner of the company. The sculpture will be featured at the Florida Museum of Natural History's temporary exhibit, "Megalodon: Largest Shark that Ever Lived," to be held June 16 through January 6, 2008.

Knowles was contacted by Project Manager Kurt Auffenberg and Ian Breheny, a museum operations specialist and designer for the display of the Megalodon exhibit, in February. When Knowles visited with them, he saw a model Breheny had made of this shark, and as he examined it, he started imagining what the real sculpture would look like.

"An open-framed, walk-through shark seemed doable, and aluminum sheet and tube seemed like a reasonably light and strong construction material," Breheny said. So, he tried to devise the simplest structure that would show the outline and volume of the shark. "The components were originally drawn in Adobe Illustrator, and exported as CAD files to be waterjet cut," he said. "I included bolt-holes, which simplified the assembly."

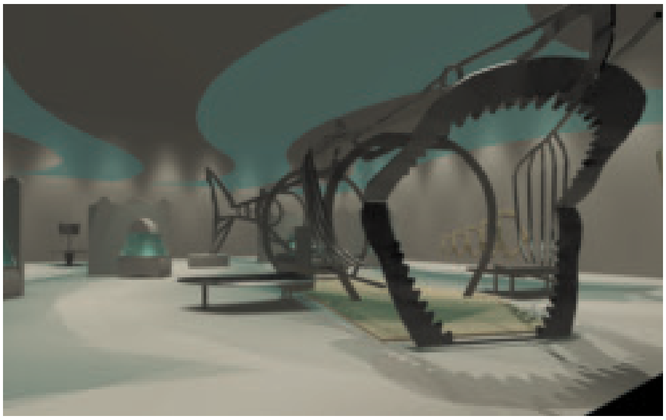
The Megalodon is fairly recent in geologic terms, living from about 17 to 2 million years ago, according to Breheny. "Its teeth are considerably larger than any other shark's, so, by inference, it's the largest shark ever," he explained.

Knowles started working on this project around the first week of March along with employees Ralph Wiker, Terry Conner, and his son, Kenny. "It was a full-time job," Knowles said.

The 60-ft-long, 12-ft-wide, and 14-ft-high aluminum shark contains a wide-open mouth with numerous teeth, a nose that is attached above the shark's mouth, two round eyes on top of the mouth, two gill structures, two bulk heads, which are almost like a rib cage, a dorsal fin, and a tail. "Most of the shark itself was constructed out of ⅛-in. aluminum," Knowles added.

Sixty to 65 pieces were used to construct the Megalodon. "It's like painting by numbers," Knowles said of the process. The museum provided the company with about 50 to 55 pieces that were waterjet cut, along with a schematic of the completed shark showing where the pieces fit, but the other pieces had to be fabricated, including the expanded metal around the bottom of the creation, different cutouts to conform and shape this expanded metal, and braces.

Welder Ralph Wiker performs gas tungsten arc welding on a gill arch for the Megalodon sculpture. "This is the biggest project we've ever done as a museum piece," said Archie Knowles, owner of Archie's Welding Services. (Florida Museum of Natural History photo by Eric Zamora.)



The computer rendering above shows what the Megalodon shark will look like when it is completed for the museum's exhibit. (Photo courtesy of the Florida Museum of Natural History.)

The sculpture weighs between 2000 and 3000 lb. A hand-held plasma torch, jig saws, a band saw for cutting aluminum, and a small sheet metal brake to bend the aluminum were among the tools used. As the welders were tacking the parts together, gas metal arc welding was used; when they were doing finishing work, gas tungsten arc welding (GTAW) was performed.

For the purpose of transportation and ease of assembly and disassembly, the various parts were designed to be bolted together.

The Megalodon was primarily constructed outdoors, because there was not enough headroom and area in the facility, but GTAW was performed inside. Local townspeople, including adults and children, were fascinated with seeing it being built.

"The shark turns to the left if you're looking from the front," Knowles said, meaning everything on the left side runs a little bit shorter than the right side, and the right side is longer than the left side. This gives the appearance that the shark is swimming.

Breheny estimates the total cost at around $20,000.

Of course, there were some obstacles along the way. “The biggest thing was the size — it was just so huge,” Knowles said, but the welders always found a way to make everything work.

“The gills were a real challenge,” Knowles said. Round tubing that was 2½ in. OD was used for this. “The wall thickness was thin, and our tubing wanted to collapse on us, so we had to go to a different direction and that was to take saw cuts in the tubing and to shape it in the configuration of the gills, weld the cuts up, and then regrind it and sand it down,” he explained.

With the dorsal fin, quite a bit of stiffening work had to be done to get this piece to stand up while the rest of the project was getting finished. “The wind was our biggest enemy there trying to do all that,” Knowles said.

Breheny suspects that this 60-ft shark is the largest shark display ever built, but added he has no way of knowing this for sure. He did mention that there is a realistic 35-ft Megalodon model at the San Diego Natural History Museum.

At the museum, solid PVC flexible interlocking tiles will be placed underneath the shark. “They’re pretty heavy, and our hope is that they’ll lay well without adhesives,” Breheny said.

In addition, benches are going to be put beside the sculpture. “The benches provide a way to include the pectoral and pelvic fins in the design, and also to help anchor the shark,” Breheny said.

The joy people will get out of seeing the completed shark is satisfying to Knowles and the other welders who helped to create it.“Mainly that’s our livelihood — going and seeing the finished product and seeing the people enjoy it,” Knowles said.

After the shark’s museum run has ended, Breheny is optimistic that other venues will be found for the exhibit. *Kristin Campbell, Assistant Editor.*

Motor Guard Launches Improved Web Site for the Welding and Gases Industry

Motor Guard Corp., Manteca, Calif., a provider of filtration products for critical compressed air applications, has launched an improved Web site at www.motorguardplasma.com *featuring an updated “Where To Buy” list, new product literature, and the latest features, advantages, and benefits of the company’s products for plasma arc cutting applications. The site allows visitors to view product illustrations, application data, and technical information; learn the benefits of clean air for plasma cutting; select the product that is right for each application; and locate the nearest stocking distributor.*

American Welding Society's JobFind Selected to WEDDLE's Top 350 Career Web Portals

The American Welding Society, Miami, Fla., recently announced AWS JobFind, the Society's career Web site, is featured in WEDDLE's *2007/8 Guide to Employment Sites on the Internet* (Guide). WEDDLE's guides are the leading source of information for the more than 40,000 job boards and career portals now operated on the Internet.

Since its inception in May 2001, AWS JobFind at *http://www.aws.org/jobfind* has seen growth. Currently housing nearly 1900 active resumes and almost 1800 registered employers, it averages 20,000 new visitors per month. Also, JobFind's average job postings have increased from ten postings per month during its launch to more than 40 per month at present, and nearly 1500 jobs have been posted to date.

With more than 3000 Web sites reviewed for inclusion in this year's Guide, only 350 were selected. These top 10% are represented in the Guide as the best employment-related resources available on the Web.

Macsteel Service Centers USA Opens New Tucson Facility

Macsteel Service Centers USA has opened its $10 million metals processing and distribution service center in Tucson, Ariz.

On May 17, the company held a western-themed open house celebration for employees, customers, suppliers, and local government officials to mark the start up of the facility in Tucson's Century Park Research Center. The company's employees and plant officials also greeted guests and took them on tours of the 73,400-sq-ft Greenfield facility.

In Tucson, Ariz., Macsteel Service Centers USA recently opened a facility that processes and distributes carbon and nonferrous metals for customers throughout the Southwest U.S. and Mexico. The photo above shows the slitting line. Thickness range of the slitter will be 0.011 to 0.187 in.

A 72-in. Braner slitting line and a 60-in. blanking line are up and running in the plant. The slitter has a 60,000-lb master coil capacity and features a turret recoiler. The 60-in. blanking line has a 40,000-lb master coil capacity and will process material ranging from 0.020 to 0.138 in. in thickness.

Both the slitter and blanking line are capable of processing cold rolled, galvanized, prepainted, hot rolled pickled and oiled, galvanneal, electrogalvanized, stainless steel, and aluminum.

Tregaskiss Welding Products Celebrates 40 Year Anniversary

Tregaskiss Welding Products, Windsor, Ont., Canada, is celebrating 40 years of manufacturing gas metal arc welding products. Founded in 1967 by toolmaker William Tregaskiss, the company introduced the Auto 350 gas metal arc gun to meet the harsh demands of the automotive plants. It was designed in cooperation with Ford Motor Co.

The company's R&D efforts led to the launch of its TOUGH GUN® line of semiautomatic and robotic guns and a patented TOUGH LOCK® contact tip system.

In 2005 and 2006, the company was a winner of Canada's 50 Best Managed Companies program. In addition, in 2006, Tregaskiss embarked on a joint venture with Browne Distribution International creating Tregaskiss International.

Industry Notes

- RoMan Engineering Services (RES), Madison Heights, Mich., recently announced the acquisition of the SORPAS (Simulation and Optimization of Resistance Projection And Spot welding processes) resistance welding simulation software. SORPAS is an integrated professional software package designed to aid in the determination and refinement of resistance spot and projection welding process parameters.

- Rimrock-Wolf Robotics, Fort Collins, Colo., in cooperation with the National Shipbuilding Research Program Welding Technology Panel, hosted a tour of its manufacturing facility on March 27 as part of the winter meeting agenda. The NSRP organization held its annual two day meeting in Fort Collins, Colo., and it included several presentations on panel projects, recent welding technologies, and tours of the Wolf Robotics facility and the Colorado School of Mines.

- Rolled Alloys, Temperance, Mich., has acquired SMS Alloys. Located in the city of Lyon, approximately 260 miles south of Paris, this 16,000-sq-ft facility serves aerospace and corrosion-resistant alloy customers throughout central Europe and beyond. This location will continue operations and be known as SMS Alloys. Also, this location will now become Rolled Alloys' primary stocking location in Central Europe.

- Flomerics Group plc will provide its *Engineering Fluid Dynamics* (EFD) simulation software to universities and colleges around the world for teaching and research purposes. Flomerics' EFD for Education Initiative provides mechanical engineering students and researchers access to the latest fluid dynamics software used in industry. EFD operates inside the mechanical CAD tools that engineers are familiar with.

- Hobart Brothers, Troy, Ohio, has added a new product selection tool to its Web site. The Hardfacing Product Cross Reference Guide, found at *Hobartbrothers.com/cross-reference*, allows visitors to quickly and easily cross-reference competitive hardfacing covered electrodes and welding wires to find equivalent products by the company. Via two drop-down menus, visitors can select from one of fifteen competitive filler metal manufacturers and their respective hardfacing products. The Web page provides a recommendation for equivalent Hobart Brothers' hardfacing filler metals.

Canadian University Teams with Local High Schools for Welder Training

Travis Pinning, a student at the Chilliwack campus of University College of the Fraser Valley, practices his cutting skills. Soon, area high school students will be able to finish their level C certification at the college.

University College of the Fraser Valley (UCFV), Chilliwack, BC, Canada, has formed a partnership with the local school district that will allow high school welding students to start their welding level C certification in high school and complete it at UCFV. Level C certification is the provincially recognized welder credential.

Currently, Chilliwack high school students, in both public and private schools, can begin a trades apprenticeship path, usually in the tenth grade. Under the new arrangement, they'll do half the C-ticket program in high school and the other half during 14 weeks at UCFV, from February to May during twelfth grade. The program components are designed to synch properly, with UCFV having reviewed and endorsed the curriculum and available equipment and resources at the high school level.

"Having (our apprenticeship students) complete their ticket at UCFV will give them a taste of the university experience and a valuable postsecondary credential that's recognized across the province. It's a great way to kick off a solid career," said Garry Wall, school district apprenticeship coordinator.

Harv McCullough, dean of trades and techology at UCFV, sees the Chilliwack welding partnership as a pilot program that could lead to similar partnerships in other trades. "We really want to focus on bridging that gap between high school and university," he said.

The students will train at the school's new state-of-the-art Trades & Technology Center, scheduled to open in September. Equipment at the two-acre facility will include the first robotic welding equipment in western Canada to be used for training.

Employers Worldwide Struggling to Find Qualified Job Candidates

Forty-one percent of employers across the globe are finding it more difficult to fill jobs, specifically openings for sales representatives, skilled manual tradespeople and technicians, which are in-demand technical workers in areas such as production/operations, engineering, and maintenance, according to a survey by Manpower, Inc., Milwaukee, Wis.

The company surveyed 37,000 employers in 27 countries and territories as a follow-up to its 2006 survey, to determine which positions employers are having difficulty filling this year due to lack of available talent. "Our data for 2007 reflect the ebb and flow in the demand for talent within the global labor market, as companies and governments seek ways to alleviate talent problems due to demographic shifts, immigration, and other issues," said Jeffrey A. Joerres, Manpower's chairman and CEO.

Skilled manual trades workers are at the top of the employers' wish list in Germany, United Kingdom, Canada, Australia, Spain, Sweden, Italy, Belgium, Austria, France, and Switzerland. In the United States, Japan, Hong Kong, Taiwan, Singapore, New Zealand, Ireland, and Peru, sales representatives topped the list. Europe is the best place to be for workers in the skilled trades, such as welding, carpentry, and plumbing. These positions are ranked as the first or second-most difficult jobs to fill in all countries surveyed in the region, besides Ireland.

The complete results of the survey can be downloaded at *www.manpower.com/researchcenter.*

American Tank Joins Forces with Danish Company for New Armor Technologies

The American Tank & Fabricating Co., Cleveland, Ohio, a provider of alloy, steel, and metallic armored components to original equipment manufacturers, recently formed a joint venture with Composhield A/S, Hobro, Denmark. The new subsidiary, AMTANK Armor, LLC, will be located in northeast Ohio, and will benefit from American Tank's manufacturing capabilities and business relationships and introduction of new armor technologies from Composhield.

John Mayles, formerly with Armor Holdings, Inc., will become president of the new company.

Composhield develops and qualifies survivability systems against blast, ballistic impacts, and other hostile actions. It has the newest and most reliable composite material technologies and can provide lightweight solutions for a variety of threats. American Tank specializes in rolling, forming, and welding the heaviest, longest, and hardest steel plate, as well as oxyfuel and plasma arc cutting, and contour beveling for custom shapes.

Mature European Welding Equipment Market Expected to See Marginal Growth

The European welding equipment market has now reached the mature stage. Some product segments are in the final stages of maturity, while newer technologies such as lasers are in a growth phase, giving the market a much-needed boost, according to a report from Frost & Sullivan, a global growth consulting company.

Given the large number of end-user sectors such as shipbuilding, offshore construction, aerospace, and chemical industries, the market is expected to see marginal growth. However, the shifts of manufacturing projects to East Asian countries combined with the lack of welders are preventing the market from growing.

"The welding equipment market in Europe is forging ahead despite a large number of restraining factors," according to the European Welding Equipment Market analysis. Frost & Sullivan Research analyst Archana Chauhan reports the market faces a marginal growth owing to the maturity of the market at the product level; however, certain regional developments are also spurring revenue growth in the welding equipment market. Apart from introducing new, automated technologies, market participants have to provide high-quality equipment with product differentiation in order to be competitive.

Visit *www.frost.com* for more information.◆

BY DAMIAN J. KOTECKI

Measuring Ferrite Number Follow-up

The January 2007 column reported a reader finding what appeared to be high FN measurements using a Fischer Feritscope®, making the measurements while the weld metal was still at about 300°F (150°C) as compared to measurements at room temperature. My subsequent observations agreed. Michael Haller of Fischer Technology, manufacturer of the Feritscope, provided the following commentary on that phenomenon, edited for brevity.

The probe of the Feritscope reacts to changes of temperature. In the case of complete thermal equilibrium of probe and material (probe and material over a long time period in a temperature-controlled cabinet), an apparent increase of the Ferrite Number of approximately 1 to 1.5 FN occurs when the temperature increases from 20° to 60°C (68° to 140°F) — material of FN 5.0 with probe calibrated at 20°C reads approximately FN 6.0 when probe and material are at 60°C.

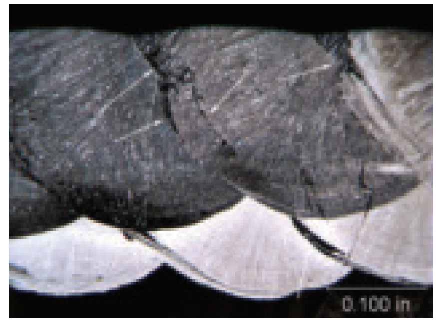


Fig. 1 — Cross section of two-layer stainless steel cladding.

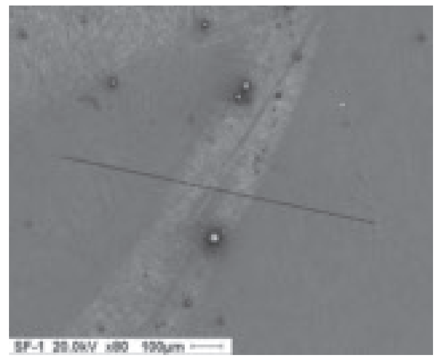


Fig. 2 — An SEM image of an oddly etching area in the first layer of Fig. 1.

The probe is not designed for use at higher temperatures. The probe will get damaged and it will eventually lead to the destruction of the probe.

The actual problem at hand, however, is that the measurements are done with the probe at room temperature on hot materials. The probe warms up uncontrolled and unevenly, starting from the tip (probe pole) when placed on the sample. This changes the inductance of the probe coils, among other things. This in turn causes faulty measurements within the described range.

In summary, the probe should not be used at the described elevated temperatures, because of a temperature-induced drift in the probe properties. Materials should always be allowed to cool down sufficiently, in order to avoid false measurements. The suggested temperature range of the probe should not be exceeded. The temperature dependence observed is not due to material properties. Rather, they are probe related when operated outside the specified temperature range.

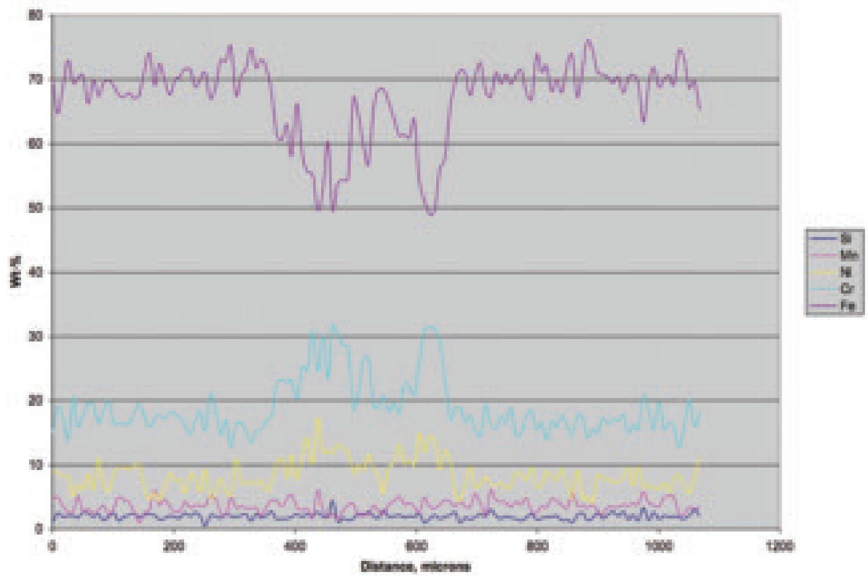


Fig. 3 — SEM line scans for Fe, Cr, Ni, Mn, and Si across the oddly etching area of Fig. 2.

Q: We produce two-layer cladding of carbon steel with overalloyed stainless steel metal cored wire by submerged arc welding. Cross sections of the cladding often, but not always, reveal oddly etching features, typically at the interface between two passes. A concern has been expressed that these oddly etching areas might be low in alloy content and therefore susceptible to selective corrosion if exposed to the corrosive medium.

A: Figure 1 shows a metallographic cross section of the weld. The "oddly etching" areas can be more easily seen in the first layer, but they are also visible in the second layer, as indicated by arrows in the figure. This cross section was examined in a scanning electron microscope. Line scans were performed across these oddly etching areas, giving semiquantitative analysis profiles for iron, chromium, nickel, manganese, and silicon. Every one of the areas, both first layer and second layer, had the same general composition profile.

Figure 2 shows the SEM image of the oddly etching area in the first layer of the cross section of Fig. 1 that can be easily seen just above the scale marker in the lower right corner of Fig. 1. It should be noted that there is a mirror image inversion between Figs. 1 and 2, such that the center of curvature of the oddly etching area appears in Fig. 1 to be to the right of the area, while it appears to be to the left of the area in Fig. 2. The path of the line scan for alloy element concentration is indicated by the dark line across this area in Fig. 2.

Figure 3 shows the semiquantitative composition of the weld metal along this line scan. The direction of scanning is from left to right in both Fig. 2 and Fig. 3. It can be clearly seen that the chromium and nickel contents are higher in the oddly etching area than they are in the bulk of the weld metal. Correspondingly, the iron content appears lower in that area. Manganese and silicon exhibit no discernable composition change in the area versus in the bulk of the weld metal.

So the oddly etching areas are indeed inhomogeneities, but they are actually richer in alloy content than the bulk of the weld metal, not leaner as was originally supposed. One might wonder how such inhomogeneities arise. The flux in use is known to not contain any alloy element additions, so that can be ruled out as the source. The metal cored wire is made with virtually all of the alloy elements in the core. It is expected that the melting of the mild steel tube does not always occur at the same rate as the melting of the core alloy elements. Then incomplete mixing of the melted core with the bulk of the weld pool gives rise to the inhomogeneities.

Since the inhomogeneities are overalloyed, not underalloyed, they are unlikely to lead to preferential corrosion in these areas.

DAMIAN J. KOTECKI is technical director for stainless and high-alloy product development for The Lincoln Electric Co., Cleveland, Ohio. He is a past president of the American Welding Society, a vice president of the International Institute of Welding, a member of the A5D Subcommittee on Stainless Steel Filler Metals; D1 Committee on Structural Welding, D1K Subcommittee on Stainless Steel Welding; and a member and past chair of the Welding Research Council Subcommittee on Welding Stainless Steels and Nickel-Base Alloys. Questions may be sent to Dr. Kotecki c/o Welding Journal, 550 NW LeJeune Rd., Miami, FL 33126; or e-mail to Damian_Kotecki@lincolnelectric.com.

Charting the Course in Welding: U.S. Shipyards
Newport News • Omni Hotel
Oct. 18-19, 2007

Sensor Torch Based Adaptive Intelligent System for Circumferential Welding of Pipe
YuMing Zhang, President, Adaptive Intelligent Systems LLC, Lexington, Ky.

Induction Brazing Equipment for Shipbuilding Applications
Tom Brown, Regional Sales Manager, EFD Induction Inc., Madison Heights, Mich.

Introduction to TERAC-Fairing with Induction
Mark Wells, Product & Application Manager, EFD Induction A.S., Skien, Norway

Single-Pass GMAW of Pipe Socket Welds
Michael Ludwig, Chief Welding Engineer, General Dynamics–Bath Iron Works, Bath, Maine

Orbital Pipe Welding Today: An Overview
Kenneth J. LeDuc, Technical Specialist–Training & Service, Magnatech Limited Partnership, East Granby, Conn.

Tandem Gas Metal Arc Welding for Out-of-Position High-Strength Steel Erection Joints
Nancy C. Porter, Project Manager, Edison Welding Institute, Columbus, Ohio

Development of a Large Tee Welder
Michael Ludwig, Chief Welding Engineer, General Dynamics–Bath Iron Works, Bath, Maine

Hybrid Laser-Arc Welding of Pipe and Thin Steel Panel Structures
Shawn Kelly, Research Associate, Applied Research Laboratory, Penn State University, State College, Penn.

FSW for Naval Shipbuilding
Maria Posada, Materials Engineer, Naval Surface Warfare Center, West Bethesda, Md.

Tandem MAG
Lars-Erik Stridh, IWE, Process R&D, Application Manager, ESAB AB, Gothenburg, Sweden

Independent Control of Melting Speed and Base Metal Current Using Double-Electrode GMAW
YuMing Zhang, Professor, University of Kentucky, College of Engineering, Lexington, Ky.

Transient Thermal Tensioning to Control Buckling Distortion
Randal M. Dull, P.E., Senior Engineer, Edison Welding Institute, Columbus, Ohio

High Speed Tandem SAW
Nancy C. Porter, Project Manager, Edison Welding Institute, Columbus, Ohio

Development of a Cr-Free Consumable for Joining Austenitic Stainless Steels
John C. Lippold, Professor, The Ohio State University, Edison Joining Technology Center, Columbus, Ohio`

The Use of Portable XRF for Rapid Alloy Verification and Analysis
Bree Allen, Director, Sales, Thermo Scientific NITON Analyzers LLC, Billerica, Mass.

Impact of the New OSHA Hexavalent Chromium Standard
Susan R. Fiore, Senior Engineer, Edison Welding Institute, Columbus, Ohio

Evaluation of Modeling and Simulation Software for Multi-Pass Welded Structures
Garrett Sonnenberg, Engineer IV, Northrop Grumman Newport News, Newport News, Va.

Conference price is $550 for AWS members, $680 for nonmembers.To register or to receive a descriptive brochure, call (800) 443-9353 ext. 229, (outside North America, call 305-443-9353), or visit www.aws.org

Highlighting Safety and Health

First Aid and Emergency Burn Kits Made for Welders

The Welder's First Aid Kit, part number 019736-0023L, puts the unitized first aid supplies that welders need right where they can find them. Color-coded cartons hold individually sealed unit dose applications that simplify inspections and replenishment. It features the following: 24-unit, wall-mountable, steel kit with carrying handle, and standard supplies to treat common, minor injuries encountered by welders. Additionally, the company is offering the North Welder's Emergency Burn Kit, part number 019726-0013L, that contains the necessary supplies for emergency treatment and care of welding-related burns. This wall- mountable kit with carrying handle has 13 pieces per kit and includes medical gloves, angled scissors, and self-adherent wrap. It also has eight Water-Jel® burn dressings in four sizes.

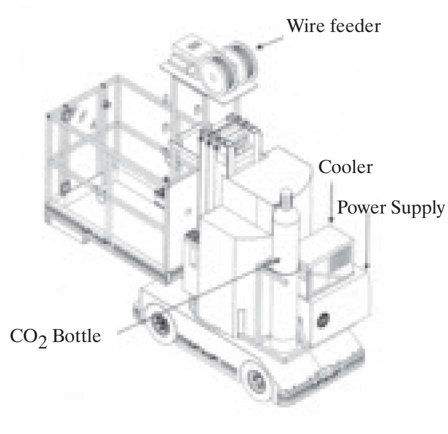
North Safety Products
www.northsafety.com
(401) 943-4400

Autodarkening Helmets Developed for Hobbyist and Professional Welders

The company is offering the Pro-Hobby™ Series, an entry-level line of helmets, and Performance Series™, which replaces the previous Xli and Xlix helmet lines. The Performance Series helmets, designed for professional and production welders who weld for extended periods nearly everyday, feature three arc sensors that darken the lens between shades 8 and 13 in 1/20,000 of a second. This line has the company's auto-on/auto-off feature, which activates the lens shade without having to manually turn the helmet on, and grind mode, which stops the lens from darkening while grinding. Also, the series adds two helmet designs — Fire Storm™ and Motorsports™. The Pro-Hobby Series, designed for the light-duty welder who does not weld professionally, offers many of the same features as the Performance and Elite™ Series', including the company's graphics and headgear. Both lines of autodarkening helmets introduce a magnifying lens holder and a fixed #3 shade lens for better visibility between welds.

Miller Electric Mfg.Co.
www.MillerWelds.com
(800) 426-4553

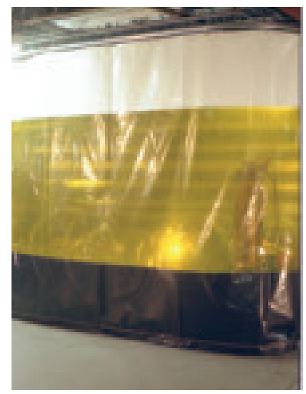
Aerial Work Platform Contains Room for On-Board Welding System



The AMV40-20 offers 360-deg continuous rotation and can elevate to 20 ft of platform height. The unit is 41 in. wide and can be driven at full elevation. Welding equipment can be installed per the customer's specifications and can include the following: power supply, cooler, wire feeder, CO_2 bottle, and torch. The platform measures 36 in. wide × 54 in. long to provide the welder sufficient working area. In addition, all lines are run from the base to the platform in a cat track system. An overhead wire feeder location keeps this equipment up and out of the operator's way. A shelving area and hooks are provided for miscellaneous materials and tools as well.

Lift-A-Loft Corp.
www.liftaloft.com
(765) 288-3691

Vinyl Engineered for Durability



The line of industrial safety products by the company features a newly developed fabric, Steel-Scrim® vinyl. The 15-oz laminate vinyl with polyester scrim is designed with a tri-lateral scrim, creating over 406 lb of tensile strength per square inch. Also, this advanced tri-lateral scrim design has the ability to resist tears by bunching up and collapsing upon itself when attempted to tear, keeping small punctures from becoming large tears. The vinyl is available in several product lines including industrial curtains, welding curtains, roll-up curtains, warehouse dividers, and custom covers.

Steel Guard Safety Corp.
www.steelguardsafety.com
(800) 347-8368

Reusable Earplugs Receive High Noise Reduction Rating

The company recently announced a new formulation that receives a Noise Reduction Rating (NRR) 27 for its Rockets® brand reusable earplugs. (The product obtained this NRR in accordance with ANSI

Specs S3.19-1974, through an independent NRR testing laboratory.) The higher rating is the result of reformulating the materials with a new sound-dampening additive. The following Rockets® part numbers have an NRR 27: 6400 – Uncorded; 6404 – Corded (w/o Pocket-Pak®); 6405 – Corded; 6415 – Metal Detectable, Corded; 6420 – Cloth Corded; 6480 – Special Ops™, Uncorded; and 6485 – Special Ops™, Corded.

Moldex-Metric, Inc.
www.moldex.com
(310) 837-6500

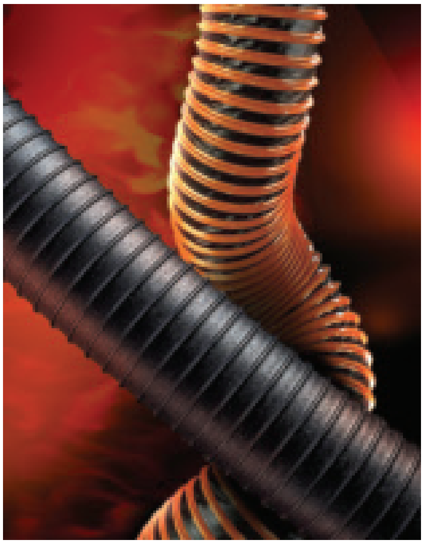
Boots Feature External, Protective Metatarsal Shield

The Met Guard 6-in. Steel Toe and Met Guard 8-in. Steel Toe Waterproof are traditional metatarsal protection boots featuring a hinged, asymmetrically designed shield for optimal movement and comfort. They feature an external, protective metatarsal shield with high-impact ABS material and OrthoLite® polyurethane foam. The product is also designed with Timberland PRO® Ever-Guard™ leather for additional durability and abrasion resistance. Additional features include the following: anatomically contoured insole with integral steel shank for support; antimicrobial lining; electrical hazard protection; and a wide assortment of sizes.

Timberland PRO
www.timberlandpro.com
(800) 258-0855

Flexible Hoses Useful for Confined Spaces

2PN, a polyester hose coated with neoprene and reinforced with a wire helix, provides durability for positive or negative



pressure movement of light particles or materials as well as for blower, exhaust, or smoke-removal systems in welding sites. Withstanding service temperatures from –40° to 250°F, it is available in one- or two-ply versions in diameters of 1–24 in., with or without cuffed ends, and can be fabricated for static-discharge or non-conductive applications. TD-S/TD-HS, a one- or two-ply vinyl laminate polyester hose with an enclosed helix of spring steel for flexibility, features a heavy-duty wearstrip that resists abrasion in temporary or mobile applications requiring the hose to be dragged. These UL-recognized hoses, withstanding service temperatures from –40° to 180°F, are available in diameters of 3–12 in. as well as custom diameters and lengths.

Hi-Tech Duravent
www.hitechduravent.com
(864) 297-2201

Pants Come in Five Styles

The Blåkläder line of pants is available in a variety of materials, and features reinforced utility pockets, lightweight kneepad pockets, four bellowed pockets, webbed hammer loop and detachable screwdriver pocket, and wide and thin belt loops. The five styles are Heavy Worker — poly/cotton canvas with extra-strength Cordora® reinforcements; Roughneck — poly/cotton twill; Bantam — 8-oz cotton canvas; Brawny — 12-oz cotton canvas; and Toughguy — 13-oz cotton twill.

Blåkläder
www.blaklader.com
(866) 248-5452

Protective Eyewear Features Distortion-free Lenses

The company has extended its KleenGuard* brand with the launch of a line of protective eyewear. KleenGuard* V10 standard eye protection has features that include distortion-free lenses, impact protection, a range of styles, and a dual wraparound design that is sleek and lightweight and fits both men and women. KleenGuard*V20 comfort eye protection also features distortion-free lenses and impact protection, plus a colorful range of styles. It includes comfortable, padded temples, and a contemporary, wraparound design. KleenGuard*V30 flexible eye protection features include a padded nose bridge, as well as a ratcheted temple for an easily adjustable lens angle. Temples are flexible to help reduce slippage. KleenGuard*V40 contour eye protection has distortion-free lenses that enhance vision and safety, while the wraparound design provides more comfort. The eyewear features a soft gel, adjustable nose piece, dual-molded rubber temples, and a durable vented frame with cushioned brow protection.

Kimberly-Clark Professional
www.kc-safety.com
(800) 255-6401

Safety Enclosure Gives Worker Sight Protection

The Enviro Saf-T-Cell™ is a standardized safety cell enclosure with an integral air filtration system. The enclosure not only limits access to peripheral employees, but protects them and nearby machinery from flying debris, weld flash, machine noise, and fumes. Additional safety features include the lightweight, top-mounted fume- collecting hood system designed to protect employees from fumes by collecting airborne particulates and contaminants with prefilters and bag filters. Hearing discomfort is further minimized with sound attenuating panels.

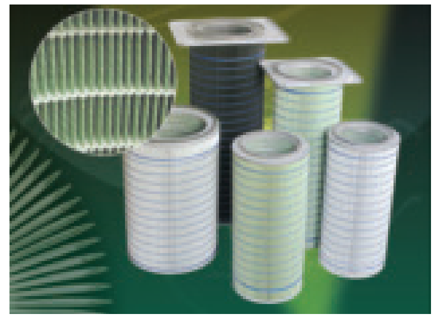
Frommelt Safety Products
www.frommeltsafety.com
(800) 553-5560

Gloves Feaure Coated Palms

The line of Tuff-Coat™ palm-dipped gloves includes a 'hybrid' style. A lightweight stretchy nylon liner provides flexibility and dexterity combined with a durable latex coating for resistance to cuts, punctures, and abrasion. In addition to two cut-resistant styles made with DuPont™ Kevlar® brand fiber shells and two general-purpose styles made with cotton/polyester blend shells, a high-visibility, acrylic-dipped glove with thermal protection for use in high activity/low light settings is available.

Perfect Fit Glove Co., LLC
www.perfectfitglove.com
(800) 245-6837

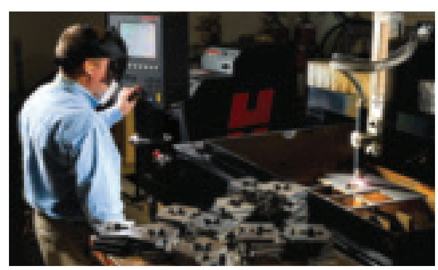
Retrofit Cartridges Offer Upgraded Dust Collector Performance



A full line of HemiPleat™ retrofit cartridges may be used to upgrade performance or solve problems of existing dust collector systems. A patent-pending pleating technology opens up the pleats uniformly for more effective cleaning and better airflow. The cartridges are made with the HemiPleat PolyTech™ media. This silicone-treated polyester/cellulose blend offers high moisture resistance and filtration efficiency of 99.99% on 0.5 micron particles and larger.

Farr Air Pollution Control
www.farrapc.com/html_hemipleat/retrofit/
(800) 479-6801

Plasma System Offers Long Consumable Life



The HySpeed HSD130 is a mechanized plasma system that includes the company's patented LongLife® technology to deliver double the consumable life. The product cuts dross-free at 5/8 in. (16 mm) on mild steel. Production pierce capability is 1 in. (25 mm), with maximum cutting at 1½ in. (38 mm). With faster cut speeds and virtually dross-free cutting, secondary operations are eliminated.

Hypertherm, Inc.
www.hypertherm.com
(603) 643-3441

Safety Light Curtains Available in Three Versions

The MiniSafe® MS4800 series safety light curtains are available in Advanced, Standard, and Basic versions. Advanced and Standard models allow users to select automatic start or start/restart mode for point-of-operation or perimeter guarding. Advanced and Basic models can be used with an intuitive and easy-to-use programming diagnostic module. The MS4800 family is available in resolutions ranging from 14 to 40 mm, with sensing ranges from 7 m for 14 mm resolution systems and 20 m for 20, 30, and 40-mm resolution systems. The product provides protected heights from 280 to 1800 mm for 14 and 20-mm resolution systems, 360 to 2120 mm for 30-mm resolution systems, and 360 to 2160 mm for 40-mm resolution systems.

Omron Scientific Technologies, Inc.
www.sti.com
(800) 479-3658

Welding Fume Extractor Powered by Two Motors

The Miniflex™ is a portable, high-vacuum, low-volume system. The unit automatically switches on when the arc is established with a 15-s delay upon completion of welding. It is constructed with impact-resistant synthetic components and is lightweight at 33 lb. With a preseparator, LongLife-H® main filter with a surface area of 130 sq ft, an efficient HEPA particle arrestor, and optional carbon filter, the product's four-stage filtration process is effective in removing welding fumes. The system operates at 70 dB(A) with torch extraction installed. The unit is powered by two 1.34-hp motors. In high mode, both motors are working at 100% capacity, while in low mode, both motors work at 50% capacity.

The Lincoln Electric Co.
www.lincolnelectric.com
(888) 355-3213

How to Choose Electrodes for Joining High-Strength Steels

Technical insight is provided for evaluating the variety of GMAW and FCAW electrodes available for joining high-strength steel

BY K. SAMPATH

All over the world, adoption of gas metal arc welding (GMAW) and flux cored arc welding (FCAW) processes continues to grow for low-cost fabrication of various grades of structural steels, including high-strength steels. The growth of GMAW/FCAW is driven primarily by the increased availability of numerous consumables, including solid, fluxcored, and metalcored wire electrodes. But, how does one select an electrode for joining a particular grade of high-strength steel? Will a simple reliance on relevant AWS/ANSI electrode specifications be adequate? How does one evaluate data from a multitude of electrode manufacturers? This article offers to provide technical insight into those questions.

Factors to Consider

Selection of an electrode for a particular application is based on several factors. Chief among them is a fundamental understanding of the relationships among chemical composition, processing, microstructure, and mechanical properties of the steel being welded. Also, specific design requirements for mechanical properties of the welded component or structure should be known.

The "things to-do" list is long while underlying issues are complex. However, such an understanding is a prerequisite for achieving quality, productivity, and improved performance of welded constructions, while controlling overall fabrication cost.

Basic Principles of Electrode Selection

Electrode selection is based on an electrode's ability to provide weld metal that is chemically compatible with the base metal. Electrodes that offer a similar (not same but matching)

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chemical composition as the base metal minimize potential adverse effects of base metal dilution, which can include localized corrosion.

Welding electrodes are also selected to enhance weldability. A major aspect of weldability is the ability to obtain crack-free weldments. In the case of high-strength steels, the primary concern is achieving resistance to hydrogen-assisted cracking (HAC) in both the weld metal and the heat-affected zone (HAZ). Resistance to solidification cracking is seldom a concern. Most often, solidification cracking in weld metal is attributed to segregation of impurities such as sulfur and phosphorus along the weld centerline. Control of impurities (sulfur and phosphorus, each at 0.01 wt-% maximum) and trace elements in the welding electrode, and control of weld solidification conditions through manipulation of travel speed, most often avoid solidification cracking in weld metal.

Microstructure

Microstructure underpins mechanical properties. The term microstructure includes type, size distribution, morphology, and volume fraction of various microstructural constituents. Microstructure, in turn, is dependent on chemical composition and processing conditions, especially cooling rate. Based on a need to achieve desired mechanical properties, weldability may be looked upon as the ability to "recreate and/or retain" microstructures similar to the base metal.

Various carbon equivalent formulas allow one to relate chemical composition with weldability of steel. In particular, Yurioka's carbon equivalent number (CEN), as shown in Equation 1, offers a viable means to assess relative effects of various alloy elements on weldability.

$$CEN = C + A(C) \times \left\{ \frac{Si}{24} + \frac{Mn}{6} + \frac{Cu}{15} + \frac{Ni}{20} + \frac{Cr + Mo + V + Nb}{5} + 5B \right\} \quad (1)$$

where $A(C) = 0.75 + 0.25 \times \tanh[20 \times (C - 0.12)]$, and concentrations of all elements are expressed in wt-%.

Although the CEN equation was originally developed to assess hydrogen cracking sensitivity of structural steels, the equation is also relevant to weld metal. The higher the CEN, the lower is the resistance to HAC. Carbon has by far the greatest impact on weldability. So, it is essential to select welding electrodes with a carbon content lower than that of the steel being welded. Considering possible carbon pick-up from CO_2 in the weld shielding gas, and base metal dilution, it is prudent to select welding electrodes with about 0.02 to 0.04 wt-% lower carbon than the base metal. Lowering carbon content must be compensated for by using other alloy elements to maintain or further increase CEN. A 0.12 wt-% for carbon is considered an appropriate upper limit in high-strength steel welding electrodes, as twinned martensite, which has an extremely poor resistance to HAC, is likely to form above this limit.

The CEN equation is helpful in selecting various principal alloy elements in the welding electrode. Alloy elements with a lower coefficient (nickel, copper, and manganese) are preferable to those with a higher coefficient (chromium and molybdenum). Yet, weld metal must remain chemically compatible with the base metal. A prior knowledge of the chemical composition of the base metal and the roles of various alloy elements is valuable.

Overmatching Strength and Overall Alloy Content

Welding electrodes must provide weld metals with a minimum required weld tensile strength and acceptable impact toughness properties, either in the as-welded or postweld heat treated condition. Use of a welding consumable that offers a deposited weld metal with higher weld tensile strength than the tensile strength of steel being welded is called overmatching. Overmatching is used primarily to "protect" the weld deposit from the presence of fabrication-related weld flaws. These flaws when subjected to occasional excessive service loads can potentially lead to catastrophic consequences.

However, overmatching of high-strength steels using welding electrodes with high-carbon content requires expensive preheat, interpass, and occasionally post-soak temperature controls during welding to ensure against HAC, thus hurting productivity and overall economics of fabrication. Therefore, overmatching is an option only when the overmatched weld metal offers adequate toughness, particularly acceptable low-temperature impact toughness, and overmatching allows cost-effective fabrication.

Other aspects of strength consideration are heat input and cooling rates. It is well known that high weld energy input and associated slow weld cooling rates produce a lower strength weld metal, and vice versa. Depending on the electrode diameter, the weld energy input commonly ranges between 20 and 80 kJ/in. A high-performance welding electrode is expected to overmatch at the highest usable weld energy input while meeting or exceeding weld metal toughness requirements. This invariably means that at the lowest usable weld energy input, the same welding electrode may overmatch the minimum specified tensile strength of the base metal, possibly in excess of 10%. In other words, an electrode that provides marginal overmatching at the highest usable energy input is likely to offer excessive overmatching at the lowest usable weld energy input. Fortuitously, the high-strength weld metal simultaneously offers higher toughness, primarily due to the presence of refined grains and microstructural constituents. Expectedly, CEN of the corresponding welding electrode would be higher than the base metal, in excess of 10%.

The strength and other mechanical properties of a clean, defect-free weld metal depend primarily on chemical composition, and secondarily on weld cooling rate. As shown in Equation 1, a higher alloy content results in a higher CEN, and thus a higher tensile strength. As a higher CEN progressively impairs weldability, control of alloy content of the selected electrode to a desirable range of CEN is crucial. The inherent conflict requires "balancing" or optimization of competing criteria. When there is an inability to resolve this underlying conflict, as in the case of certain very high-strength steels such as HY-130, overmatching may no longer be a viable option.

Toughness and Transformation Temperature

How does one select a welding electrode to improve weld metal toughness? Besides chemical composition, welding conditions (particularly weld cooling rate) contribute to microstructure development.

The following on-cooling transformation temperatures are important with regard to microstructural development in high-strength steels: 1) austenite-to-ferrite (A_{r3}), 2) austenite-to-pearlite (i.e., eutectoid transformation), 3) austenite-to-bainite (i.e., B_S, bainite-start and B_F, bainite-finish), and 4) austenite-to-martensite (i.e., M_S, martensite-start and M_F, martensite-finish) temperatures.

Controlled lowering of the relevant transformation temperatures allows one to refine grains and microstructural constituents in weld metal, and thus simultaneously improve both strength and overall toughness. Here again, several constitutive equations allow one to relate chemical composition with transformation temperatures, thus further allowing selection and manipulation of various microstructural constituents.

The A_{r3} temperature is approximately related to chemical composition as shown in Equation 2. Likewise, B_S, B_F, and M_S temperatures are statistically related to chemical composition of low-alloy steels as shown in Equations 3–5.

$$A_{r3}\ (°C) \sim 910 - (310 \times C) - (80 \times Mn) - (80 \times Mo) - (55 \times Ni) - (20 \times Cu) - (15 \times Cr) \quad (2)$$

$$B_S\ (°C) = 830 - (270 \times C) - (90 \times Mn) - (37 \times Ni) - (70 \times Cr) - (83 \times Mo) \quad (3)$$

$$B_F\ (°C) = 710 - (270 \times C) - (90 \times Mn) - (37 \times Ni) - (70 \times Cr) - (83 \times Mo) \quad (4)$$

$$M_S\ (°C) = 561 - (474 \times C) - (33 \times Mn) - (17 \times Ni) - (17 \times Cr) - (21 \times Mo) \quad (5)$$

The above statistically valid relationships between chemical composition and transformation temperatures were originally developed for particular types of steels, under specific experimental conditions. Nevertheless, these equations are useful for manipulating alloying elements in welding electrodes, thus targeting desirable ranges of transformation temperatures.

The objective is to select a welding electrode or control its alloy content within a desirable range of CEN, while achieving a 30° to 50°C lowering of the relevant transformation temperatures compared to the characteristics of the high-strength steel being welded. Thus, a complete understanding of chemical composition and microstructures of the base metal is a prerequisite to selecting a high-performance welding electrode.

Besides alloy content, increasing (weld) cooling rate is known to suppress (undercool) transformation temperatures. The welding operational envelope controls weld cooling rate. As mentioned previously, increasing the weld cooling rate contributes to a further refining of both grain size and various microstructural constituents, thus strengthening the weld metal while simultaneously increasing its toughness.

Despite this potential, it must be recognized that in fusion welding situations, because of epitaxial growth considerations, the level of undercooling achieved is often minimal, not exceeding a few degrees.

Dissolved Gases and Toughness

Weld metal toughness can be severely impaired by the presence of dissolved gases such as oxygen and nitrogen (in excess of 500 ppm, total), and too many inclusions that contribute to "a dirty weld." Proper control of shielding gas during welding, and the presence of controlled amounts of aluminum, titanium, and zirconium (each at 0.03 wt-% maximum) in the welding electrode are necessary to minimize air ingress, and effectively deoxidize, fix nitrogen in weld metal, allow "scavenging and grain refining," and thus enhance weld metal toughness.

Specifications

Standard setting organizations such as the American Welding Society (AWS) codify the above rationale and knowledge for welding electrode selection into appropriate welding electrode specifications, such as AWS A5.28/A5.28M:2005, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, and A5.29-05, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*. Underlying parameters in a specification are supported by both historical data and test data developed by electrode manufacturers and researchers, among others. The specification parameters allow users to select one or more electrode classification(s), and corresponding electrodes offered by one or more welding electrode manufacturer(s).

Welding electrode specifications simplify the above complex electrode selection criteria, and present the recommendations, as clearly and concisely as possible. To maintain neutrality or eliminate bias, the recommendations are classified into groups of welding electrodes based on chemical composition of the electrode or the as-deposited weld metal (as in the case of cored electrodes), and appropriate and acceptable mechanical property (commonly strength and toughness) test results of undiluted, buttered, or diluted weld metal. The relevant electrode classification system also recognizes the fact that electrode manufacturers often produce one type of electrode that can be used to join a broad range of high-strength steels.

It is instructive to recognize that despite a strong attention to detail in reducing various risks inherent to welding electrodes while enhancing reliability of welded structures, welding electrode specifications do not offer an ability to distinguish the combined effects of critical elements in electrodes and weld metals. All the same, as shown by the effects of CEN and calculated transformation temperatures on weldability, microstructure development, and weld mechanical properties, such an ability is essential to achieving desirable combinations of high productivity and superior performance.

Current welding electrode specifications do not distinguish a high-performance welding electrode composition from either a rich or a lean welding electrode composition, although all of them meet electrode specification requirements. Compared to either a rich or a lean welding electrode composition, a high-performance welding electrode composition is flexible or "more forgiving" when it allows welding over a wide welding operational envelope while providing weld metals meeting minimum mechanical property requirements.

Current welding electrode specifications also do not highlight to a potential user various fabrication-related cost risks in selecting either a rich or a lean welding electrode composition that otherwise meets electrode specification requirements. Such limitations could adversely impact weld procedure qualification efforts, particularly in terms of meeting schedules and cost estimates.

Summary

Selection and use of GMAW/FCAW electrodes that eliminate a need for expensive preheat, interpass, and post-soak temperature controls during welding of high-strength steels, yet perform satisfactorily over a broad welding operational envelope, while providing weld metal with an overmatched tensile strength and acceptable toughness, offer exceptional value to both electrode manufacturers and weld fabricators.

To find such high-performance GMAW/FCAW electrodes, first, know the chemical composition, microstructure, and mechanical properties (strength and toughness) of the steel being welded. Know the actual carbon content, and calculate CEN. Based on microstructures of the high-strength steel, identify and calculate relevant transformation temperatures.

Second, know the minimum acceptable structural design requirements for strength and toughness.

Third, refer to AWS A5.28/A5.28M:205, *Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding,* and A5.29/A5.29M:205, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding,* and identify appropriate electrode classifications based on minimum acceptable requirements for transverse-weld tensile strength and toughness.

Fourth, obtain electrode manufacturers' data sheets for the relevant electrode classification. Identify an electrode that has 0.02 to 0.04 wt-% less carbon, is chemically compatible, and shows a desirable CEN and 30° to 50°C lower calculated transformation temperatures than the steel being welded.

Lastly, evaluate the candidate welding electrode using previously certified welding procedures, and determine that minimum acceptable requirements for weld metal strength and toughness can be consistently achieved.◆

Energy Saving Tips for Ducted Weld Fume Systems

Four weld fume system design improvements yield energy cost savings

BY ED RAVERT

The system's collection hood should be located as close as possible to the point of weld fume generation to reduce the volume of air required to collect the fume. Positioned directly over a process, this type of swing arm can be used in combination with a fume collector or stand alone.

The design and location of a weld fume dust collection system's hood, ducting, collector, and fan can collectively add sufficient static pressure requirements to the point where larger, more expensive to operate motors are necessary to maintain effectiveness. Optimizing these areas can make it possible to use smaller, more energy efficient brake horsepower motors. The electrical savings potential for a simple ducted weld fume dust control system is at least $1800 per year, and significantly more for larger systems.

System Design Improvement Areas

Hood Design/Location

Bell mouth-shaped hoods (Fig. 1), with an entry loss coefficient factor of 0.04, are ideal for energy savings. In comparison, plain, or raw edge collection orifices (Fig. 2), have a factor of 0.93. At a velocity of 2500 ft/min, the velocity pressure (VP) of the duct has a factor of 0.39. With a bell mouth hood, the water gauge static pressure (wgSP) is 0.41 in., or 1.00 + 0.04 × 0.39. The plain opening design requires 0.75 in. wgSP, or 1.00 + 0.93 × 0.39 for an increase of 0.34 in. wgSP.

Additionally, the collection hood should be located as close as possible to the point of weld fume generation to reduce the volume of air required to collect the fume. If the fume generated is 12 in. from the hood opening, a volume of 1000 ft^3/min might be required. But, if the hood opening is 24 in. away, the required ft^3/min volume increases as the square of the distance to 4000 ft^3/min.

Duct Design

The air velocity needed to carry collected weld fume is an important consideration. If the collected fume can be conveyed at 2500 ft/min (where VP = 0.39), it would be a mistake to convey them at 4000 ft/min (where VP = 1.0). At 2500 ft/min, the fume friction factor is 0.015 VP/ft of duct (0.015 VP × 100-ft = 1.5 VP × 0.39 = 0.23 in. SP). At 4000 ft/min, the fume friction factor is 0.019 VP/ft of duct (0.019 × 100-ft = 1.9 VP × 1.0 = 1.9 in. SP). The slower speed saves 1.67 in. of wgSP.

Ducting with a well-designed branch entry of 30 deg has a factor of 0.18, whereas a 45-deg branch entry has a 0.28 factor. At 2500 ft/min, VP = 0.39 (0.28 × 0.39 = 0.11 wgSP) for the 45-deg branch. In comparison, the 30-deg branch entry only requires 0.18 × 0.39 = 0.07 in. wgSP for a savings of 0.04 in. wgSP.

Duct elbows with a 1.5 diameter radius can have a factor of 0.24. A 2.0 duct elbow radius can have a factor of 0.19. Using the same factors as above, the 2.0 diameter radius will save 0.02 in. wgSP.

Added up, the total savings gained from well-designed ducting for a simple weld fume collection system is 1.67 + 0.04 + 0.02 for a total of 1.73 in. wgSP.

Dust Collector Operation

If the dust collector can operate with

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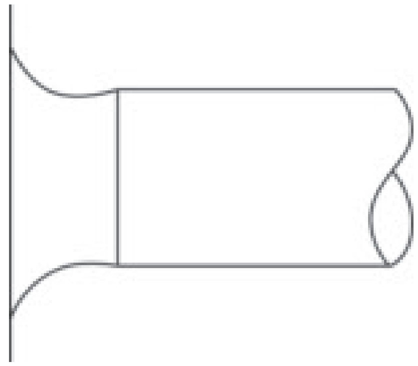

Fig. 1 — Bell mouth-shaped hood is good for energy savings.

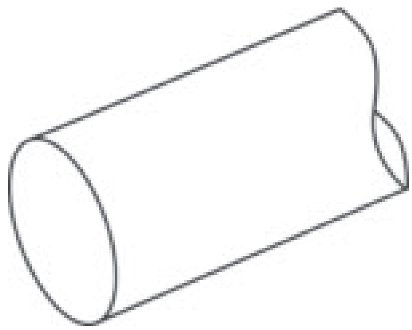

Fig. 2 — Plain or raw edge collection orifice.

nominally dirty filters at 4 in. wgSP, instead of the more common 5 in. wgSP, a savings of 1.0 in. wgSP can be achieved.

Additional savings can be obtained using a Photohelic® gauge to control the pulse-jet cleaning cycle in place of the traditional Magnehelic® gauge that keeps the compressed air on all of the time. Controlled cleaning with a Photohelic gauge not only saves compressed air and its associated energy costs, it also extends filter media life.

Fan Ducting

Bad things can happen if the ducting in and out of the fan is not properly designed and installed. Poor design is to install a two-diameter 90-deg radius duct elbow right at the fan inlet. This serves to add 1.0 in. VP. With inlet velocity at 4000 ft/min, 1.0 in. wgSP is added. Best design is to have 7 to 10 duct diameters of straight ducting into the fan inlet.

Potential Electrical Energy Savings

The extra-accumulated SP losses from poor design on a small ft^3/min system can add approximately 4.1 in. SP.

Specifically, if a small weld fume collection system has a system static pressure (SSP) of 9.0 in. wg, poor design can add an additional 4.07 in. SSP for a total of 13.07 in. wg. Assuming 2400 ft^3/min, the brake horsepower (BHP) requirement for the 9.0-in. wg system would be 5.40. At 13.07 in. SSP, 7.84 BHP would be required.

Assuming the use of motors having the same efficiency, operating 8760 hours per year, and electrical costs of $0.11 per kilowatt-hour, the annual operating cost of the larger 7.84 BHP motor would be $5881. In comparison, the annual operating cost for the smaller 5.40 BHP motor in a simple weld fume dust control system would be $4003 for an overall electrical energy cost savings of approximately $1800 per year. Note that the energy cost savings potential increases in direct proportion to the size and complexity of the weld fume dust collection system.

Consult an Expert

The annual amount of electrical energy cost savings to be gained will depend on individual weld fume dust collection situations and requirements. For this reason, it is recommended that an expert be consulted to evaluate dust collection system requirements and the design approaches that will make the most economic and energy savings sense.◆

Low-alloy, gas-shielded flux cored wire excels at pipe welding due to its all-position spray transfer capabilities. (Photo courtesy of Miller Electric Mfg. Co.)

Selecting and Caring for Flux Cored Wire

BY KEITH PACKARD

Proper selection and care of low-alloy, gas-shielded wire is crucial to making sound, long-lasting welds

On applications ranging from shipbuilding to outdoor light poles, earthmoving equipment to high-pressure steam piping, gas-shielded, low-alloy flux cored wire can offer a number of advantages over other low-alloy welding methods.

Typically, flux cored wire provides significant productivity increases over covered electrodes and can be more easily alloyed than solid wire while still retaining the required mechanical and chemical properties. Due to the manufacturing process, flux cored wires can also be made in much smaller batches than solid wire. Compared to metal cored and solid wires, which can only be welded out of position with short circuit transfer or with a pulse power supply, flux cored wires are available to weld in all positions using spray transfer, greatly increasing the potential deposition rates.

However, with dozens of AWS classi-

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electrode classification	electrode composition	tensile strength	all position or flat and horizontal	shielding gas	extra info
Molybdenum Weld Metal					
E81T1-A1C	.5% Molybdenum	80ksi	all position	CO_2 gas	stress relief applications
Chromium-Molybdenum Weld Metal					
E80T1-B2C	1 – 1.5% Chrome, .5% Moly	80ksi	flat and horizontal	CO_2 gas	chrome-moly weldments
E81T1-B2C	1 – 1.5% Chrome, .5% Moly	80ksi	all position	CO_2 gas	chrome-moly weldments
E90T1-B3C	2 – 2.5% Chrome, .5% Moly	90ksi	flat and horizontal	CO_2 gas	chrome-moly weldments
E91T1-B3C	2 – 2.5% Chrome, .5% Moly	90ksi	all position	CO_2 gas	chrome-moly weldments
E91T1-B3M	2 – 2.5% Chrome, .5% Moly	90ksi	all Position	Mixed Gas	chrome-moly weldments
Nickel Steel Weld Metal					
E80T1-Ni1C	1% Nickel	80ksi	flat and horizontal	CO_2 gas	lower temp toughness
E80T1-Ni1M	1% Nickel	80ksi	flat and horizontal	Mixed gas	lower temp toughness
E81T1-Ni1CJ	1% Nickel	80ksi	all position	CO_2 gas	additional lower temp toughness
E81T1-Ni1MJ	1% Nickel	80ksi	all position	Mixed gas	additional lower temp toughness
E81T1-Ni2C	2% Nickel	80ksi	all position	CO_2 gas	lower temp toughness
E81T1-Ni2M	2% Nickel	80ksi	all position	Mixed gas	lower temp toughness
E91T1-Ni2C	2% Nickel	90ksi	all position	CO_2 gas	lower temp toughness
Manganese-Molybdenum Steel Weld Metal					
E100T5-D2C	1 – 2% Manganese, .5% Moly	100ksi	flat and horizontal	CO_2 gas	higher strength steels
Manganese-Nickel-Molybdenum Steel Weld Metal					
E81T1-K2CJ	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	80ksi	all position	CO_2 gas	lower temp toughness
E81T1-K2MJ	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	80ksi	all position	Mixed gas	lower temp toughness
E90T1-K2C	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	90ksi	flat and horizontal	CO_2 gas	higher strength steels
E91T1-K2C	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	90ksi	all position	CO_2 gas	higher strength steels
E91T1-K2M	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	90ksi	all position	Mixed gas	higher strength steels
E90T5-K2C	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	90ksi	flat and horizontal	CO_2 gas	low temp toughness
E101T1-GM*	.75 – 2.25% Mn., .5 – 2.5% Ni., .01 - .25% Moly	100ksi	all position	Mixed gas	higher strength steels
E100T1-K3C	.75 – 2.25% Mn., .5 – 2.5% Ni., .25 - .65% Moly	100ksi	flat and horizontal	CO_2 gas	higher strength steels
E110T1-K3C	.75 – 2.25% Mn., .5 – 2.5% Ni., .25 - .65% Moly	110ksi	flat and horizontal	CO_2 gas	higher strength steels
E111T1-K3CJ	.75 – 2.25% Mn., .5 – 2.5% Ni., .25 - .65% Moly, .03% chrome	110ksi	all position	CO_2 gas	lower temp toughness
E111T1-K3MJ	.75 – 2.25% Mn., .5 – 2.5% Ni., .25 - .65% Moly, .03% chrome	110ksi	all position	Mixed gas	lower temp toughness
E110T5-K3C	.75 – 2.25% Mn., .5 – 2.5% Ni., .25 - .65% Moly	110ksi	flat and horizontal	CO_2 gas	lower temp toughness
E120T5-K4C	.75 – 2.25% Mn., .5 – 2.5% Ni., .25 - .65% Moly, .15 - .65% chrome	120ksi	flat and horizontal	CO_2 gas	higher strength steels
Weathering Steel Weld Metal					
E81T1-W2C	Addition of copper for weathering steels	80ksi	all position	CO_2 gas	weathering steels

Fig. 1 — Electrode classifications and properties for use with a variety of weld metals.

fications for low-alloy, gas-shielded flux cored wire, selecting the one that's right for your application might seem like a daunting task. Knowing the material you will be welding and the required mechanical and chemical properties for the weld will put you well on the way to selecting the right wire for the job. Plus, following a few simple care practices will ensure you get the best performance from your chosen wire.

Know Your Base Material

The most important factor in selecting a low-alloy, gas-shielded flux cored wire is knowing the base material to be welded. Depending on the application and the requirements of the finished weldment, the wire you select should be as similar in strength, chemical composition, and mechanical properties to the base material as possible. When welding two different strength base materials together, match the filler metal to the tensile strength of the weaker base metal.

Low-alloy filler metals typically fall into seven basic categories based on their alloying elements, with effective ranges for each alloying element as defined in AWS A5.29/A5.29M:2005, *Specification for Low-Alloy Steel Electrodes for Flux Cored Arc Welding*. These categories are as follows: molybdenum, chromium-molybdenum, nickel, manganese-molybdenum, manganese-nickel-molybdenum, weathering, and general.

Each of these alloying elements provides certain mechanical and chemical properties designed to match the base materials specific to certain industries and applications. Molybdenum, for example, is added to improve strength and creep resistance as well as to maintain its strength after stress relieving. Chromium is added for a variety of reasons, including corrosion resistance, creep resistance at elevated temperatures, and improved strength. Chromium-molybdenum steel provides the corrosion resistance and tensile strength required for petrochemical piping, high-pressure steam piping, steam boilers, and certain types of castings.

Other examples of low-alloy applications include 1–3% nickel-alloyed filler metals for offshore oil rigs, shipbuilding, and light pole construction. There are manganese-molybdenum filler metals for castings and applications that require extensive postweld heat treating and manganese-nickel-molybdenum metals for earthmoving equipment, mining equipment, and shipbuilding. Weathering steel is often used for bridges and buildings where the material is to be left exposed to the elements.

Even though wires are from the same AWS class per A5.29, the mechanical properties and chemistry can vary by manufacturer based on the amount of the alloying elements and other ingredients added to the wire. For example, all K3 flux cored wires have the same range of allowable manganese, nickel, and molybdenum, but they can vary widely in terms of tensile strength, impact toughness, weldability, and other factors depending on the manufacturer — Fig. 1.

Within the E10XT1-K3 class of wires, for example, the minimum AWS-defined CVN impact value is 20 ft-lb at –20°F. Depending on the manufacturer and the application the wire is designed for, the CVN values can vary from 20 to more than 50 ft-lb at –20°F. The different properties are achieved by varying the amount of the major alloying elements and other elements added to the flux.

Other Factors

Low-alloy flux cored wires are available in either all-position or flat and horizontal welding capabilities. The position capability can be determined by the AWS classification. For instance, if the classification is an EXX0T1-K3, the wire can be used in the flat and horizontal positions. If the classification is an EXX1T1-K3, the wire can be used in all positions — Fig. 1.

The recommended shielding gas can also be determined by the AWS classification. If the wire is classified as an EXX1T1-K3M, the wire should be used with argon/CO_2 shielding gas. If the wire is classified as an EXX1T1-K3C, the wire should be used with 100% CO_2 shielding gas. The wire can also be classified as an EXX1T1-K3M, EXX1T1-K3C, which means it can be used with either an argon/CO_2 mixture or 100% CO_2. As a general rule, using 100% CO_2 shielding gas with these wires will provide deeper penetration at the expense of arc quality and spatter. Using a 75% argon/25% CO_2 shielding gas mix with these wires will provide much better arc quality and reduced spatter, but with less penetration. Typically, using a mixed gas also produces a higher tensile strength weld, but reduces elongation and may effect lower CVN impact values compared to 100% CO_2. As with any product, always check the manufacturer's recommended shielding gas requirements.

Slag properties are another factor to consider when selecting a low-alloy, gas-shielded flux cored wire. Slag systems are classified as either basic or acidic. A basic slag, also known as a T-5, has better mechanical properties and strength than an acid slag, but the weldability is not as friendly. An acid slag, referred to as T-1, has very good weldability, such as less spatter and smoke and better arc stability, pool control, and bead appearance, but the mechanical properties are sometimes not as good as a T-5 slag.

Caring for Your Wire

The foremost rule in caring for all wires and electrodes, including low-alloy, gas-shielded flux cored wire, is to follow the manufacturers' recommendations. However, a few guidelines apply universally.

Moisture is the biggest concern in caring for almost all types of filler metals, with gas-shielded flux cored wires being no exception. To avoid potential problems, the wires should be kept in moisture-resistant packaging in an environment below 70% humidity and between 40° and 120°F. Reconditioning, or baking of the wire at a specific temperature for a period of time, is not recommended even if the product is exposed to excessive moisture. Exposing these and other wires to excessive moisture will typically void their warranty.

Low-alloy, gas-shielded flux cored wire is just one among many ways to weld low-alloy steel, but if you've decided that it is the best process for your application, selecting and properly caring for the wire is crucial to making sound, long-lasting welds. Following a few simple guidelines, starting with the base material and moving through the weld positions and desired mechanical properties, will ensure that you make the correct choice. Following the manufacturers' care requirements will ensure that your chosen wire performs at its peak when it comes time to weld.◆


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Design Considerations for Robotic Welding Cell Safety

BY RUSS WOOD

Advantages and disadvantages of various methods of reducing risk are examined

Robotic welding cells deliver remarkably high levels of quality and productivity at a substantially lower total cost of ownership than just a few years ago. Yet today's robots cannot function without human interaction so robots, people, and other machines need to be protected from one another. A safety strategy should be developed for every robotic welding cell, which involves risk assessment and risk reduction.

The usual approach is to provide fences around the cell and an entryway that enables operators to enter to load and unload parts, but keeps people out of harm's way when the cell is operating. Primary alternatives for safeguarding the cell include physical barriers, light curtains, safety mats, and laser scanners. This article will consider robotic welding cell safety in detail and consider the advantages and disadvantages of various risk reduction measures.

Robotic Work Cell Safety Concerns

Robotic welding cells present significant safety concerns. Robots lack the intelligence of a human operator, and in the event of a programming error or hardware malfunction, they have the potential to unexpectedly move large distances at a high rate of speed. The welding operation itself generates intense light flashes, smoke and fumes, and high electric currents. Protecting employees against these hazards is required to comply with regulations and to protect a company's most valuable asset, its employees. The same equipment that prevents injuries also provides an opportunity to make a positive impact on the bottom line. This is because the cost of a work-related injury goes far beyond hospital and medical costs. Additional costs that commonly result from an accident include rehabilitating and retaining the injured worker, time spent by supervision and management on the incident, machine downtime, and possible litigation.

Industry Standards

The primary regulations on robotic safety come from the Robotic Industries Association's ANSI/RIA 15.06-1999, *American National Standard for Industrial Robots and Robot Systems — Safety Standards*, and the RIA Technical Report RIA TR R15.106-2006. The purpose of these documents is to provide guidelines for industrial robot manufacture, remanufacture, and rebuild; robot system installation; and methods of safeguarding to enhance the safety of personnel associated with the use of industrial robots. ANSI/RIA 15.06-1999 provides substantial improvements over the previous 1992 standard, such as more detail on how to safeguard against specific hazards. Minimum performance standards are specified for safety circuit integrity including electronic, pneumatic, hydraulic, electrical, and mechanical components. For example, the new standard requires two separate stopping circuit functions for the robot, one for safety stops initiated by safeguarding devices and the other for emergency stops.

Developing a Safety Strategy

The standard directs companies that use robots to develop a safety strategy beginning with identifying the machine limits and functions that pose a potential hazard. The degree of risk due to the hazard is then estimated in order to provide a basis for judgment at later stages. The risk assessment should consider the severity of potential injury, frequency of exposure, and probability of injury. A risk evaluation is then performed to determine whether additional safety measures are needed to reduce the risk. Risk reduction is then performed and safety measures are selected based on the information derived from the risk assessment process. After the implementation of these measures, the risk assessment is repeated to determine whether the proper degree of safety has in fact been achieved.

Nearly every risk assessment will point to the potential for risk of injury when an operator is within the operating range of the robot during welding operations. Other possible hazards might include the potential for objects to be thrown from the cell and for light flashes from the welding operation. On the other hand, access is nearly always required to the robotic welding cell for functions such as loading and unloading workpieces and maintaining the welding equipment, robotic and other machinery in the cell. So a tradeoff is required. Protection is generally considered to be essential; however, ease of entry is often traded off against cost.

Best Approach to Safety

The best protection is the device or system that offers the maximum safety with the minimum impact on machine operations. A key factor to consider is how often entry is required. If the welding operation operates at a high rate of production, then operators will frequently need to enter the

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cell to load and unload parts. On the other hand, low production rate cells will usually require less frequent entry. The access area requires an entry method that will allow employees to enter the cell when it is safe to do so and keep people out when the cell is operating.

Fixed hard guards or fences are typically used to protect the majority of the robotic welding cell. Hard guards provide the maximum amount of protection, not only keeping people out but also protecting people outside the perimeter from flashes and flying objects. Of course, hard guards cannot normally be used for the entire perimeter because this would make it very difficult to access the robotic cell. Typically, a gap in the hard guarding is defined as an entry to the cell and a more flexible guarding solution is provided here to enable personnel to safely enter the cell.

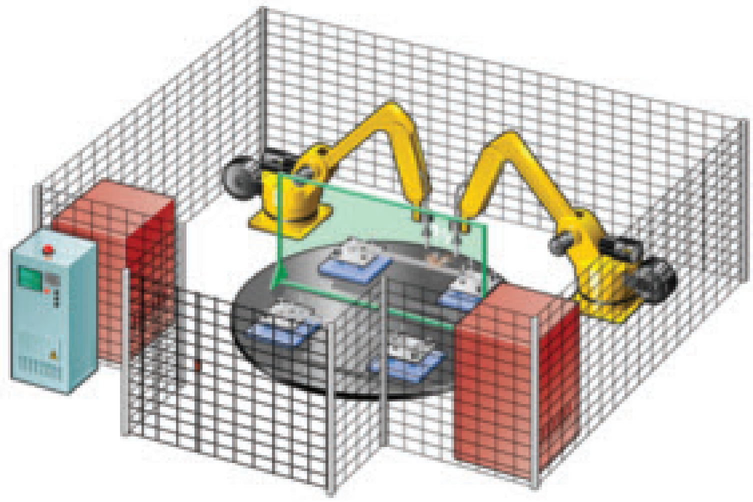

Fig. 1 — Interlocked gates turn power off when they are opened.

Entry Safeguards

Interlocking Gates

One approach to provide access is the use of movable guard doors (Fig. 1) with switches interlocked with the power supply in a manner that turns the power off whenever the guard door is open. The control of the robot and other dangerous machine power is routed through the safety contacts of the interlock switch. When guard door movement is detected, the interlock switch sends a stop signal to the guarded robot. Some interlock switches also incorporate a device that locks the guard door closed and will not release it until the robot is in a safe state.

When the interlocked guard is opened, its movement should be connected in the positive mode to the safety-related contacts of the switch. This ensures the contacts are physically pulled apart or "force disconnected" by the movement of the guard. This is superior to the alternative approach of relying upon spring pressure to open the contacts because spring pressure may not be able to overcome sticking or welding contacts and because the spring may break. Positive mode operation gives forced disconnection of the contacts.

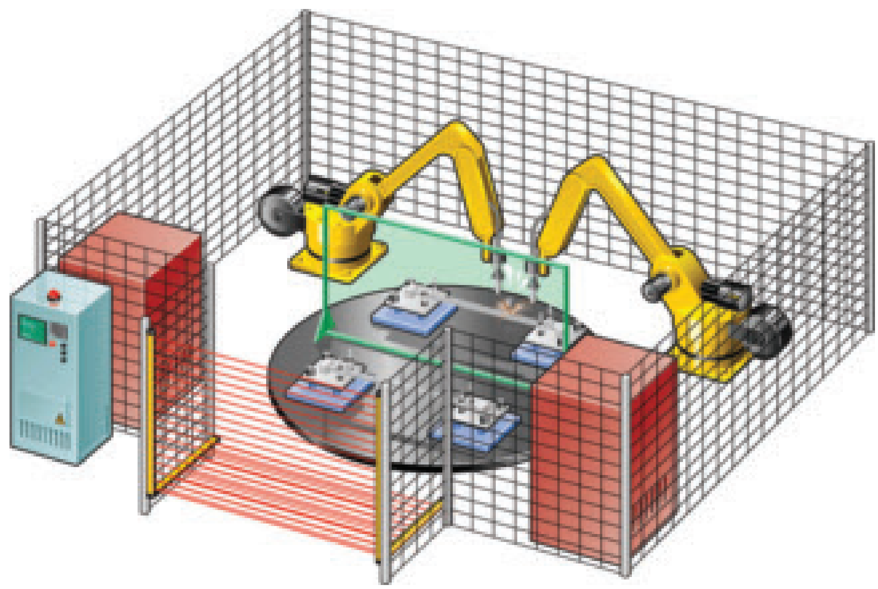

Fig. 2 — Horizontal or vertical mounted light curtains emit light beams across the entrance.

Advantages of Light Curtains

Light curtains are often used in conjunction with hard guards to protect people when the robot and other machinery is operating, while enabling easy access at other times. Light curtains control access to the robotic work cell by emitting harmless infrared light beams across the entrance — Fig. 2. When any of the beams are blocked, the light curtain control circuit sends a stop signal to the guarded machine. Light curtains are very versatile and can guard areas many meters wide — sometimes as large as 20 meters. Light curtains can be mounted either in a horizontal or vertical plane. In either case the beam should begin no more than 12 in. above the ground in order to prevent anyone from crawling under it.

Safety Mat Alternative

Pressure-sensitive safety mats (Fig. 3) provide another alternative for guarding the entrance to the weld cell, and in certain applications they can also be installed to protect the inside of the cell. A matrix of interconnected mats is laid around the entry area and an operator's footstep will cause the mat control unit to send a stop signal to the robot. Pressure-sensitive mats can be used both in the entry and inside the safe area. Trim is used to hold the mat in place, protect wiring, and provide a smooth ramped surface to prevent tripping over the mat. Caution should be used when selecting safety mats for use in heavy welding environments due to possible damage from sparks and heavy weld slag.

Newest Technology

A safety laser scanner (Fig. 4) is one of the newest technologies to be used for safeguarding robotic welding cells. The

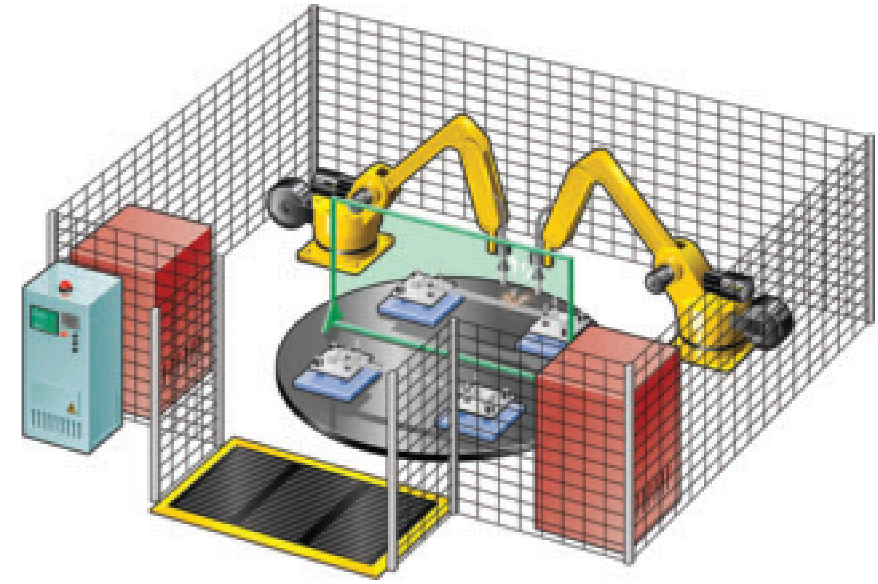

Fig. 3 — Safety mats detect footsteps to send a stop signal.

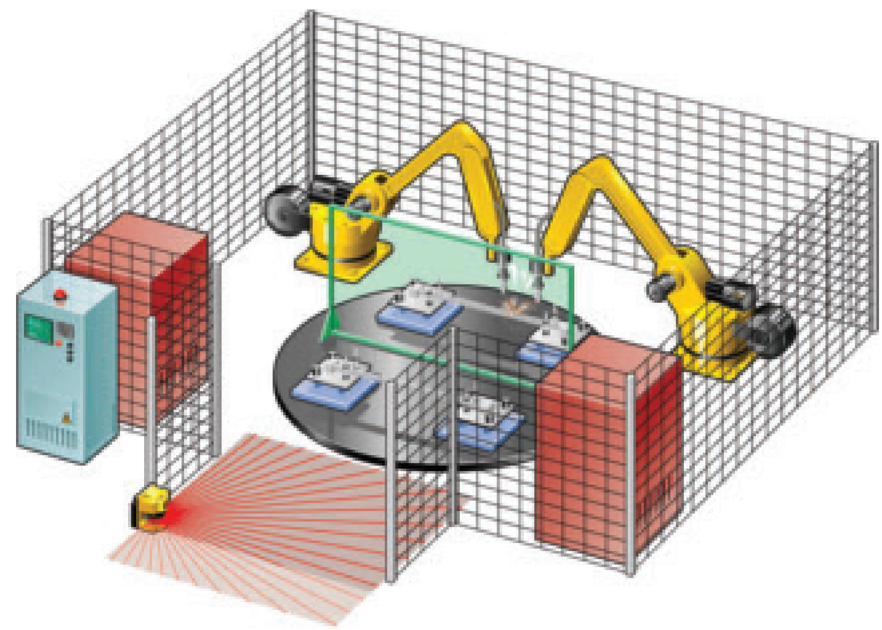

Fig. 4 — Laser scanner continually rotates to detect an instrusion into a specified area.

laser scanner can be configured to precisely specify the area that should be avoided. The hazardous area is defined as a safety zone, with a maximum defined safety area of 4 m. A warning zone as large as 15 m can be also defined to detect objects that are approaching the safety zone and can be used to initiate a warning signal before the safety zone is actually encroached. More than one guarded area can be configured.

The scanner emits a light pulse and the light hits the first object in its path and is reflected back. The scanner then compares the distance of the object against the known size of its safety zone. If the scanner detects an intrusion into the predefined zone, it sends a stop signal to the guarded machine.

Technology Comparison

Now let's compare and contrast these technologies and provide general rules for applying them to different robotic welding cell applications. The interlocked door stands apart from technologies discussed here in that it provides an actual physical barrier. A physical barrier may be required in certain applications such as where a serious risk exists of a robot hurling an object through the cell entryway. On the other hand, the interlocked door has the disadvantage that the door must be physically opened each time an operator enters the cell, and if the production rate of the cell is high, the need for frequent opening and closing of the door may have a substantial impact on the productivity of the cell.

Safety light curtains, safety mats, and safety laser scanners are all trip devices because they do not restrict access but only sense it. Working without physical barriers, they allow free access for loading and unloading parts, and cleaning. Trip devices will generally enable operators to service the machine faster but will not provide protection against objects that might accidentally come out of the cell nor will they protect against visual hazards. In cases where these risks are considered to be significant, they can often be substantially reduced by strategic positioning of the entry.

Be Careful

The greatest concern with interlock switches is the potential for an undetected failure that could leave the machine unguarded. This is because all mechanical devices are subject to failures and interlock switches are generally checked only when the switch is cycled, such as during scheduled maintenance. Light curtains, on the other hand, have no moving parts and continuously perform self-diagnostic routines that ensure that they are operating properly. If their safety functionality should ever stop operating, they will fail safely by sending a stop signal to the guarded machine. Laser scanners also provide diagnostics that will immediately sense a failure and issue a warning while sending a stop signal to the guarded cell.

A key difference between light curtains and laser scanners is that light curtains can detect an object as small as a finger moving into the hazard zone while safety laser scanners are normally designed to detect lower extremities such as feet and legs. Light curtains also provide faster response time than laser scanners so they can be mounted closer to the machine hazard, which saves floor space.

Minimum Safe Distance

Because an operator can walk or reach directly into the cell, it is important that the time required to stop the cell is less

Safety Is a Good Investment

According to a poll conducted by the Liberty Mutual Group, 61% of executives claim for every dollar spent on investments in workplace safety, three dollars are saved. OSHA's Office of Regulatory Affairs provides similar, although even more encouraging results, suggesting four to six dollars saved for every dollar invested. Furthermore, 95% of executives in Liberty Mutual's poll believe workplace safety has a positive impact on a company's financial performance.

The poll by Liberty Mutual also revealed that 40% of the executives reported that one dollar spent on direct accident costs generates from three to five dollars of indirect costs. So consider that an accident with direct medical and compensation payments of $15,000 will likely cost between $45,000 and $75,000 more in indirect cost. Now consider that indirect costs account for the majority of the accident expenses and are typically not covered by insurance.

than the time for the operator to trip the safeguard and reach a dangerous spot. Accurate determination of the safe mounting distance is important in maintaining safety and productivity. The goal is to keep the light curtain as close as possible to the hazard in order to avoid interfering with the operator's normal motion and conserve floor space while at the same time ensuring that the robot will stop before the operator's hand or other body part can reach a hazardous point. The American National Standard Institute provides the following formula for calculating the minimum safe distance:

$$D_s = K\,(T_s\,T_c + T_r + T_{spm}) + D_{pf}$$

where D_s is the minimum safe distance. K is the maximum speed at which an individual can approach the hazard in inches per second (a common value for K is 63 in./s). T_s is the total time in seconds for the hazardous motion to stop or for the hazardous portion of the cycle to be completed. T_c is the response time in seconds for the machine control circuit to activate the machine's brake. T_r is the response time in seconds of the safety system. T_{spm} is the additional time in seconds allowed by the stopping performance monitor before it detects stop time deterioration.

The stopping performance monitor will halt the machine when the stop time exceeds the set limit. If the machine does not have a stopping performance monitor, then a percentage increase factor should be added to the measured stop time (T_s–T_c) to allow for brake system wear. A typical value is 20%.

Conclusion

This article provides an overview of the major considerations involved in robotic work cell safety. There is no one best way to protect personnel from injury while operating a robotic welding cell. Inherent differences in robotic welding cells make it important to develop a safety strategy for each cell and select the optimal technologies to match that strategy.◆

Sorting out Certifications for Welding Consumables

Certificates for arc welding consumables come in many different types, and it pays to know the differences among them and which certifications you really need for each job

BY HARRY SADLER

As fabricators and product manufacturers are faced with ever-increasing demands for documentation that attests to the quality of their products, they in turn are requiring certificates from their suppliers to establish accountability or traceability. Because there are many different types of certifications, a company often requests a level of accountability that is higher than necessary, which can increase product cost. On the other hand, an inappropriate certificate may fall short of proving that a product has the desired attributes.

Why Certification?

Certification is often required for highly critical work such as aircraft, nuclear, or government contracts as well as a growing number of commercial projects. In other cases, certification also may be used to help establish a documented level of quality that can build customer confidence and loyalty, forestall competition, and minimize future problems. However, inappropriate certification can cause a business to lose customers because of either excessive costs or unmet expectations.

Appropriate certification plays a key role in an effective quality assurance program by attesting that a product or raw material meets the specified requirements. The type and level of certificate required is based in large measure on the critical nature of the item being manufactured and the need to prove it was built, tested, and inspected in accordance with recognized standards. For example, many civil engineering infrastructure projects require a high degree of accountability regarding materials and activities. These projects typically include those in the bridge and commercial building industry, especially those construction projects in targeted seismic zones.

Defense contracts are also prime projects where certification is most often required. Other related areas include the nuclear and shipbuilding fields. In addition to internal company requirements and industry standards, work for customers in these fields typically must meet the requirements of the Department of Defense or the Nuclear Regulatory Commission. It's easy to understand, for reasons of safety, security, and seaworthiness, that the requirements for a nuclear submarine are much more stringent than those typically called for to fabricate a scrap hopper.

The Value of Certificates

A certificate is simply a document testifying that an item meets specified requirements. Certification is the act of attesting to that truth. While there can be several different types of certificates, all contain certain basic elements. First is identification of the issuer, which is the company or organization that accepts responsibility for the information presented. This can be the manufacturer of the product or a reseller, if the reseller has a system that ensures the information from the manufacturer is being accurately conveyed to the purchaser.

In either case, a quality statement is needed. This statement designates the quality system used for verification, such as ISO 9001:2000 or ASME NCA 3800, and names the party verifying that the system is being followed. Third-party verification is done by numerous organizations including the American Society of Mechanical Engineers (ASME), American Bureau of Shipping (ABS), Det Norske Veritas (DNV), and the Department of Defense (DOD) for companies doing business with the DOD. The American Welding Society prepares and issues standards but does not perform third-party verification of quality systems.

The certificate must identify the product being certified. It may link the product to a

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Certification plays a key role in an effective quality assurance program by attesting the product meets the specified requirements. Consumables are manufactured at Lincoln Electric's Mentor, Ohio, plant where Doug Lance is superintendant.

The consistency and integrity of your welds relies in large part on the consistency and integrity of your welding consumables.

specific contract or order, although this is not always necessary. It must contain a clear and unequivocal statement of compliance such as "this material meets all requirements," rather than vague statements such as "should meet," or "to the best of our knowledge meets." The amount of supporting data and information included will depend on the type and level of certification.

A certificate usually will be signed by the responsible party at the issuing organization. Whether or not an actual signature is required depends on contractual requirements and specification requirements. Although military specifications still require traditional signatures, some codes now will accept electronic signatures. With any type of signature, it is important to know who takes responsibility for the accuracy and content of the certificate.

Certificates for Arc Welding Consumables

Certificates for arc welding consumables can come in many different types, starting with the basic certificate. It contains the basic elements of a certificate, including issuer, product, quality system, specification, statement of compliance, and signature. However, it does not include any supporting test data.

A typical certificate contains all the elements of a basic certificate with some added details on the specification and compliance. It lists the specification requirements and may also include test results or ranges of values. These values may not be related to a single specific test. Instead, the values are commonly an average of result values or a range of result values from a series of tests conducted over several years. In addition, they may include results from more than one welding electrode diameter.

A certificate of conformance goes beyond this to include specific test results from a sample product of the same design and manufacturing process as the product furnished. The test results are compared to the specification requirements. Sometimes details of the welding procedure are included but they are not required. If not stated, the welding procedure defaults to any procedures referenced in the governing specification, when that detail exists. Also included is a statement such as "tested in accordance with," that names the specification used. This is an all-or-nothing document, so a statement such as "meets with exception," actually means "does not conform." The certificate of conformance also includes the date when the testing was performed. Some authorities, such as the Federal Highway Administration, require testing on a periodic basis such as annually or tri-annually.

A certified material test report goes even further than a certificate of conformance. It includes test results from a representative sample of the lot or batch of product actually shipped. However, it is important to know how the sample was defined and how much material was represented by that sample. This information frequently comes from documents such as the AWS A5.01, *Filler Metal Procurement Guidelines, ASME Boiler & Pressure Vessel Code* Section III NB2400, or various military specifications for the lot size represented by the samples. Whether or not the sample is truly representative of the lot will depend on the manufacturer's quality system and resulting product consistency.

Certification does not necessarily require a document. For example, the American Welding Society standard A5.1, *Specification for Carbon Steel Electrodes for Shielded Metal Arc Welding,* allows for

At Lincoln Electric, every coil of incoming rod (typically 2500 to 4500 lb of raw steel wire) is tested twice for chemical composition before it is put into production.

To control chemical composition, optical emissions spectrometers are used to verify chemical composition for both the start and finish ends of all incoming steel coils, forming the basis of detailed manufacturing traceability and accountability.

certification by placing the AWS specification and classification on the package and imprinting the AWS classification on the electrode. In other cases, sources such as ASME, DOD, the Nuclear Regulatory Commission, or internal company quality requirements may call for additional documentation that includes a certificate. To simplify communication of the requirements, a standard such as AWS A5.01, *Filler Metal Procurement Guidelines,* is sometimes used.

Heat Number vs. Controlled Chemical Composition

There are several ways to define the parameters that control steel used in producing welding consumables. Lot definitions are contained in documents such as AWS A5.01, *Filler Metal Procurement Guidelines; ASME Boiler and Pressure Vessel Code,* Section III NB2400, and various military specifications. There are several definitions for lot size based on tonnage, time, or production schedule. Lot control by itself does not give traceability, but it does require control of the manufacturing process. All lot definitions address control of raw materials and lot size. For example, AWS A5.01 controls steel by either heat number or chemical composition.

Heat control requires that all the steel in a finished product lot be from a single heat. This assumes that all the steel in a given heat is of the same chemical composition and that a single chemical sample is representative of the entire heat, regardless of heat size. The problem with relying on heat certifications is that heat sizes at the mill can vary from a few thousand to more than 300,000 lb.

Typically, three test samples are averaged and reported as the ladle composition for the entire lot. However, during the continuous casting of steel, segregation of elements can occur in the ladle from bottom to top as the heat is being cast. The end of the heat may contain an accumulation of residuals and elements that are not indicative of the rest of the heat. Because the composition reported on a heat certification is generally an average of the start, middle, and end of the heat, there is a probability that the end of the heat may contain steel that does not meet agency or manufacturer requirements. Therefore, heat certifications alone offer no real assurance that the chemical composition of a welding electrode is within the desired specification.

Controlled chemical composition requires that the chemical composition of each coil of steel rod used in manufacturing a welding consumable be checked. Coil sizes produced at the mill can range from 1000 to 5000 lb. This thorough verification may include testing the composition of samples from the beginning and end of each incoming coil and matching its specific property with the qualities required to produce specific electrodes. Instead of three checks for a 300,000-lb heat, there will be at least 60 checks of chemical composition from the coils produced throughout the heat. This also allows any out-of-specification steel to be pulled from final product production before it is used, whether it resulted from variations within the mill heat or the occasional misidentification of material from the steel mill.

Common Misconceptions

There is a common misconception that a "mill test report" is the same as a certificate covering a welding filler metal. A mill test report is a chemical composition report from the mill that supplied the steel as a raw material. However, in almost all cases, welding filler metal specifications and certificates are based on finished consumable products, not raw material requirements. These filler metal specifications cover a variety of product attributes. In addition to their steel content, finished product performance and weld metal properties are highly dependent on such things as core materials for flux cored (FCAW) wire electrodes and flux coverings applied for shielding on manual electrodes (SMAW). Even in something as straightforward as the steel wire used for gas metal arc welding, the chemical composition of the finished product may differ from that of the steel because of copper plating.

Another common misconception is that a certificate automatically gives traceability, although certificates routinely provide only accountability. The issuing organization and the authorized representative signing the certificate are fully accountable for the contents of the certificate, the quality system behind the certificate, the product being certified, and any documentation that supports the certificate. This does not necessarily imply traceability.

There are various levels and definitions of traceability. The need for traceability depends on the type of work being performed, governing codes, contractual requirements, and any third-party regulations. Accountability is required for most welding applications, but most commercial and code welding does not require

Certified electrode is an assurance of controlled chemical composition, adequate manufacturing standards, and reliable, consistent welding performance.

traceability. The requirement for traceability frequently comes from third parties such as the Nuclear Regulatory Commission, or contractual requirements such as the U.S. Navy's Subsafe Program.

Certification Simplified

In an effort to simplify the process of certification, one filler metal manufacturer has introduced a program designated the Q Cert Program. The new program has three levels of certification. All levels start with lot control and include actual finished product testing as part of the program. The three levels are as follows:

Q-1 Certification. This includes lot control in accordance with AWS A5.01 and certificates of conformance for filler metals. At this level, the manufacturing processes are driven by lot control, and representative samples of finished product are tested periodically to verify compliance with recognized national standards such as the AWS A5 standards and *ASME Boiler and Pressure Vessel Code,* Section II, Part C. Be aware that testing is not necessarily completed on the specific material in a particular customer shipment.

Q-2 Certification. Begins with lot control but also includes traceability through manufacturing and testing as well as testing of lot-specific samples to a national standard. Records are archived for at least ten years.

Q-3 Certification. This certification is for the most demanding applications such as nuclear and military. At this level, certification includes lot control and traceability directly to a specific customer order and shipment. Testing of lot samples is customer specific. Testing can be to a national standard or to unique customer requirements such as chemical composition limits, specific postweld heat treatments, and specific mechanical property requirements. All records are archived for at least ten years, or in accordance with customer requirements.

Relating these levels to existing certification requirements, Q-1 certificates meet the requirements of a certificate of conformance. Q-2 and Q-3 certificates are intended for applications requiring certified material test reports, and a Q-3 certificate is supported by traceability down to a specific customer, order, and shipment.

While it is safe to say that the nature of certification and its many varying requirements can never be simplified completely, programs such as this are a step in the right direction toward bringing certification requirements more closely in line with the actual needs of users. If the industry will adopt an approach such as the Q-Cert Program, it can expect to reduce the waste of overcompliance while ensuring that certification actually confirms the characteristics that the application requires.♦

Conference on the Explosion of New Processes
San Diego • Doubletree Golf Resort
August 14-15, 2007

The welding industry is now in the midst of an explosion of new welding technologies, many of which have made quick passage from the research lab to the production line. This kind of activity has not been seen for decades. Presentations on many of these technologies will form the body of this first-of-its-kind conference. Two of the main thrusts will explore interesting variations and improvements on laser technologies and on friction stir welding.

Friction Stir Welding and Processing—An Update of Recent Developments
William J. Arbegast, Director, NSAF Center for Friction Stir Processing, and Director, Advanced Materials Processing and Joining Center, South Dakota School of Mines and Technology

The Deformation Resistance Welding Process
Menachem Kimchi, Technology Leader, Edison Welding Institute

A New Approach (Double Electrode) to High Productivity GMAW
Dr. YuMing Zhang, James R. Boyd Professor, Director of Graduate Studies, Center for Manufacturing, Department of Electrical and Computer Engineering, College of Engineering, University of Kentucky

Magnetic Pulse Welding Extends Its List of Applications
Erik de Jongh, Vice President, Sales and Field Operations, Pulsar Ltd.

The Fiber Laser Opens Up New Opportunities for Laser Welding
Bill Shiner, Director, Industrial Market Development, IPG Photonics Corp.

Ultrasonic Joining of Metals: Advances in Welding, Soldering and Brazing
Matt Short, Project Engineer, Edison Welding Institute

Friction Stir Welding and Processing of Advanced Materials—Advances and Challenges
Dr. S. A. David, Corporate Fellow and Group Leader, Materials Joining Group, Oak Ridge National Laboratory

Friction Stir Welded Components Are Headed to Mars
Mike Skinner, Business Development Manager, MTS Systems Corp.

Single-Sided Plasma Spot Welding and Plasma Brazing Process—A Review of Applications
R. V. Hughes, Technical Director, Camarc LLC

Laser Stir Welding of Aluminum Alloys
R. P. Martukanitz, Head, Laser Processing Division, Applied Research Laboratory, Pennsylvania State University; and Israel Stol, Senior Manufacturing Specialist, Joining and Assembly, Alcoa Technical Center

Novel Heat Source Enables Brazing at Room Temperature
Dr. Timothy P. Weihs, President, Reactive NanoTechnologies Inc.

CSC-Controlled Short Circuit Transfer—A New GMAW Process That Solves Old Weld Problems
Tom Rankin, Vice President and General Manager, ITW Jetline Engineering

A New Process (Ultrasonic Impact Treatment) for Improving Fatigue Strength of Welds
Sougata Roy, Research Scientist III, ATLSS Center, Lehigh University

Conference price is $550 for AWS members, $680 for nonmembers.To register or to receive a descriptive brochure, call (800) 443-9353 ext. 224, (outside North America, call 305-443-9353), or visit www.aws.org/conferences

Explosion of New Processes
San Diego, California
August 14, 15

There was a time years ago when new welding processes were being introduced in fairly rapid succession. Industry then went into a long stretch during which hardly anything new was being introduced. The tide has since turned. We are now entering into another period of new welding technology. Some of the new processes include higher-powered ultrasonic welding, the various types of friction stir welding, the fiber laser, additive manufacture, hybrid welding, laser stir welding, and gas metal "buried" arc welding. These processes will bring new life to the industry.

Weld Cracking VI
Las Vegas, Nevada
October 16, 17

The popular Weld Cracking Conference continues to attact large audiences wherever it is held. In this conference, leading experts will describe the various problems that trigger cracking in weldments and also the steps that can be taken to prevent the problems from occurring in the first place. This conference is not just confined to steels. Attention will also be paid to the stainless steels, aluminum, and titanium. There will be a great amount of useful information for everybody.

5th Charting the Course in Welding U.S. Shipyards Conference
Newport News, Virginia
October 18, 19

Welding is the most vital and fundamental manufacturing process in the construction of ships and metal hull boats. Given welding's critical importance, the Shipbuilding Conference endeavors to provide up-to-date information on new and emerging technologies being developed for shipbuilding applications. The conference serves as a forum for communicating the focus and progress of these new, innovative developments, as well as their potential value and impact to the shipbuilding community.

Friction Stir Welding Conference
Chicago, Illinois
FABTECH International & AWS Welding Show
November 12

The big three of friction welding — conventional friction welding, linear friction welding, and friction stir welding — will all be included in a full-day conference on Monday, November 12, at the FABTECH International & AWS Welding Show in Chicago. Among the presentations will be talks on such topics as direct drive vs. inertia friction welding, the friction welding of automotive pistons, the linear friction welding of blades onto discs in aircraft engines, the marriage of robotics and friction stir welding, and the ability of any process within this family to weld just about any metal or alloy or even plastic. Also, experts will be on hand to discuss the ability to use any of these processes to weld dissimilar metals on the fly.

Hot Wire Welding and Cladding Conference
Chicago, Illinois
FABTECH International & AWS Welding Show
November 13

There is a great deal of interest lately regarding hot wire welding and cladding. Although invented many years ago, this technology never really saw the light of day until recently. One version or other is already being used by participants in the oil and gas industry, by the U.S. Navy, and by builders of aircraft engines. Hot wire welding and cladding will be the subjects of a one-day conference at the FABTECH International & AWS Welding Show in Chicago. Presentations on both the hot wire GTA and plasma processes will be on the agenda. One topic that will be addressed will be the popular use of hot wire GTA cladding of tube and piping for the offshore oil and gas industries. In another, hot wire GTA "narrow groove" welding will be shown to perform well on titanium. The overall advantages are increased deposition rates and faster travel speeds.

For more information, please contact the AWS Conferences and Seminars Business Unit at (800) 443-9353, ext. 223. You can also visit the Conference Department at *www.aws.org* for upcoming conferences and registration information.

Do You Have Some News to Tell Us?

If you have a news item that might interest the readers of the *Welding Journal*, send it to the following address:
Welding Journal Dept.
Attn: Mary Ruth Johnsen
550 NW LeJeune Rd.
Miami, FL 33126.
Items can also be sent via FAX to (305) 443-7404 or by e-mail to *mjohnsen@aws.org*.

Developing GMA Procedures for Welding Thin Titanium Structures to Meet NAVSEA Requirements

A Navy ManTech project has been initiated to develop gas metal arc welding (GMAW) procedures that are appropriate for thin titanium structures and to demonstrate their ability to meet Naval Sea Systems Command (NAVSEA) requirements for Navy ship structures.

This Navy ManTech project, led by the Navy Joining Center (NJC) and Edison Welding Institute (EWI) in collaboration with a Navy shipbuilder, developed efficient and cost-effective GMAW procedures for the fabrication of thin titanium structures. These procedures will allow U.S. Navy shipyards to weld thin titanium structures with maximum quality and productivity while minimizing the cost for any Navy vessel that incorporates titanium sheet metal in its design.

Titanium offers a number of advantages as a lightweight metal for Navy ship structures and components, including good strength-to-weight ratio, high-temperature strength, and corrosion resistance.

The benefits to the Navy include reduced ship weight, extended service life, and reduced maintenance costs. The end result is reduced total life-cycle costs. Currently, the use of titanium on Navy ships is limited to piping and component parts. The LPD-17 program is taking advantage of the benefits of commercially pure titanium for seawater piping systems.

Titanium is also being considered by system designers for a number of applications for future ship platforms. NAVSEA and the *Littoral* Combat Ship (LCS) program are interested in using titanium for large sheet metal structures — Fig. 1. Welding large, thin titanium structures poses many technical and logistical challenges for the shipbuilder.

Fig. 1— The Littoral *Combat Ship (LCS) is shown here in an artist's rendition.*

Presently, gas tungsten arc welding (GTAW) is the only NAVSEA-approved process for U.S. Navy shipbuilders to weld titanium. Gas tungsten arc welding provides very high quality welds and lends itself to the protective gas shielding necessary for titanium. However, the productivity of GTAW is low and therefore costly in comparison to more commonly used shipbuilding welding processes such as GMAW. The high heat input required by GTAW also results in significant welding-induced distortion, requiring additional labor to correct distorted components.

Navy shipbuilders are concerned about their ability to cost-effectively fabricate large, sheet metal titanium structures for future Navy vessels. The primary concern is the large number of production labor hours necessary to fabricate large sheet metal structures using current manual GTAW procedures for the current designs of stainless steel alloy components that are produced with the GMAW process. Gas metal arc welding is the preferred process to fabricate these sheet-metal structures for several reasons: GMAW is much more productive, requires less operator skill, and results in less distortion in comparison to manual GTAW processing. Unfortunately, GMAW of titanium has not been approved for use in the U.S. Navy shipbuilding industry.

Working closely with Navy shipbuilder Bath Iron Works (BIW), the NJC developed GMAW procedures, shielding methods, and established procedures to meet NAVSEA requirements via mechanical testing. The process procedures were recently demonstrated at EWI for representatives from NAVSEA, Naval Surface Warfare Center — Carderock Division, and BIW. Bath Iron Works is currently in the process of developing detailed cost estimations for GTAW vs. GMAW fabrication, and is preparing a fabrication document for NAVSEA approval.

For more information on this project, contact Nancy Porter, *nporter@ewi.org;* (614) 688-5194. ♦

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

Gas Metal Arc Welding Electrodes

The consumables in gas metal arc welding (GMAW) consist of electrodes and shielding gases. The chemical compositions of the electrode, the base metal, and the shielding gas determine the chemical composition of the weld metal. This composition largely determines the metallurgical and mechanical properties of the weldment. The following are factors that influence the selection of the shielding gas and the welding electrode:

1. Base metal type
2. Required weld metal mechanical properties
3. Base metal condition and cleanliness
4. Type of service or applicable specification requirement
5. Welding position
6. Intended mode of metal transfer.

Electrodes

The electrodes (filler metals) for GMAW are specified by various American Welding Society filler metal specifications (Table 1). In addition, other standards-writing societies publish filler metal specifications for specific applications. The AWS specifications define requirements for sizes and tolerances, packaging, chemical composition, and in some cases, mechanical properties. AWS also publishes *Filler Metal Comparison Charts*, which lists trade names for each of the filler metal classifications.

Electrode Selection

In the engineering of weldments, the objective is to select filler metals that produce a weld deposit with the following basic characteristics:

1. A deposit that either closely matches the mechanical and physical properties of the base metal or provides some enhancement to the base material such as corrosion or wear resistance.

2. A sound weld deposit that is free from unacceptable discontinuities.

In the first case, the weld deposit — even one with a composition nearly identical to that of the base metal — will possess uniqe metallurgical characteristics. These are dependent on factors such as the energy input and weld bead configuration. The second characteristic is generally achieved through use of a formulated filler metal electrode; for example, one containing deoxidizers that produce a relatively discontinuity-free deposit.

Compatibility

The electrode must meet certain demands of the process relative to arc stability, metal transfer behavior, and solidification characteristics. The electrode must also provide a weld deposit compatible with one or more of the following base metal characteristics.

- Chemistry
- Strength
- Ductility
- Toughness

- Other properties dictated by specific service conditions or environments.

Excerpted from the *Welding Handbook,* Vol. 2, ninth edition.

Table 1 — Specifications for Various GMAW Electrodes

Base Material	AWS Specification[(a)]
Carbon steel	*Specification for Carbon Steel Electrodes and Rods for Gas Shielded Arc Welding*, AWS A5.18/A5.18M:2005
Low-alloy steel	*Specification for Low-Alloy Steel Electrodes and Rods for Gas Shielded Arc Welding*, AWS A5.28/A5.28M:2005
Aluminum alloys	*Specification for Bare Aluminum and Aluminum-Alloy Welding Electrodes and Rods,* AWS A5.10/A5.10M:1999
Copper alloys	*Specification for Copper and Copper Alloy Bare Welding Rods and Electrodes,* AWS A5.7/A5.7M:2007
Magnesium	*Specification for Magnesium Alloy Welding Electrodes and Rods, ANSI*/ AWS A5.19-92(R2006)
Nickel alloys	*Specification for Nickel and Nickel-Alloy Bare Welding Electrodes and Rods,* AWS A5.14/A5.14M:2005
300-Series stainless steel	*Specification for Bare Stainless Steel Welding Electrodes and Rods,* AWS A5.9/A5.9M:2006
400-Series stainless steel	*Specification for Bare Stainless Steel Welding Electrodes and Rods,* AWS A5.9/A5.9M:2006
Titanium	*Specification for Titanium and Titanium Alloy Welding Electrodes and Rods,* AWS A5.16/A5.16M:2004

(a) It is to be understood that the latest edition of the document referred to applies. The reader is encouraged to consult the most recent edition.

Consideration should also be given to properties such as corrosion, heat-treatment response, wear resistance, and color response. These must all be secondary, however, to the metallurgical compatibility of the base metal and filler metal.

Electrode Type

Both solid and tubular wire electrodes are used with gas metal arc welding. Tubular wires have a powdered metallic core that includes small amounts of arc-stabilizing compounds and the appropriate alloying elements. These wires have good arc stability and deposition efficiencies similar to those offered by solid wire. Their deposition rates can exceed those of solid wire of the same size. The tubular approach permits the manufacture of high-efficiency metallic electrodes in compositions that would be difficult and costly to manufacture as a solid wire.

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

India Machine Tools Show 2007. July 24–27, Pragati Maidan, New Delhi, India. Visit *www.engimach.com.*

♦**Explosion of New Processes Conf.** Aug. 14, 15, San Diego, Calif. To include higher-powered ultrasonic welding, laser and various types of friction stir welding, fiber laser, additive manufacture, hybrid welding, and GMA "buried" arc welding. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

SES Annual Conf. — Standards: The Bridge to Global Markets. Aug. 20, 21, Hyatt at Fisherman's Wharf, San Francisco, Calif. E-mail H. Glenn Ziegenfuss at *hgziggy@worldnet.att.net,* or visit *www.ses-standards.org.*

Metalriciclo 2007: Second Run; Int'l Exhibition on Technologies for the Recovery and Recycling of Ferrous and Nonferrous Metals. Sept. 13–15, Garda Exhibition Center, Montichiari, Brescia, Italy. Visit *www.metalriciclo.com/ENG/home.asp.*

EMO Hannover — World of Machine Tools and Metalworking. Sept. 17–22, Hannover Fairgrounds, Hannover, Germany. Visit *www.hf-usa.com/emo.*

24th Annual ASM Int'l Heat Treating Society Conf. and Expo. Sept. 17–19, Cobo Hall, Detroit, Mich. Visit *www.asminternational.org/heattreat.*

***Marine Log* Global Greenship Conf. & Expo.** Sept. 20, 21, Washington Marriott, Washington, D.C. Will focus on cost-effective solutions for meeting pollution-prevention regulations. Visit *www.marinelog.com.*

Die Mold Expo. Sept. 25–27, Tech Center, Auburn Hills, Mich. Contact (800) 552-3288; *www.makino.com.*

METALFORM Mexico. Sept. 25–27, Cintermex, Monterrey, Mexico. Contact Precision Metalforming Assn., *www.pma.org;* (216) 901-8800.

National Robot Safety Conf. XIX. Oct. 1–4, Marriott Center East, Indianapolis, Ind. Contact Robotic Industries Assn., *www.roboticsonline.com/public/calendar/details.cfm?id=95.*

SOUTH-TEC and SME Motorsports. Oct. 2–4, Charlotte Convention Center, Charlotte, N.C. Cosponsored by Society of Mfg. Engineers, Assn. for Mfg. Technology, and American Machine Tool Distributors' Assn. Visit *www.amtda.org.*

National Maritime Salvage Conf. & Expo. Oct. 9–11, Hyatt Regency Crystal City, Arlington, Va. Sponsored by American Salvage Assn. and *Marine Log* magazine. Visit *www.marinelog.com.*

ASME India Oil and Gas Pipeline Conf. Oct. 15–18, Le Meridien, New Delhi, India. Contact: American Society of Mechanical Engineers. Visit *www.asmeconferences.org/PipelineIndia07.*

3rd Annual Careers in Construction Week. Oct. 15–19, Gainesville, Fla. Contact: National Center for Construction, Education, and Research, *www.nccer.org.*

Southeast Asia Wire and Tube Trade Fairs. Oct. 16–18, Bangkok, Thailand. Contact: Messe Düsseldorf North America, *info@mdna.com; www.mdna.com.*

♦Weld Cracking VI Conf. Oct. 16, 17, Imperial Palace Hotel, Las Vegas, Nev. To include conditions that trigger cracking in weldments and steps to prevent cracking in steel, stainless steels, aluminum, and titanium. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

ICALEO® 2007 Conf. Oct. 29–Nov. 1, Hilton Hotel, Walt Disney World Resort, Orlando, Fla. Contact: Laser Institute of America, Conference Dept., *conferences@laserinstitute.org*.

Kiev Technical Trade Show 2007. Oct. 31–Nov. 2, National Complex Expocenter of Ukraine, Kiev, Ukraine. Contact *www.weld-expo.com.ua.*

Safety Management Academy. Nov. 3–9, Clemson University, Clemson, S.C. Hosted by National Center for Construction Education and Research. Contact *www.nccer.org;* (888) 622-3720.

16th Steelmaking Conf. and 6th Ironmaking Conf. Nov. 6–8, Metropolitano Convention Center, Rosario, Argentina. *www.siderurgia.org.ar.*

♦FABTECH International & AWS Welding Show. Nov. 11–14, McCormick Place, Chicago, Ill. This show is the largest event in North America dedicated to showcasing a full spectrum of metal forming, fabricating, tube and pipe, and welding equipment and technology. Contact: American Welding Society, (800/305) 443-9353, ext. 462; *www.aws.org.*

♦Friction Welding. Nov. 12, 13, Chicago, Ill., during the FABTECH Int'l and AWS Welding Show. Will include numerous short presentations on linear friction, friction stir, and conventional friction welding. Contact: AWS Conferences and Seminars Business Unit, (800) 443-9353, ext. 223; *www.aws.org/conferences.*

PACE 2008, The Power of Paint + Coatings. Jan. 27–30, Los Angeles Convention Center, Los Angeles, Calif. Visit *www.PACE2008.com.*

PICALO 2008. April 16–18, Capital Hotel, Beijing, China. Third Pacific Int'l Conf. on Applications of Lasers and Optics. For information, visit *www.laserinstitute.org/conferences.*

Educational Opportunities

ASME Section IX Seminars. Oct. 23–25, Houston, Tex.; Dec. 3–5, Atlanta, Ga.; April 8–10, 2008, Las Vegas, Nev. Contact: ASME Continuing Education Institute, (800) 843-2763; *www.asme.org/education.*

Automotive Body in White Training for Skilled Trades and Engineers. Orion, Mich. A 5-day course covers operations, troubleshooting, error recovery programs, and safety procedures for automotive lines and integrated cells. Contact: Applied Mfg. Technologies, Inc., (248) 409-2000; *www.appliedmfg.com.*

Boiler and Pressure Vessel Inspectors Training Courses and Seminars. Columbus, Ohio. Contact: Richard McGuire, (614) 888-8320; *rmcguire@nationalboard.org*; *www.nationalboard.org*.

Certified Laser Safety Officer® Exams. Sept. 21, San Francisco, Calif.; Nov. 2, Orlando, Fla. Contact: Board of Laser Safety®, *www.lasersafety.org.*

Continuing Education for Welding Inspectors and CWIs. July 17–20, Sept. 25–28, Dec. 11–14. Chicago, Ill. Atema, Inc. Contact (312) 861-3000; *atemasolutions.com.*

CWI/CWE Course and Exam. This 10-day program prepares students for the AWS CWI/CWE exam. Contact: Hobart Institute of Welding Technology, (800) 332-9448; *www.welding.org*.

CWI Preparation. Courses on ultrasonic, eddy current, radiography, dye penetrant, magnetic particle, and visual at Levels 1–3. Meet SNT-TC-1A and NAS-410 requirements. Contact: T.E.S.T. NDT, Inc., (714) 255-1500; *ndtguru@aol.com*; *www.testndt.com.*

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

Environmental Health and Safety-Related Web Seminars. These 30-min-long Web seminars on various topics are online, real-time events conducted by industry experts. Most seminars are free. Visit *www.augustmack.com/Web%20Seminars.htm.*

EPRI NDE Training Seminars. EPRI offers NDE technical skills training in visual examination, ultrasonic examination, ASME Section XI, and UT operator training. Contact: Sherryl Stogner, (704) 547-6174; *sstogner@epri.com*.

AWS Certification Schedule

Certification Seminars, Code Clinics and Examinations

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

Certified Welding Inspector (CWI)

Location	Seminar Date	Exam Date
Miami, FL	EXAM ONLY	Jul. 12
Orlando, FL	Jul. 8-13	Jul. 14
Spokane, WA	EXAM ONLY	Jul. 14
Bakersfield, CA	Jul. 15-20	Jul. 21
Louisville, KY	Jul. 15-20	Jul. 21
Beaumont, TX	Jul. 22-27	Jul. 28
Milwaukee, WI	Jul. 22-27	Jul. 28
Denver, CO	Jul. 29-Aug. 3	Aug. 4
San Antonio, TX	Aug. 5-10	Aug. 11
Pittsburgh, PA	Aug. 5-10	Aug. 11
Columbus, OH*	Aug. 6-10	Aug. 11
San Diego, CA	Aug. 12-17	Aug. 18
Miami, FL	Aug. 12-17	Aug. 18
Rochester, NY	EXAM ONLY	Aug. 18
Charlotte, NC	Aug. 19-24	Aug. 25
Portland, ME	Aug. 19-24	Aug. 25
Corpus Christi, TX	EXAM ONLY	Sep. 1
Miami, FL	EXAM ONLY	Sep. 20
Anchorage, AK	EXAM ONLY	Sep. 22
Salt Lake City, UT	Sep. 23-28	Sep. 29
Philadelphia, PA	Sep. 23-28	Sep. 29
Tulsa, OK	EXAM ONLY	Sep. 29
Seattle, WA	Sep. 30-Oct. 5	Oct. 6
Minneapolis, MN	Sep. 30-Oct. 5	Oct. 6
St. Louis, MO	Oct. 14-19	Oct. 20
Miami, FL	Oct. 14-19	Oct. 20
Baton Rouge, LA	Oct. 21-26	Oct. 27
Long Beach, CA	Oct. 21-26	Oct. 27
Newark, NJ	Oct. 28-Nov. 2	Nov. 3
Roanoke, VA	Oct. 28-Nov. 2	Nov. 3
Corpus Christi, TX	EXAM ONLY	Nov. 3
Nashville, TN	Nov. 25-30	Dec. 1
Dallas, TX	Nov. 25-30	Dec. 1
Portland, OR	Dec. 2-7	Dec. 8
Columbus, OH*	Dec. 3-7	Dec. 8
Sacramento, CA	Dec. 9-14	Dec. 15
Miami, FL	Dec. 9-14	Dec. 15
Syracuse, NY	Dec. 9-14	Dec. 15
Reno, NV	Dec. 16-21	Dec. 22
Houston, TX	Dec. 16-21	Dec. 22

* Mail seminar registration and fees for Columbus seminars only to National Board of Boiler & Pressure Vessel Inspectors, 1055 Crupper Ave., Columbus, OH 43229-1183. Phone (614) 888-8320. Exam application and fees should be mailed to AWS.

For information on any of our seminars and certification programs, visit our website at **www.aws.org/certification** or contact AWS at (800/305) 443-9353, Ext. 273 for Certification and Ext. 224 for Seminars.

Please **apply early** to save Fast Track fees. **This schedule is subject to change without notice.** Please verify the dates with the Certification Dept. and confirm your course status before making final travel plans.

9-Year Recertification for CWI and SCWI

Location	Seminar Dates	Exam Date
San Diego, CA	Aug. 13-18	NO EXAM**
Dallas, TX	Oct. 29-Nov. 3	NO EXAM**
Orlando, FL	Dec. 3-8	NO EXAM**

**For current CWIs needing to meet education requirements without taking the exam. If needed, recertification exam can be taken at any site listed under Certified Welding Inspector.

Certified Welding Supervisor (CWS)

Location	Seminar Dates	Exam Date
Atlanta, GA	Jul. 23-27	Jul. 28
Seattle, WA	Aug. 13-17	Aug. 18
Atlanta, GA	Sept. 24-28	Sept. 29
Tulsa, OK	Oct. 15-19	Oct. 20
Atlanta, GA	Nov. 12-16	Nov. 17
Long Beach, CA	Nov. 26-30	Dec. 1

CWS exams are also given at all CWI exam sites.

Certified Radiographic Interpreter (RI)

Location	Seminar Dates	Exam Date
Manchester, NH	Jul. 23-27	Jul. 28
St. Louis, MO	Sept. 24-28	Sept. 29
Philadelphia, PA	Oct. 22-26	Oct. 27
Seattle, WA	Nov. 5-9	Nov. 10
Jacksonville, FL	Nov. 26-30	Dec. 1

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

Certified Welding Educator (CWE)

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

Senior Certified Welding Inspector (SCWI)

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

Certified Welding Fabricator

This program is designed to certify companies to specific requirements in the ANSI standard AWS B5.17, *Specification for the Qualification of Welding Fabricators*. There is no seminar or exam for this program. Call ext. 448 for more information.

Code Clinics & Individual Prep Courses

The following workshops are offered at all sites where the CWI seminar is offered (code books not included with individual prep courses): Welding Inspection Technology (general knowledge and prep course for CWI Exam-Part A); Visual Inspection Workshop (prep course for CWI Exam-Part B); and D1.1 and API-1104 Code Clinics (prep courses for CWI Exam-Part C).

On-site Training and Examination

On-site training is available for larger groups or for programs customized to meet specific needs of a company. Call ext. 219 for more information.

International Courses

The Mexico AWS-accredited seminar and testing location is Dalus, S.A. de C.V., Monterrey, N.L. It employs S.E.N.S.E. (Schools Excelling Through Skill Standards Education) programs. Contact Lorena Garza at *info@dalus.com.*

Location	Seminar Dates	Exam Date
Monterrey, Mexico	Jul. 9-13	Jul. 14
Monterrey, Mexico	Nov. 5-9	Nov. 10

BY HOWARD M. WOODWARD

Santa Clara Valley and Detroit Sections Kick off the AWS Welding Scholarship Campaign

In April, the American Welding Society Foundation Trustees and the AWS Board of Directors approved expansion of the District and Section Named Endowed Scholarship funding levels. Endowment levels for both have now been established at $10,000, $15,000, $25,000, $50,000, and higher. Trustee Chairman **Ronald Pierce** said, "This gives greater flexibility for individuals, companies, Sections, and Districts to support locally the need we have to attract and build our welding workforce. These scholarships are determined and awarded at the local level and are awarded by our local volunteers who know what the need is in their area."

Sam Gentry, executive director, AWS Foundation, Inc., said, "We will be able to attract many more supporters to our educational efforts with the new flexibility of the multiple funding levels. We hope by 2009, the 90th anniversary of the American Welding Society, to have at a District level, endowments of at least $50,000 in each District which will provide an additional $2500 for Districts to award local scholarships annually."

To begin this effort, the AWS Foundation has received the largest initially funded Section Named Scholarship, the Louis DeFreitas-Santa Clara Valley Section Named Scholarship in the amount of $60,000. This endowment will provide $3000 annually in scholarship funds that will be awarded locally by the AWS Santa Clara Valley Section.

The endowment honors **Louis DeFreitas.** DeFreitas began his career in 1947 as a welding student at New Bedford Vocational High School. He worked in the industry in various capacities, and for 30 years was a professor and chairman of the Welding Technology Department at the College of San Mateo, San Mateo, Calif. He has taught more than 3000 welding students and at least 330 of them have graduated with associate of science degrees. Many of his students went on to earn engineering degrees at notable universities throughout the United States. More importantly, the vast majority of his students entered the welding workforce and have been a part of the welding profession for many years.

Lou DeFreitas (center, in sweater) is surrounded by Santa Clara Valley Section well-wishers during the announcement of the $60,000 scholarship named in his honor.

DeFreitas has been a very active member of AWS for many years and has served in many volunteer roles for the Society. After he retired in 1995, he partnered with Arc Gas in the Silicon Valley and helped to create a training institute to train welders, and to upgrade and enhance the skills of welders to support local business needs.

Wallace Erichsen, a past Section chairman, AWS District director, and director-at-large, said to DeFreitas, "This is a well-deserved recognition for your activities over a period of at least 40 years. Your eager participation in AWS such as your enthusiastic support for educational activities involving your students for many years was much appreciated. You could always be counted on for introducing your students to the advantages of AWS membership and attendance at Student Chapter meetings."

Tom Erichsen, Wallace's son, who is Santa Clara Valley Section chairman, said, "Lou personally, and because of his efforts for the welding workforce, was responsible for the many donations we received that made this endowment possible. People and industry gave because of Lou's efforts and contributions."

The Detroit Section announced the establishment of two $25,000 endowments: The Detroit Arc Welding District 11 Named Scholarship and the Detroit Resistance Welding District 11 Named Scholarship. The announcement was made by **Ray Roberts,** Detroit Section chairman, and **André Odermatt,** Section treasurer. Roberts said, "With the support of our past Chairman **Don DeCorte,** current AWS Foundation Trustee **Amos Winsand,** and our full executive committee, we decided this is a legacy that we can establish that will provide two additional $1250 scholarships at the District level to support welding education. We are happy to be a part of the 'Welding for the Strength of America Capital Campaign' by this action." Gentry said, "The Detroit Section is always at the forefront and in a leadership role at AWS. This assures a long-term commitment for educational support by the Detroit Section, which has always provided educational opportunities. Currently," Gentry added, "I am working with the leadership in many other Districts and Sections with the goal to establish endowments for funds to be used locally for additional education opportunities. Small or large depending on the ability to secure funding is not important, it is our ability to do what can be done locally to foster recruitment by offering educational support to attract a workforce to the welding profession. All funds matter because they represent future educational opportunities."♦

Tech Topics

Technical Committee Meetings

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

Aug. 15, International Standards Activities Committee. Pella, Iowa. Contact: Andrew Davis, ext. 466.

Aug. 16, Technical Activities Committee. Pella, Iowa. Contact: John Gayler, ext. 472.

Standards for Public Review

AWS was approved as an accredited standards-preparing organization by the American National Standards Institute (ANSI) in 1979. AWS rules, as approved by ANSI, require that all standards be open to public review for comment during the approval process. The following standards are submitted for public review. A draft copy may be obtained from Rosalinda O'Neill, *roneill@aws.org;* (800/305) 443-9353, ext. 451.

A5.34/A5.34M:2007, *Specification for Nickel-Alloy Electrodes for Flux Cored Arc Welding.* New Standard — $25. 7/2/07.

C7.4/C7.4M:200X, *Process Specification and Operator Qualification for Laser Beam Welding.* New Standard — $25. 6/25/07.

D15.1:200X, *Railroad Welding Specification for Cars and Locomotives.* Revised Standard — $123. 6/25/07.

Copies of the following Draft International Standards are available from your national standards body, which in the United States is ANSI, 25 W. 43rd St., 4th Floor, New York, NY 10036; (212) 642-4900. Any comments regarding ISO documents should be sent to your national standards body. In the United States, if you wish to participate in the development of International Standards for welding, contact Andrew Davis, *adavis@aws.org*; (800/305) 443-9353, ext. 466.

ISO/DIS 10675-1, *Non-destructive testing of welds — Acceptance levels for radiographic testing — Part 1: Steel, nickel, titanium and their alloys.*

ISO/DIS 17677-1, *Resistance welding — Vocabulary — Part 1: Spot, projection and seam welding.*

ISO/DIS 24394, *Welding in aerospace — Qualification test for welders and welding operators — Welding of metallic components.*

AWS Seeks Volunteers for On-Premise Sign Structures

The American Welding Society seeks volunteers to help draft a new AWS standard for the welding of on-premise sign structures. Experts involved in the manufacture and installation of signs and their related structures as well as users of on-premise sign structures are urged to participate. Volunteers associated with the International Sign Association, *www.signs.org,* initiated this project, and will be active participants. Contact John Gayler, *gayler@aws.org;* (800/305) 443-9353, ext. 472. ♦

Standards Approved by ANSI

A5.7/A5.7M:2007, *Specification for Copper and Copper-Alloy Bare Welding Rods and Electrodes.* Approved: 4/12/07.

B4.0:2007, Standard Methods for Mechanical Testing of Welds. Revised. 5/2/07.

C4.3/C4.3M:2007, *Recommended Practices for Safe Oxyfuel Gas Heating Torch Operation.* Revised. 4/30/07.

A5.17/A5.17M-97 (R2007), *Specification for Carbon Steel Electrodes and Fluxes for Submerged Arc Welding.* Reaffirmed. 4/20/07.

New Standards Projects

Development work has begun on the following two revised standards. You are invited to contribute to their development. For information, call **Stephen Borrero,** (800/305) 443-9353, ext. 334.

C3.4M/C3.4:2007, *Specification for Torch Brazing.* This specification presents the minimum fabrication, equipment, and process procedure requirements, as well as inspection requirements for the torch brazing of steels, stainless steels, copper, copper alloys, and heat- and corrosion-resistant alloys and other materials that can be adequately torch brazed. This specification provides criteria for classifying torch brazed joints based on loading, the consequences of failure, and quality assurance criteria defining the limits of acceptability in each class. Stakeholders include engineers, torch brazers, and quality control personnel.

C3.5M/C3.5:2007, *Specification for Induction Brazing.* This specification provides the minimum fabrication, equipment, and process procedure requirements, as well as inspection requirements for the induction brazing of steels, copper, copper alloys, and heat- and corrosion-resistant alloys and other materials that can be adequately induction brazed. This specification provides criteria for classifying induction brazed joints based on loading, the consequences of failure, and quality assurance criteria defining the limits of acceptability in each class. Stakeholders include engineers, torch brazers, and quality control personnel. ♦

Nominees Solicited for Robotic Arc Welding Awards

Nominations are solicited for the 2008 Robotic and Automatic Arc Welding Award. December 31 is the deadline for submitting nominations.

The nomination packet should include a summary statement of the candidate's accomplishments, interests, educational background, professional experience, publications, honors, and awards.

Send your nomination package to Wendy Sue Reeve, awards coordinator, 550 NW LeJeune Rd., Miami, FL 33126.

For more information, contact Reeve at *wreeve@aws.org,* or call (800/305) 443-9353, ext. 293.

In 2004, the AWS D16 Robotic and Automatic Arc Welding Committee, with the approval of the AWS Board of Directors, established the Robotic and Automatic Arc Welding Award. The award was created to recognize individuals for their significant achievements in the area of robotic arc welding. This work can include the introduction of new technologies, establishment of the proper infrastructure (training, service, etc.) to enable success, and any other activity having significantly improved the state of a company and/or industry. The Robotic Arc Welding Award is funded by private contributions. It will be presented this year at the AWS Awards and AWS Foundation Recognition Ceremony and Luncheon to be held in conjunction with the FABTECH International & AWS Welding Show, Nov. 11–14, in Chicago, Ill. ♦

New AWS Supporting Members

Sustaining Company

Anderson Steel Supply, Inc.
3811 River Dr. N.
Great Falls, MT 59405
www.andersonsteel.com
Representative: **Dan Rooney**

Anderson Steel Supply is a structural steel fabricator, servicing industrial commercial and residential construction. Although steel fabrication is its specialty, it offers a wide range of products and services. These include supplying steel, structural and miscellaneous metals, rebar, commercial doors and frames, finish hardware, and specialty products.

Supporting Companies

Applied Laser Technologies, LLC
8404 Venture Circle
Schofield, WI 54476

KVA Resistance Welding Supply
1371 C Brass Mill Rd.
Belcamp, MD 21017

RMSA, Inc.
1600 Walnut St.
Lansdale, PA 19446

Affiliate Companies

Blue Ridge Forge, Inc.
316 W. Cedar St.
Chillicothe, IL 61523

Mega Building Systems
3210 E. Roeser Rd., Ste. 17
Phoenix, AZ 85040

S & R Environmental Consulting, Inc.
5801 Logan St.
Denver, CO 80216

Wilkerson Welding, Inc.
PO Box 1503
High Springs, FL 32655

Winchester Metals, Inc.
195 Ebert Rd.
Winchester, VA 22603

Educational Institutions

Butler C. C.
901 S. Haverhill Rd.
El Dorado, KS 67042

Chattanooga State Technical C. C.
4501 Amnicola Hwy.
Chattanooga, TN 37406

Franklin Technology Center
2020 Iowa
Joplin, MO 64804

Montgomery College — Conroe Center
102 Longview St.
Conroe, TX 77301

Mott C. C.
1401 E. Court St.
Flint, MI 48503

Pima C. C.
1255 N. Stone Ave.
Tucson, AZ 85709 ♦

Henry C. Neitzel Membership Award Winners

The **North Texas Section,** District 17, won the Henry C. Neitzel National Membership Award for the greatest net numerical increase in membership for 2006–07. The **Stark Central Section,** District 10, won the Henry C. Neitzel National Membership Award for the greatest net percentage increase.

The following list shows the Section in each District that achieved the greatest percentage increase in membership for the year.

1 — Boston
2 — none
3 — York-Central Pennsylvania
4 — Tidewater
5 — North Central Florida
6 — Allegheny
7 — Johnstown-Altoona
8 — Northeast Mississippi
9 — Acadiana
10 — Stark Central
11 — Western Michigan
12 — Fox Valley
13 — Illinois Valley
14 — Louisville
15 — Northern Plains
16 — Eastern Iowa
17 — North Texas
18 — Corpus Christi
19 — Alaska
20 — Colorado
21 — Cuautitlan Izcalli (Mexico)
22 — San Francisco ♦

Membership Counts

Member Grades	As of 6/1/07
Sustaining	464
Supporting	285
Educational	423
Affiliate	391
Welding distributor	46
Total corporate members	**1,609**
Individual members	46,349
Student + transitional members	5,329
Total members	**51,678**

New Distinguished Member Named

Ervin G. Stoch, Arrowhead Section, District 15, has attained the status of Distinguished Member for his participation in the Society's leadership, professional development activities, and membership recruitment.To qualify for distinguished membership status, applications must accrue 35 points or more from these categories: national AWS leadership, local AWS leadership, professional development, and AWS member recruitment. If you believe that you may qualify as a Distinguished Member, call the Membership Dept. (800/305) 443-9353, ext. 260. ♦

Prof. Koichi Masubuchi Award Nominees Sought

October 14, 2007, is the deadline for submitting nominations for the 2008 Prof. Koichi Masubuchi Award, sponsored by the Dept. of Ocean Engineering at Massachusetts Institute of Technology. It is presented each year to one person who has made significant contributions to the advancement of materials joining through research and development. The candidate must be 40 years old or younger, may live anywhere in the world, and need not be an AWS member. The nomination should be prepared by someone familiar with the research background of the candidate. Include a résumé listing background, experience, publications, honors, awards, plus at least three letters of recommendation from researchers.

This award was established to recognize Prof. Koichi Masubuchi for his numerous contributions to the advancement of the science and technology of welding, especially in the fields of fabricating marine and outer space structures.

Submit nominations to Prof. John DuPont at *jnd1@lehigh.edu.* ♦

Member-Get-A-Member Campaign

Listed are the members participating in the 2006–2007 Campaign for the period June 1, 2006, through May 31, 2007. See page 65 for rules and the prize list. Call the Membership Dept. (800/305) 443-9353, ext. 480, for information about your status as a member proposer. Listings are for May 16, 2007.

Winners Circle

AWS Members who have sponsored 20 or more new members, per year, since 6/1/1999. The superscript denotes the number of times Winners Circle status has been earned if more than once. Status awards will be determined at the close of each membership campaign year.

J. Compton, San Fernando Valley[6]
E. H. Ezell, Mobile[4]
J. Merzthal, Peru[2]
G. Taylor, Pascagoula[2]
B. A. Mikeska, Houston
R. L. Peaslee, Detroit
W. Shreve, Fox Valley
M. Karagoulis, Detroit
S. McGill, NE Tennessee
T. Weaver, Johnstown/Altoona
G. Woomer, Johnstown/Altoona
R. Wray, Nebraska
M. Haggard, Inland Empire

President's Guild

AWS Members sponsoring 20 or more new Individual Members between June 1, 2006, and May 31, 2007.

L. Taylor, Pascagoula — 85
J. Compton, San Fernando Valley — 30

President's Roundtable

AWS Members sponsoring 9–19 new Individual Members between June 1, 2006, and May 31, 2007.

E. Ezell, Mobile — 17
M. Palko, Detroit — 16
W. Shreve, Fox Valley — 15
C. Daon, Israel — 11
R. Myers, L.A./Inland Empire — 10
R. Ellenbecker, Fox Valley — 9
A. Hoover, Northwestern Pa. — 9
L. Mathieu, International — 9
G. Mulee, Charlotte — 9

President's Club

AWS Members sponsoring 3–8 new Individual Members between June 1, 2006, and May 31, 2007.

D. Eck, Houston — 8
G. Fudala, Philadelphia — 8
R. Wilsdorf, Tulsa — 7
J. Bruskotter, New Orleans — 5
G. Taylor, Pascagoula — 5
B. Converse, Detroit — 4
T. Ferri, Boston — 4
H. Jackson, L.A./Inland Empire — 4
J. Leen, Chicago — 4
K. Smythia, Kansas City — 4
B. Trees, Detroit — 4
P. Zammit, Spokane — 4
S. Chuk, International — 3
J. Goldsberry Jr., SE Nebraska — 3
G. Lau, Cumberland Valley — 3
P. Phelps, Western Carolina — 3
T. White, Pittsburgh — 3
C. Yeager, NE Carolina — 3

President's Honor Roll

AWS Members sponsoring 1 or 2 new Individual Members between June 1, 2006, and May 31, 2007. Only those sponsoring 2 AWS Individual Members are listed below.

C. Amick, Columbia
A. Badeaux, Washington, D.C.
G. Beer, Northern New York
W. Cash, Fresno — 2
G. Cottrell, South Florida
G. Cunningham, North Texas
A. Demarco, New Orleans
J. Dolan, New Jersey
T. Gamble, New Orleans
D. Gillies, Green & White Mts.
R. Gollihue, Tri-State
S. Harris, Triangle
D. Herr, York-Central Pa.
D. Irvin, Mid-Ohio Valley
J. Jones, Maine
G. Koza, Houston
M. Lamarre, Palm Beach
E. Lamont, Detroit
D. Lawrence, Peoria
J. Little, British Columbia
D. Malkiewicz, Niagara Frontier
S. Modrow, Northwest
P. Newhouse, British Columbia
E. Norman, Ozark
R. Pierce, Mobile
K. Price, Northern Plains
M. Rieb, Inland Empire
D. Robinson, Arizona
D. Shackelford, L.A/Inland Empire
D. Malkiewicz, Niagara Frontier
T. Shirk, Tidewater
W. Sims, Long Island
L. Weathers, Tulsa
E. White, Southwest Virginia
D. Wright, Kansas City
R. Wright, San Antonio

Student Member Sponsors

AWS Members sponsoring 3 or more new AWS Student Members between June 1, 2006, and May 31, 2007. Members with 5 or more points are listed.

C. Daily, Puget Sound — 225
G. Euliano, Northwestern Pa. — 116
D. Williams, North Texas — 116
A. Demarco, New Orleans — 45
H. Hughes, Mahoning Valley — 44
H. Jackson, L.A./Inland Empire — 43
S. Burdge, Stark Central — 34
J. Ciaramitaro, N. Central Florida — 34
S. Siviski, Maine — 30
B. Yarrison, York-Central Pa. — 30
B. Suckow, Northern Plains — 26
A. Zinn, Eastern Iowa — 24
R. Durham, Cincinnati — 23
T. Kienbaum, Colorado — 22
A. Reis, Pittsburgh — 22
M. Anderson, Indiana — 21
T. Geisler, Pittsburgh — 21
G. Putnam, Green & White Mts. — 21
D. Ketler, Willamette Valley — 20
D. Schnalzer, Lehigh Valley — 20
D. Zabel, SE Nebraska — 20
B. Lavallee, Northern New York — 19
G. Smith, Lehigh Valley — 18
M. Arand, Louisville — 17
D. Berger, New Orleans — 17
H. Browne, New Jersey — 17
R. Boyer, Nevada — 17
D. Marks, Lehigh Valley — 17
M. Pointer, Sierra Nevada — 17
W. Harris, Pascagoula — 16
R. Robles, Corpus Christi — 16
C. Donnell, Northwest Ohio — 15
R. Hutchison, Long Bch./Or. Cty. — 15
D. Kowalski, Pittsburgh — 15
B. Butela, Pittsburgh — 14
S. Robeson, Cumberland Valley — 14
A. Badeaux, Washington D.C. — 13
J. Daugherty, Louisville — 13
L. Loney, Saginaw Valley — 12
L. Collins, Puget Sound — 11
M. Koehler, Milwaukee — 11
T. Najor, Detroit — 11
R. Norris, Maine — 11
J. Cox, Northern Plains — 10
B. Faccio, Saginaw Valley — 10
G. Kirk, Pittsburgh — 10
G. Koza Jr., Houston — 10
S. Luis Jr., Calif. Central Coast — 10
J. Smith Jr., Mobile — 10
A. Dropik, Northern Plains — 9
A. Kitchens, Olympic — 9
M. Harris, Northwest — 9
J. Compton, San Fernando Valley — 8
L. Davis, New Orleans — 8
A. Mattox, Lexington — 8
J. Morash, Boston — 8
D. Newman, Ozark — 8
W. Younkins, Mid-Ohio Valley — 8
T. Bridigum, Northwest — 7
M. Jones, Saginaw Valley — 7
J. Robillard, Columbus — 7
C. Schiner, Wyoming — 7
D. Vranich, North Florida — 7
T. Buchanan, Mid-Ohio Valley — 6
C. Chancy, Long Beach/Or. Cty. — 6
D. Combs, Santa Clara Valley — 6
G. Gammill, Northeast Mississippi — 6
D. Gibson, Oklahoma City — 6
R. Grays, Kern — 6
L. Hjelle, Northwest — 6
C. Kipp, Lehigh Valley — 6
G. Saari, Inland Empire — 6
J. Angelo, El Paso — 5
J. Carney, Western Michigan — 5
B. Hallila, New Orleans — 5
D. Parker, Idaho/Montana — 5 ♦

SECTION NEWS

DISTRICT 1

Director: Russ Norris
Phone: (603) 433-0855

CONNECTICUT

April 24
Speaker: **Gary Shubert,** vice chair
Affiliation: Pratt & Whitney, senior engineer
Topic: What welders need to know about hexavalent chromium
Activity: The meeting was held at ironworkers Training Center in Hartford, Conn.

Eastern Maine C. C. Student Chapter

April 24
Speaker: **Chris Maseychik,** welding instructor
Affiliation: Eastern Maine C. C.
Topic: Creating a positive work ethic to advance career potential
Activity: **Timothy L. Kennedy,** Eastern Maine Community College Student Chapter president, was presented with the Student Chapter Member Award from welding instructor **Stan Siviski.**

Timothy Kennedy (left) receives the Student Chapter Member Award from Stan Siviski at the Eastern Maine C. C. Student Chapter meeting.

DISTRICT 2

Director: Kenneth R. Stockton
Phone: (732) 787-0805

NEW YORK

April 16
Speaker: **Robert F. Waite,** P.E., vice chair
Affiliation: Welding Metallurgy
Topic: Welding supports for cranes on a military cargo supply ship
Activity: Section Chairman **Dominick Colasanto** received the Silver Membership Award for 25 years of service to the Society. The program was held at Buckley's Restaurant in Brooklyn, N.Y.

Speaker Robert Waite (left) is shown with Chairman Dominick Colasanto at the New York Section program.

PHILADELPHIA

May 14
Speaker: **Robert Tabernik**
Affiliation: The Lincoln Electric Co.
Topic: Employment opportunities in the welding industry
Activity: This Students' Night program featured small group discussions led by **Gary Atherton** and Chair **James Korchowsky.** The program was held at Gloucester County Institute of Technology in Sewell, N.J.

Speaker Robert Tabernik (left) is shown with James Korchowsky, Philadelphia Section chair, at the Students' Night program.

DISTRICT 3

Director: Alan J. Badeaux Sr.
Phone: (301) 753-1759

Career Institute of Technology Student Chapter

May 8
Activity: **Felicia Buss** has been selected by **Richard Gallagher Jr.,** Student Chapter advisor, to receive the Student Chapter Member Award. Buss is a member of the National Technical Honor Society Honor Roll, and the Principal's 90% Club. She is a recipient of the Elmer Gates Enterprise Award, and served this year as a Pennsylvania State SkillsUSA officer. The Student Chapter is affiliated with the Lehigh Valley Section.

Submit Your Nominations for Image of Welding Awards Now

August 15 is the deadline for submitting your nominations for the Image of Welding Awards. The awards are presented in seven categories: 1) Individual; 2) AWS Section; 3) Large Business (200+ employees); 4) Small Business; 5) Welding Products Distributor; 6) Educator; and 7) Educational Facility. The awards recognize those who have shown notable dedication to promoting the image of welding in their communities. The winners will be announced Nov. 12 at a special ceremony held during the FABTECH International & AWS Welding Show in Chicago, Ill.

Nominations will be judged by the Welding Equipment Manufacturers Committee (WEMCO).

Send your nominations to **Adrienne Zalkind,** *azalkind@aws.org;* or mail to Image of Welding Awards, 550 NW LeJeune Rd., Miami, FL 33126. Include your name, phone number, e-mail and mailing addresses.♦

Shown at the Reading Section program are (from left) Seminar Chair Joe Young, with presenters Dave Hibshman and Chris Ochs.

Speaker Bill Cotton is shown with Chair Margaret Malehorn at the York Central Pennsylvania Section program.

Margaret Malehorn receives a plaque for serving as past chair of the York Central Pennsylvania Section from Dave Herr, vice chairman.

Speaker David McQuaid (left) is shown with Ted Alberts, Southwest Virginia Section chairman.

READING

MARCH 28

Activity: The Section members participated in a hands-on seminar with demonstrations of oxyacetylene welding and hardfacing techniques. The leaders of the program included Section Chairman **Chris Ochs,** Dairymaster USA, Inc., and Section Treasurer **David Hibshman,** of Hibshman Welding and Hardfacing. The seminar was held at Berks County Career and Technology Center in Leesport, Pa.

YORK CENTRAL PA.

APRIL 5

Speaker: **Bill Cotton,** district manager

Affiliation: Thermadyne Industries

Topic: Oxyfuel safety

Activity: **Margaret Malehorn** received an appreciation plaque for serving as Section chair from **Dave Herr,** vice chairman. Welding student **Paul Lutz** displayed his senior project, an illuminated Ford logo. The meeting was held at York County School of Technology in York, Pa.

DISTRICT 4

Director: Roy C. Lanier
Phone: (252) 321-4285

SOUTHWEST VIRGINIA

APRIL 26

Speaker: **David McQuaid,** consultant

Affiliation: D. L. McQuaid and Associates

Topic: Orthotropic bridge deck fabrication

Activity: The program was held at Dynasty International Super Buffet.

DISTRICT 5

Director: Leonard P. Connor
Phone: (954) 981-3977

Lee Clemens (left), outgoing Florida West Coast Section chairman, is shown with incoming Chair Al Sedory.

FLORIDA WEST COAST

MAY 12

Activity: The Section hosted its annual Shrimp-A-Roo dinner and dance with food prepared by the Section members. A special attendee was **Lenny Nielson Sr.,** the founder and a charter member of the Florida West Coast Section. About 125 people attended the event, held at Sons of Italy Hall in Tampa, Fla.

SOUTH CAROLINA

APRIL 19

Activity: **Scott Collier,** operations manager, led the Section members on a tour of Metal Trades, Inc., in Hollywood, S.C. **Billy Reid** demonstrated subarc welding techniques. The officers were elected for the 2007–2008 term.

DISTRICT 6

Director: Neal A. Chapman
Phone: (315) 349-6960

NIAGARA FRONTIER

APRIL 19

Activity: **Tom Christ,** manufacturer's representative for All-State Welding Products, presented a program on techniques for maintenance and repair welding. Following the demonstrations, the members had a hands-on opportunity to try the techniques. The meeting was held at the BOCES facility in West Seneca, N.Y.

DISTRICT 7

Director: Don Howard
Phone: (814) 269-2895

Beaver Valley Student Chapter

Tyler Davidson has been selected by **Tom Geisler,** Beaver Valley Student

Lenny Nielson Sr. (left), founder of the Florida West Coast Section, is shown with his son, Lenny Nielson Jr., at the Section's Shrimp-A-Roo dinner and dance.

Chapter advisor, to receive the AWS Student Chapter Member Award. Davidson works full time as a welder while going to school and serves as Chapter vice president. He has been involved with the local Habitat for Humanity community project and placed second in the SkillsUSA District competition. The Beaver Valley Student Chapter is associated with the Pittsburgh Section.

PITTSBURGH

APRIL 10
Speaker: **Steve Latvis**
Affiliation: Miller Electric Mfg. Co.
Topic: Induction heat treatment equipment and its use in pre- and postweld heat treatment
Activity: The program was held at Steam Fitters Local 449 in Pittsburgh, Pa.

MAY 10
Speaker: **Behram M. Kapadia**
Topic: Fatigue failures in welded structures, the causes and prevention.
Activity: This Pittsburgh Section program was held at Holiday Inn in Pittsburgh, Pa.

DISTRICT 8

Director: Wallace E. Honey
Phone: (256) 332-3366

NE TENNESSEE

APRIL 17
Activity: **Kenneth Barks,** president, led the Section members on a tour of Laser Precise, Inc., in Knoxville, Tenn. On display were three- and six-axis laser beam cutting machines.

DISTRICT 9

Director: George D. Fairbanks
Phone: (225) 673-6600

Steve Latvis demonstrated heat treatment equipment at the April Pittsburgh Section program. Shown are (from left) Dale Glavin, Steve Latvis, Tom White, and Carl Ott.

Tyler Davidson, member of the Beaver Valley Student Chapter, received the AWS Student Chapter Member Award.

Carl Ott (right) welcomes speaker Behram Kapadia to the May Pittsburgh Section program.

Kenneth Barks discusses a 3-kW laser beam cutting machine for Northeast Tennessee Section members.

Lawson State C. C. Student Chapter

Michael S. Isbell was nominated for the AWS Student Chapter Member Award by the Birmingham Section members. The presentation was made at Lawson State Community College on May 1.

Michael S. Isbell, a member of the AWS Lawson State Community College Student Chapter, received the Student Chapter Member Award from the Birmingham Section.

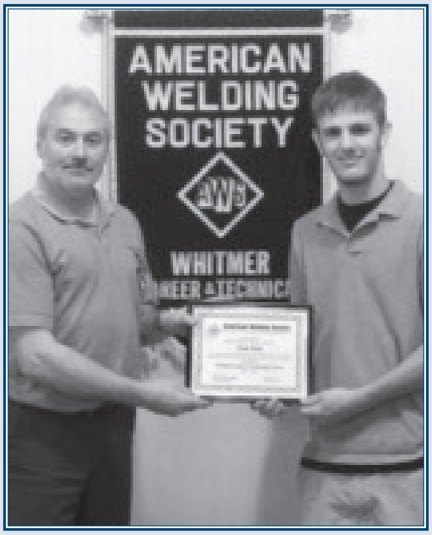
Shown at the Mobile Section program are (from left) Vice President John Bruskotter, District 9 Director George Fairbanks, Life Member Johnny Dedeaux, Mobile Section Chair Eleanor Ezell, AWS President Gerald Uttrachi, District Meritorious Awardee Dale Kite, and Ronald Pierce, an AWS past president and chairman, board of trustees, AWS Foundation, Inc.

Harry Sadler (right) receives a speaker gift from Vice Chair Mark Brereton at the Northwestern Pennsylvania Section meeting in April.

The winners in the Detroit Section welding contest are shown with Steve Slavick, Section vocational programs chair.

Shown at the May meeting of the Northwestern Pennsylvania Section are speaker Marty Siddall (left) and Mark Brereton, Section vice chairman.

Detroit Section Chairman Ray Roberts (far right) presented Detroit Section Patron Awards to Larry Vanderstelt (left) and Don Czerniewski.



Tom West (right) receives the Student Chapter Member Award from Craig Donnell, advisor, Whitmer Career & Technical College Student Chapter.

MOBILE

April 12
Speaker: **Gerald D. Uttrachi,** AWS president
Affiliation: WA Technology, LLC
Topic: Welding cars and street rods
Activity: **Johnny Dedeaux,** a past chair of the Mobile Section, received his Life Membership Award for 35 years of service to the Society. **Dale Kite** received the District Meritorious Award. Present at the program were AWS Vice President **John Bruskotter,** District 9 Director **George Fairbanks,** and past AWS President **Ronald Pierce.**

DISTRICT 10

Director: Richard A. Harris
Phone: (440) 338-5921

NW PENNSYLVANIA

April 17
Speaker: **Harry Sadler**
Affiliation: The Lincoln Electric Co.
Topic: The tragedies and triumphs in the evolution of the welding code
Activity: More than 100 members, students, and local employers attended this program. The meeting was held at Tri-State Business Institute in Erie, Pa.

May 8
Speaker: **Marty Siddall**
Affiliation: The Lincoln Electric Co.
Topic: Welding robotics
Activity: This Northwestern Pennsylvania Section program was held at Tri-State Business Institute in Erie, Pa., for 35 attendees.

DISTRICT 11

Director: Eftihios Siradakis
Phone: (989) 894-4101

DETROIT

May 17
Speaker: **John J. Kargul,** director of technology transfer
Affiliation: U.S. Environmental Protection Agency
Topic: Advances in hydraulic hybrid technology for heavy-duty truck applications
Activity: The Section held its Patrons' Night program to honor the companies and individuals who have provided long-term support for the various Section scholarship programs. Patron Awards were presented to **Larry Vanderstelt** of Wilson Welding & Medical Gases (30 years), and **Don Czerniewski** of Industrial Control Repair, Inc. (10 years). Introduced were the top ten finishers in the Section's annual welding contest. Presented were **Jeremy Tabor, Sarah Gambill, David Wyatt, Kenneth Penrod, Chad Klavinger, Steve Slavick, Zachary Wyatt, Joseph Balowski, Tavis Stafford, Ronald Washick,** and **Ryan Black.**

Whitmer Career & Technical College Student Chapter

Tom West was chosen to receive the AWS Student Chapter Member Award by Chapter Advisor **Craig Donnell.** West was cited for his outstanding commitment to his school, community, and the welding trade. The Student Chapter is affiliated with the Northwest Ohio Section.

DISTRICT 12

Director: Sean P. Moran
Phone: (920) 954-3828

LAKESHORE

April 28
Activity: Ten Section members met for a sporting clay shoot outing at Triple-J Game Farm and Sporting Clays in Reedsville, Wis. In attendance were Secretary **Dave Ramseur, Curt Klieber, Dick Klieber, Lee Levenhagen, Dave Meier, Curt Johnson, Milt Kemp, Bill Krcma, Jim Becker,** and **Jack Krcma.**

Shown at the Lakeshore Section clay shoot outing are (from left) Dave Ramseur, Curt Klieber, Dick Klieber, Lee Levenhagen, Dave Meier, Curt Johnson, Milt Kemp, Bill Krcma, Jim Becker, and Jack Krcma.

DISTRICT 13

Director: W. Richard Polanin
Phone: (309) 694-5404

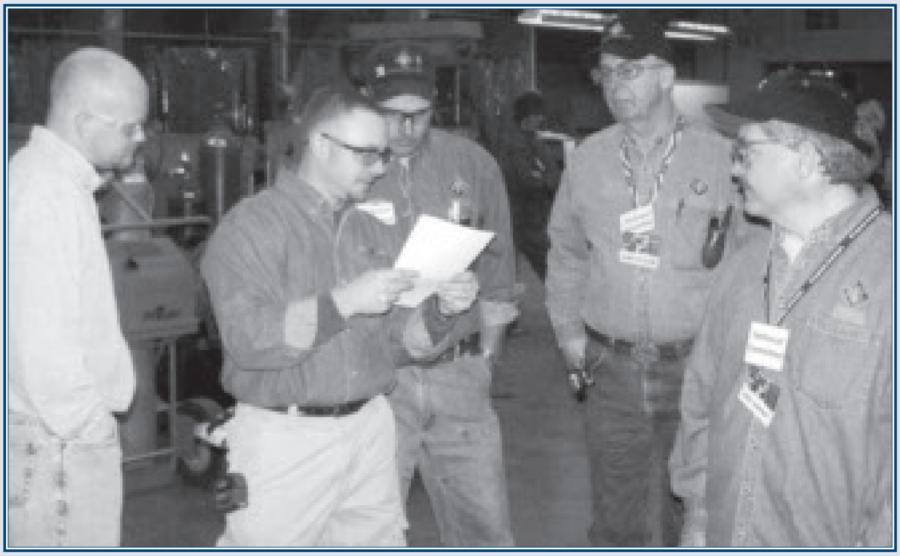
DISTRICT 14

Director: Tully C. Parker
Phone: (618) 667-7744

INDIANA

April 10–12
Activity: The Section hosted its 29th annual Mid-West Team Welding Contest involving 24 teams from schools in Illinois, Indiana, and Kentucky. It was held at New Castle Area Vocational School (NCAVS). More than 180 participated in the event. The students competed for trophies and $5000 in door prizes. The winning teams included Fountain Central from Veedersburg, Ind., and Kentucky Tech Nelson County, Bardstown, Ky. Coordinating the event were Treasurer **Mike Anderson,** Secretary **Robert Richwine,** Chairman **Gary Dugger,** Vice Chair **Bennie Flynn,** District 14 Director **Tully Parker, Tony Brosio,** plant manager at Lift-A-Loft, **Dennis Klingman,** The Lincoln Electric Co., and the NCAVS staff, including Di-

The Fountain Central High School team took top honors at the Indiana Section's Mid-West Welding Tournament. Shown are (from left) Jarrett Owen, Chris Maxwell, Andy Rehmel, Wade Yater, and Sam Maxwell.



Judging the Indiana SkillsUSA contest were (from left) Eric Cooper, Rick Ferguson, Vice Chair Bennie Flynn, Chair Gary Dugger, and Mike Johnson.

Lexington Section Chair Frank McKinley (far right) is shown with the welding contest winners in April.

Indiana Section Chair Gary Dugger (left) and Tony Brosio present LaDonna Dugger with a gift for her help with scoring the SkillsUSA contest.

rector **Robert Hobbs** and Career Counselor **Jerry Walden**. This event was the lead story for June 2007 Society News.

April 14
Activity: The Indiana Section members participated in the Indiana SkillsUSA state welding contest held at Walker Career Center in Indianapolis, Ind. Serving as judges and scorers were Chairman **Gary Dugger, LaDonna Dugger, Tony Brosio, Eric Cooper, Rick Ferguson,** Vice Chair **Bennie Flynn,** and **Mike Johnson.**

LEXINGTON

April 19
Speaker: **Les Joiner,** director
Affiliation: Ocean Corporation
Topic: Commercial diving
Activity: **Joe Pawley** was presented the Section Educator of the Year Award. Special guests were the winners in the recent welding competition.

DISTRICT 15

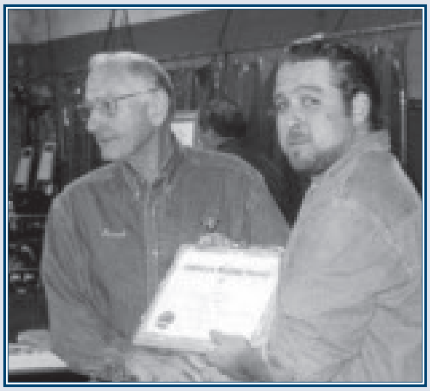
Director: Mace V. Harris
Phone: (952) 925-1222

District 15 Director Awards

District 15 Director **Mace Harris** has nominated **Takamitsu Nakazaki** and **Huawei Guo** of the Saskatoon Section as recipients of the District Director Award. This award provides a means for District directors to recognize individuals who have contributed their time and effort to the affairs of their local Section and/or District.

ARROWHEAD

April 19
Activity: The Section members toured the General Electric Apparatus Repair Shop in Mountain Iron, Minn., to study the repair of heavy equipment used in the iron

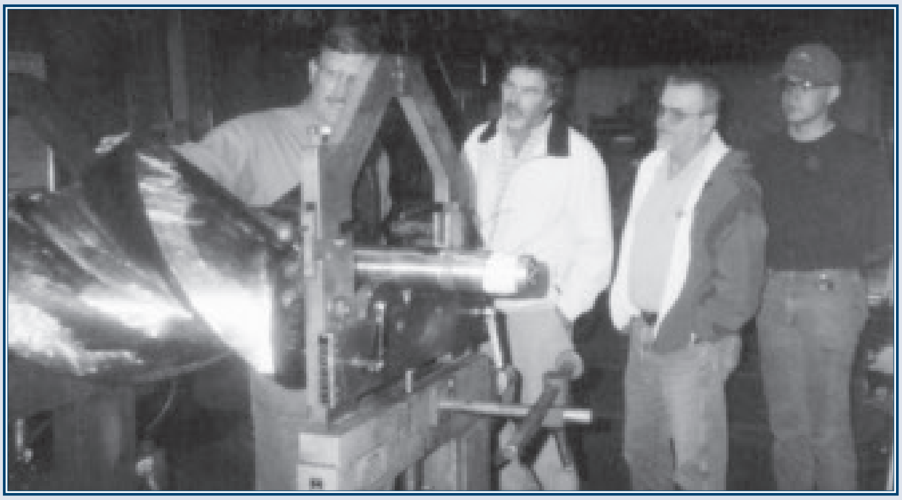


Joe Pawley (right) receives the Section Educator of the Year Award from Lexington Section Chair Frank McKinley.

mining industry and for Great Lakes shipping vessels. **John Hahn,** general shop manager, led the tour. Following the tour, the members had lunch at Sawmill Saloon and Eatery in Virginia, Minn.

MAY 4
Activity: The Arrowhead Section hosted the District 15 conference at Mesabi Range Community and Technical College in Eveleth, Minn. Representatives from the Arrowhead, Northern Plains, Northwest, and Saskatoon Sections attended.

Hosted by the Arrowhead Section, the attendees at the District 15 conference posed for a group photo in May.



Shown during the Arrowhead Section tour in April are (from left) shop manager John Hahn, Robert L'Heareax, Chairman Tom Baldwin, and Lee Radaich.

DISTRICT 16

Director: David Landon
Phone: (641) 621-7476

KANSAS CITY

APRIL 12
Activity: The Section members participated in a program at Johnson County Community College then toured the welding school facilities. About 50 members and guests attended the program.

KANSAS CITY/KANSAS

MAY 3
Activity: The Kansas City Section and the Kansas Section held a joint meeting to tour the Taylor Forge Engineered Systems facilities in Paola, Kan.

MID-PLAINS

APRIL 19
Activity: The Section members toured Valmont Industries, Inc., in McCook, Neb., to study the manufacture of irrigation equipment. The tour included the robotic welding of pipe, galvanizing, and shipping areas.

DISTRICT 17

Director: Oren P. Reich
Phone: (254) 867-2203

Central Arkansas members are shown studying an orbital tube welding machine.

CENTRAL ARKANSAS

APRIL 5
Activity: **Jimmy Brewer** and **George Seahorn** demonstrated the AMI orbital tube welding machine for the Section members. This Central Arkansas Section program and tour were held at the Greater Little Rock Plumbers and Pipefitters JAC Local #155.

CENTRAL TEXAS

MAY 14
Activity: The Section held an executive officers meeting. New officers were elected. **Veronica Covey,** outgoing chair, received an appreciation plaque for her services. The incoming chair is **Ryan Rummel.** The meeting was held at Logan's Roadhouse.

Shown at the East Texas program are (from left) Chairman Bryan Baker, speaker Jerica Cadman, and Prof. Robert Warke.

Shown at the Ozark Section program are (from left) Phil Walker, speaker Jerry Mirgain, and Chairman James Gardner.

District 17 Director Oren Reich (right) presents the North Texas Section Meritorious Award to incoming Chair Robert Tessier.

Shown at the North Texas Section program are (from left) Eric Germann, Dawn Duncan, Chairman Howie Sifford, and Tammy Garrett.

EAST TEXAS

April 26
Speaker: **Jerica Cadman,** engineering student
Affiliation: LeTourneau University, Longview, Tex.
Topic: Brazing titanium to carbon fiber composite tubing
Activity: The program was held at Vaughans Catfish Restaurant in Tyler, Tex.

NORTH TEXAS

May 17
Activity: The incoming slate of officers was announced. The scholarship nominees were introduced, including **Eric Germann, Dawn Duncan, Tammy Garrett, Craig Browning,** and **Dewight Grayson. Kirk Jordon** and **Robert Tessier,** incoming chairman, received Section Meritorious Awards. **Donnie Williams** received the Private Educator's Award, and **Paul Stanglin** received the Section Educator Award. Present were Past AWS President **Ernest Levert** and District 17 Director **Oren Reich.**

Donnie Williams (right) receives the Educator's Award from District 17 Director Oren Reich at the North Texas Section program.

OZARK

April 19
Speaker: **Jerry Mirgain,** regional manager
Affiliation: AlcoTec Wire Co.
Topic: Aluminum welding in shipyards and fabrication
Activity: Chairman **James Gardner** received an appreciation award for his services as chairman. The program was held at Ryan's Steak House in Springfield, Mo.

TULSA

April 24
Activity: The Section members toured the Thermal Engineering International manufacturing plant in Sapulpa, Okla. **Bill Escue,** plant manager, explained how the company manufactured heat recovery steam generators, steam condensers, duct work, feed water heaters, etc., in sizes up to 300 tons.

May 4
Activity: The Tulsa Section participated in the Oklahoma state welding contest. The Section's judges included **Tim Cruse, Jerry Knapp,** and **Jerry Allen.**

DISTRICT 18

Director: John L. Mendoza
Phone: (210) 353-3679

District 18 Conference

May 4, 5
Speaker: **Ray Shook,** executive director
Affiliation: American Welding Society
Topic: AWS national activities report
Activity: District 18 Director **John Mendoza** chaired the conference and displayed a citation from Texas Gov. **Rick Perry** proclaiming April 2007 as Welding Month in the state of Texas. Mendoza demonstrated use of the new *Welding Journal* DVDs. The Houston Section announced the establishment of the **Ronald S. Theiss** national scholarship to be coor-

The District 18 conference delegates are shown at Boardwalk Inn in Kemah, Tex.

Speaker Jack Couch (left) is shown with Dennis Eck, Houston Section chair.

dinated with the AWS Foundation. **John Bray** was elected District 18 director-elect, to take office January 1, 2008. **Raul Robles** was presented the CWI of the Year Award. The event was held at Boardwalk Inn in Kemah, Tex.

HOUSTON

APRIL 18

Speaker: **Jack Couch,** technical manager
Affiliation: Oceaneering International
Topic: Underwater structural platform repairs using wet and dry hyperbaric welding
Activity: The program was held at Brady's Landing in Houston, Tex.

SABINE

APRIL 27

Activity: The Section members toured the Metalforms, Inc., facility in Beaumont, Tex., to study the manufacture and repair of pressure vessels and heat exchangers. **Don Popielarczyk,** quality control manager, conducted the program. The incoming officers are **Ken Dillard,** chairman; **Morris Weeks** and **James Amy,** vice chairs; **Tom Holt,** secretary; and **Ruel Riggs,** treasurer.

Shown at the District 18 conference are (from left) Julie Theiss, AWS Executive Director Ray Shook, Nora Mendoza, and Ron Theiss.

Judging the Oklahoma state welding contest entries for the Tulsa Section are (from left) Tim Cruse, Jerry Knapp, and Jerry Allen.

Shown at the Sabine Section program are (from left) John Hussey, Mark White, tour guide Don Popielarczyk, and Chairman Glynn Savage.

Cornelio Ontiveros, shown at the San Antonio Section program, was elected president of the student body of the Texas SkillsUSA College/Postsecondary division.

The Spokane Section members are shown at the April program.

Linda Guillory receives a speaker gift from District 18 Director John Mendoza at the San Antonio Section program.

Shown at the San Antonio Section program are recent welding technology grads Steve Wilson (left) and Chris Perales.

Gene Morrill demonstrated plasma arc cutting for the Spokane Section members.

SAN ANTONIO

May 9
Speaker: **Linda Guillory**
Affiliation: Bechtel & Becon
Topic: The shortage of welders
Activity: Three welding students were recognized for their accomplishments. **Steve Wilson** and **Chris Perales** were cited for their graduation from St. Philip's College with associate degrees in applied science in welding technology. **Cornelio Ontiveros** was recognized for being elected president of the student body of the Texas SkillsUSA College/Postsecondary division. Cornelio led the Texas delegation at the national SkillsUSA conference held in Kansas City, Mo., last month. The meeting was held at La Posada Del Rey Restaurant in San Antonio, Tex.

DISTRICT 19

Director: Neil Shannon
Phone: (503) 201-5142

SPOKANE

April 4
Speaker: **Gene Morrill,** technical sales representative
Affiliation: Hypertherm Welding Systems
Topic: Plasma arc cutting process and technology
Activity: The talk was followed by demonstrations of the equipment. Attendees then had a hands-on opportunity to work with the machines to cut various metals.

DISTRICT 20

Director: William A. Komlos
Phone: (801) 560-2353

DISTRICT 21

Director: Jack D. Compton
Phone: (661) 362-3218

LONG BEACH/ ORANGE COUNTY

April 19
Activity: The Section hosted its Students' Night program at Summit Gas and Gear in Paramount, Calif. Representatives from Lincoln Electric, ESAB, Thermal Dynamics, TEC Torch, and MK Products demonstrated their products. The scholarship winners were **Angelque Weber, Scott Tullius, Ricky Runser, Gary Reynolds, Michael Bowman,** and **Christian Waldron.** They are students at Long Beach City College and Orange Coast College.

DISTRICT 22

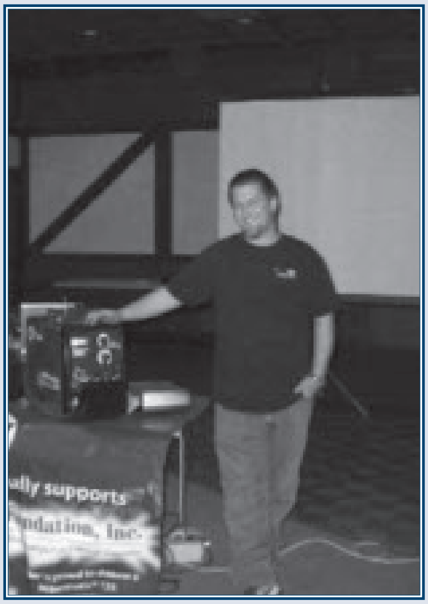
Director: Dale Flood
Phone: (916) 933-5844

SAN FRANCISCO

May 9
Speaker: **Sam Gentry,** executive director
Affiliation: AWS Foundation, Inc.
Topic: Welder work force development
Activity: The program was held at the San Francisco Golden Gate Rugby Club.

SANTA CLARA VALLEY

May 8
Speaker: **Sam Gentry,** executive director
Affiliation: AWS Foundation, Inc.
Topic: The future of welding and the AWS Foundation
Activity: The meeting honored **Lou DeFreitas** and his accomplishments during his many years in welding education. The Section members established the Lou DeFreitas Scholarship Endowment to be managed by the AWS Foundation. The Section presented Gentry with a check for $60,000 to establish the scholarship. The program was held at Harry's Hofbrau. Read more about this event on page 57 of this issue of *Welding Journal.*



Tom Erichsen, Santa Clara Valley Section chair, is shown at the May meeting.

Shown at the Long Beach/Orange County Section's Students' Night program are (from left) Winford Sartin, Secretary Larry Gustafson, Angelque Weber, Chairman Richard Hutchison, Scott Tullius, Ricky Runser, Gary Reynolds, and Michael Bowman.

The Santa Clara Valley Section members and guests are shown with Louis DeFreitas displaying the Section's check for $60,000 to establish the Louis DeFreitas Scholarship. The full story is on page 57 of this issue of Welding Journal.

Shown at the San Francisco Section program are (from left) Chairman Richard Hashimoto, AWS Foundation Executive Director Sam Gentry, Treasurer Sharon Jones, Dale Phillips, District 22 Director Dale Flood, Andre Lopez, Vice Chair Tom Smeltzer, and Doug Williams.

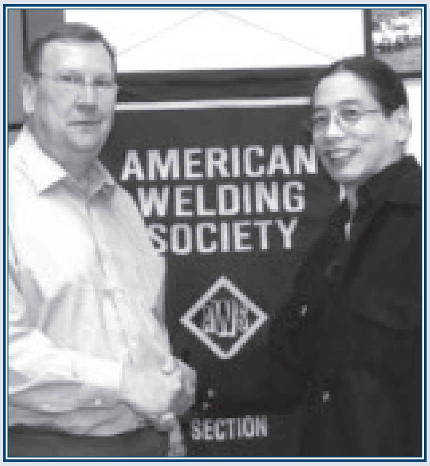
Your Opinion Counts — Take the Online Survey

The AWS Product Development Committee is conducting a survey to evaluate ideas for new AWS products. Your input is a crucial part of developing new products and services that meet the needs of the welding industry. To complete this brief survey, visit *www.aws.org/education/pdc07-survey.html.*

I thank you in advance for participating in this important effort.

Harvey Castner, chairman
Product Development Committee

Ben Anderson (left) and Marty Shober (right) of Summit Gas and Gear are shown with Richard Hutchison, chairman of the Long Beach/Orange County Section.



Speaker Sam Gentry (left) is shown with Richard Hashimoto, chairman of the San Francisco Section.

Guide to AWS Services

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Publishes the Society's monthly magazine, *Welding Journal*, which provides information on the state of the welding industry, its technology, and Society activities. Publishes *Inspection Trends*, the *Welding Handbook,* and books on general welding subjects.

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Director, Education Product Development
Christopher Pollock.. *cpollock@aws.org* (219)

Tracks effectiveness of programs and develops new products and services. Coordinates in-plant seminars and workshops. Administers the S.E.N.S.E. program. Assists Government Liaison Committee with advocacy efforts. Works with Education Committees to disseminate information on careers, national education and training trends, and schools that offer welding training, certificates, or degrees.
Also responsible for conferences, exhibitions, and seminars on topics ranging from the basics to the leading edge of technology. Organizes CWI, SCWI, and 9-year renewal certification-driven seminars.

AWS AWARDS, FELLOWS, COUNSELORS
Senior Manager
Wendy S. Reeve.. *wreeve@aws.org* . . . . .(293)
Coordinates AWS awards and AWS Fellow and Counselor nominees.

CERTIFICATION OPERATIONS
Department Information . . . .(273)

Managing Director
Peter Howe.. *phowe@aws.org* . . . .(309)

Director, Operations
Terry Perez.. *tperez@aws.org* . . . .(470)

Director, Int'l Business Accreditation and Welder Certification
Walter Herrera.. *walter@aws.org* . . . .(475)
Provides information on personnel certification and accreditation services.

TECHNICAL SERVICES
Department Information . . . .(340)

Managing Director
Andrew R. Davis.. *adavis@aws.org* . . . . .(466)
Int'l Standards Activities, American Council of the Int'l Institute of Welding (IIW)

Director, National Standards Activities
John L. Gayler.. *gayler@aws.org* . . . .(472)
Machinery and Equipment Welding, Robotic and Automatic Welding, Computerization of Welding Information, Personnel and Facilities Qualification

Manager, Safety and Health
Stephen P. Hedrick.. *steveh@aws.org* . . .(305)
Metric Practice, Safety and Health, Joining of Plastics and Composites

Technical Publications
AWS publishes about 200 documents widely used throughout the welding industry.
Senior Manager
Rosalinda O'Neill.. *roneill@aws.org* . . . .(451)

Staff Engineers/Standards Program Managers
Annette Alonso.. *aalonso@aws.org* . . . . .(299)
Automotive Welding, Resistance Welding, Oxyfuel Gas Welding and Cutting, Definitions and Symbols

Stephen Borrero.. *sborrero@aws.org* . . .(334)
Welding Iron Castings, Joining of Metals and Alloys, Brazing and Soldering, Brazing Filler Metals and Fluxes, Brazing Handbook, Soldering Handbook

Rakesh Gupta.. *gupta@aws.org* . . . .(301)
Filler Metals and Allied Materials, Int'l Filler Metals, Instrumentation for Welding, UNS Numbers Assignment

Brian McGrath . *bmcgrath@aws.org* . . . .(311)
Methods of Inspection, Mechanical Testing of Welds, Thermal Spray, Arc Welding and Cutting, Welding in Marine Construction, Piping and Tubing, Titanium and Zirconium Filler Metals, Filler Metals for Naval Vessels

Selvis Morales.....*smorales@aws.org* . . . .(313)
Welding Qualification, Structural Welding

Reino Starks....*rstarks@aws.org* . . . .(304)
Welding in Sanitary Applications, High-Energy Beam Welding, Aircraft and Aerospace, Friction Welding, Railroad Welding

Note: *Official interpretations of AWS standards may be obtained only by sending a request in writing to the Managing Director, Technical Services. Oral opinions on AWS standards may be rendered. However, such opinions represent only the personal opinions of the particular individuals giving them. These individuals do not speak on behalf of AWS, nor do these oral opinions constitute official or unofficial opinions or interpretations of AWS. In addition, oral opinions are informal and should not be used as a substitute for an official interpretation.*

Nominees for National Office

Only Sustaining Members, Members, Honorary Members, Life Members, or Retired Members who have been members for a period of at least three years shall be eligible for election as a director or national officer.

It is the duty of the National Nominating Committee to nominate candidates for national office. The committee shall hold an open meeting, preferably at the Annual Meeting, at which members may appear to present and discuss the eligibility of all candidates.

To be considered a candidate for the positions of president, vice president, treasurer, or director-at-large, the following qualifications and conditions apply:

President: To be eligible to hold the office of president, an individual must have served as a vice president for at least one year.

Vice President: To be eligible to hold the office of vice president, an individual must have served at least one year as a director, other than executive director and secretary.

Treasurer: To be eligible to hold the office of treasurer, an individual must be a member of the Society, other than a Student Member, must be frequently available to the national office, and should be of executive status in business or industry with experience in financial affairs.

Director-at-Large: To be eligible for election as a director-at-large, an individual shall previously have held office as chairman of a Section; as chairman or vice chairman of a standing, technical, or special committee of the Society; or as District director.

Interested persons should submit a letter stating which office they seek, including a statement of qualifications, their willingness and ability to serve if nominated and elected, and a biographical sketch.

E-mail the letter to Gricelda Manalich, *gricelda@aws.org,* c/o Damian J. Kotecki, chair, National Nominating Committee.

The next meeting of the National Nominating Committee is scheduled for November 2007. The terms of office for candidates nominated at this meeting will commence January 1, 2009.

Honorary Meritorious Awards

The Honorary-Meritorious Awards Committee makes recommendations for the nominees presented for Honorary Membership, National Meritorious Certificate, William Irrgang Memorial, and the George E. Willis Awards. These awards are presented during the FABTECH International & AWS Welding Show held each fall. The deadline for submissions is December 31 prior to the year of awards presentations. Send candidate materials to Wendy Sue Reeve, secretary, Honorary Meritorious Awards Committee, *wreeve@aws.org;* 550 NW LeJeune Rd., Miami, FL 33126. Descriptions of the awards follow.

National Meritorious Certificate Award: This award is given in recognition of the candidate's counsel, loyalty, and devotion to the affairs of the Society, assistance in promoting cordial relations with industry and other organizations, and for the contribution of time and effort on behalf of the Society.

William Irrgang Memorial Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor the late William Irrgang. It is awarded each year to the individual who has done the most over the past five-years to enhance the American Welding Society's goal of advancing the science and technology of welding.

George E. Willis Award: This award is administered by the American Welding Society and sponsored by The Lincoln Electric Co. to honor George E. Willis. It is awarded each year to an individual for promoting the advancement of welding internationally by fostering cooperative participation in areas such as technology transfer, standards rationalization, and promotion of industrial goodwill.

International Meritorious Certificate Award: This award is given in recognition of the recipient's significant contributions to the worldwide welding industry. This award reflects "Service to the International Welding Community" in the broadest terms. The awardee is not required to be a member of the American Welding Society. Multiple awards can be given per year as the situation dictates. The award consists of a certificate to be presented at the awards luncheon or at another time as appropriate in conjunction with the AWS president's travel itinerary, and, if appropriate, a one-year membership in the American Welding Society.

Honorary Membership Award: An Honorary Member shall be a person of acknowledged eminence in the welding profession, or who is accredited with exceptional accomplishments in the development of the welding art, upon whom the American Welding Society sees fit to confer an honorary distinction. An Honorary Member shall have full rights of membership.

AWS Publications Sales

Purchase AWS standards, books, and other publications from World Engineering Xchange (WEX), Ltd.
Toll-free (888) 935-3464 (U.S., Canada)
(305) 824-1177; FAX (305) 826-6195
www.awspubs.com

Welding Journal Reprints

Copies of *Welding Journal* articles may be purchased from Ruben Lara.
Call toll-free
(800/305) 443-9353, ext. 288; *rlara@aws.org*

Custom reprints of *Welding Journal* articles, in quantities of 100 or more, may be purchased from
FosteReprints
Toll-free (866) 879-9144, ext. 121
sales@fostereprints.com

AWS Foundation, Inc.

The AWS Foundation is a not-for-profit corporation established to provide support for educational and scientific endeavors of the American Welding Society. Information on gift-giving programs is available upon request.

550 NW LeJeune Rd., Miami, FL 33126
(305) 445-6628; (800) 443-9353, ext. 293
e-mail: *vpinsky@aws.org*
general information:
(800) 443-9353, ext. 689

AWS Mission Statement

The mission of the American Welding Society is to advance the science, technology, and application of welding and allied processes, including joining, brazing, soldering, cutting, and thermal spraying.

It is the intent of the American Welding Society to build AWS to the highest quality standards possible. The Society welcomes your suggestions. Please contact any staff member or AWS President Gerald D. Uttrachi, as listed on the previous page.

Conference on Weld Cracking
Las Vegas • Imperial Palace Hotel & Casino
October 16-17, 2007

Weld cracking was brought to the attention of government, engineers, and the public during World War II, when incidents of cracking appeared in the mass-produced Liberty ships that were used to deliver our troops to the battlefield. Metallurgists propelled to investigate the causes of the cracking and to find solutions. But the interest in cracking did not stop there. The metallurgists dug deeper and found that the problem was more widespread than just Liberty ships. They discovered that welds are made up of three constituents—the base metal, the weld itself, and something called the heat-affected zone (HAZ). And it was in the HAZ where many cracks were initiated. Often, the HAZ and weld cracking can go hand in hand.

Much has been learned about weld cracking over the years, and most of it has been put to use in plants and infrastructure throughout the world. But industry continues to develop new materials and new welding processes, so cracking can arise in new and unexpected ways.

The latest AWS-sponsored conference on the subject, Weld Cracking 6, will take place in Las Vegas on October 16-17, 2007. Fourteen experts will be on hand to discuss the many types of cracking that take place in welds, the causes, and best of all, the solutions, many of which are very interesting.

Experts will speak on the cracking situations facing numerous materials, including stainless steel, aluminum, titanium, nickel-base superalloys, and the latest popular material, grade 91 steel.

Cracking and Heat Treatment Problems in Grade 91 Welds
Jeffrey Henry, Associate, Structural Integrity Associates, Inc., Chattanooga, Tenn.

Weld Cracking of Stainless Steel and Nickel Alloys—Causes and Cures
Donald J. Tillack,Tillack Metallurgical Consulting, Inc., Consultant to the Nickel Institute, Catlettsburg, Ky.

Avoid Hot Cracking in Aluminum Welds
William Hamilton, Quality Assurance Manager, AlcoTec Wire Corp., Traverse City, Mich.

How to Avoid Cracking in Titanium Welds
John Lawmon, Principal Engineer, American Engineering & Manufacturing, Inc., Sheffield, Ohio

A Gleeble-Based Method for Ranking the Strain-Age Cracking Susceptibility of Nickel-Base Superalloys
David A. Metzler, Senior Mechanical Metallurgist, Haynes International, Kokomo, Ind.

Characterization of the Number and Sizes of Flaws in Reactor Pressure Vessel Welds
Fredric A. Simonen, Laboratory Fellow, Engineering Mechanics Group, Pacific Northwest National Laboratory, Richland, Wash.

Practical Weld Failure Analysis, and Repair Procedure Development for Cyclically Loaded Structures
Alma Olsen, Welding Engineer and Owner, ARO Testing, Parma, Idaho

Quality Improvements in Heat Treatment
Gary Lewis, Director of Business Development, Superheat FGH, Mooresville, N.C.

Measuring Residual Stress Using X-Ray Diffraction
Robert Drake, Physicist, Proto Manufacturing Ltd, Oldcastle, Ontario

Prediction of Hydrogen Cracking Delay Time to Define Inspection Delay
Aaron Dinovitzer, President and Principal Engineer, BMT Fleet Technology, Ltd., Kanata, Ontario

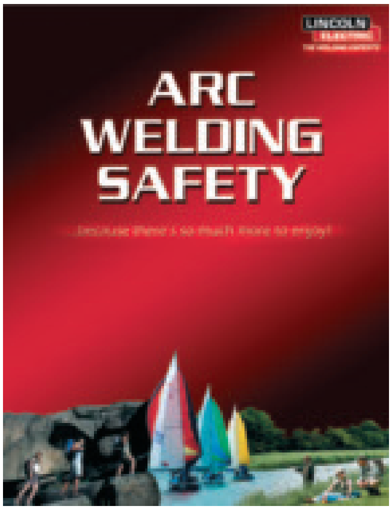
Weldability Tests: The Best Way to Prevent Cracking
Bruce Madigan, Assistant Professor, Welding Engineering, General Engineering Department, Montana Tech of The University of Montana,Butte, Mont.

Fracture Mechanics—Operating with Defects
Kyle Koppenhoefer, Principal, Advanced Computational and Engineering Services, Gahanna, Ohio

Semiautomated Ultrasonic Testing for Solidification Cracking in High Nickel Alloy Butt Welds
Ronald W. Kruzic, Corporate QA/NDE Consultant, Chicago Bridge & Iron Company, Plainfield, Ill.

Experience with Alloy 52M Temperbead Weld Overlays on Dissimilar Metal Welds of PWR Pressurizer Nozzles
Richard E. Smith, PhD, Associate, Structural Integrity Associates, Inc., Mooresville, N.C.

Arc Welding Safety Guide Updated

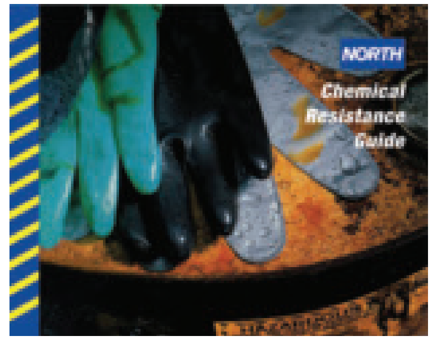


Published continuously since 1922, the updated 24-page *Arc Welding Safety Guide* (E205) explains safety issues relating to arc welding in a straightforward way. It incorporates recommended safe practices for the shop floor. Written with the welder in mind, the topics include personal protective equipment, arc rays, noise, inspecting and maintaining equipment and workplaces, handling gas cylinders, shock hazards, fire risks, fume and gas ventilation, and many other topics. The guide may be used to train and remind welders about the safe practices they should follow daily. The guide can be downloaded from *content.lincolnelectric.com/pdfs/products/literature/e205.pdf.*

The Lincoln Electric Co.
www.lincolnelectric.com
(216) 481-8100

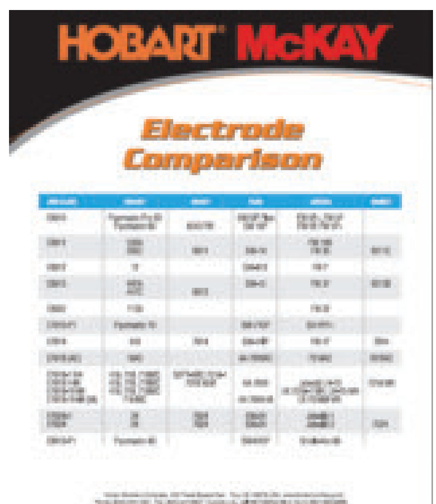
Chemical-Handling Gloves Illustrated

The company's complete lines of chemical-handling gloves are displayed in an 8-page, color-coded chart format that guides the reader through the glove-selection process. Gloves are specified for protecting the hands from 138 potentially hazardous chemicals. Featured types include Viton® gloves to resist chlorinated and aromatic solvents; Silver Shield®/4H® gloves resistant to more than 280 chemicals, butyl gloves recommended for use with gas and water vapors, Chemsoft® industrial gloves for dexterity in picking up small parts, NitriGuard unsupported nitrile gloves for superior resistance to cuts, punctures, and abrasions, and natural rubber gloves with embossed palm and fingers for wet grip and comfort. The guide can be downloaded from *www.linkpath.com/data/issuePDF/N-USA16/8500000370-N-USA16.pdf.*



North Safety Products
www.northsafety.com
(800) 430-4110

Hardfacing Product Guide Posted on Internet

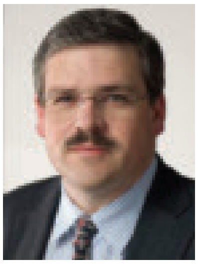


A one-page hardfacing electrode comparison chart lists 15 AWS classifications with the products manufactured by Hobart, McKay, ESAB, Lincoln Electric, and Murex. Suitable for hanging on the shop wall, the guide can be downloaded from *www.hobartbrothers.com/pdf/support/Competitive_Comparison.pdf.*

Hobart Brothers Co.
www.hobartbrothers.com
(800) 424-1543

— continued on page 82

MAG Industrial Automation Appoints President



Robert Wassmer

MAG Industrial Automation Systems, Sterling Heights, Mich., has appointed **Robert Wassmer** president. Prior to joining the company, Wassmer was director of research and development at the Locomotive and Freight division at Bombardier Transportation.

Sales VP Appointed at NanoSteel

The NanoSteel Co., Inc., Providence, R.I., a producer of nano-structured steel alloy materials, has appointed **David Hart** as vice president of sales — welding products, focusing on the company's hardfacing products. Hart previously worked for Wall Colmonoy Corp. as marketing and sales manager.

Sales Manager Named at Applied Mfg. Technologies

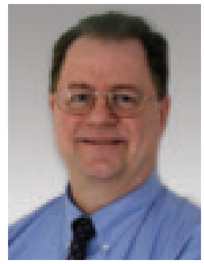
Jordan Merhib

Applied Manufacturing Technologies, Orion, Mich., has appointed **Jordan Merhib** sales manager. Merhib, who brings 20 years of industrial experience to the job, is responsible for worldwide sales of factory automation engineering, design, and consulting services.

FMA Names Directors

The Fabricators & Manufacturers Assn., Rockford, Ill., has elected **Matthew Hotch, Bryan Hawkins, Cynthia VanderWaal, Marcia Arndt,** and **Jeffrey Knauf** to its board of directors for a two-year term on the nine-member board. Hotch is president of Matt Hotch Designs, a motorcycle business. VanderWaal is a marketing manager for Roper Whitney, Inc. Arndt is dean of manufacturing technology at Moraine Park Technical College. New members Hawkins and Knauf are the presidents of Hawkeye Industries, Inc., and Medalist Laserfab, Inc., respectively.

Director of Training Appointed at MISTRAS



Michael Allgaier

MISTRAS Group, Inc., Princeton Junction, N.J., has named **Michael Allgaier** director of training and certification. For the past five years, Allgaier worked for GE Inspection Technologies as training manager and inspection services QA manager.

Tregaskiss Names Two Specialists

Tregaskiss Welding Products, Windsor, Ont., Canada, has named **Mark Morgan**

Member Milestones

Blodgett Receives His Alma Mater's Highest Honor

Omer W. Blodgett (center) received the University of Minnesota's highest honor, its Outstanding Achievement Award, on May 4. Shown with him are university Regent Patricia S. Simmons and Steven L. Crouch, dean, Institute of Technology.

Omer W. Blodgett was presented the University of Minnesota's highest honor, its 2007 Outstanding Achievement Award. He was formally recognized during the Department of Civil Engineering graduation ceremony on May 4 in Minneapolis. His citation reads:

Distinguished graduate of the University of Minnesota. Acclaimed senior design consultant, Lincoln Electric Co., Cleveland, Ohio.

Honored Fellow of the American Society of Civil Engineers and the American Society of Mechanical Engineers; and Honorary Member of the American Welding Society and Ironworkers Local 563, Duluth, Minnesota.

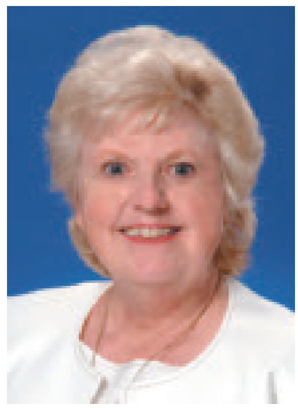
Preeminent author of texts that formed the foundations for the field of welding design, and of industry codes and standards for the American Welding Society and the American Institute of Steel Construction.

Resourceful pioneer whose lifelong research and contributions to education and the promotion of national safety and inspection standards have improved the safe and economical use of structural steel across our nation's construction industry.

Dr. Blodgett, an AWS member since 1938, and an AWS Fellow, is well known for his texts *Design of Weldments,* and *Design of Welded Structures,* and his courses on welding design.

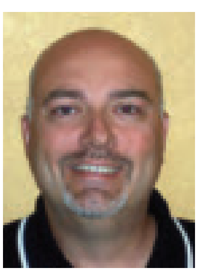
He received the AWS A. F. Davis Silver Medal Award for best papers contributing to the progress of structural design in 1962, 1973, 1980, and 1983.

Nancy Cole Receives UT's Highest Engineering Honor



Nancy Cole

Nancy Cole received the Nathan W. Dougherty Award, the highest honor bestowed by the University of Tennessee's Engineering Dept. Cole was the first woman to graduate from the university's metallurgical engineering program with a bachelor's degree in 1963, and a master's in 1988. She began her career at Oak Ridge National Laboratory (ORNL) researching corrosion on metals. Later she joined ORNL's welding and brazing laboratory where she researched the joining of stainless steels, refractory metals, and ceramics. She worked for Combustion Engineering for 17 years before returning to ORNL in 1991 as manager of fossil energy materials. More recently, she formed her own company to provide technical assistance with joining techniques and procedures. She and her husband established the Leon and Nancy Cole Outstanding Teacher Award that UT has given annually for the past 20 years. Cole has served AWS in many capacities since joining the Society in 1967. She is an Honorary Member, an AWS Fellow, and currently serves as a Director-at-Large. She has received the Prof. Dr. Rene Wasserman Memorial Award and the McKay-Helm Award.



Mark Morgan

Judy Wilson

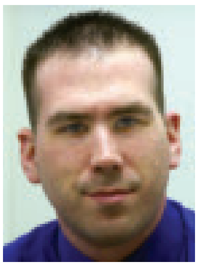
customer training specialist, and **Judy Wilson** customer service specialist. Morgan, with 20 years of industry experience, is responsible for the company's Mid-West and Pacific Northwest regions. Wilson has 20 years of experience in accounting and customer service.

Defayette Joins Bosch Rexroth Marketing Team


Amy Defayette

Bosch Rexroth Corp., Buchanan, Mich., has announced the addition of **Amy R. Defayette** to product marketing for its VarioFlow™ conveyor product line. Defayette brings years of product management experience to the position.

Western Designates Product Marketing Manager


Steve Varga

Western, a Scott Fetzer Co., Westlake, Ohio, a provider of high-pressure gas technology, has named **Steve Varga** product marketing manager. Varga previously worked for The Lincoln Electric Co. and The Home Depot.

Obituaries

John J. Stephens Jr.

John J. Stephens Jr., 51, died March 22 in Palo Alto, Calif., after a long illness. He was a Principal Member of the technical staff in the Materials Science and Engineering Center at Sandia National Laboratories in Albuquerque, N.Mex. Dr. Stephens had a distinguished career in physical and mechanical metallurgy during the 20 years he worked at Sandia. He received his bachelor's degree in physics from Cornell University in 1977, master's in metallurgy from Stevens Institute of Technology in 1980, and PhD in materials science from Stanford University in 1984, under the advisement of Dr. William D. Nix. Dr. Stephens was a member of the American Welding Society, ASM International, American Society for Testing and Materials, and The Minerals, Metals, and Materials Society. He served on the AWS C3 Committee on Brazing and Soldering, other C3 subcommittees, and A5H Subcommittee on Brazing Filler Metals and Fluxes. Dr. Stephens was a founding organizer for the International Brazing & Soldering Conferences held in 2000, 2003, and 2006, and was coeditor of the 2006 proceedings. He published and presented numerous papers on his research in the areas of active metal brazing and soldering. He was a Fellow of ASM International, and received the Robert L. Peaslee Brazing Award in 2000 and 2001.

Richard Otto Drossman


Richard Drossman

Richard Otto Drossman, 81, died May 5 in Sewickley, Pa. An AWS member for 48 years, he served on the C2 Committee on Thermal Spraying, and was an advisor to the D11 Committee on Welding Iron Castings. During WW II, he served in the U.S. Air Force. Mr. Drossman was a lifelong resident of Beaver County, Pa. He was an accomplished businessman who worked until a week before his death as president of Wear Management Services, Inc., and as a partner in the operation of Surface Engineering in Aliquippa, Pa. He was the creator of Tribolite™, a registered trademark, and held U.S. patents for the Tribolite thermal spray powder and tubular metal core wires. Mr. Drossman also invented self-lubricating cladding alloys used in aluminum pusher furnaces. He is survived by his wife, Jeanne, a daughter, five grandchildren, and a brother.

Cecil Bailey


Cecil Bailey

Cecil Bailey, 83, died March 31 in Ridley Park, Pa. He was a past chairman of the AWS Philadelphia Section. During WW II, he served as an Army Air Corps pilot in the China-Burma-India theater. He was awarded the Asiatic Pacific Theater Ribbon with four battle oak leaf clusters, the Distinguished Flying Cross with two oak leaf clusters, the Air Medal with three oak leaf clusters, the American Victory Medal, and the Air Force Medal. His Third Combat Cargo Squadron (10th Air Force) was awarded a Presidential Unit Citation for meritorious service. Mr. Bailey earned his degree in mechanical engineering from Bucknell University. He was retired from General Electric Co. Switchgear Plant in Philadelphia, Pa., where he served as manager of welding engineering. While there he was granted ten U.S. patents. He was a member of the American Society of Mechanical Engineers, and American Vacuum Society. He served as a past high priest of the Masonic Ivanhoe Royal Arch Chapter and was a past commander of the American Legion, Vandiver-Moylan Post #355 in Bala Cynwyd, Pa. Mr. Bailey is survived by a daughter, a sister, and two grandchildren.

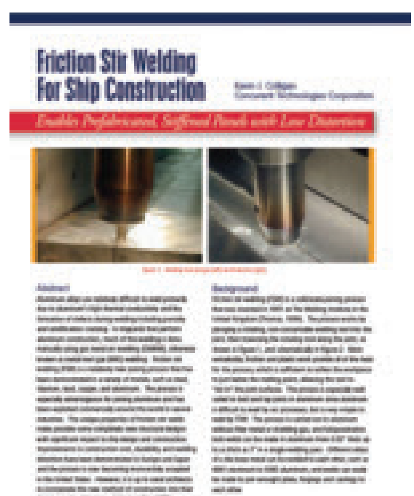
NEW LITERATURE

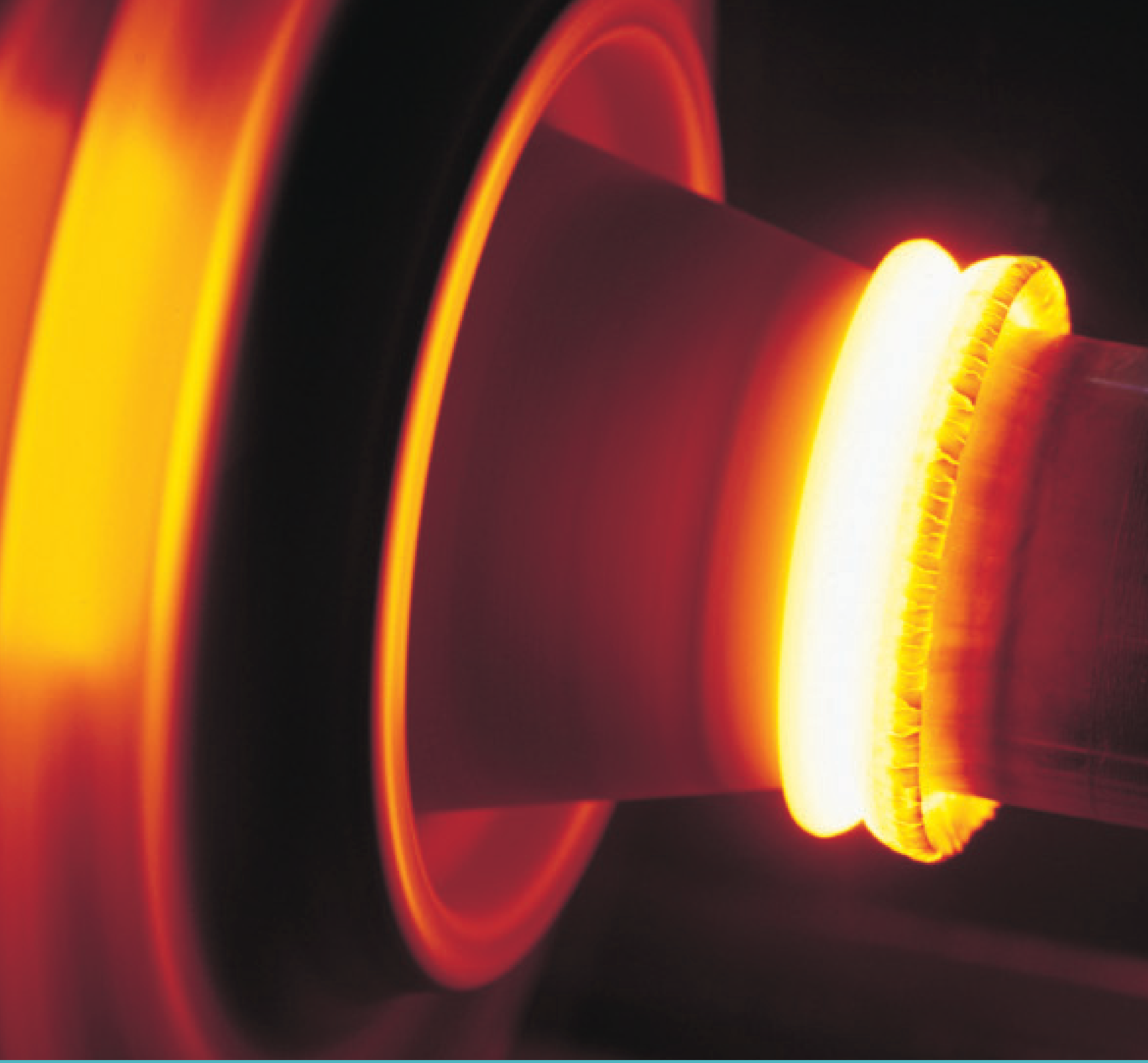
— continued from page 78

Friction Stir Welding for Shipbuilding Explained

Friction Stir Welding for Ship Contruction, subtitled *Enables Prefabricated, Stiffened Panels with Low Distortion,* written by Kevin J. Colligan as part of the Navy ManTech Program, is a 6-page discussion of the friction stir welding (FSW) process with full-color illustrations. The history of the process is presented in considerable detail along with specifics for its applications for joining aluminum parts used for stiffening bulkheads, decks, and hulls. A chart compares FSW with gas metal arc welding for ultimate tensile strength, yield strength, and elongation, with a sketch comparing arc welds with FS welds. It concludes that FSW is desirable for its characteristically low distortion, ability to join extrusions into dimensionally accurate assemblies, and reducing the need for highly skilled aluminum welders. To download the paper, visit *www.nmc.ctc.com/Library/publications/FSW%20Ship%20Construction.pdf.*

Navy Metalworking Center, operated by **Concurrent Technologies Corp.**
www.nmc.ctc.com
(717) 565-4405





The AWS Foundation is proud to announce its 2007-2008 National Scholarship Recipients

Howard E. and Wilma J. Adkins Memorial Scholarship

Richard Baumer
LeTourneau University
Materials Joining Engineering

"I am greatly honored to have received the Howard E. and Wilma J. Adkins Memorial Scholarship. I appreciate the support the AWS Foundation provides, and I look forward to continuing my education in the field of materials joining engineering."

Airgas–Jerry Baker Scholarship

Leland Kienbaum
Ferris State University
Welding Engineering Technology

"I am honored to be the recipient of the 2007-2008 Airgas–Jerry Baker Scholarship. I would like to thank the American Welding Society scholarship committee for selecting me as this will truly help me achieve all my goals to become a welding engineer."

Airgas–Terry Jarvis Memorial Scholarship

Joseph Walko
The Ohio State University
Welding Engineering

"I feel very honored to be awarded the Airgas–Terry Jarvis Memorial Scholarship. I would like to thank the American Welding Society and Airgas for their support and generosity. I plan to continue my studies at The Ohio State University and hope that I can be an asset to the welding community in the future."

Each year, the American Welding Society Foundation provides scholarship funds to help hundreds of students who otherwise would be unable to afford a welding education. We are the only industry foundation with the specific mission of helping to fund the education of welding students. In so doing, we create the careers that sustain and grow our industry.

We get these funds from your contributions. The more you contribute, the more students we can help educate.

To make a scholarship contribution or set up your own National Scholarship, contact Sam Gentry at the AWS Foundation. Call 800-443-9353, x331, or email to ***sgentry@aws.org***.

Thank you for your continued support.

William A. and Ann M. Brothers Scholarship

Daniel M. Gipson
Ferris State University
Welding Engineering Technology

"I am honored to be the recipient of the William A. and Ann M. Brothers Scholarship. I would like to thank Mr. and Mrs. Brothers and the AWS Foundation for their contribution to my education. It is a great encouragement to know that the future of welding is so highly valued."

Donald F. Hastings Scholarship

Stephanie J. Irvine
Pennsylvania College of Technology
Welding & Fabrication Engineering Technology

"The moment I was named the recipient of the Donald F. Hastings Scholarship was the moment I realized dreams do come true. With help from this scholarship my ultimate dream of earning my bachelor's degree in welding fabrication and engineering will come true after all.Thank you all—my future is looking bright because of you."

Donald and Shirley Hastings Scholarship

Jerica L. Cadman
LeTourneau University
Materials Joining Engineering

"What a blessing (again!) it is to receive the Donald and Shirley Hastings Scholarship! I thank God for the many ways he has provided opportunities and funds for my education. I anticipate being able to give back to others like me. Thank you!"

John C. Lincoln Memorial Scholarship

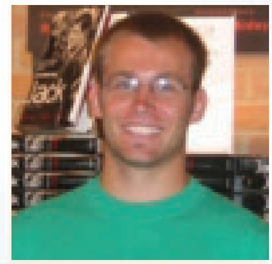
Anna M. Wolfgang
LeTourneau University
Materials Joining Engineering

"It is an honor to be the recipient of the John C. Lincoln Memorial scholarship, and a great encouragement towards my academic pursuits. I would like to thank the American Welding Society for all of their support in helping students achieve their academic goals."

Matsuo Bridge Company Ltd. of Japan Scholarship

Martin Denault
Pennsylvania College of Technology
Welding & Fabrication Engineering Technology

"I am honored to receive the Matsuo Bridge Company Ltd. of Japan Scholarship. I would like to thank the American Welding Society Foundation for awarding me this scholarship and helping me to further my education as a welding engineer."



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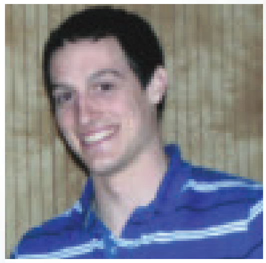

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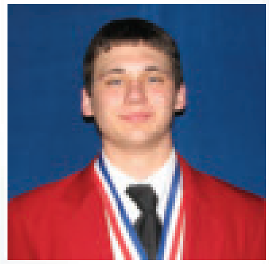

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"It is both an honor and privilege to have received the William B. Howell Memorial Scholarship. Recognition from such a prestigious organization as AWS provides me the drive to succeed in my educational goals. It is wonderful to know that individuals other than professors or parents believe in my abilities as a student, person, and professional."

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Welding Engineering Technology

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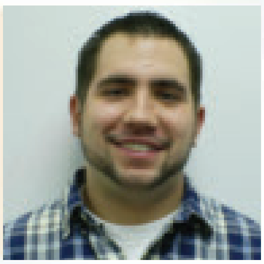

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WELDING RESEARCH

SUPPLEMENT TO THE *WELDING JOURNAL*, JULY 2007
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Comparison of Friction Stir Weldments and Submerged Arc Weldments in HSLA-65 Steel

Friction-stir weldments in HSLA-65 steel made on a production-size machine using a W-Re tool exhibited satisfactory mechanical properties and minimal transverse weld distortion

BY P. J. KONKOL AND M. F. MRUCZEK

ABSTRACT. Friction stir welding (FSW) is of interest to the shipbuilding community because of the need to reduce weld distortion in thin structures to improve fairness. The project objectives were to evaluate FSW tools and equipment, develop procedures, and demonstrate the feasibility of FSW 0.25-in.- (6-mm-) thick HSLA-65 steel weldments fabricated from 10-ft- (3-m-) long plate sections, on a production-size, purpose-built FSW machine. Measurements were taken to compare the amount of weld distortion with that of a conventional submerged arc weldment (SAW). In addition, the mechanical properties and microstructures of the weld regions were evaluated to further compare the two welding processes.

Two types of tool materials were evaluated: a polycrystalline cubic boron nitride (PCBN) tool and a tungsten-25% rhenium (W-25%Re) tool. W-Re was evaluated as a pin material in a two-piece FSW tool using a Mo-1%Ti-0.3%Zr-0.15%C (Mo-TZM) shoulder. The W-Re pin performed well with minimal wear, but the Mo-TZM shoulder wore excessively during fabrication of the 10-ft weldment. Transverse and longitudinal weld distortion measurements were obtained on a usable 6.0-ft (1.8-m) length of this weldment and compared to those of a similar length of the submerged arc weldment. Transverse weld tensile, Charpy V-notch (CVN) impact and guided bend tests were obtained from the W-Re friction stir and submerged arc weldments.

Both the friction stir and submerged arc weldments exhibited significant longitudinal weld distortion. The submerged arc weldment was bowed in the transverse direction, while the friction stir weldment exhibited no transverse distortion. The transverse weld tensile strengths of both weldments were acceptable, and the CVN toughness of the FSW stir zone was significantly higher than that of the submerged arc weld metal. There was little difference in heat-affected-zone toughness.

The present trials indicate that FSW is technically feasible for joining HSLA-65 steel for structural applications.

P. J. KONKOL and M. F. MRUCZEK are with Concurrent Technologies Corp. (CTC), Johnstown, Pa.

Introduction

Friction stir welding (FSW) is a welding process that reportedly results in less weld distortion than does arc welding. It has been successfully applied to the joining of aluminum and other relatively low-melting-temperature metals; however, the application of FSW to joining high-melting-temperature metals such as steel is more challenging due to the higher operating temperatures (typically 1000°–1200°C [1830°–2190°F]) that the tools have to withstand, as well as the lower thermal conductivity and higher material flow stress in some cases. Thus, refractory metals or ceramics are being evaluated for use as tool materials for FSW of steels. FSW of steels has been conducted by several researchers (Refs. 1, 2), but these trials were generally conducted on short weld lengths in a laboratory setting.

KEYWORDS

Friction Stir Weld
FSW
High-Strength Steel
HSLA-65
SAW
Shipbuilding
Submerged Arc Welding

HSLA-65 (ASTM A 945) is a high-strength, low-alloy steel with 65-ksi (448-MPa) specified minimum yield strength that has been approved by the U.S. Navy as a substitute for conventional higher-strength steels such as DH-36 (51 ksi or 351 MPa yield strength) for ship structures to reduce weight and/or allow higher design loads. Most of the steel used in shipbuilding is joined as structural assemblies that are welded on panel lines. A substantial quantity of plates will be as thin as 0.25 in. (6 mm). Production experience indicates that weld distortion increases substantially as component thickness decreases below 0.5 in. (13 mm). This results in increased fabrication costs due to the labor involved in distortion mitigation or correction.

HSLA-65 was first FS welded through an internal research project at Concurrent Technologies Corp. (CTC) and supported by The Welding Institute, Cambridge, UK (Ref. 3). Single-pass butt-joint welds in 0.25-in.- (6-mm-) thick plates and two-pass butt-joint welds in 0.5-in.- (13-mm-) thick plates were successfully made. These trials were conducted using a laboratory FSW facility and an early FSW tool made from tungsten-rhenium (W-Re) that exhibited significant wear after a short length of weld. Subsequent trials were conducted for CTC on EH-36 steel at Brigham Young University, Provo, Utah, and at MegaStir, Provo, Utah, on high-

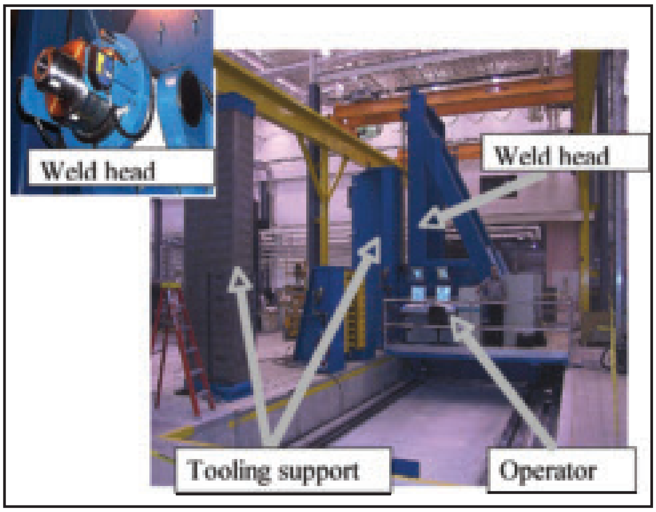

Fig. 1 — Friction stir welding facility at CTC in Johnstown, Pa.

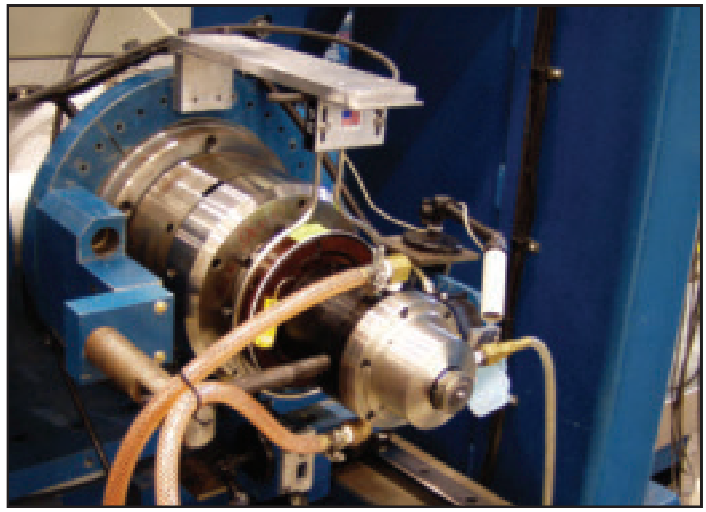

Fig. 3 — PCBN tool assembly in place.

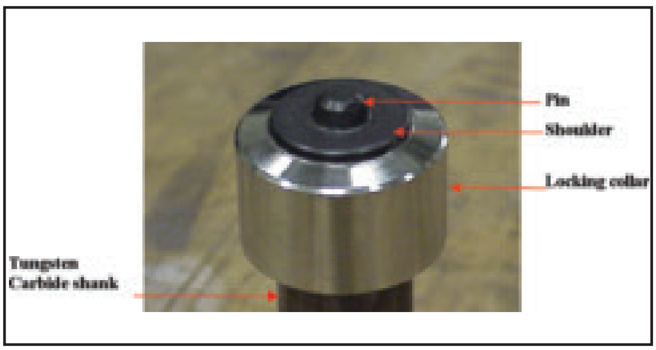

Fig. 2 — Details of PCBN tool used in FSW.

hardness armor steel using a tool system of polycrystalline cubic boron nitride (PCBN) (Ref. 4).

The above welds were made on short lengths of steel using a rigid converted milling machine built to stringent machine tool tolerances. In order to demonstrate the feasibility of FSW steel for fabricating large structures, additional trials should be conducted on a production-size FSW system on longer weld lengths to evaluate tool durability.

For FSW of steel, the major benefit is the expected reduction of weld distortion. Preliminary trials on short (28 in. or 711 mm in length) welds in HSLA-65 showed that FSW resulted in less angular distortion than single-pass, gas metal arc welds (Ref. 5). However, distortion comparisons have not been demonstrated for longer welds.

The objective of this task was to determine the production process conditions leading to successful application of the FSW process for HSLA-65 in ship construction. This was accomplished by evaluating tool materials and equipment, developing procedures, demonstrating the feasibility of FSW long sections on a purpose-built FSW machine, measuring and comparing the amount of weld distortion with that of a conventional submerged arc weldment, and characterizing the mechanical properties and microstructures of the weld regions.

Experimental Procedure

FSW Machine

The production-scale FSW machine used at CTC is shown in Fig. 1. It was designed as a post and column type machine to avoid the size limitations of a gantry machine, and is capable of welding in a 13-ft vertical by 26-ft horizontal (4-m by 8-m) envelope. It has been used primarily to fabricate demonstration components of aluminum alloys for combat vehicles, but is flexible enough for other applications and process development. Most FSW equipment is not made to machine tool standards. Thus rigidity and tolerances are usually not as precise as in machine tools.

PCBN Tools and Equipment

The initial work on FSW of HSLA-65 steel (Ref. 3) was conducted using a tungsten-rhenium (refractory metal) tool. However, severe tool wear was encountered after a few feet of welding, which is considered a major impediment to FSW of steels in a shipyard environment. To

Table 1 — Chemical Composition of HSLA-65 Plate

Element	*CTC* Analysis[(a)]	ASTM A 945 Requirement
C	0.084	0.10 max
Mn	1.3	1.10–1.65
P	0.016	0.025 max
S	0.018	0.010 max
Si	0.01	0.10–0.50
Cu	0.09	0.35 max
Ni	0.028	0.40 max
Cr	0.05	0.20 max
Mo	0.01	0.08 max
V	0.056	0.10 max
Ti	0.008	—
Nb	0.031	0.05 max
Al	0.041	0.08 max

(a) Glow discharge spectrometer.

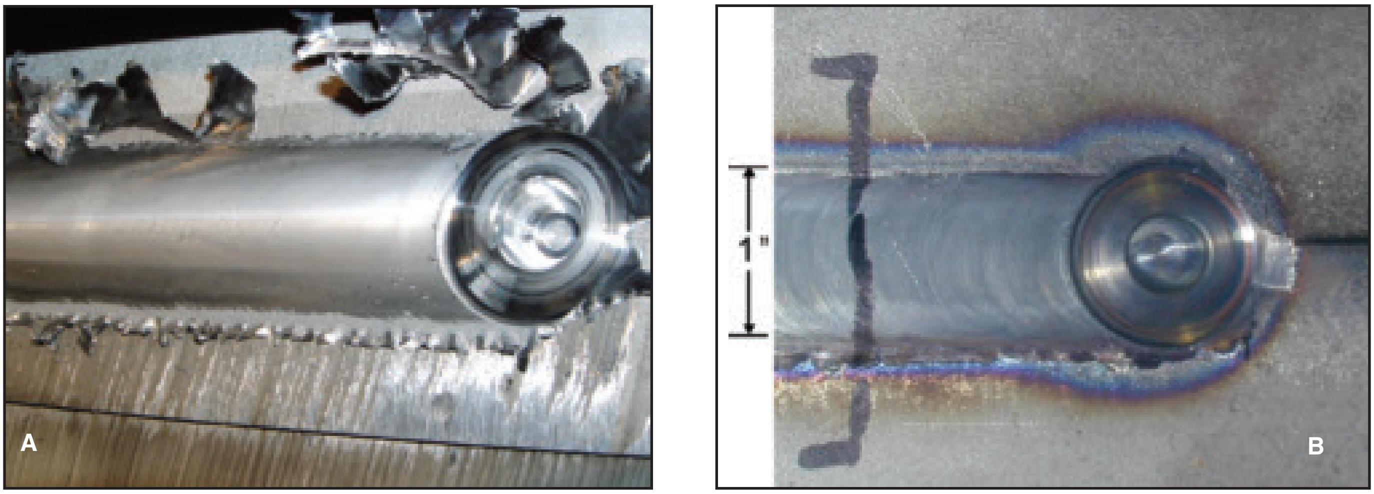

Fig. 4 — Appearance of FS welds in steel. A — With argon shielding; B — without argon shielding.

overcome such an impediment, a FSW tool made from polycrystalline cubic boron nitride (PCBN) has been developed for joining steel (Ref. 6) by MegaStir, a business alliance between Advanced Metal Products, West Bountiful, Utah, and Megadiamond, Provo, Utah. The high temperatures generated during FSW and differences in thermal expansion among the various materials in the welding tool required a special tool design for fastening the PCBN tool to the tungsten-carbide shank by a superalloy locking collar. The welding tool is shown in Fig. 2. A fluid-cooled tool holder is used to limit the temperature rise in the shank of the tool, thereby solving problems that were encountered with overheating of the shank during welding. Although the initial welds were made without external gas shielding, weld appearance was improved and tool life extended by use of an argon gas shroud to protect the weld region during welding. The limiting factor in PCBN tool life is currently considered to be tool breakage, which can occur if the tool is improperly plunged or extracted, if the operating temperature is too high or low, or if the tool system has excessive eccentricity or runout. Limited tool life trials at MegaStir have shown that PCBN tools should be useful for producing welds in steel that are several hundred feet in length.

A tool assembly, radio-frequency telemetry system for transmitting tool temperature, and several PCBN tools were procured from MegaStir. Tool temperature was measured by a thermocouple adjacent to the tool inside the shoulder. The spindle on CTC's machine is a modified 60-taper, thus an adapter was designed and machined to accommodate the existing 50-taper tool holder. The spindle and adapter were precision ground in place to minimize the tool runout. MegaStir emphasizes that an extremely low value of runout (less than 0.0003 in. or 0.008 mm) is required to prevent breakage of its PCBN tools. Runout as measured on the tool holder in the middle of its body on a ground surface was 0.0005 in. (0.013 mm) and was 0.0028 in. (0.071 mm) on the shaft of the PCBN tool. Thus, the runout was higher than recommended, but as suggested by MegaStir, satisfactory runout was demonstrated by successfully plunging a small-diameter carbide bit into a steel plate multiple times while held in the tool holder. Additionally, the CTC machine does not have the rigidity found in a milling machine; however, this is not considered a significant factor in tool life.

Initially, two tools were obtained with a pin length of 0.1765 in. (4.5 mm). Subsequently, four additional tools were obtained that were designed for welding 0.25-in.- (6-mm-) thick steel from one side. The latter tools were reportedly made from an improved grade of PCBN and had a pin length of 0.242 in. (6.15 mm).

The completed assembly installed on the CTC machine is shown in Fig. 3. The tool holder was cooled by use of an ethylene-glycol/water mixture circulated through an ice bath to extract heat from the coolant. Initial trials resulted in moderate oxidation of the weld surface; thus, an adapter was designed (not shown) to extend to the gas shroud so that the shroud would cover the entire length of the tool and provide better shielding of the weld region.

Argon inert gas shielding through the shroud surrounding the tool is not necessary, but it is recommended by MegaStir to improve weld quality and enhance tool performance. Comparisons of the surface appearances of two friction stir welds made at MegaStir with and without argon shielding are shown in Fig. 4.

W-Re Tools and Equipment

As a potential alternative to the PCBN tools, which are costly and susceptible to breakage, refractory metal tools were also evaluated. Various investigators reported that the most promising material is a tungsten-25% rhenium (W-Re) alloy. Earlier trials on one-piece W-Re FSW tools exhibited significant pin wear because the bar stock, made by cold isostatic pressing and sintering, contained porosity at the center region of the bar.

Table 2 — Friction Stir Welding Parameters

Groove	Tool Material	Pin Length	Spindle Speed, rpm	Travel Speed	Energy Input(a)
Square butt	W-25%Re pin Mo-TZM shoulder	0.235 in. (5.97 mm)	400	3 in./min (1.27 mm/s)	97 kJ/in. (3.82 kJ/mm)

(a) Calculated based on power, torque, and travel speed.

Fig. 5 — Photograph of two-piece refractory metal pin and shoulder assembly with locking screw.

Table 3 — Submerged Arc Welding Parameters

Groove	Electrode	Flux	Voltage	Current	Travel Speed	Energy Input
Square butt, 1⁄16-in. (1.6-mm) root opening	MIL-100S, 1⁄16-in. (1.6-mm) diameter	Lincoln 800H	28 V	400 A	20 in./min (8.5 mm/s)	33.6 kJ/in. (1.32 kJ/mm)

Table 4 — Transverse Tensile Properties of SAW and FSW in 0.25-in. (6-mm) HSLA-65

Code	Ultimate Tensile Strength (ksi)	0.2% Offset Yield Strength (ksi)	Original Gauge Length (in.)	Elongation Increase (%)	Reduction of Area (%)	Fracture Location
SAW1	87.7	73.0	2.00	14.5	52.0	Base Metal
SAW2	85.0	72.0	2.00	12.0	49.5	Base Metal
Mean	86.4	72.5	2.00	13.3	50.8	
FSW1	87.5	70.5	2.00	18.0	48.4	Base Metal
FSW2	86.1	69.2	2.00	16.5	55.3	Base Metal
Mean	86.8	69.8	2.00	17.3	51.9	

ksi × 6.89=MPa

Thus, the pin was located in the region of inferior material. The material vendor, Rhenium Alloys, Elyria, Ohio, recommended using a two-piece tool in which the shoulder can be made from a one-in.-diameter bar, and a pin can be made from a more highly compacted smaller diameter bar. A 1.25-in. (31.8-mm) diameter by 4.25-in.- (108.0-mm-) long piece of shoulder stock and 0.625-in. (15.9-mm) diameter by 4.75-in.-(120.7-mm-) long piece of pin stock were provided to CTC by Rhenium Alloys. The pin stock was machined into two 0.375-in.- (9.5-mm-) diameter pins. Machining of the shoulder stock was abandoned because of the difficulty of boring a hole for the pin and machining a threaded hole for a set screw to hold the pin in place.

To enable evaluation of the W-Re as a FSW pin material, a shoulder was obtained that was made of molybdenum TZM (Mo-1%Ti-0.3%Zr-0.15%C). This material had shown good wear performance in preliminary FSW trials. A photograph of the two-piece tool is shown in Fig. 5.

Plate Materials

A plate identified as HSLA-65 (ASTM A 945) steel, 10 ft × 20 ft × 0.25 in. (3 m × 6 m × 6 mm), was procured from a secondary steel supplier; thus, no information on mechanical properties or composition was supplied. Subsequently, chemical analysis of the plate material revealed that the S and Si in the steel did not meet A 945 requirements, as shown in Table 1. The high S and low Si would not be expected to have a significant effect on the FSW characteristics or degree of distortion; however, it would have an effect on mechanical properties. The plate was cut into several short panels for setup trials and several 10-ft × 6-in. (3-m × 152-mm) panels for process demonstration trials. The panels were cut by water jet to eliminate thermal distortion and provide a suitable square edge for a butt joint, and were subsequently grit blasted.

FSW Trials/PCBN Tools

The PCBN tools were used in various trials to validate the equipment setup and to establish suitable operating parameters. The plates to be welded were held by hydraulic clamps and welded in the vertical position with downward travel progression. A Type 304 stainless steel backing bar was positioned to support the backside of the weld. Several trials resulted in tool breakage; thus no satisfactory operating parameters were established.

W-Re TOOLS

Preliminary trials using the W-Re pins with the Mo-TZM shoulder were encouraging; thus, a trial was conducted to demonstrate the feasibility of making a 10-ft- (3-m-) long weld in HSLA-65 to evaluate tool life in a simulated production weld and to measure and compare weld distortion with that of a SAW weldment of similar length. The FS welding parameters are shown in Table 2. Figure 6 shows the FS weld in progress.

Submerged Arc Welds

To compare the FS weldments with conventional arc weldments, a pair of 10-ft- (3-m-) long HSLA-65 plates was joined by the submerged arc welding (SAW) process in a single pass using 1⁄16-in.- (1.6-mm-) diameter MIL-100S electrode, Lincoln 800H flux, and a square butt groove geometry. The plates were tack welded at 10-in. (254-mm) intervals with a 1⁄16 -in. (1.6- mm) root opening and held in place over a grooved copper backing bar by clamps. The submerged arc welding parameters are shown in Table 3.

Machining of Weldments for Characterization

Portions of the 10-ft- (3-m-) long SA and FS W-Re weldments were sectioned to obtain duplicate rectangular transverse-weld tensile specimens, ½-size Charpy V-notch (CVN) toughness specimen blanks, from the weld region and base metal, and a metallographic specimen. The tensile and CVN specimens were machined in accordance with ASTM A 370. The CVN blanks were etched and notched (five each) in the stir zone or weld metal, the weld interface, the heat-affected zone (HAZ) at 1 mm from the weld interface and the unaffected base metal. The CVN specimens were tested at –20°F (–29°C), which is the test temperature typically prescribed for consumables for welding HSLA-65. The polished transverse section of each weldment was photographed, along with a transverse section of a PCBN friction stir weldment.

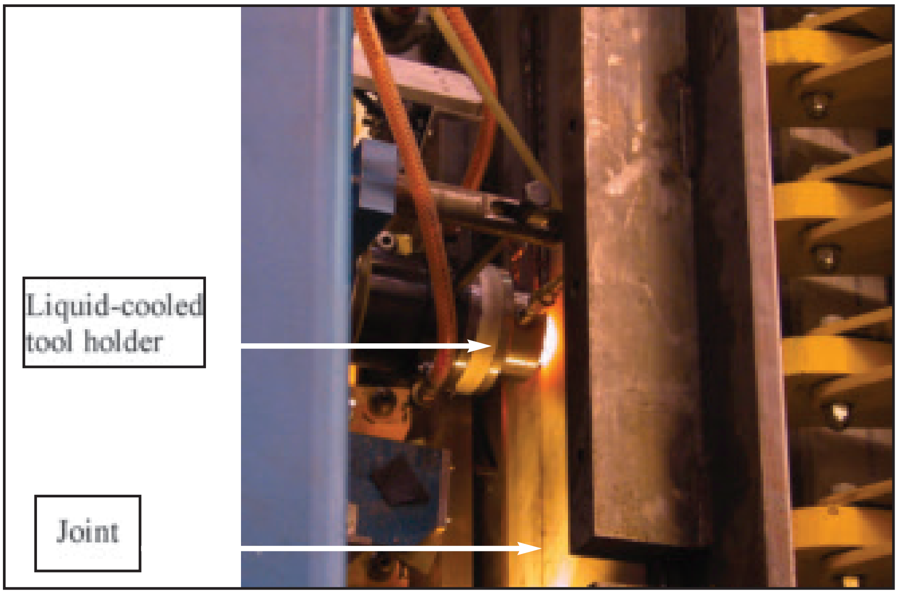

Fig. 6 — FSW of HSLA-65 with W-Re tool in progress.

Results and Discussion

PCBN Welding Trials

Varying degrees of success were experienced during establishment of process parameters when using the PCBN tools. Although the tools exhibited little or no wear when operated properly, they were sensitive to operating temperatures, which were difficult to control, especially whenever the thermocouple located behind the PCBN shoulder did not work properly. MegaStir recommended a tool temperature, as measured by the thermocouple, of 800°–900°C (1472°–1652°F). (Due to thermocouple location, this is not the actual tool temperature, which would be somewhat hotter.) In welds made at lower temperatures, tool breakage occurred. At higher temperatures, tool wear and/or separation of the PCBN insert from the locking collar were experienced. All of the available tools were consumed during process development; thus, CTC was unable to make a 10-ft- (3-m-) long weldment with the PCBN tools for comparison of tool life or comparison of distortion with the W-Re weldment or the submerged weldment.

A photograph of the weld surface of a PCBN FS bead-on-plate weld is shown in Fig. 7. There is a slight degree of surface oxidation compared to the gas shielded FS weld made at MegaStir — Fig. 4. The MegaStir weld was made in the flat position, whereas the CTC weld was made in the vertical position. Due to convection effects from the surrounding hot metal, the CTC weld may have had insufficient gas coverage.

W-Re Welding Trials

In general, the welding of the 10-ft (3-m) length of HSLA-65 with the two-piece refractory alloy tool (W-25%Re pin + Mo-TZM shoulder) was successful. The W-Re pin exhibited essentially no wear or change in length at the completion of the weld. The surface of a setup weld is shown in Fig. 8. The metal flash is attributed to excessive shoulder depth during welding. However, during welding of the 10-ft (3-m) joint the Mo-TZM shoulder did wear excessively during the trial, which was not observed during the shorter setup trials. This wear caused the tool to plunge deeper into the workpiece during welding and resulted in the W-Re pin penetrating through the HSLA-65 and into the backing bar after about six feet of welding. The length of weldment that was not fused to the backing bar was cut and the amount of distortion in a 6-ft (1.8-m) length was measured, as will be described later.

Weld Distortion

The amount of longitudinal distortion in both the original 10-ft (3-m) W-Re FS weldment and the SA weldment can be seen in Fig. 9. At first it appears that the FSW exhibits less overall distortion than the SAW. However, as described previously, the final 4 ft of weld was welded to the backing bar, which would provide additional restraint. To directly compare the distortion of the 10-ft (3-m) SA weldment with that of the 6-ft (1.8-m) FS weldment, the final four feet of both the FS and the SA weldments were removed and the lon-

Table 5 — CVN Toughness of SAW and FSW in 0.25-in. (6-mm) HSLA-65

Material	Location	Test Temperature, °F	Specimen Size, in.	CVN Toughness ft-lb	Shear %
SAW	Weld metal	–20	1/2	13	47
SAW	Weld interface	–20	1/2	12	57
SAW	HAZ 1-mm	–20	1/2	9	47
FSW	Stir zone	–20	1/2	55	76
FSW	Weld interface	–20	1/2	10	52
FSW	HAZ 1-mm	–20	1/2	12	61
Base Metal	Plate, Transverse	–40	1/2	7	41

ft-lb × 1.356=J

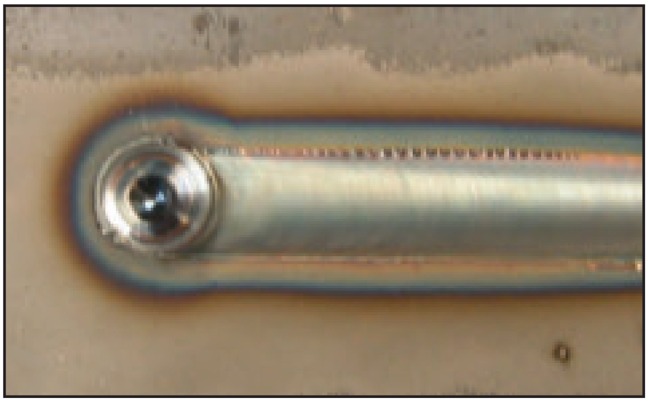

Fig. 7 — Appearance of a FS bead-on-plate weld in HSLA-65 with PCBN tool.

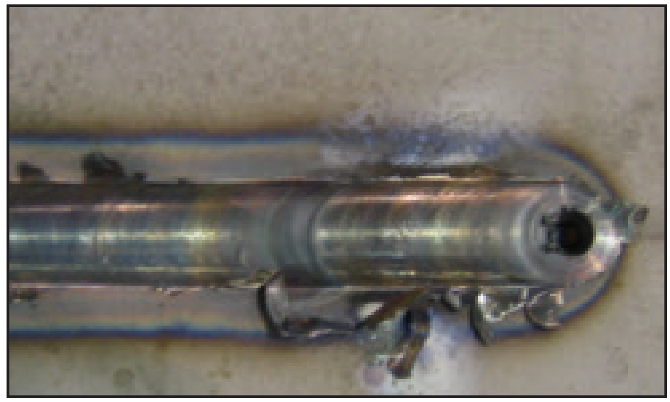

Fig. 8 — Appearance of weld surface in 0.25-in.- (6-mm-) thick HSLA-65 FSW weldment using W-Re tool.

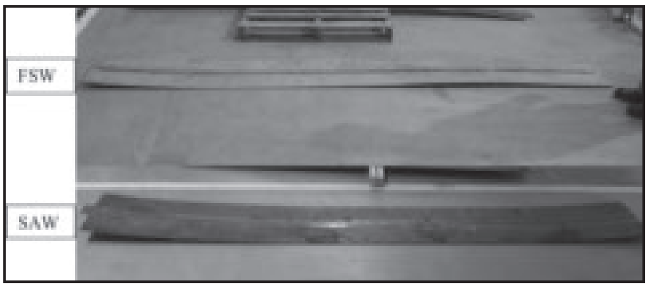

Fig. 9 — Completed 10-ft- (3-m-) long, 0.25-in.- (6-mm-) thick HSLA-65 weldments.

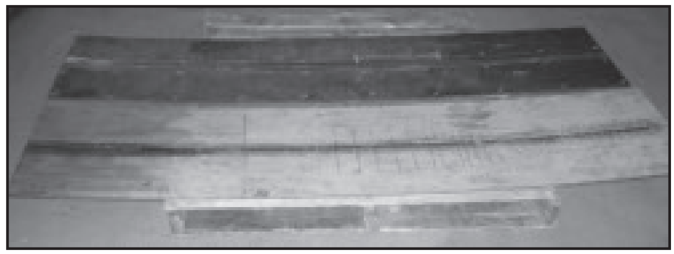

Fig. 10 — Appearance of 0.25-in.- (6-mm-) thick × 6-ft- (1.8-m-) long SA (top) and FS (bottom) weldments in HSLA-65.

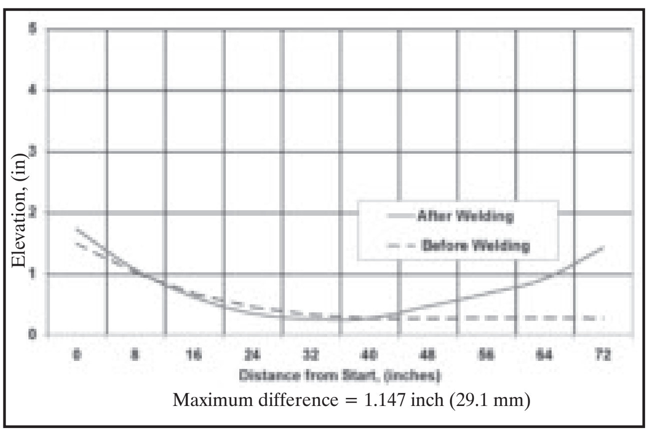

Fig. 11 — Longitudinal distortion in 6-ft (1.8-m) length of 0.25-in.- (6-mm-) thick HSLA-65 FS weldment.

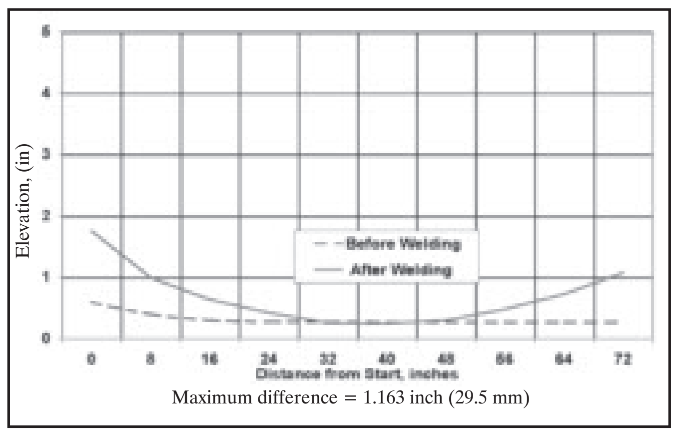

Fig. 12 — Longitudinal distortion in 6-ft (1.8-m) length of 0.25-in.- (6-mm-) thick HSLA-65 SA weldment.

gitudinal distortion was remeasured. The results are shown in a side-by-side comparison in Fig. 10.

An additional complicating factor is that the unwelded plates also exhibited longitudinal distortion prior to welding. The before-and-after distortion measurements for FSW and SAW are shown in Figs. 11 and 12, respectively. The initial distortion was subtracted from the final distortion measurements, and was 1.15 in. (29.21 mm) for FSW and 1.16 in. (29.46 mm) for SAW. Thus, for this trial, there was essentially no difference in longitudinal distortion between the two weldments. However, others (Ref. 7) have determined that longitudinal distortion is dependent on FS welding parameters; thus, longitudinal distortion could likely be improved by proper selection of process parameters.

However, there was a substantial improvement in transverse distortion with the FSW process. Distortion readings were obtained using the top plate surface as a reference point. As shown in Figs. 13 and 14, the SA weldment exhibited a 0.090-in. (2.29-mm) reverse bow across the 12-in.- (305-mm-) wide weldment; whereas, the FS weldment remained essentially flat.

Mechanical Properties

The results of transverse weld tension,

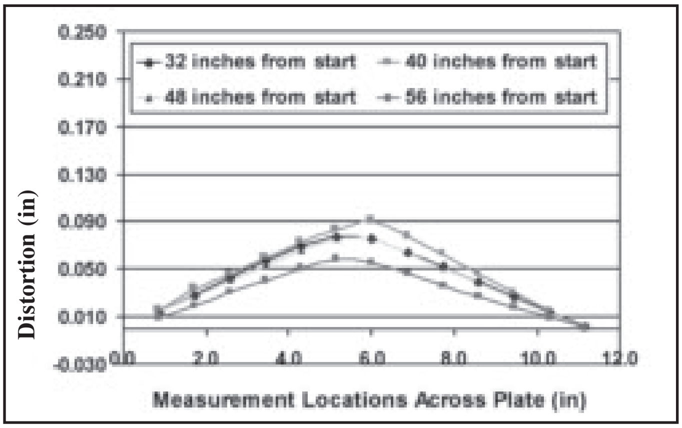

Fig. 13 — Transverse distortion in 6-ft (1.8-m) length of 0.25-in.- (6-mm-) thick HSLA-65 SA weldment.

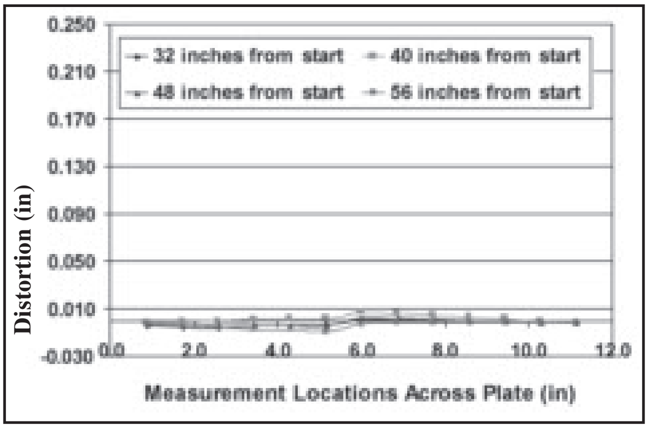

Fig. 14 — Transverse distortion in 6-ft (1.8-m) length of 0.25-in.- (6-mm-) thick HSLA-65 FS weldment.

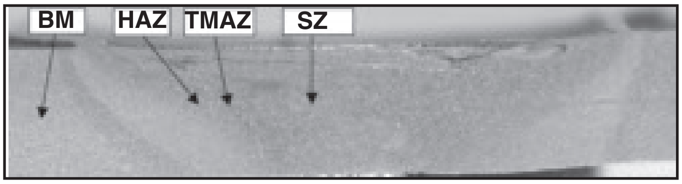

Fig. 15 — Transverse section of 10-ft- (3-m-) long W-Re FSW in 0.25-in. (6-mm) HSLA-65.

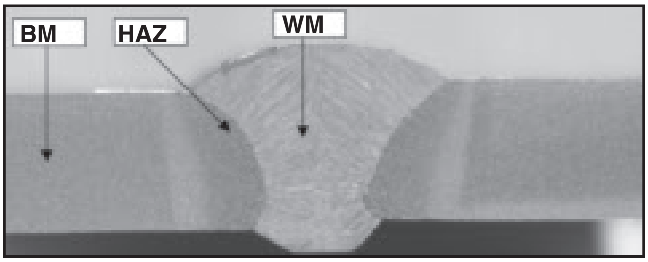

Fig. 16 — Transverse section of 10-ft- (3-m-) long SAW in 0.25-in. (6-mm) HSLA-65.

CVN toughness, and guided face- and root-bend tests on the FS and SA weldments are shown in Tables 4–6, respectively. For both weldments, the weld region was overmatching in tensile strength and the specimens fractured in the plate material. (Yield strength and ductility values are not meaningful in transverse weld tensile tests because the results can be affected by weld geometry and gauge length, thus they are reported for information only.)

The CVN properties are summarized in Table 5. Because the plate is only 0.25 in. (6 mm) thick, ½-size CVN specimens were used. The weld region specimens were tested to the Navy's weld metal and HAZ requirement for HSLA-65 (–20°F or –29°C) and the base metal at the –40°F (–40°C) base-metal requirement. Note that the base metal toughness is low: 7 ft-lb (9.5 J) at –40°F (–40°C). The ASTM A 945 requirement for full-size specimens is 20 ft-lb (27 J) transverse, and the Navy requirement is 70 ft-lb (95 J) at –40°F (–40°C). As discussed previously, this plate was procured from a steel supplier; thus, the certified plate composition was not initially available prior to the welding trials. The out-of-specification S and Si

Table 6 — Guided Bend Test Results for SAW and FSW in 0.25-in. (6-mm) HSLA-65

Code	Bend Type	Original Specimen Width (in.)	Original Specimen Thickness (in.)	Plunger Radius (in.)	Maximum Load Obtained (lbf)	Test Comments
SAW FB-1	Face	1.9957	0.2404	0.50	5762	No cracking was observed.
SAW FB-2	Face	1.9961	0.2400	0.50	5745	No cracking was observed.
SAW RB-1	Root	1.9959	0.2365	0.50	5850	Acceptable edge cracking
SAW RB-2	Root	1.9953	0.2420	0.50	5837	No cracking was observed.
FSW FB-1	Face	1.9958	0.2355	0.50	5822	Cracking greater than 1/8 in.
FSW FB-2	Face	1.9957	0.2388	0.50	5920	No cracking was observed.
FSW RB-1	Root	1.9939	0.2377	0.50	6033	No cracking was observed.
FSW RB-2	Root	1.9955	0.2381	0.50	6123	No cracking was observed.

in. × 25.4=mm lbf × 4.448=N

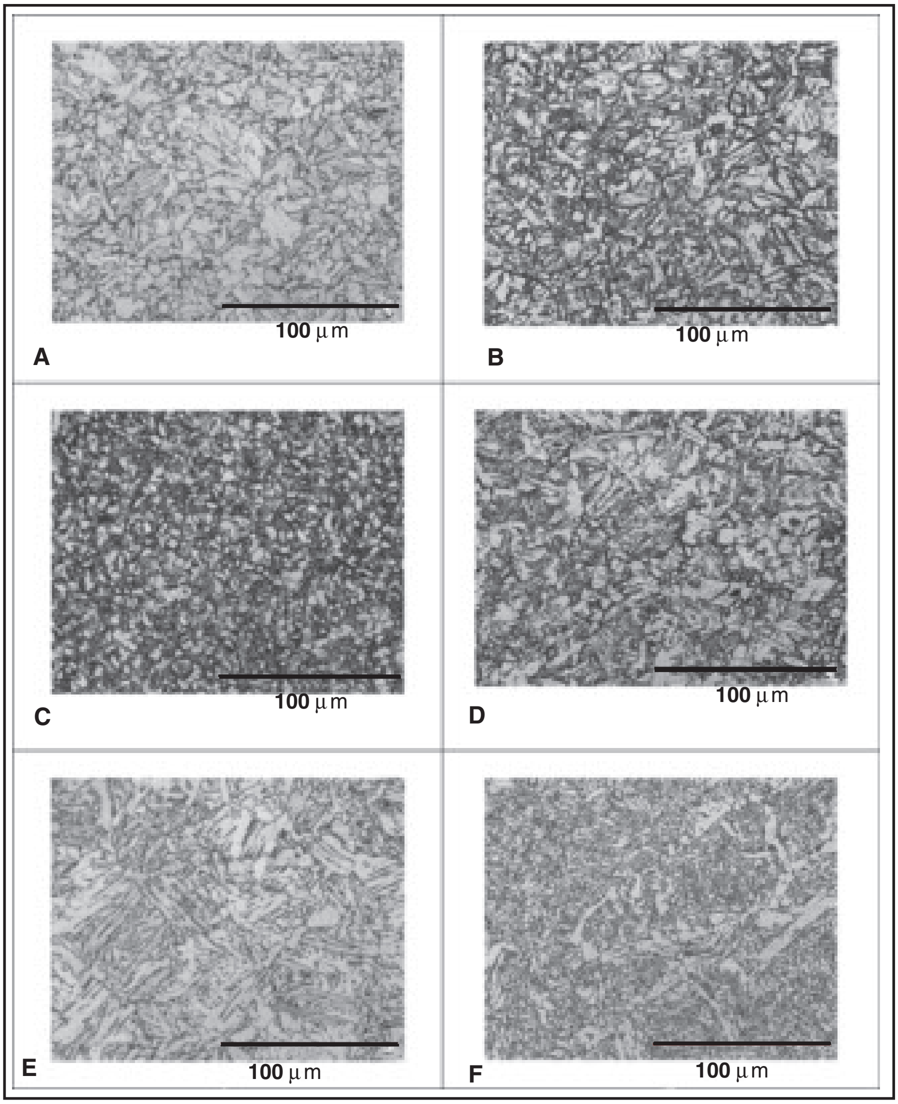

Fig. 17 — Microstructures of HSLA-65. A — Base metal; B — FSW HAZ; C — FSW TMZ; D — FSW SZ; E — SA HAZ; F — SA weld metal.

contents noted in Table 1 most likely contributed to the low base-metal toughness. The MIL-100S weld metal exhibited 13 ft-lb (18 J) toughness at –20°F (–29°C), which is typical for this electrode in a single-pass thin-gauge weldment. The FSW stir zone exhibited much higher toughness: 55 ft-lb (75 J). This may be attributed to the very fine grain size in the stir zone discussed in the following section. Because of the curved boundary between the FSW stir zone and plate material and the indistinct transition among the SZ, TMAZ, and HAZ, it was not possible to locate the CVN notch entirely within a specific region. Specimens with the notch mid-length centered at the weld interface and HAZ (at 1.0 mm from the weld interface) also exhibited low toughness, and there was little or no difference between the SA and FS weldments.

The results of the 2T bend radius (T = specimen thickness) face- and root-bend tests are shown in Table 6. The four SAW face and root bend tests exhibited satisfactory performance (no cracking or edge crack less than ⅛ in. or 3.2 mm). Three of the four FSW bend specimens were satisfactory; however, one of the face-bend specimens had a tear, which could not immediately be attributed to a specific cause. It may have been associated with a subsurface region of stirred-in oxides, as will be discussed.

Metallographic Examination

Transverse metallographic sections of the 10-ft- (3-m-) long FS and SA weldments are shown in Figs. 15 and 16, respectively. BM, HAZ, TMAZ, and SZ refer to base metal, heat-affected zone, thermomechanically affected zone, and stir zone, respectively.

The FSW has a relatively wide stir zone and a visually indistinct transition between the SZ, TMZ, and HAZ. Some swirls of dark-etching regions are apparent near the top of the stir zone in the FSW. Microscopic examination confirmed that this material is debris from the Mo-TZM shoulder, which wore significantly during the trial. The SAW has a large weld reinforcement, a sharp weld interface and a visible coarse-grain HAZ. The solidification structure is also apparent. There is also some vertical offset of the two plates.

The microstructures of the various weld regions are shown in Fig. 17. The HSLA-65 base metal, Fig. 17A, consists of fine-grain ferrite (light etching) with small pockets of dark-etching unresolved components, which could be carbides or martensite-austenite clusters. The FSW HAZ (Fig. 17B) also consists of packets of ferrite, with increasing packet size (related to prior-austenite grain size) closer to the SZ. The FSW TMZ, Fig. 17C, has a very fine ferrite grain size. The FSW SZ, Fig. 17D, has a somewhat coarser ferrite grain size than the TMZ. The SAW HAZ, Fig. 17E, has a large ferrite packet size adjacent to the weld interface, which is indicative of the higher peak temperatures experienced in arc welds vs. FS welds. The SA weld metal, Fig. 17F, displays the classic columnar solidification structure with pro-eutectoid ferrite on prior austenite grain boundaries and acicular ferrite interior.

Microhardness Measurements

Vickers microhardness (HV) traverses with a 1-kg load across the W-Re FS and SA weld regions are shown in Figs. 18 and 19, respectively. The hardness across the FSW base metal, HAZ, TMAZ, and SZ is generally uniform, with most readings between about 190 and 230 HV, and one reading of 243 HV in the SZ. The SAW base metal and HAZ is also fairly uniform, but the weld metal hardness is 256–282 HV. This is attributed to the strengthening effects of the Mn, Ni, Cr, and Mo in the MIL-100S electrode, which is designed for welding the HY/HSLA-80 and HY/HSLA-100 steels. Shipyards have selected this electrode for SAW of HSLA-65 to achieve the specified CVN toughness requirements in the weld metal.

Summary and Conclusions

• CTC installed a spindle adapter, liquid-cooled tool holder, and telemetry system for tool temperature monitoring on their production-size FSW facility and was able to make friction stir welds in 0.25-in.-

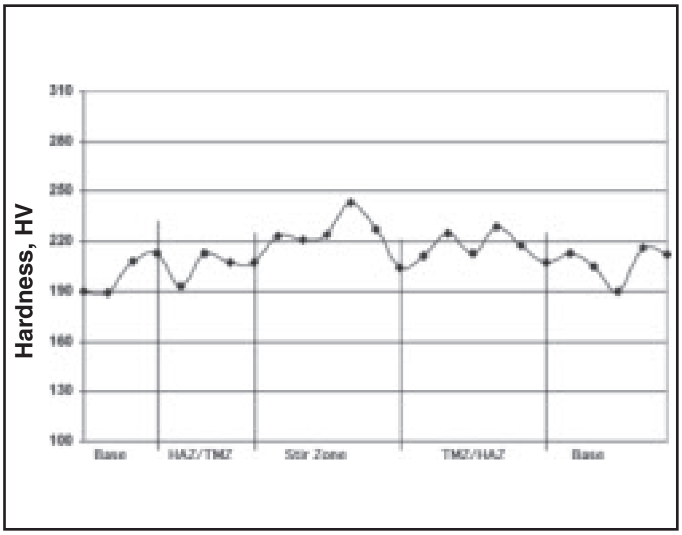

Fig. 18 — Microhardness across the weld region of W-Re FSW.

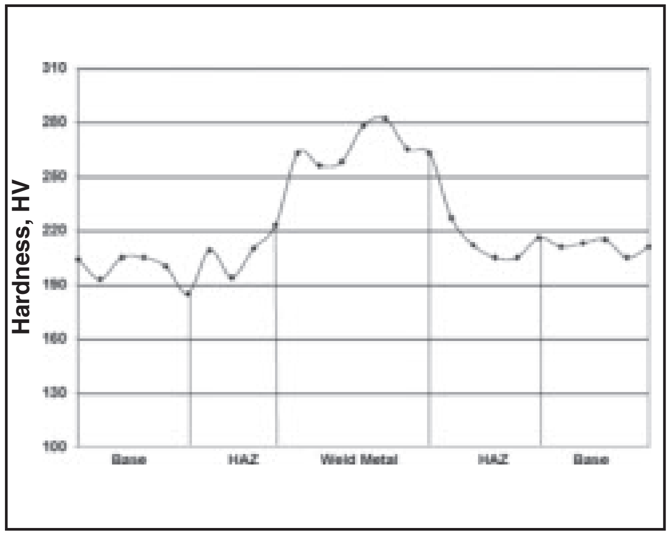

Fig. 19 — Microhardness across the weld region of SAW.

(6-mm-) thick HSLA-65 steel.

- It was difficult to establish process parameters and techniques for using the PCBN tools, due to breakage of all six tools before a long demonstration weld for distortion comparison could be made.
- A two-piece refractory alloy tool (W-25%Re pin + Mo-TZM shoulder) was successfully used to make a 10-ft- (3-m-) long butt-joint weld in 0.25-in.- (6-mm-) thick HSLA-65. However, the Mo-TZM shoulder exhibited excessive wear after about 6 ft of weld length.
- Both the W-Re FS and the SA weldments exhibited overmatching transverse weld tensile strength and fractured in the base metal. The face- and root-bend tests were acceptable for the SA weldment; however, one of the FSW face-bend specimens exhibited a rejectable tear that was attributed to imbedded tool shoulder material. It is expected that use of a W-Re shoulder material would eliminate this problem.
- The CVN toughness of the FSW stir zone was significantly higher than that of the MIL-100S SAW weld metal. There was little difference in heat-affected zone toughness for FSW and SAW.
- Both the FS and SA weldments exhibited significant longitudinal weld distortion, with the FS weldment having marginally less distortion. The SA weldment was bowed in the transverse direction, while the FS weldment exhibited no transverse distortion.
- The present trials indicate that FSW is technically feasible for joining HSLA-65 steel for structural applications.

Acknowledgments

This work was conducted by Concurrent Technologies Corp. (CTC) through the Navy Metalworking Center under contract No. N00014-00-C-0544 to the Office of Naval Research as part of the U.S. Navy Manufacturing Technology Program. Special thanks is given to The Welding Institute, Brigham Young University, and MegaStir for providing some of the earlier FS weldments, to Rhenium Alloys for donating the W-Re tool material, and to John Gover and James McHenry of CTC for their efforts in making the HSLA-65 weldments.

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Variable AC Polarity GTAW Fusion Behavior in 5083 Aluminum

Field emission of electrons and dielectric breakdown of surface oxides lead to enhanced weld metal fusion on electrode positive polarity portions of AC current cycles in the variable polarity GTAW process

BY M. A. R. YARMUCH AND B. M. PATCHETT

ABSTRACT. Aluminum alloys are typically welded on AC with the gas tungsten arc welding (GTAW) process. Many power sources have “max penetration” indicated when more than 50% of the AC cycle is spent on electrode negative polarity and “max cleaning” when more than 50% of the cycle is on electrode positive polarity. In the work reported here, weld bead dimensions, notably penetration and bead width, increase with the percentage of electrode positive polarity during the unbalanced square wave AC welding of aluminum alloys with the GTAW process. This is in direct contradiction of conventional assumptions about the role of electrode positive and electrode negative contributions to surface cleaning and fusion behavior during AC welding.

The primary source of the extra base metal melting during electrode positive operation is in the nature of cold cathode field emission of electrons from the base metal. The dielectric breakdown of surface oxide as electrons are emitted also contributes to the increased fusion, but this is not a contributory factor once the weld metal surface is completely clean. Both phenomena require extra energy to be supplied to the cathode, which results in the increased fusion. Earlier works on the gas metal arc welding (GMAW) process confirm this behavior of enhanced melting at the cathode. Positive ion bombardment, thermal convection from the plasma jet, and radiation from the plasma complete the thermal input to the cathode for metal fusion.

Introduction

When discussing the physics of variable polarity arc welding, the simplest case to consider is a DC electric arc with inert gas shielding and a tungsten cathode capable of thermionic emission. The basic schematic is shown in Fig. 1. The arc can be broken up into five distinct regions: anode spot, anode fall space, arc plasma column, cathode fall space, and cathode spot. During electrode negative polarity, electrons flow from the tungsten cathode to the anode (base material) by means of the arc plasma.

The anode spot is the positive electrode that attracts the negative electrons. Collection of electrons at this region leads to intense heating of the anode substrate (discussed in detail below). The small arc region adjacent to the anode spot is termed the anode fall space. This thin layer, estimated to be a micrometer, has a negative space charge and is characterized by a steep voltage gradient that maintains passage of the current. The arc column is electrically neutral plasma consisting of electrons, ions, and neutral atoms or molecules that are in quasi-thermal equilibrium. The voltage gradient, as shown in Fig. 1, is uniform along the length of the column for a given shielding gas. The cathode fall region is the electrical connection between the cathode and the arc column, but is the most poorly understood region of the welding arc. The region is narrow with a voltage gradient steeper than the anode fall region, and there is a net positive space charge. The cathode spot is the location of electron production by thermionic emission. This emission mechanism is only applicable for high melting point and low work-function materials such as carbon, molybdenum, tantalum, or tungsten.

During AC welding, portions of the welding cycle are spent on both electrode negative and positive polarity. The workpiece now produces the electrons during the EP cycle of the waveform. Typical construction materials such as steel and aluminum melt at temperatures much lower than that necessary for thermionic emission. Hence, these materials are nonthermionic and are often termed “cold cathodes.” Field emission processes, whereby electrons are removed from the base materials due to the strong localized voltage gradients, are facilitated by an increase in the cathode fall voltage during electrode positive polarity (Ref. 1). The electrode positive cycle during AC welding permits the removal of tenacious surface oxides from aluminum alloys by “cathode sputtering.” This phenomenon produces clean weld surfaces and good fusion characteristics in both the gas tungsten arc welding (GTAW) and plasma arc welding (PAW) processes.

Previous arc physics studies suggest that maximum weld depth and fusion volume occur on electrode negative polarity, when electrons stream toward the metal being welded. This is supported by early energy balance work on the GTAW process using DC electrode negative (DCEN) polarity, where approximately 60–80% (Ref. 2) of the heat generated is absorbed at the anode (Refs. 3, 4). This heat input from the arc is primarily from electron condensation plus convection and radiation from the plasma. Radiation and convection heating account for a tiny proportion of the total heat input (Ref. 5). The anode heating due to electron condensation is

$$H_a = I\left(\varnothing + V_a + \frac{3kT}{2e}\right) \quad (1)$$

where H_a = anode heat input, I = arc current, Ø = anode thermionic work function, V_a = anode fall space voltage, and 3kT/2e = electron thermal energy in the high-temperature plasma.

In contrast, the emission processes and thermal characteristics at nonthermionic cathodes, where electrons are emitted primarily by field emission, are not well understood and no similar comprehensive equation exists (Ref. 6). Nonthermionic

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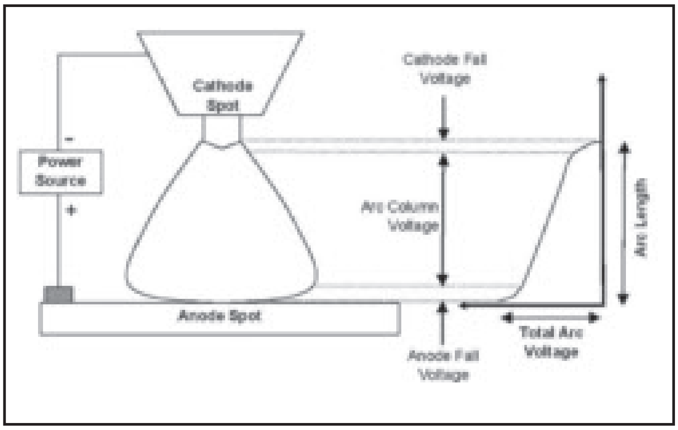

Fig. 1 — Nonconsumable thermionic cathode welding arc: regions of the arc and arc voltage behavior (electrode negative polarity).

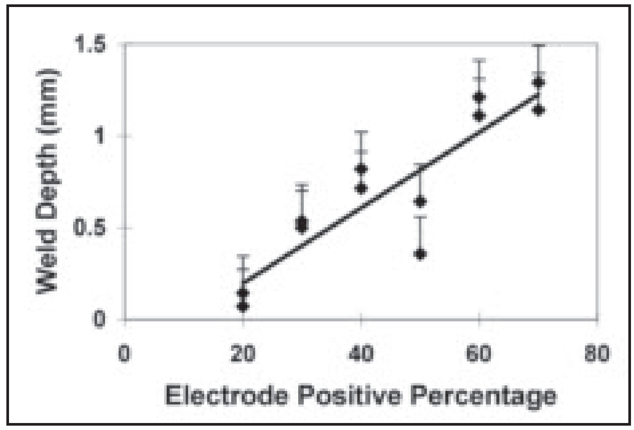

Fig. 2 — Autogenous GTA weld penetration vs. electrode polarity balance — wire-brushed surface.

electrodes emit electrons under large voltage gradients at specific sites, called cathode spots. These spots are highly mobile and often appear at inclusions of lower work function rather than the metallic phase. Aluminum alloys do not have many such inclusions and the electron extraction at an aluminum cathode will normally occur under field emission conditions at many sites on the metal surface.

Previous work on heat transfer in the GTAW and PAW processes has usually been done on copper (Ref. 7) or austenitic stainless steel (Refs. 4, 8) anodes to measure the anode heat input. Little experimental data exist for other metals, especially electrode positive AC effects on aluminum. The low currents and large tungsten electrodes (along with different electrode tip geometry) required for DC electrode positive (DCEP) or AC investigations of heat transfer make duplication of the DCEN experiments for direct comparison very difficult. There has been some investigation of heat inputs to aluminum alloys using AC waveforms, but primarily for the PAW process. Fuerschbach (Ref. 1) found that fusion zone size depended only on net power; no apparent influence of variable polarity on weld fusion dimensions was noted. The same anode/cathode heat balance seen in DC electrode negative GTAW and PAW weld metal fusion is still assumed for AC operation in some publications concerning the processes (Ref. 9).

During the early development of the GTAW process in the 1940s, only balanced 50 or 60 Hz sine wave AC power (50% of each cycle on electrode negative and electrode positive polarity) was available in commercial power sources. Crude forms of square wave AC power became available in the early 1960s, still with balanced waveforms. Power sources including unbalanced waveforms first appeared in the early 1980s with maximum cleaning as 55% electrode positive and maximum penetration as 40% electrode positive. This rather restricted variability in polarity within one AC cycle was due to electronic wave shaping limitations and the need to avoid thermally overloading the tungsten electrodes with excessive percentages of the electrode positive cycle.

General literature on the GTAW process suggests that this characterization of cleaning and penetration is due to "the advantage of surface cleaning associated with conventional AC power and deep penetration obtainable with DCEN power (Refs. 10, 11)." Our experience with these settings in welding process laboratory experiments has been the opposite, i.e., maximum penetration occurs on the maximum cleaning setting, where the majority of each AC cycle is on electrode positive polarity.

Recent developments in solid-state power source design using inverters and advanced wave shape control provide square wave AC at frequencies between 20 and 240 Hz with unbalanced waveforms from 70% electrode positive (maximum cleaning) to 1% electrode positive (maximum penetration). There is also the capacity in some power sources to choose differing levels of current in the positive and negative portions of the current cycle. These enhancements of unbalanced wave capabilities offer significant opportunities to investigate the fundamental effects of AC power on fusion characteristics. The purpose of the work reported in this article was to assess the influence of unbalanced polarity AC waveforms, of constant current magnitude, on the GTAW fusion characteristics of aluminum.

Experimental Program

Autogenous GTA fusion welds were produced on 5083 Al-Mg alloy bars 10 mm thick × 75 mm wide × 300 mm long. Differing types of surface oxide were created by treatments of wire brushing, heat treating (375°C for one hour), and anodizing in nitric acid. All welds used a current of 125 A and a welding speed of 0.8 mm/s (nominal heat input of 1.3 kJ/mm). The 3.2-mm pure tungsten electrode was conditioned at 125 A on a balanced (50% electrode positive) AC cycle for 60 seconds before each run, to ensure that electrode tip geometry was consistent and not a variable in weld bead formation. Arc length was set at 2 mm and the welding-grade argon shielding gas had a constant flow rate of 30 L/min. Electrode positive settings of between 70% and 20% of each AC cycle were assessed using a fixed frequency of 60 Hz. After the pattern of fusion behavior was established for 60 Hz, a set of 50% electrode positive welds using 20, 120, and 240 Hz were made to assess any effects of frequency variations at a fixed electrode positive/negative ratio.

Fusion characteristics were assessed by observing the cleaned surface zone width and by measuring fusion width and depth with a low magnification stereo microscope. Three cross sections were assessed from each weld pass and three welds were made for each experimental condition.

Results

The initial experimental welding was done on aluminum plates that had been degreased and then wire brushed with a stainless steel brush. This ensured both a minimum oxide layer thickness and an even oxide layer thickness. These charac-

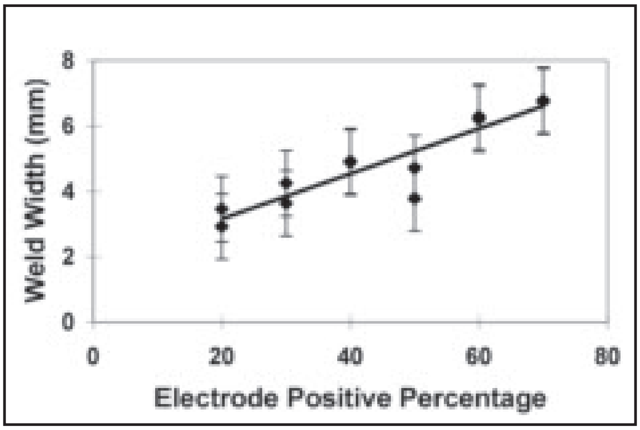

Fig. 3 — Autogenous GTA weld width vs. electrode polarity balance — wire-brushed surface.

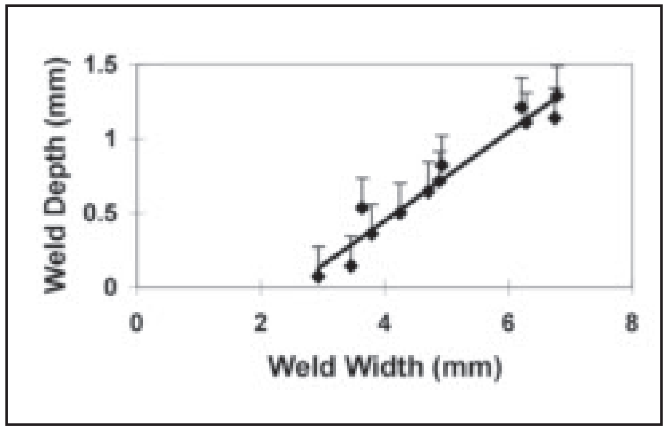

Fig. 4 — Autogenous GTA weld penetration vs. weld width — wire-brushed surface.

teristics were considered important reference states for other welds, where oxide thickness and regularity could be altered via heat treatment and oxide enhancement techniques, e.g., anodizing. Fusion characteristics on the cleaned and wire brushed surface clearly show that increasing the percentage of electrode positive polarity in the AC cycle increases both penetration depth and bead width of an autogenous GTA weld on aluminum, shown in Figs. 2 and 3. As shown in Fig. 4, the penetration increased linearly with the bead width, indicating that the energy for fusion increased with the percentage of electrode positive polarity. Figure 5 shows typical weld cross sections used to measure bead dimensions.

Welds on the heat-treated specimen did not reveal a significant difference in the weld penetration pattern from the wire-brushed specimen. Figure 6 shows the two sets of data for the penetration behavior (error bars are omitted for clarity and are of the same order as reported earlier). The pattern is still consistent with respect to electrode positive polarity in the AC cycle; penetration increased with percent electrode positive in the unbalanced cycle. These results show that a heat-treating cycle (in this case annealing at 375°C) has no measurable effect on arc behavior.

Increasing the oxide layer thickness by anodizing the base metal in nitric acid produced two changes. The weld penetration for a given percent electrode positive in the AC cycle increased from the value for the wire-brushed specimen. These results for the weld depth are shown in Fig. 6 for comparison. Figure 7 shows a similar but lesser result for the weld width. The second difference in the anodized specimens was that the observed sputtered width (not the fusion width) was reduced in comparison with the wire brushed and heat-treated specimens. This suggests that the thicker oxide produced by anodizing is more difficult to disrupt via cathode sputtering. The extra energy used to pull electrons from the aluminum cathode on electrode positive polarity in the presence of a thick oxide layer enhances fusion, rather than reducing it.

The final experiment assessed the effect, if any, of AC frequency on fusion characteristics. Variable frequency AC waveforms have been readily available since the advent of inverter power supplies. The power source used in these experiments was capable of frequency variations between 20 and 240 Hz, which offered a good experimental range around the standard frequency of 60 Hz. The results, shown in Fig. 8, indicate that frequency has no effect on fusion characteristics for a balanced 50% electrode positive AC waveform. It remains to be determined whether or not there is a measurable effect of unbalanced waveforms on fusion behavior at differing frequencies.

Discussion

The results show that maximum fusion width and penetration occurs in GTAW procedures on aluminum with a maximum cleaning (more electrode positive percentage) setting on an unbalanced AC waveform. This phenomenon occurs on cleaned and wire-brushed surfaces with minimum oxide and increases with enhanced oxide thickness developed on anodized specimens. When the GTAW process is on electrode positive polarity, the electrons needed to maintain the majority of the current flow must be extracted from the weld pool. As aluminum is a cold cathode material, the electrons are extracted from mobile cathode spots via field emission. Longer times spent on electrode positive polarity increase the weld penetration via the extra energy input from field emission and increase the weld width via the enhanced area covered by the mobile cathode spots seeking new locations for electron emission.

When up to 70% electrode positive waveforms are used, thicker surface oxides enhance penetration and (to a lesser extent) weld width, shown in Figs. 6 and 7, but restrict sputtered width. Thick oxides produced by anodizing are more difficult to disrupt. This resilience restricts the area of arc impingement and increases the energy density forming the weld pool at a given arc power. This is confirmed by the narrower cleaned zone (not weld width) produced on anodized vs. heat-treated specimens. The cleaned (sputtered) zone is slightly wider than the fused weld width.

Oxides on the surface of the weld metal are disrupted during the electrode positive portion of the AC cycle. The two probable mechanisms, which likely work in concert, are positive ion bombardment (Ref. 12) (primarily from inert gas atoms from the shielding gas) and dielectric breakdown of the oxide during electron extraction from the cathode (Ref. 13). Both phenomena add energy to the cathode and are capable of enhancing the amount of fusion. Oxide disruption is reasonably complete in balanced wave AC operation. In the case of the unbalanced AC wave, increasing the percentage of electrode positive current increases the time spent extracting electrons from aluminum via field emission. The energy required for this process then increases the amount of fusion. Figure 9 summarizes these effects in schematic form.

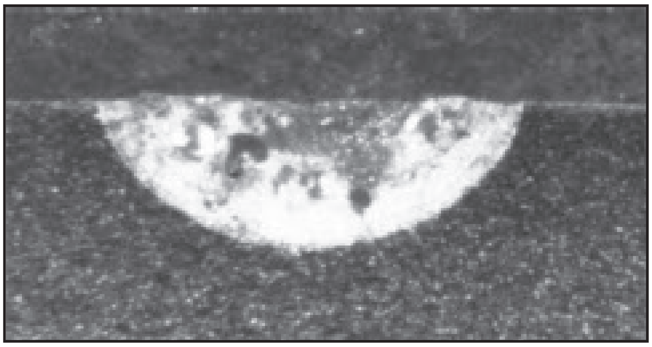

Fig. 5 — *Typical cross section of weld zone used for bead measurements.*

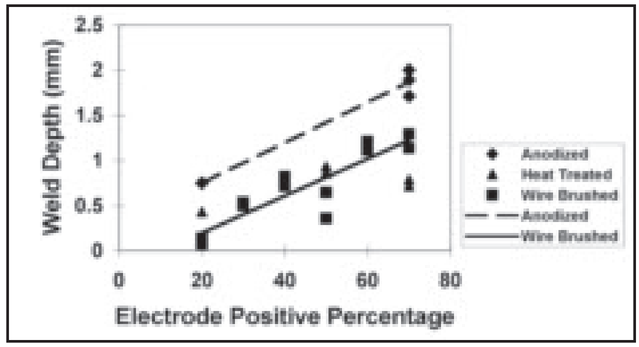

Fig. 6 — *Effect of heat treating and anodizing on autogenous weld penetration vs. electrode polarity balance.*

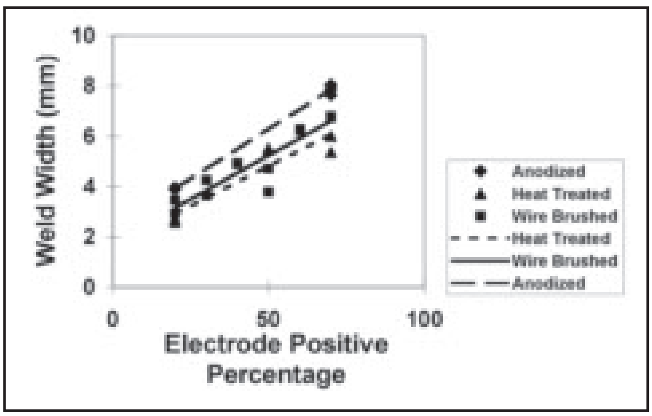

Fig. 7 — *Effect of heat treating and anodizing on autogenous weld width vs. electrode polarity balance.*

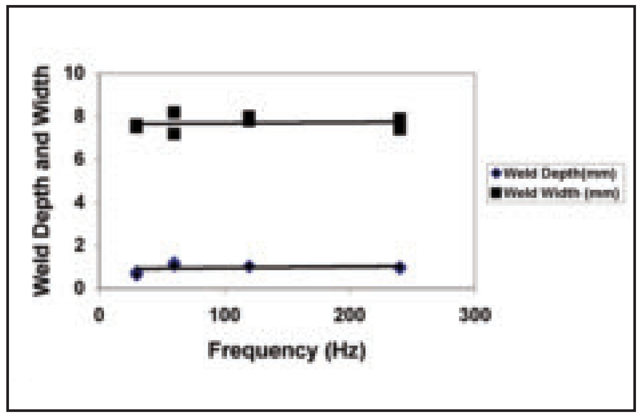

Fig. 8 — *Weld metal depth and width vs. AC waveform frequency for a balanced waveform (50% electrode positive).*

To some degree, the confusion over the relative melting rates of the anode and cathode in GTAW on AC is caused by the effects of electrode positive polarity on the melting of the tungsten electrode. The tungsten anode is heated by electron condensation and the poor thermal conductivity of tungsten leads to overheating and melting. This effect suggests that the max cleaning mode increases the heat input into the tungsten anode and at the same time reduces the heat input into the weld metal cathode. This is not necessarily the case. When the tungsten is the cathode, thermionic electron emission cools the tungsten as the electrons "evaporate." For nonthermionic emitters, there is an increase in cathode (workpiece) heating due to the absence of the cathode cooling phenomenon during the field emission process. An increase in the cathode fall voltage (Ref. 1) and the corresponding increase in energy required to extract electrons from the cold cathode similarly contribute to the increased workpiece fusion observed in the variable polarity experiments.

The most clearly documented cold cathode effect on cathode heat input is the electrode melting rate in the gas metal arc welding (GMAW) process, which is always higher on electrode negative polarity for cold cathode metals (Refs. 14, 15). The cathode melting rate is up to double the rate for an anode in similar welding conditions. Although some papers assume that the same heat partition exists between anode and cathode for both GTAW and GMAW (Ref. 16), the experimental facts clearly show that the heat input (melting rate) to a GMAW cold cathode is substantially higher than for an anode of similar geometry (Refs. 13, 14). This effect can be reduced through the addition of oxidizing atoms to the shielding gas, for example chlorine in argon, which reduces the energy required to extract electrons from the surface of the cathode (Refs. 17, 18), and therefore reduces the electrode melting rate, or by using emissive coatings on the electrode surface, which provide a similar function (Ref. 13). Electrode melting rates are reduced from bare wire values in both cases. In the absence of such electron emission enhancers, the extra energy required to extract the electrons from the cold cathode metal increases the melting rate.

In the GTAW process, the cold cathode material also experiences the higher heat input, causing the larger weld beads observed here as the percentage of electrode positive time increases. Enhanced oxide thickness, particularly from anodizing, increases the difficulty of extracting electrons, thus further concentrating and increasing heat input.

Pang et al. found that AC welding of aluminum with the plasma arc welding (PAW) process produces welds of superior mechanical and aesthetic quality when compared to DCEN (Ref. 19). Fuerschbach highlighted that a higher percentage of DCEN during variable AC welding with PAW does not translate into greater fusion/penetration, due to the now greater influence of the cold cathode field emission mechanism (Ref. 1). An area of future work would be to completely characterize weld fusion in tungsten arc processes as a function of phase balance

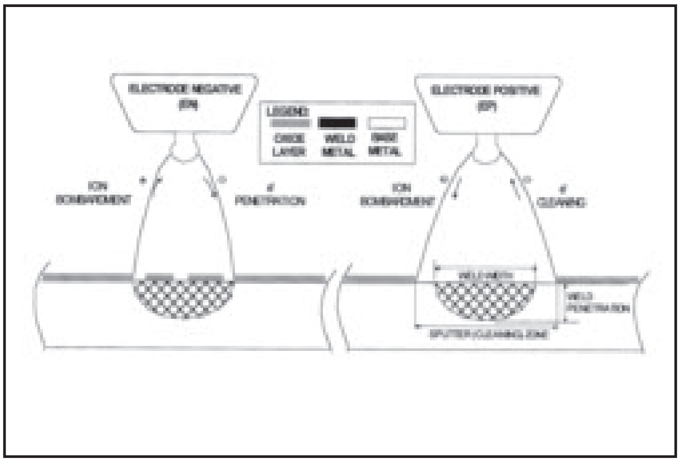

Fig. 9 — Schematic of electron and ion effects in electrode negative and electrode positive GTAW fusion.

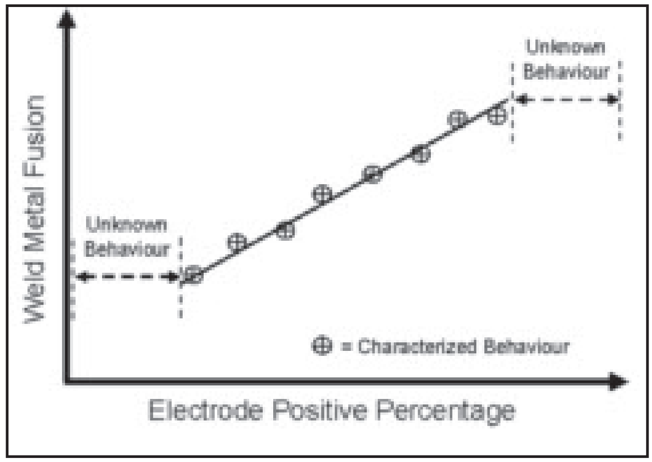

Fig. 10 — Schematic of weld metal fusion behavior as a function of electrode positive percentage during AC welding of aluminum.

(i.e., from 1 to 100% DCEP), and determine the theorized locations of the maximum and minimum weld metal fusion — Fig. 10. This information will further advance the knowledge of welding arc physics, and determine the electron mechanisms that dominate fusion behavior for the entire range of variability polarity welding. A practical effect is possible in the root welding of aluminum pipe, where control of the penetration is critical.

Conclusions

1) Increased weld bead fusion, penetration, and volume occur in autogenous GTAW of 5083 aluminum alloy as the electrode positive polarity (cleaning) portion of the cycle in square wave AC welding increases. This is contrary to conventional expectations and occurs primarily because the field emission characteristics of cold cathode materials increase the energy input to the cathode.

2) Oxidized surface layers enhance fusion volume and penetration. This occurs primarily due to a physical constriction of the sputtered surface area on electrode positive polarity (thus increasing energy density in the weld zone). There may also be a secondary effect in the energy required to extract electrons from the cathode surface via dielectric breakdown of a thicker oxide during electrode positive parts of the AC cycle, which would increase energy input to the cathode (weld pool).

3) Frequency variations of the AC cycle between 20 and 240 Hz apparently do not affect the fusion geometry dimensions, at least for balanced polarity (50% electrode positive) waveforms.

Acknowledgments

The authors wish to thank Clark Bicknell of the Welding Laboratory at the University of Alberta for valuable technical assistance, and students Patricia Cameron, Evan McKnight, and Marcy Wine for assistance in the execution of the experimental program.

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Thermal Stresses in Butt-Jointed Thick Plates from Different Materials

Photothermoelastic models were used to investigate the formation of thermal stress concentrations

BY Z. ABDULALIYEV, S. ATAOGLU, AND D. GUNEY

ABSTRACT. A variety of materials are used as elements and constructions in many branches of industry. These materials are exposed to heavy variable mechanical and thermal loads during service. The resultant stresses of variable thermal and mechanical loads are added and they may reach high levels in the stress concentration regions of the elements, leading to the formation of cracks. In this study, the formation of thermal stress concentrations was investigated using photothermoelastic models for butt-jointed thick plates from different materials at the weld zone. In the models, the effect of the slope of the materials' connection plane with respect to the normal plane of the plate on the stress distribution was studied. In the stress concentration regions of the considered joints, the effect of the different geometric factors was also investigated on the models in order to arrange the concentration of the thermal stresses as required.

Introduction

Many constructions, widely used in engineering and other sectors, are made of different materials using welding. Temperature changes during the working process result in thermal stresses in the welding region of the different materials. These thermal stresses reach high magnitudes and vary with high gradients (Refs. 1–6). These stresses can combine with the stresses from the other variable mechanical loads acting on the elements of the constructions. Thus, they can lead to the formation of cracks due to the variation of all those stresses in the welding region. Value and distribution of the thermal stresses are affected in the connected region of different materials by the slope and location of the contact plane. Investigation of thermal stresses in the associated regions can provide important information for the optimum design of the welding region. Depending on the information obtained from this kind of research, the slope angle of the contact plane of the different materials and the optimum geometry of the welding region in the design can be modified.

Elliott and Fessler (Ref. 7) measured the elastic, elastic-plastic, and residual plastic strains in the surfaces of sections of weldments using photoelastic coatings and Moiré interferometry. The effect of the slope of the joint plane on thermal stress distribution is an important subject for the strength of the construction, as is optimum design of the region. In this study, thermal stresses due to uniform temperature changes, which form in thick butt-joint-welded plates from different materials, are examined by the photothermoelastic method (Refs. 8, 9). The effects of some geometric factors and slope of the connection plane with respect to the plates' normal plane on value and distribution of the thermal stresses were also investigated. In the jointed constructions, the thermal stress distribution for the single-V weld joint could be obtained by superimposing the results of the experiments. The following assumptions are valid in the tests:

- The plates of different materials are jointed with each other on a plane;
- No variation in the material properties due to temperature in the process of welding;
- The residual stresses due to the welding process aren't taken into account;
- Reinforcement and throat are in the same plane with those of jointed plates.

KEYWORDS

Thermal Stresses
Joint Materials
Photothermoelasticity
Joint Design

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Analysis Technique of the Models

In order to model thermal stresses in the joint regions of the different materials, the mechanical modeling method of photothermoelasticity is employed because of its precision and availability of easy application (Refs. 5, 6, 8, 9). Mechanical modeling of thermal stresses is based on the freezing/unfreezing property of strains of some optically sensitive materials. Mechanical modeling of thermal stresses as known is summarized below (Refs. 5, 6, 8, 9).

A geometric simulation factor is set up to measure the stresses accurately in the concentration regions of the structure. It is assumed that the structure is divided into "i" number of free elements with uniform thermal expansion, depending on the material characteristics, geometry, and gradient of the temperature distribution. The free thermal expansion, ε_i, of the elements is calculated as follows:

$$\varepsilon_i = \alpha_i \Delta T_i \qquad (1)$$

where α_i is the thermal expansion coefficient and ΔT_i represents the increment of the temperature of the relevant elements, respectively. The model of the structure is constructed from the parts associated with the elements of the structure mentioned previously. The modeling scale of the free thermal expansions κ, is chosen as $\kappa = [(\varepsilon_i)_n/(\varepsilon_i)_m]$, where $(\varepsilon_i)_n$ denotes the free thermal expansion of the element of the structure and $(\varepsilon_i)_m$ is the uniform strain that will be freezed by a mechanical load in the relevant part of the related model. The uniform strains, which are equal to the strains in the related parts of the model, $(\varepsilon_i)_m$, are formed in the samples via the mechanical loads, and then they are frozen under the proper loads in the relevant samples. The parts of the model are cut out from the uniform deformation regions of the relevant samples. The parts are glued together with a special adhesive along the required surfaces. The prepared model is heated to its critical temperature in the oven. The strains, which earlier had

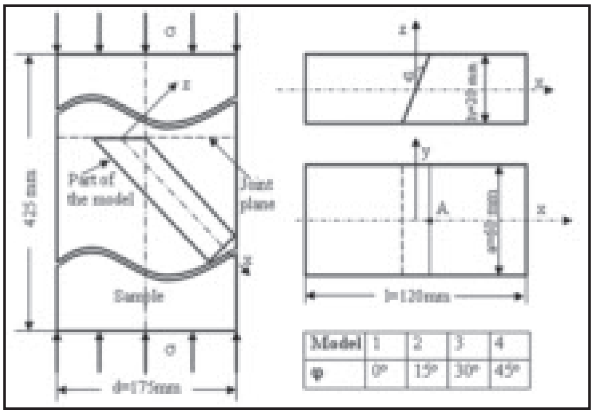


Fig. 1 — Schemes of models and samples used in the experiments.

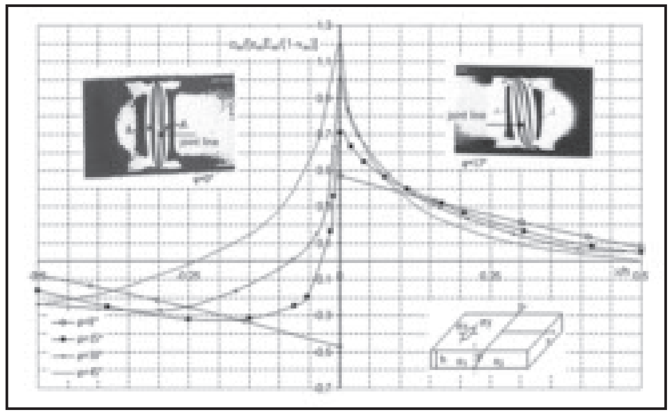


Fig. 2 — Variations of dimensionless stress component, σ_x, on the free surface for the model of joints for different bevel angles with the photos of isochromatic patterns.

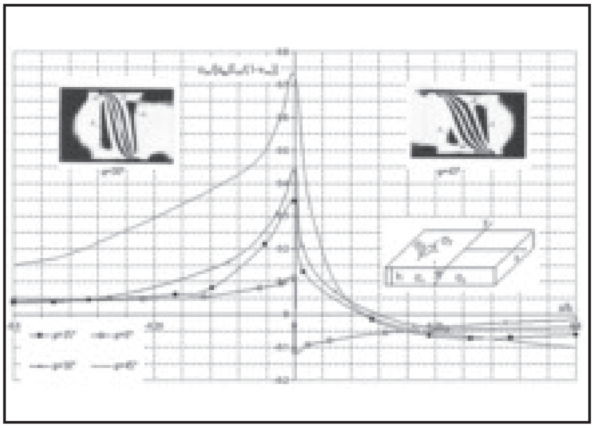


Fig. 3 — Variations of dimensionless stress component, σ_y, on the free surface for the model of joints for different bevel angles with the photos of isochromatic patterns.

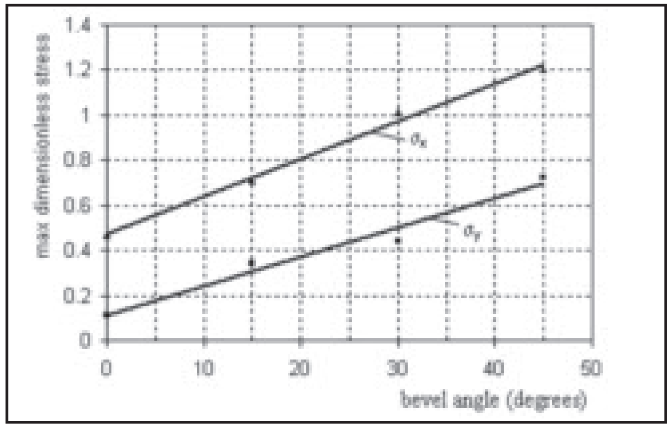


Fig. 4 — Variation of the maximum dimensionless thermal stress components, σ_x and σ_y, on the free surface vs. the bevel angle.

been frozen in the parts, are unfrozen and the stress state associated with the thermal stresses to be examined in the structure is formed in the model. The model is cooled to room temperature. The stress-strain state of the model is frozen in this way. The stress state of the model is researched using photoelasticity techniques (Refs. 10, 11). The actual stresses in the structure, σ_n, are calculated by the stresses obtained in the model, σ_m, using the following formula:

$$\sigma_n = \frac{1 - v_m E_n}{1 - v_n E_m} \kappa \sigma_m \qquad (2)$$

where v represents the Poisson's ratio and E is the modulus of elasticity of the materials. Indexes m and n refer to the model and the actual structure, respectively.

In this study, the mechanical modeling method is applied in order to investigate the thermal stresses of the butt-joint-welded thick plates made of the materials in the uniform temperature change, which differ from each other with the value of the thermal expansion coefficients. The effect of the different bevel angles in joints on stress distribution and some different geometric factors to reduce the stress magnitude in the region of the interface were investigated.

Preparation of the Model of the Butt-Joint-Welded Thick Plates

It is assumed that the thermal expansion coefficients of the materials of these welded plates are α_1 and α_2, respectively. Thermal stresses due to uniform temperature changes, ΔT, in the examined butt-jointed plates are proportional to the difference of free thermal expansion $[(\alpha_2 - \alpha_1)\Delta T]_n$ of the welded materials. As understood, the model can be constructed in two parts and to form is enough uniform strain associated with the difference obtained above in a part of the model. This uniform strain is computed as $\varepsilon_{rm} = \varepsilon_{\theta m} = 0.015$ using the modeling scale of the free thermal expansion, κ. The calculated expansion must be formed and frozen in a sample, taking into account the modeling scale of the free thermal expansion, κ, for preparing the model. The expansions are formed by axial compression and frozen in long cylindrical samples prepared from an optic-sensitive material based on epoxy resin. A model part is cut out from the uniformly deformed center region of the sample. The plane of the part, which will be glued with another part, must coincide with the cross section of the sample as shown in Fig. 1. The other part of the model is made of the same material without any prestraining applications. Two parts are glued together with epoxy resin-based cement. The final shape and dimensions of the model are formed by machine tools.

In the experiments, the angle between the interface and the normal of the plate plane, represented by φ, is varied as 0, 15, 30, and 45 deg, and the thermal stresses are investigated for each joint. Optically sensitive material-based epoxy resin, free from residual stress, which is employed for the models, has the characteristics at its own critical temperature of 150°C, as follows:

Elastic modulus, E_m = 21 MPa, fringe-

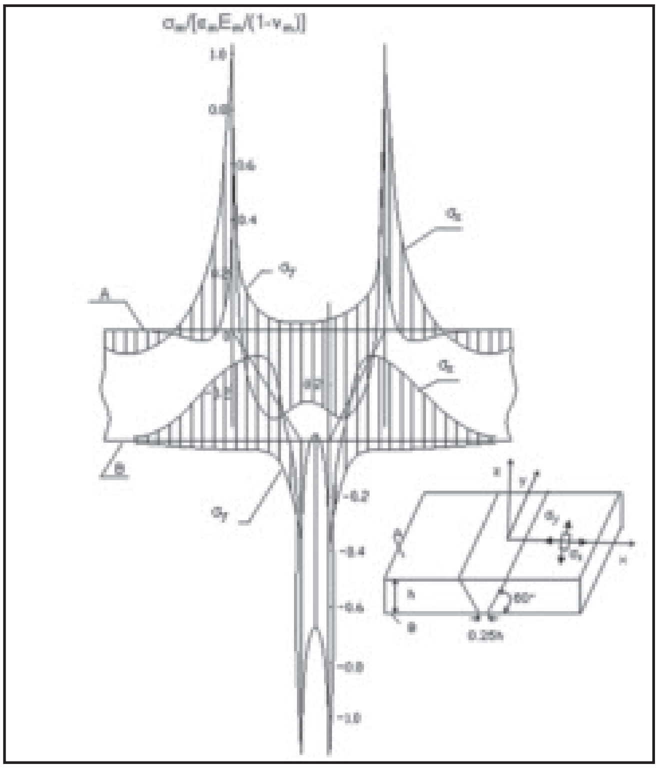


Fig. 5 — Distribution of stress components in a single-V weld joint with bevel angle φ = 30 deg.

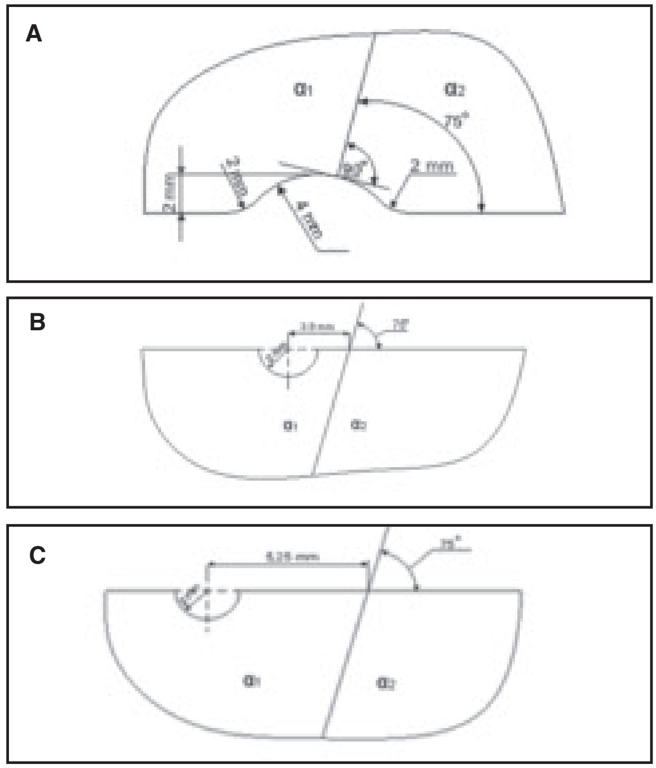


Fig. 6 — The examined geometric factors for the effect on the concentration of thermal stress components on the joint region. A — Changing bevel angle by the help of a cylindrical surface; B — the cylindrical cavity is located 3.90 mm away from the connection line; C — the cylindrical cavity is located 5.25 mm away from the connection line.

stress value, $\sigma_0^{1.0}$ = 0.365 N/(cmxfringe) and Poisson's ratio $v_m \cong 0.5$.

Stress State Analysis of the Models

It is enough to investigate the stresses acting on the symmetry plane, x0z, in the tested models since this section is related to the diametrical plane of the constructions having relatively big diameters. Stress distribution of the models on the symmetry plane is only related to the plate's thickness h, because the mentioned plane is far away from free lateral planes. Therefore, distributions of dimensionless stress components, $\sigma_m/[E_m \varepsilon_m/(1–v_m)]$, in this region on dimensionless coordinates, x/h and z/h, don't depend on the h value. On the symmetrical planes of the tested models, the photographs of isochromatic patterns, characterizing the distributions of the thermal stress, are given with variations of dimensionless stress components σ_x and σ_y vs. x/h on the surface (z = h/2 plane) in Figs. 2 and 3. The stress distribution is skew-symmetric on the (±h/2) surfaces of the examined jointed plates. Therefore, the graphs of stresses are given only in surface (z = h/2). It is apparent from Figs. 2 and 3 that distributions of dimensionless thermal stress components σ_x and σ_y, around the interface are local and include the region, which approximately is a distance, h, away from the interface. When the bevel angle of joint, φ, is 0 deg, dimensionless stress component, σ_x, increases with the high gradient while approaching the contact line of the materials and reaches the value of ±0.47 as shown in Fig. 2. Here, the value of dimensionless stress component, σ_x, which is calculated by a numerical method, is equal to ±0.5 (Ref. 12). The obtained results show that values of the thermal stress components increase in the joint region when the bevel angle is getting greater, for instance, ±1.2 for 45 deg, but their gradients decrease in that region as shown in Figs. 2 and 3.

The skew-symmetric property of mentioned stress on the examined joints is used for evaluating the time-edge effect (Refs. 10, 11) of the model material to its stress distribution. It is noted that this is done taking the mean value acting stresses on the relevant point of the surfaces, z=±h/2, for every joint.

Graphs of variations of the max dimensionless thermal stress components, σ_x and σ_y, vs. slope angle of the interface in the connection zone of the different materials around the point A (see Fig. 1) are shown in Fig. 4. According to Fig. 4, variation of the maximum dimensionless stress components vs. bevel angle can be considered as linear.

The results obtained in the model where the slope angle of the interface is 30 deg are used in order to evaluate the thermal stress components in a single-V weld joint by the superposition method — Fig. 5.

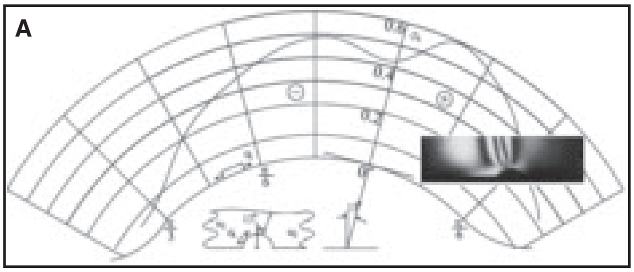
The aforesaid statement in the experiments can be exemplified by assuming a couple of stainless steel-carbon steel materials. If the maximum stress is computed at the joint of the couple by a bevel of 45 deg for ΔT = 200°C of the structure, using Equation 2 with constants as follows:

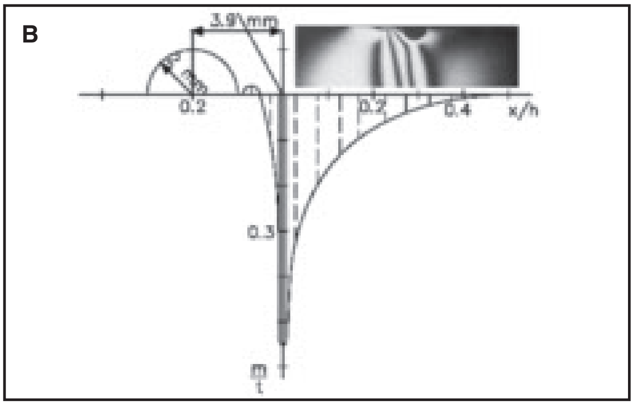
α_{steel} = 12.10^{-6} 1/°C,
$\alpha_{stainlesssteel}$ = 16.10^{-6} 1/°C,
$E_{steel} = E_{stainlesssteel}$ = 200 GPa, and
$v \cong 0.3$ (Ref. 4).

The results obtained of σ_x and σ_y for the structure are 274 and 168 MPa, respectively.

It can be concluded that the thermal stress components in combination with stresses from other loads and defects due to the joining technology could cause crack generation in the joint region of the constructions.

Different methods of reducing the thermal stress level in the connection zone of different materials were investigated. In this way, the effect of some geometrical factors on the concentration of thermal





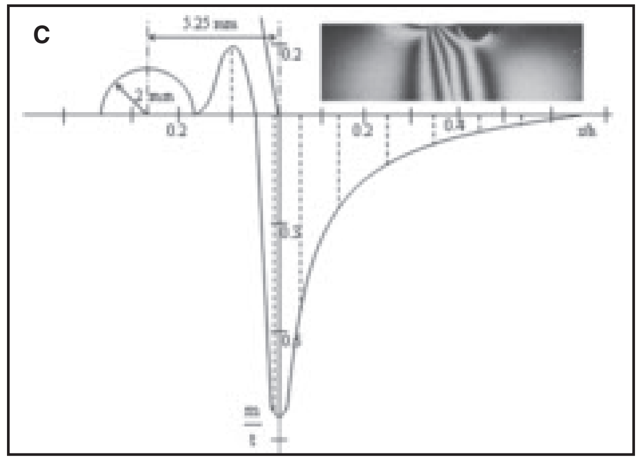


Fig. 7 — The effects of the examined geometric factors on distribution of the thermal stresses in the joints. A — Distribution of thermal stress component σ_t in the case that bevel angle is 0 deg from 15 deg with the help of the cylindrical surface with a 4-mm radius; B — distribution of m/t values where the cylindrical cavity is located 3.90 mm away from the connection line; C — distribution of m/t values where the cylindrical cavity is located 5.25 mm away from the connection line.

stress components was also investigated around the contact line on the free surface — Fig. 6A–C. As an example, mentioned factors are examined in the joint where the slope angle is 15 deg. The slope angle of the interface near the free surface of the joint was changed from 15 to 0 deg using a cylinder surface whose radius is 4 mm and the axis is parallel to y-axis (Figs. 1, 6A) was considered for this case. The max dimensionless stress component, σ_t, around the contact point (Fig. 7A) corresponds to the value of $\varphi = 0$ deg — Fig. 2. It is seen from Figs. 2 and 7A that dimensionless stress value decreases from 0.7 to approximately 0.42.

The effect of the cylindrical cavities at the free surface of the joints, made parallel to the contact line and also at different distances from the line (Fig. 6B, C), are investigated in two different models. Photographs of isochromatic patterns, characterizing the effect of the cylindrical cavities on the thermal stress distribution, are shown in Fig. 7B and C, respectively. These effects can be evaluated by comparing the changes in the relevant m/t graphs for the models, where m is the fringe order and t is the thickness of the slice on the measured points. In comparison, the smaller the distance, the lower the value of the stress components at the contact line. Thus, as the distance decreases by 25%, the maximum value of m/t decreases by approximately 23%.

Conclusions and Discussions

It is important to compute values of local thermal stresses in the weld region for jointed constructions such as pressure vessels applied in nuclear power plants, the chemical industry, etc. In this study, mechanical modeling of thermal stresses was used to investigate the concentration of thermal stress components in butt joints in thick plates and the effect of variation of the bevel angle value on the stress distribution in joints. The following assumptions were made in the experiments for simplification:

- Materials are continuous in the welding zone;
- The plates of different materials are jointed with a plane;
- Reinforcement and throat, which occur during the welding process, are in the same plane with those of jointed plates;
- No variation in the material properties and toe and underbead cracks due to temperature in the process of welding;
- The residual stresses due to the welding process aren't taken into account in the joint, and can be investigated with some specific methods.

The following was observed:

1. Thermal stress components around the contact line on the free surfaces of the jointed plates increase with the increase in the bevel angle, but the gradients decrease.

2. There is a relationship between the bevel angle and the maximum thermal stress components on the free surfaces just near the contact line, which can be considered as linear.

3. The maximum values of thermal stress components around the contact line on the free surface of the joint can be regulated by applying some design proposals based on the experiments presented herein.

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Examining the Bimetallic Joint of Orthorhombic Titanium Aluminide and Titanium Alloy (Diffusion Welding)

Factors providing for bimetallic joint quality include absence of a continuous intermetallic layer and mutual adjustment of lattices near the contact surface

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ABSTRACT. An excellent set of strength properties, which are inherent to orthorhombic titanium aluminides, provides a good outlook for their successful use in the development of bimetallic joints. Bimetallic joints of the orthorhombic titanium aluminide (Ti-30Al-16Nb-1Zr-1Mo) and a titanium alloy (Ti-7.7Al-1.8V) were prepared by diffusion welding. The phase composition and the microstructure of the bimetallic joint were studied using x-ray diffraction analysis, metallography, x-ray microspectrum analysis, scanning, and transmission electron microscopy. It was found that the titanium alloy mainly recovered its initial state, whereas the aluminide transformed into a disordered BCC phase upon diffusion welding. The diffusion zone had a multilayered structure. Phases forming the layers were identified. The difference between the composition of the phases and the composition of the initial alloys was due to diffusion flows of Nb and Al to the titanium alloy and Ti to the orthorhombic aluminide. The main role in the formation of the joint belonged to $\alpha_2 \rightarrow \beta$ and O→β transformations of intermetallic phases to a disordered β phase. This caused, first of all, the increase in the diffusion coefficients. As a result, opposite diffusional fluxes of atoms arise, which ensure adhesion of the layers near the contact surface. The mutual adjustment of the BCC lattices was a factor favoring a good-quality bimetallic joint. One more important factor was the absence of a continuous intermetallic layer near the contact surface, which could cause embrittlement. These factors were revealed earlier in our study of a bimetallic joint of the same titanium alloy and a stainless steel, which was made by diffusion welding.

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Introduction

Alloys of the Ti-Al-Nb system comprise a numerous group of alloys (Refs. 1, 2) including, on the one hand, compounds with a low concentration of Nb, which are based predominantly on the α_2 (HCP) phase, and, on the other hand, Nb-enriched compounds based on the orthorhombic O phase — Fig. 1. The O phase actually represents a weakly distorted variant of the α_2 phase. In addition to the aforementioned phases, the orthorhombic alloys may contain BCC phases depending on the composition — a disordered β phase or ordered B2 phase.

The low-temperature ductility of the O phase is higher than that of the α_2 phase and γ-TiAl (Refs. 3–6). Moreover, the O phase may be in equilibrium with the γ, α_2, and β_0 phases. Consequently, it is relatively easy to form a wide spectrum of strength and ductility characteristics in alloys based on orthorhombic titanium aluminide by varying their chemical compositions and thermal treatment conditions.

A remarkable complex of strength properties, which are inherent to orthorhombic titanium aluminides, includes the high values of the specific strength (the strength/density ratio), good ductility at room temperature, adequate fracture toughness, a high resistance to creep and oxidation, and good tensile properties (for certain compositions). An especially attractive feature is the possibility to make one phase as a disordered solid solution, which possesses high ductility and toughness, and, thus, can act as a buffer element in the structure of a multiphase alloy based on intermetallics. The practical application of orthorhombic titanium aluminides in real structures requires the knowledge of the phase composition, properties, and the structure of not only intermetallics, but also their fusion zones with various constructional materials.

Bimetallic joints of the orthorhombic titanium aluminide and a titanium alloy were prepared by diffusion welding (Ref. 7) and explosive welding (Ref. 8). The objective of this study was to analyze the microstructure of the joints. It was to determine which phase and structural transformations took place during diffusion welding and which factors were responsible for good-quality joints.

KEYWORDS

Diffusion Welding
Orthorhombic Titanium Aluminide
Titanium Alloy
Bimetallic Joint
Microstructure
Intermetallic Layer

Experimental Procedure

The orthorhombic titanium aluminide Ti-30Al-16Nb-1Zr-1Mo and a titanium alloy (Ti-7.7Al-1.8V) were chosen as the initial materials. The alloy compositions are given in at.-%.

Ingots of the orthorhombic alloy were made by double vacuum arc remelting. Untreated ingots had an inhomogeneous coarse-grain plate-like structure with the characteristic grain size d = 1.2 mm. To refine grains and improve the cast structure, the alloy was treated under the following conditions. Ingots were pressed at T = 1180°C to 60% reduction. Then ingots were placed in an isothermal die block, which was heated to 1000°C, and were upset in three steps to 20-, 20-, and 47% reduction. As a result, forged disks 360 × 60 mm in size were prepared. Plates 70 ×

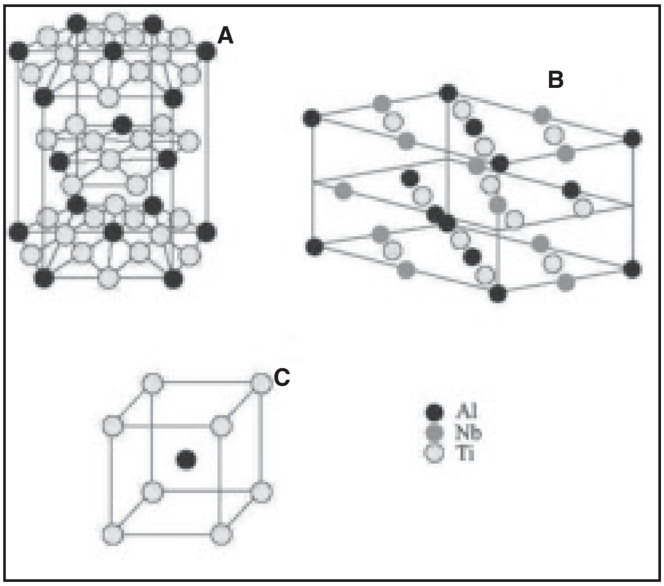

Fig. 1 — Unit cells of phases of the orthorhombic titanium aluminide. A — α_2; B — O; C — B2.

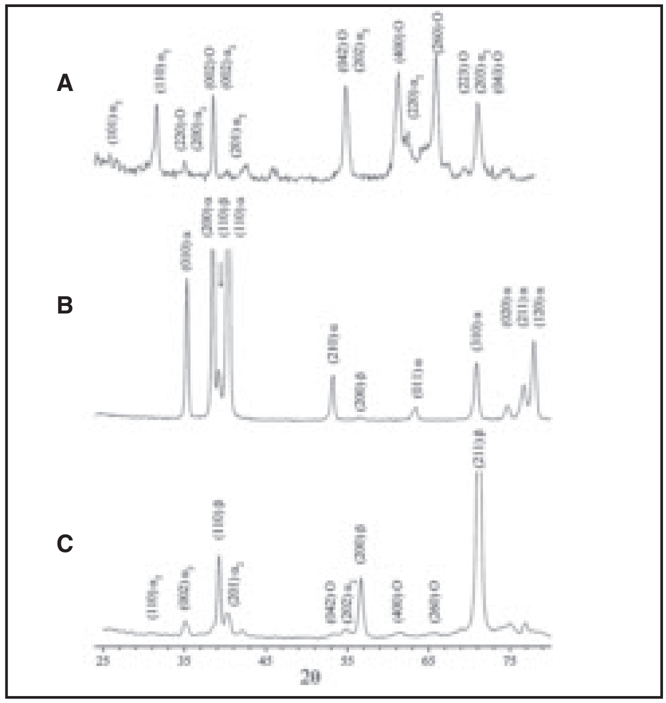

Fig. 2 — Diffraction patterns of the alloys studied. A — The initial state of the orthorhombic aluminide; B — the initial state of the titanium alloy; C — the orthorhombic aluminide after welding.

40×12 mm in size were cut out of the disks by the electric erosion method and rolled to a thickness of 0.5 mm. The rolled sheets were annealed under the following conditions: heating to 950°C, holding for 5 min, quenching in water, and annealing at 700°C for 3 h. Table 1 gives deformation characteristics of the alloys studied, including the yield stress $\sigma_{0.2}$, the ultimate strength σ_B, and the ductiltiy δ.

The diffusion welding operation was performed under different loads and different temperature and time conditions. Then mechanical properties of the joint were determined. The best properties were obtained at 960 ± 10°C for 5 min in a vacuum of 0.133 Pa at a load of 10 MPa. This joint was studied further.

The microstructure, phases, and the redistribution of alloying elements in the joint zone were examined using optical metallography (Neophot 2, EPIQUANT with the SIAMS computing system), transmission electron microscopy (JEM 200CX), x-ray spectral microanalysis (a scanning electron microscope with an energy dispersion detector), and x-ray analysis (in monochromatized Cu-K_α radiation).

Results

Initial Microstructure

Aluminide. It is seen from the diffraction pattern (Fig. 2A) that the orthorhombic titanium aluminide contained predominantly the α_2 phase (the $D0_{19}$ structure) and the orthorhombic O phase. The aluminide also included a small quantity of the BCC β phase with traces of ordering after the B2 type.

As the metallographic study showed, the structure of the orthorhombic aluminide represented regions of the globular shape against a homogeneous structural component. Regions of the globular shape had a bimodal size distribution. The coarse and fine fractions were characterized by sizes of 20 and 2 μm, respectively. The TEM examination showed that the globular regions had a layered internal structure and represented the α_2 phase at different decomposition stages, which was accompanied by precipitation of polydomains of dispersed plates of the O phase. The "background" component looked quite different. It was a duplex structure comprising relatively coarse grains of the α_2 and O phases, which filled the space between globules.

Ti-alloy. It is seen from the diffraction pattern (Fig. 2B) that the titanium alloy contained predominantly the α phase (HCP) and a small volume fraction (~8%) of the β phase (BCC), i.e., the compound represented the so-called pseudo-α-alloy (Ref. 9). The optical and transmission electron microscopic examinations revealed a lamellar structure, which is typical of the pseudo-α-alloy. Parallel plates of the α phase 1–3 μm thick, which were almost devoid of dislocations, formed colonies of 5 to 10 plates. Adjacent plates were separated by thin (about tenth fractions of a micrometer thick) interlayers of the β phase.

Postweld Microstructure

The x-ray spectra microanalysis of the distribution of elements in the transition zone (Fig. 3) showed that the process of diffusion welding was accompanied by intensive diffusion mixing of atoms of various chemical elements — niobium and aluminum passed from the aluminide to the titanium alloy, while titanium moved in the opposite direction. The zone of intensive diffusion mixing extended for about 10–20 μm. It is only in this zone near the contact surface (CS) that diffusing elements showed their effect on phase transformations that took place during welding.

It is seen from the diffraction pattern (Fig. 2C) that the main postweld phase of the aluminide was the β phase with traces of the α_2 and O phases. The diffraction pattern, which was obtained for the titanium alloy after welding, differed little from the initial diffraction pattern — Fig. 2A. These observations agree with results of the optical microscopy examination. The optical microphotograph (Fig. 4) shows the structure of the welded bimetal-

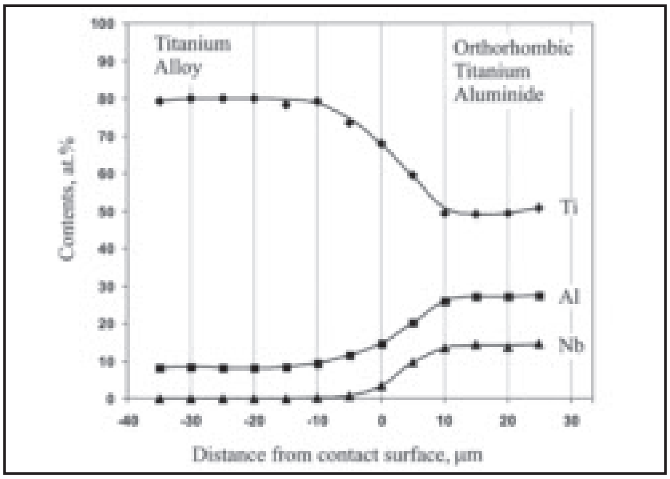

Fig. 3 — Distribution of elements in the welded joint zone as determined from the x-ray spectral microanalysis.

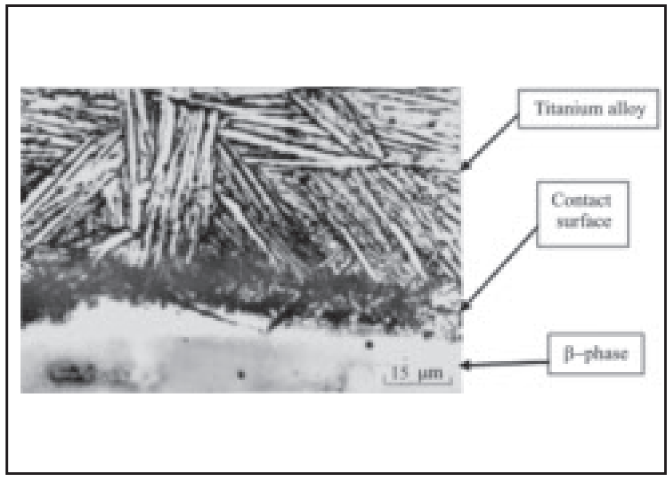

Fig. 4 — Optical image of the microstructure of the bimetallic joint.

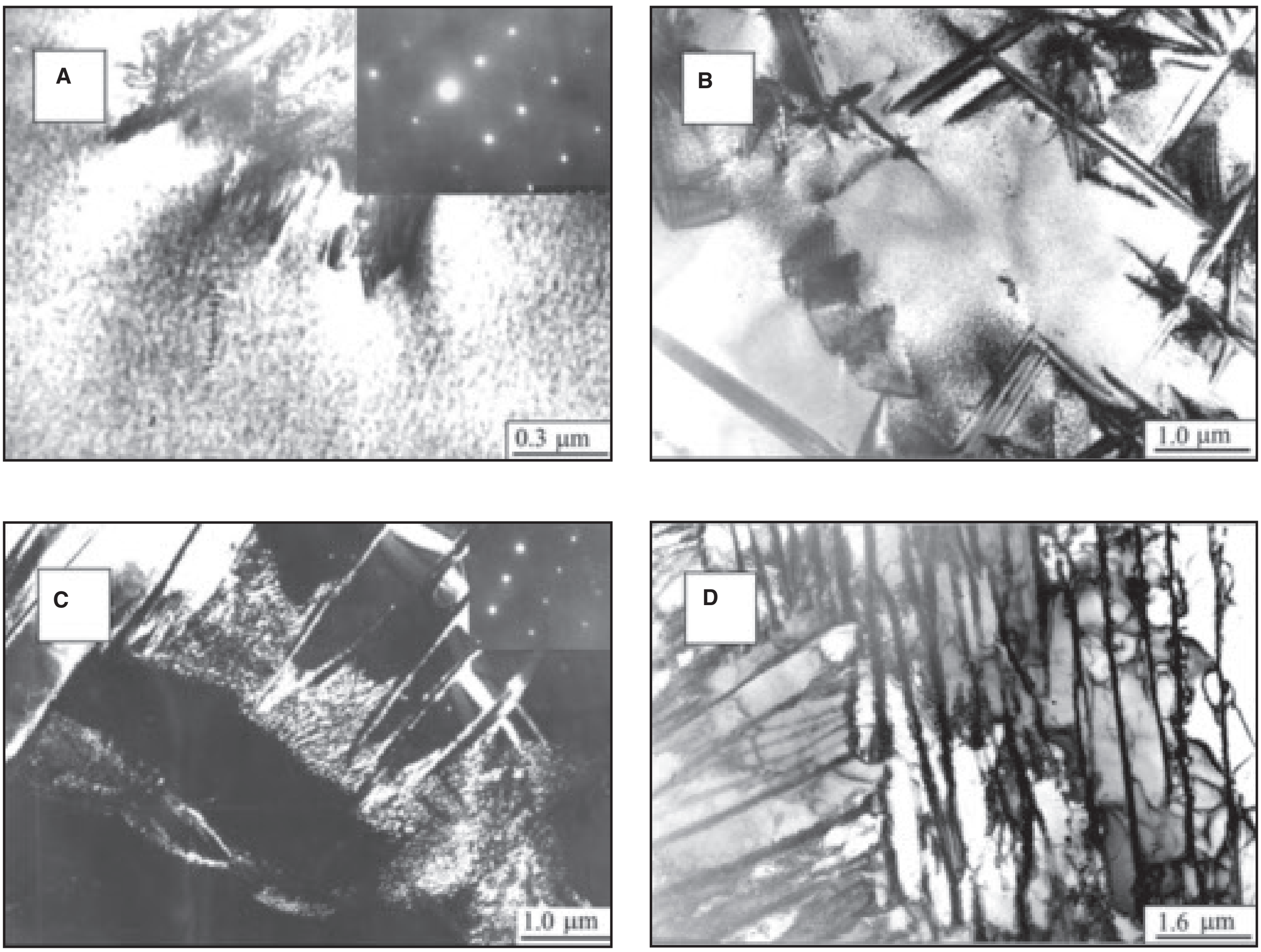

Fig. 5 — Structure of the orthorhombic aluminide far from CS (A) and near CS (B) and that of the titanium alloy near CS (C) and far from CS (D). A — Bright-field image of the β phase; B — bright-field image of the β phase with lamellar precipitates of the α_2 and O phases; C — dark-field image in the $(200)_{\alpha 2}$ reflection; D — bright-field image of plates of the α phase with interlayers of the β phase.

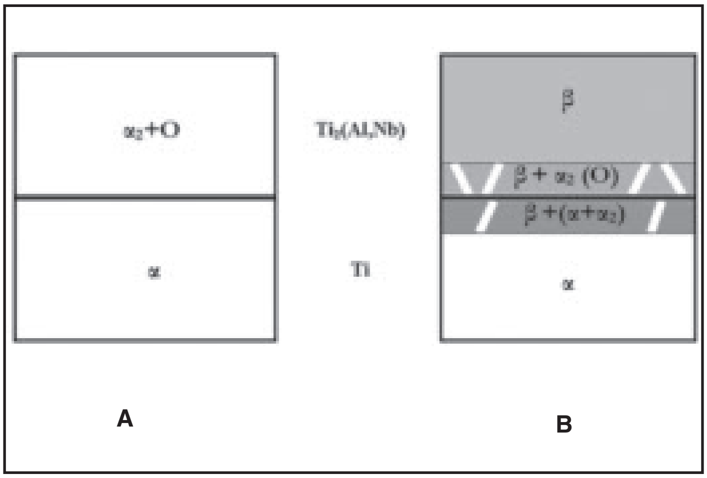

Fig. 6 — Schematic drawing of the structure of the bimetallic joint. A — Initial materials; B — after diffusion welding.

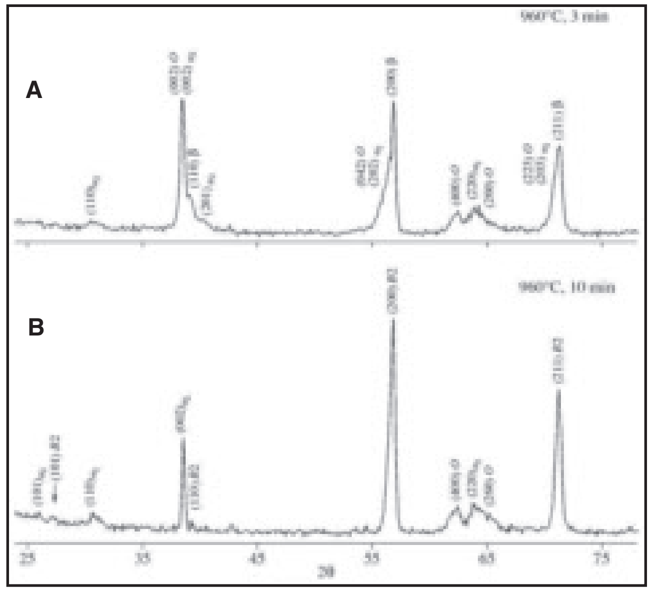

Fig. 7 — Diffraction patterns of the orthorhombic alloy after annealing at 960°C and quenching in water. A — 3 min; B — 10 min.

lic joint. The lamellar structure of the pseudo-α-alloy is seen on one side of CS. A single-phase structure of the titanium aluminide is observed on the other side.

Thus, the titanium alloy mainly recovered its initial structure (the pseudo-α-alloy), whereas the titanium aluminide turned to a disordered β phase after welding.

Welded Joint as Multilayered Sandwich (TEM)

Aluminide, far from CS. Figure 5A presents a bright-field image of the aluminide structure far from CS. The interpretation of selected-area electron diffraction patterns of this area and other areas demonstrated that these areas contained a disordered β phase.

Aluminide, near CS. Lamellar precipitates of the α_2 and O phases were seen and their volume fractions increased when CS was approached. Figure 5B presents a bright-field image of the β phase with inclusions of the α_2 and O phases. Regions of the disordered β phase were observed predominantly near CS on the side of the orthorhombic alloy.

Ti-alloy, near CS. Figure 5C presents the microstructure of the titanium alloy in the immediate vicinity to CS. The single-phase region bounded on a colony including α plates and interlayers of the β phase. The analysis of the selected area diffraction pattern revealed that the single-phase region was filled with the β phase (BCC). Fine precipitates of the α_2 phase are seen in the α plates.

Ti-alloy, far from CS. As the distance to CS increased, the aforementioned single-phase region vanished and the β phase remained in the form of interlayers between the α phase plates, which no longer contained precipitates of the α_2 phase — Fig. 5D. At a distance from CS the structure progressively resembled the structure of the pseudo-α-alloy, which was observed before welding.

Thus, the bimetallic joint represented a multilayered "sandwich" schematically depicted in Fig. 6.

Discussion

Phase Transformations during Diffusion Welding

Aluminide. To elucidate reasons for the surprising fact that the aluminide turned to a disordered β phase after diffusion welding, it was necessary to determine the cross section of the phase equilibrium diagram for the composition at hand. For this purpose, some test samples were annealed at temperatures from 900° to 970°C for different intervals of time and then water quenched. The obtained phase equilibrium diagram differed from the phase equilibrium diagrams (Refs. 1, 10), which contained the B2 phase of a similar composition only at temperatures exceeding 1000°–1100°C. It was shown that the alloy in the initial state was predominantly a two-phase (α_2+O) compound. At 900°–950°C it contained three phases (α_2+O+B2) and the proportion of the B2 phase increased sharply with temperature. The alloy included mainly the B2 phase and traces of the α_2 phase above 960°C. Therefore, one might expect indeed that at a temperature equal to the welding temperature, the α_2 and O phases turned, being nonequilibrium ones, to the B2 phase.

Short-time annealings were performed at 960°–970°C to see the process of the $\alpha_2 \rightarrow$B2 and O$\rightarrow$B2 phase transformations. It was found that a BCC phase was observed already after 3-min annealing, and this phase represented a disordered β phase. The corresponding diffraction pattern is given in Fig. 7A. However, lines of the B2 phase appeared already after 8- to 10-min annealing — Fig. 7B. The TEM examinations of the microstructure also confirmed the formation of a disordered BCC phase after short-time annealing and its ordering as the annealing time increased. Early stages of ordering were observed after the samples were annealed at 960°C

Table 1 — Mechanical Properties of the Alloys under Study at Room Temperature

Alloy	Direction	$\sigma_{0.2}$, MPa	σ_B, MPa	δ, %
Ti - 30Al - 16Nb -1Zr - 1Mo	along the sheet	1150	1290	4.1
	across the sheet	1114	1291	6.6
Ti-7.7Al-1.8V		588	753	9-10

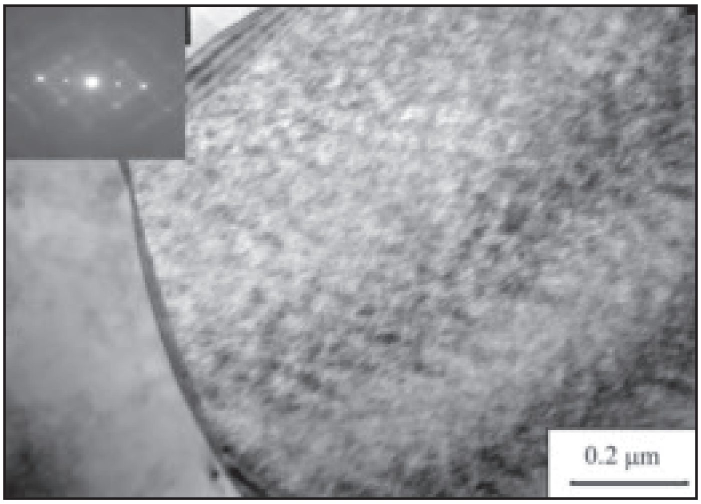

Fig. 8 — TEM image of the microstructure of the orthorhombic alloy after annealing (960°C, 8 min) and quenching in water; the B2 phase at early stages of ordering.

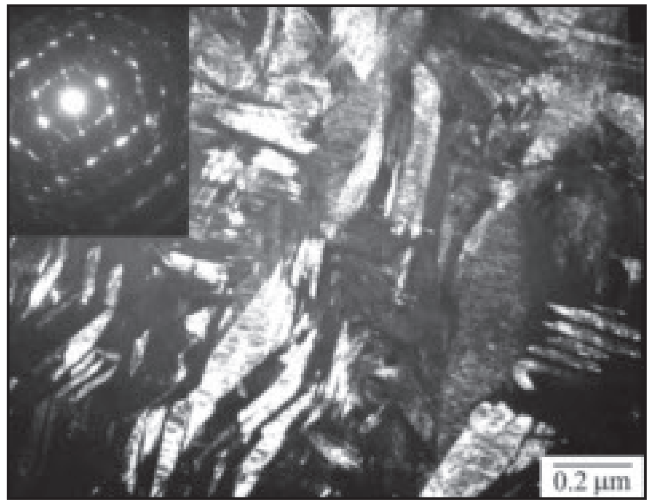

Fig. 9 — TEM image of the microstructure of the orthorhombic alloy after reconstruction of welding joint.

for 8 min — Fig. 8.

Thus, the $\alpha_2 \rightarrow$B2 and O$\rightarrow$B2 phase transformations were realized as follows: a quick transformation $\alpha_2 \rightarrow \beta$ and O$\rightarrow \beta$ to the disordered phase and subsequent ordering. The disordering process was only realized during welding — Fig. 5A. Since the aluminide composition changed near CS, namely, approached the Ti_3Al composition, lamellar inclusions of the α_2(O) phases could be formed in the β phase — Fig. 5B.

Ti-alloy. The diffusion welding temperature was sufficient for the $\alpha \rightarrow \beta$ transformation in the Ti alloy of the given composition. The reverse $\beta \rightarrow \alpha$ transformation could take place upon subsequent cooling — Fig. 5D. The lamellar structure, which is seen in the optical microphotograph (Fig. 4), is typical of the titanium alloy when it is cooled exactly from the β range. This also confirms the occurrence of $\alpha \rightarrow \beta \rightarrow \alpha$ transformations during welding.

The layer near CS contained not only regions having the aforementioned lamellar structure, but also regions filled with the β phase. Colonies of α plates (Fig. 5C) were enriched in aluminum. This was confirmed by the appearance of fine precipitates of the α_2 phase in the α phase plates. Moreover, the observation of the α_2 phase suggested that the Al concentration of the α phase considerably increased. Indeed, the said particles can precipitate upon cooling only if Al concentrations exceed 10 at.-%. Oppositely, isolated regions of the β phase (Fig. 5C) were enriched in Nb. In this case, Nb acted as the β stabilizer.

Factors Determining the Quality of the Welded Joint

The structures, which were observed on both sides near CS (Fig. 5B, C), had many features in common. They contained BCC β phases of the corresponding compositions and lamellar inclusions of other phases. The joint under study was formed mostly due to the $\alpha_2 \rightarrow \beta$ and O$\rightarrow \beta$ transformations of the intermetallic phases to a disordered β phase. Below is a list of the factors that create favorable conditions for a good-quality bimetallic joint.

1. The increase of the diffusion coefficients that is typical of disordering (Ref. 11). As a result, counterdiffusional fluxes of atoms arise, which ensure adhesion of the layers near CS.

2. One and the same BCC lattice on both sides of CS. This circumstance facilitated their mutual adjustment despite the fact that a continuous layer of the β phase was only observed on the side of the aluminide and separate isolated regions of this phase were present on the side of the titanium alloy. Constants of the BCC lattices in the orthorhombic aluminide and the titanium alloy were 0.3242 and 0.3249 nm, respectively. Internal stresses arising from the mismatch of the lattices can be decreased due to the formation of dislocations. This leads to a partially coherent conjugation of the phases (Ref. 11), which is facilitated by large plasticity of the disordered β phase as compared with plasticity of the initial α_2 and O phases.

3. The absence of a continuous intermetallic layer near CS. Although the BCC phases near CS contained inclusions of the intermetallic phases, a continuous intermetallic layer, which could lead to embrittlement, did not appear.

The choice of the diffusion welding conditions proved to be successful — the heating temperature was sufficiently high so that the initial phases became nonequilibrium and started transforming to the BCC phases; the heating time was sufficiently short so that the initial phases had time only to transform to the β phase.

To restore the intermetallic phases, the welded joint was annealed under the same conditions as those used for preparation of the initial orthorhombic alloy (700°C, 3 h). The initial α_2 and O phases were actually reconstructed — Fig. 9. Continuity of the joint was not broken.

Comparison with the Structure of a Bimetallic Joint of Titanium Alloy and Stainless Steel

The structure of a bimetallic joint (diffusion welding) of a titanium alloy of the same composition as the one used in this study and a stainless steel was analyzed earlier (Ref. 12). The results are analogous to the aforementioned findings. The same lamellar structure of the pseudo-α-alloy as in Fig. 5D was observed in the titanium region far from CS. As CS was approached, β interlayers became much thicker, i.e., the concentration of the β phase increased. However, the α phase formed, as before, the basis of the alloy. However, as distinct from the aluminide joint, a continuous layer of the β phase of the titanium alloy was present near CS. This was due to the fact that the structure of the said surface layer was determined mainly by the diffusion flow of Fe in the stainless steel joint and the diffusion flows of Nb and Al in the aluminide joint. Moreover, the diffusion zones differed considerably by their width — the diffusion zone was much wider (~40 μm) in the stainless steel joint. This was due primarily to the fact that the diffusion coefficient of Fe in β-Ti was more than one order of magnitude larger than the diffusion coefficient of Nb (Ref. 13).

In the region of the stainless steel the initial FCC γ-Fe phase (far from CS) transformed continuously to the BCC α-Fe phase (near the CS) via several layers — one layer was formed by some nonequilibrium phase, and the other layer comprised a work-hardened austenite.

It was remarkable that two BCC phases — iron-enriched β-titanium and titanium-enriched α-Fe — conjugated in the immediate vicinity to CS. It was the mutual adjustment of the BCC lattices near CS that was very favorable for a good-quality joint. One more important factor was the absence of a continuous intermetallic layer. Considering relevant phase equilibrium diagrams and the obtained concentration profiles, it was reasonable to expect the formation of Ti-Fe intermetallics by diffusion mixing. Since the intermetallic was absent, then the experiment duration was insufficient for its formation.

Comparison with the Structure of a Bimetallic Joint of Orthorhombic Titanium Aluminide and Titanium (Explosion Welding)

A bimetallic joint of orthorhombic titanium aluminide and titanium was obtained (explosion welding). Orthorhombic titanium aluminide (a sheet 0.5 mm thick) comprising Ti–30Al–16Nb–1Zr–1Mo (at.-%) was used (Refs. 8, 14). The explosion welding parameters were as follows: the sheet speed of 500 m/s; the collision angle of 12–14 deg; heating temperature from surface friction and wave detonation equal to 900°C; and the pressure of 6 GPa. In the case of explosion welding, despite a strong shock-wave loading, the phase composition of the materials under study differed little from the initial composition. However, the structure changed drastically. Structural elements, which are typical of strongly deformed materials (Ref. 15), were observed on both sides of the contact surface. The concurrent presence of a cellular structure, a band structure with a high density of dislocations, and new grains pointed to different stages of fragmentation, which were due to an inhomogeneous plastic deformation over the volume of sheets. The fact that the mixture of phases (O+α_2) was preserved did not mean the invariability of each of the phases. It was found that phase transformations $\alpha_2 \rightarrow$O and B2→O took place during the explosion welding. Different variants of the interrelation between recrystallization and phase transformations in the heterophase structure under shock-wave loading were considered.

Conclusions

• The structure of a bimetallic joint (diffusion welding) of the orthorhombic titanium aluminide (Ti-30Al-16Nb-1Zr-1Mo) and a titanium alloy (Ti-7.7Al-1.8V) was studied using different methods.

• The diffusion zone had a multilayered structure — the β phase (the aluminide, far from contact surface (CS)); the β phase and a lamellar mixture of (α_2+O) phases (the aluminide, near CS); the β phase and plates of the α phase with the α_2 phase inclusions (Ti alloy, near CS); and the β phase with interlayers of the β phase (Ti alloy, far from CS).

• It was found that the $\alpha_2 \rightarrow$B2 and O→B2 phase transformations were realized as follows: a quick transformation $\alpha_2 \rightarrow \beta$ and O→β to the disordered phase and subsequent ordering. The disordering process was only presented during welding.

• To restore the intermetallic phases, the welded joint was annealed under the same conditions as those used for preparation of the initial orthorhombic alloy. The initial α_2 and O phases were actually reconstructed. Continuity of the joint was not broken.

• Factors that favor a good-quality bimetallic joint are as follows:

1. The increase of the diffusion coefficients that is typical of disordering;
2. One and the same BCC lattice on both sides of CS and their mutual adjustment;
3. The absence of a continuous intermetallic layer near CS.

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